technical-economic study of solid waste disposal needs and practices

This study was financed by a contract with the Bureau of Solid Waste Management, Environmental Control Administration, U.S. Department of Health, Education, and Welfare, and the report has been reproduced as received from the contractor. No editorial or other changes have been made, although a new title page and foreword have been added, and the photographs have been deleted.

Since solid waste management is a relatively new field, and since the relationships of economics to solid waste technology are just being explored, the conclustions and evaluations presented should be considered as preliminaty in nature. The findings, recommendations, and opinions in the report are those of the contractor and not necessarily those of the Government. Neither do they imply any future Government study, recommendations, or position.

TECHNICAL-ECONOMIC STUDY OF SOLID WASTE DISPOSAL NEEDS AND PRACTICES

Municipal Inventory (Volume I)

Industrial Inventory (Volume II)

Information System (Volume III)

Technical-Economic Overview (Volume IV)

This report (SW-7c) was written for the Bureau of Solid Waste Management
by Combustion Engineering, Inc., Windsor, Connecticut,
under Contract No. PH 86-66-163

U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service
Consumer Protection and Environmental Health Service
Environmental Control Administration
Bureau of Solid Waste Management
Rockville, Maryland
1969

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F O R E W O R D

Rising population in the United States, increasing urbanization of this population, industrial growth, and the unparalleled affluence of American society have resulted in an ever-increasing volume of wastes in the solid state that must be regularly collected, transported, and ultimately disposed of. Per capita generation of solid wastes has risen from 2.75 pounds in 1920 to 5.3 pounds in 1968, and this figure may rise to 8 pounds by 1980. At the very time that these larger amounts of solid wastes must be managed, cities are faced with shortages of suitable disposal sites, and with present solid waste management practices that are inadequate to protect the environment.

The national character of the solid waste problem was recognized in 1965 with passage of the Solid Waste Disposal Act (PL 89-272). This legislation authorized the Department of Health, Education, and Welfare to: (1) initiate and accelerate a national research and development program for new and improved methods of proper and economic solid waste disposal; (2) provide technical and financial assistance to State and local governments and interstate agencies in the planning, development and conduct of solid waste disposal programs.

Upon assuming responsibilities under this Act, the Federal solid wastes program was confronted with a lack of comprehensive information to define the solid waste problems of municipalities and industries in specific terms, and to assess the existing state of solid waste technology.

The present study was performed under contract PH 86-66-163 to supply such information for the purpose of identifying areas requiring particular attention, and in order to draw some conclusions concerning the economics of solid waste management.

Since submission of this report, the Bureau of Solid Waste Management has completed a National Survey of Community Solid Waste Practices that provides a statistically reliable estimate of the prevailing costs, modes of collection, processing and disposal, and the quality of solid waste management in the United States. Persons interested in obtaining basic information in the solid waste field are referred to the National Survey.[*,+] In cases of statistical discrepancy between the publications, the National Survey should be considered authoritative.

--RICHARD D. VAUGHAN, *Director*

Bureau of Solid Waste Management

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*Muhich, A. J., A. J. Klee, and P. W. Britton. *Preliminary data analysis; 1968 national survey of community solid waste practices.* Public Health Service Publication No. 1867. Washington, U.S. Government Printing Office, 1968. 483 p.

+Muhich, A. J., A. J. Klee, and C. R. Hampel. *1968 National survey of community solid waste practices.* Public Health Service Publication No. 1866. Washington, U.S. Government Printing Office, 1968. (In press.)

municipal inventory
(volume i)

INTRODUCTION TO VOLUME I - MUNICIPAL INVENTORY

The study presented in this volume is part of a four-volume report. The other volumes are:

Volume II	-	Industrial Inventory
Volume III	-	Information System
Volume IV	-	Technical-Economic Overview

Volume I has three parts. Part 1, Pictorial Overview, presents photographs to indicate the scope of solid waste operations.* Part 2, Municipal Inventory, presents statistical data in order to obtain some dimensions of the solid waste problem. Part 3, Mathematical Model, presents some mathematical concepts for predicting solid waste generation and solid waste reduction requirements.

The material in the report was prepared by Mr. W. Richard Copp and Mr. Joseph H. Bacher of the Product Diversification Department. Mr. Elliot D. Ranard served as Program Manager for Combustion Engineering, Inc.; Mr. Ralph J. Black served as Project Director for the Public Health Service.

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* For reasons of economy, Part 1 has not been reproduced.

PART 2

MUNICIPAL INVENTORY

Prepared by

W. Richard Copp
Senior Product Analyst
Product Diversification Department

TABLE OF CONTENTS

SECTION I

SUMMARY

During the fall of 1966 and the spring of 1967, approximately 600 cities were surveyed and municipal officials in 50 of these cities were interviewed in person to define in limited depth the problem areas of municipal refuse generation, collection and disposal.

From the information obtained in these surveys and interviews, the amount of refuse generated from residential and commercial sources was determined. The number of installed incinerators and composting plants in operation in the United States was also defined. It was further determined that there is an apparent lack of well kept records on solid waste disposal practices and an apparent deficiency in adequate planning for solid waste disposal facilities in the majority of communities.

Mathematical models (equations) were developed to predict the capacity of installed waste reduction facilities (i.e. incinerators and composting plants) in 1975 in the United States. In addition, a mathematical model was developed for the state of Connecticut to predict quantities of commercial, residential and industrial waste production and the requirements for waste reduction facilities to handle these waste streams in 1975.

SECTION II

INTRODUCTION

The municipal refuse disposal problem is increasing every year because per capita production of refuse is increasing and vacant land is decreasing. There is also an increasing interest in the interrelationships between waste reduction equipment and air and water pollution, and therefore, solid waste disposal will ultimately be considered in the context of an overall waste generation, waste reduction system including air and water pollution control.

This report reviews municipal solid waste disposal practices with emphasis on solid waste generation, solid waste reduction equipment and planning problems.

Part 2 of this report presents statistical data obtained from a survey of approximately 600 cities and personal interviews of cognizant people in 50 cities. In addition, 5 cities were interviewed in limited depth to obtain an overview of municipal disposal practices in the central city and surrounding towns. Part 2 of this report was prepared by Mr. W. Richard Copp, Senior Product Analyst of the Product Diversification Department.

Part 3 of this report presents an inventory of solid waste reduction facilities such as incinerators and composting plants and develops mathematical models (equations) which can be used by state and county planners for predicting solid waste production and solid waste reduction facility requirements. Part 3 of this report was prepared by Mr. Joseph H. Bacher, Administrative Engineer of the Product Diversification Department. Mr. George W. Tuite and Mr. Michael L. Daversa of Combustion Engineering's Corporate Systems Group participated in a consulting capacity.

SECTION III

CONCLUSIONS

A. STATISTICAL DATA

1. Approximately 1,380,000,000 pounds of residential, commercial and industrial wastes are generated each day in the United States. Approximately one billion pounds of this solid waste must be disposed in either municipal or private contractor facilities; the remainder is disposed of in industrial sites.

2. It is estimated that a typical urban area must dispose approximately 5.5 pounds per capita per day of solid waste from all sources, and that the "national" figure based on a population of two hundred million people is 5.1 pounds per capita per day.

3. Approximately 20 percent of communities of over 25,000 population use incineration to dispose of their solid wastes; the remaining communities use sanitary landfill, open dumping, open burning or composting.

4. Approximately 9 percent of municipal refuse is incinerated.

5. As of December 31, 1966, there were 74,600 tons per day of installed incinerator capacity operating in the United States.

6. As of June 1967, there were approximately 730 tons per day of installed composting capacity in operation in the United States.

7. Many cities are not faced with long hauling distances to their current disposal site with approximately one half of the cities reporting the hauling distance of less than five miles.

8. Approximately 50 percent of the cities over 25,000 population currently using sanitary landfill have less than six years of life left in their existing facility and many of these do not know at this time where the next facility will be located.

B. PLANNING

1. Little or no data is kept by the typical municipality of the physical make-up of refuse.

2. Significant improvements can be made in the data gathering and record keeping of most municipalities.

3. There are apparent differences in solid waste problem areas from one population strata to another and these should be examined separately.

4. If present trends continue and further long range planning is not expanded, there will be a lack of facilities to handle solid waste in 1975.

5. Regionalization is recognized to be a practical solution to the solid waste disposal problem in many areas; however, considerable political and emotional objections exist to its implementation.

6. A possible short term solution to the facilities gap is expansion of the private contractor's role because of his ability to cross municipal and political boundaries. For example, he could use a private disposal site for the refuse of several communities.

C. MATHEMATICAL MODEL

1. Mathematical models (equations) can be formulated to predict installed incinerator capacity and solid waste production and these models can be tied into a "national" series of models for planning purposes in each of the states. Since any model is based in part upon historical data, the use of these models as planning tools must be continuously evaluated over a period of time.

2. Mathematical models can be developed as a function of several parameters. The best ones are (given for a region such as a town or county):

   a. Population.

   b. The ratio of population to the total possible population a town can have consistent with present zoning and land use.

   c. Manufacturing employment.

   d. Total possible manufacturing employment.

   e. Vacant land.

SECTION IV

RECOMMENDATIONS

A. Determine the quantity of solid waste generated in commercial and institutional establishments, the interaction between the two waste flows and how these should be projected for a typical urban community.

B. Clearly define the apparent planning deficiency in the majority of communities and implement programs to assist state and local authorities in eliminating this deficiency.

C. Investigate ways and means of using the private contractor's ability to cross political boundaries to hasten the regional approach to solid waste disposal.

D. Formulate and recommend standard record keeping procedures to insure uniform reporting of data.

SECTION V

METHOD OF APPROACH

In order to obtain data regarding the solid waste disposal problems of municipalities in the United States, approximately 600 cities were selected to canvass for information. These cities included two groups. The first group consisted of cities in the population class of 25,000 to 50,000. The second group consisted of cities with population of 50,000 or more. The 1960 census figures were used to determine population. All of the cities with populations of 50,000 and over were surveyed. All cities in the 25,000 to 50,000 population range in the following states were surveyed.

California	New Jersey
Connecticut	New York
Delaware	Ohio
Illinois	Pennsylvania
Indiana	Rhode Island
Maryland	Virginia
Massachusetts	West Virginia
Michigan	Wisconsin

The cities were surveyed in limited depth by using a surveying service of the Western Union Telegraph Company. The questionnaire used was designed to survey method of disposal, number of waste reduction plants in operation, the plant capacity on a twenty-four hour a day basis, the average number of hours the plant operates each week, the age of the waste reduction facilities, and the number of waste reduction plants planned for in 1967 and 1968. Appendix A is an example of the questionnaire that was used.

As a check, fifty cities were selected for personal interview in order to validate data received by the Western Union survey. They were chosen with several objectives in mind. The first of these objectives was that the selection be random in nature. The second objective was that the cities interviewed cover a broad spectrum of waste reduction facilities and the third objective was that the cities were chosen in accordance with the size ranges of from 25,000 to 50,000 and over as outlined in the contract.

Specifically, five cities were chosen in the 50,000 and over population category because they had sanitary landfill. Five additional cities were meant to be chosen in this category with composting or mechanical compactor equipment. It was discovered that only three cities with population of 50,000 and over had composting or compacting equipment. Consequently, the other two cities, both of whom had composting equipment, were in a size range below 50,000. Twenty-five cities in this population category were chosen on a random number basis from those we knew to possess waste reduction facilities. In the 25,000 to 50,000 population category, five were selected because we knew they had sanitary landfill and ten with waste reduction facilities were selected on a random number basis.

It was determined from Reference 1 that approximately twenty-seven cities in the population category of 25,000 to 50,000 (Group A) had waste reduction facilities. Numbers from one to twenty-seven were assigned to these cities and a random number table was used to pick the ten eventually interviewed. Cities with population of 50,000 and over who are known to have solid waste disposal facilities were divided into five groups or strata.

Group B	50,000 -	100,000	population
Group C	100,000 -	250,000	population
Group D	250,000 -	500,000	population
Group E	500,000 -	1,000,000	population
Group F	Over	1,000,000	population

Based on the 1960 census and the data given in Reference 1, there are twenty-nine cities in Group B which have waste reduction facilities, thirteen cities in Group C, eight cities in Group D, ten cities in Group E, and four cities in Group F. It was desired to have five cities included from each of the five groups. However, there are only four cities in Group F, and, therefore, all cities in Group F are included. Six cities were then selected from Group E and five cities from each of the remaining groups were selected. In all cases, the selections were made by the use of random number tables. The fifty cities selected are given in Appendix B.

The fifty cities selected were then interviewed by means of a personal visit and discussions with cognizant people. These interviews were to be of one day's duration maximum and to deal with data that was readily available in that time. The objectives of the municipal interviews were to validate the Western Union data and to obtain where possible the following information.

1. Past and present per capita refuse production.

2. The quantity and characteristics of municipal and industrial waste handled by the municipality.

3. The amount of waste disposed in sanitary landfill, open dump, or other methods.

4. General description of waste reduction equipment and operation.

5. Trends in vacant land.

6. Planned increases in waste reduction facilities over the next five years.

7. Comparison of local air pollution control standards and performance of incinerators.

8. Description of air pollution control equipment.

9. The types of information which would be of interest to the municipality.

10. Unit costs for waste reduction equipment such as incinerators, composting plants or other types of equipment presently in use.

11. The present or projected local ordinances which affect air pollution and water pollution control equipment in incinerators and composting plants, and solid waste disposal practices in general.

12. The kinds of records of solid waste disposal operation which are kept by the municipality and what variables are measured.

These objectives were accomplished with the help of the questionnaire described in Appendix C.

After the fifty cities were interviewed, five of these cities were interviewed in depth. A team of two people spent about three to five days interviewing cognizant people in the core city and surrounding towns. The five cities, Jersey City, New Jersey; Houston, Texas; Baltimore, Maryland; Norwalk, Connecticut; and Rome, New York were selected because they met most of the following criteria. The cities:

1. Have adequate records.

2. Have satellite towns.

3. Have both industrial and commercial sources of refuse.

4. Represent each strata.

5. Indicate geographical differences.

6. Have made a recent decision as to a method of waste disposal.

From a review of the fifty city data, it was also decided to determine the amount of solid waste handled of private contractors, and which is disposed of in other than municipal facilities in order to obtain a clearer picture of solid waste generation in urban areas.

SECTION VI

SOLID WASTE GENERATION

A. RESIDENTIAL AND COMMERCIAL SOLID WASTE

There are four sources of solid waste in urban areas: these are residential, commercial, institutional, and industrial. These waste streams are handled by private contractors and municipal collection services and are deposited in private and municipal disposal facilities. Some of these wastes are self-disposed such as a hospital incinerating its pathological wastes. In the industrial sector, the amount of waste disposed in industrial sites by industry itself and the amount of industrial waste disposed by others was determined. In the residential and commercial areas, the amount of self disposal was not determined; however, it is felt that the residential and commercial figures presented below which were determined by measurements primarily at the disposal site give a fair estimate of the residential and commercial waste generated. In order to get a more accurate picture of the amount self disposed, a comprehensive study would have to be conducted.

The estimate of solid waste generated in urban areas was obtained in the following manner.

1. The personal interviews of the fifty cities yielded solid waste disposed of in municipal facilities and included residential, commercial, and industrial waste. It was assumed that commercial waste also included institutional waste.

2. The solid waste obtained in (1) was reduced by the amount from industrial sources. In certain cases the industrial waste is broken out in detailed figures kept by the municipality, and in other cases it is estimated.

3. The staff of the Refuse Removal Journal was asked to determine the amount of residential and commercial waste collected by private contractors and disposed in private facilities. Solid waste collected by private contractors but disposed in municipal facilities is included in (1). It was also assumed that the solid waste disposed was equal to the solid waste generated.

4. An estimate was made of bulky wastes such as refrigerators, furniture, etc.

5. The industrial waste was obtained from the inventory of industrial waste conducted as part of the overall study and reported in another volume of this report.

6. It must be remembered that the figures for solid waste generation were obtained in 1966. Today they may have changed. Even in 1966 another official might have produced slightly different figures. The fact remains that these figures show the essential proportions by source involved in the makeup of the generation of solid waste in the average urban community.

The results are shown in Table 1. Only nine cities are shown because these cities were reported on by the Refuse Removal Journal, and because the industrial segment could be broken out of the data.

TABLE 1

RESIDENTIAL AND COMMERCIAL SOLID WASTE GENERATION

Lbs./Capita/Day

City	Municipal Data	Private Contractor	Total
Glendale	3.38	.83	4.21
Los Angeles	3.36	.06	3.42
San Francisco	2.54	3.00	5.54
Miami	3.11	.64	3.75
Baltimore	4.18	.09	4.27
Cleveland	1.73	.34	2.07
Philadelphia	2.41	.08	2.49
Woonsocket	2.58	.56	3.14
Norfolk	4.36	.65	5.41
Avg.	3.07	.69	3.81
*σ	.90		1.19

It can be seen from Table 1 that the residential and commercial figures range from 2.07 Lbs./Capita/Day to 5.54 Lbs.Capita/Day. This variability is due to the accuracy of the data reported and also by virtue of the fact that some towns have more commercial activity per capita than others.

B. RESIDENTIAL SOLID WASTE

Some municipalities which were interviewed were primarily residential with negligible commercial and industrial activity. In others, the residential segment was broken out in the records. These cities were used to calculate an average residential figure as shown in Table 2.

*σ = Standard deviation. There is a 68 percent probability that a city will fall within the average value plus and minus one σ.

TABLE 2

RESIDENTIAL SOLID WASTE GENERATION

Lbs.Capita/Day

City		Residential Solid Waste
Niagara Falls, New York		2.70
Los Angeles, California		2.59
Philadelphia, Pennsylvania		2.10
New York City, New York		2.42
St. Petersburg, Florida		2.14
San Francisco, California		3.16
Miami, Florida		1.75
Wilton, Connecticut		2.40
Weston, Connecticut		2.10

	Avg.	2.37 Lbs./Capita/Day
	σ	.41

C. BREAKDOWN OF WASTE GENERATION DATA

If we subtract the residential figure of 2.4 lbs. per capita per day from the residential plus commercial figure of 3.8 lbs. per capita per day, we arrive at a commercial figure of 1.4 lbs. per capita per day. It was estimated that bulky combustible and non-combustible refuse amounts to approximately .3 lbs. per capita per day.

In addition, data presented in the Industrial Inventory section indicates that approximately 3.2 lbs. per capita per day are generated by industry. This was obtained by dividing the total industrial waste generated by 200 million people. The specific industries covered in this category are defined in the Industrial Inventory section, but do not include mining wastes, junked automobiles and solid wastes which are reclaimed and sold to others. The final breakdown of solid waste generated in a typical urban area is shown in Table 3.

TABLE 3

SOLID WASTE GENERATED IN URBAN AREAS

Lbs./Capita/Day

Residential	2.4
Commercial	1.4
Bulky Waste	.3
Subtotal	4.1
Industrial	3.2
Total	7.3

If we wish to arrive at a figure which when multiplied by the total population in the United States would yield a total solid waste generation figure for the United States, we would have to reduce the commercial figure of 1.4 to a lower number because certain non-urban areas do not generate large amounts of commercial waste. If we multiply the 1.4 figure by the percent urban population of 70%, we arrive at a weighted figure of approximately 1.0 lb. per capita per day. The weighted national figure would then look as shown in Table 4.

TABLE 4

SOLID WASTE GENERATED IN UNITED STATES

Lbs./Capita/Day

Residential	2.4
Commercial	1.0
Bulky Waste	.3
Subtotal	3.7
Industrial	3.2
Total	6.9

The figures of 6.9 and 7.3 given in Tables 3 and 4 are total generation figures. It is shown in the Industrial Inventory Study that approximately 55% of the industrial waste is disposed of by the industrial concern in its own site; the remaining 45% is handled by private contractors and disposed of in either private or municipal sites. Therefore, the amount of waste to be disposed of in urban areas in private and municipal sites would be

$$7.3 - 3.2 \ (.55) = 5.5 \text{ Lbs./Capita/Day}$$

The corresponding "national" figure is

$$6.9 - 3.2 \ (.55) = 5.1 \text{ Lbs./Capita/Day}$$

In summary, the total residential, commercial and industrial waste (as defined in this report) generated per day is approximately:

$$6.9 \times 200{,}000{,}000 = 1380 \text{ million pounds per day}$$

and approximately

$$5.1 \times 200{,}000{,}000 = 1020 \text{ million pounds per day}$$

must be disposed of by municipal and private contractor facilities. The balance is disposed in private industrial sites.

SECTION VII

SOLID WASTE DISPOSAL

At present, sanitary landfill is by far the most common method of solid waste disposal in cities from the size range of 25,000 population and over. Figure 1 indicates that 190 communities use incineration.

It is shown in Part 2 of this report that there are 75,000 tons/day of incineration capacity installed at the present time. If we assume an average utilization of 60% (see Figure 4), and an average solid waste generation figure of 5.1 pounds/capita/day (see Section VI), the average percentage of waste incinerated is obtained as follows:

$$\frac{75 \times 2 \times .60}{5.1 \times 200} \times 100 = 9 \text{ percent}$$

The percentage of waste reduced in composting plants is negligible. Therefore, 81% of this waste is disposed of in landfills.

Care must be exercised in interpreting what is meant by sanitary landfill. In a large percentage of cases in the fifty city interviews, although called a sanitary landfill, the area would not be acceptable under the HEW's accepted definition of the term.

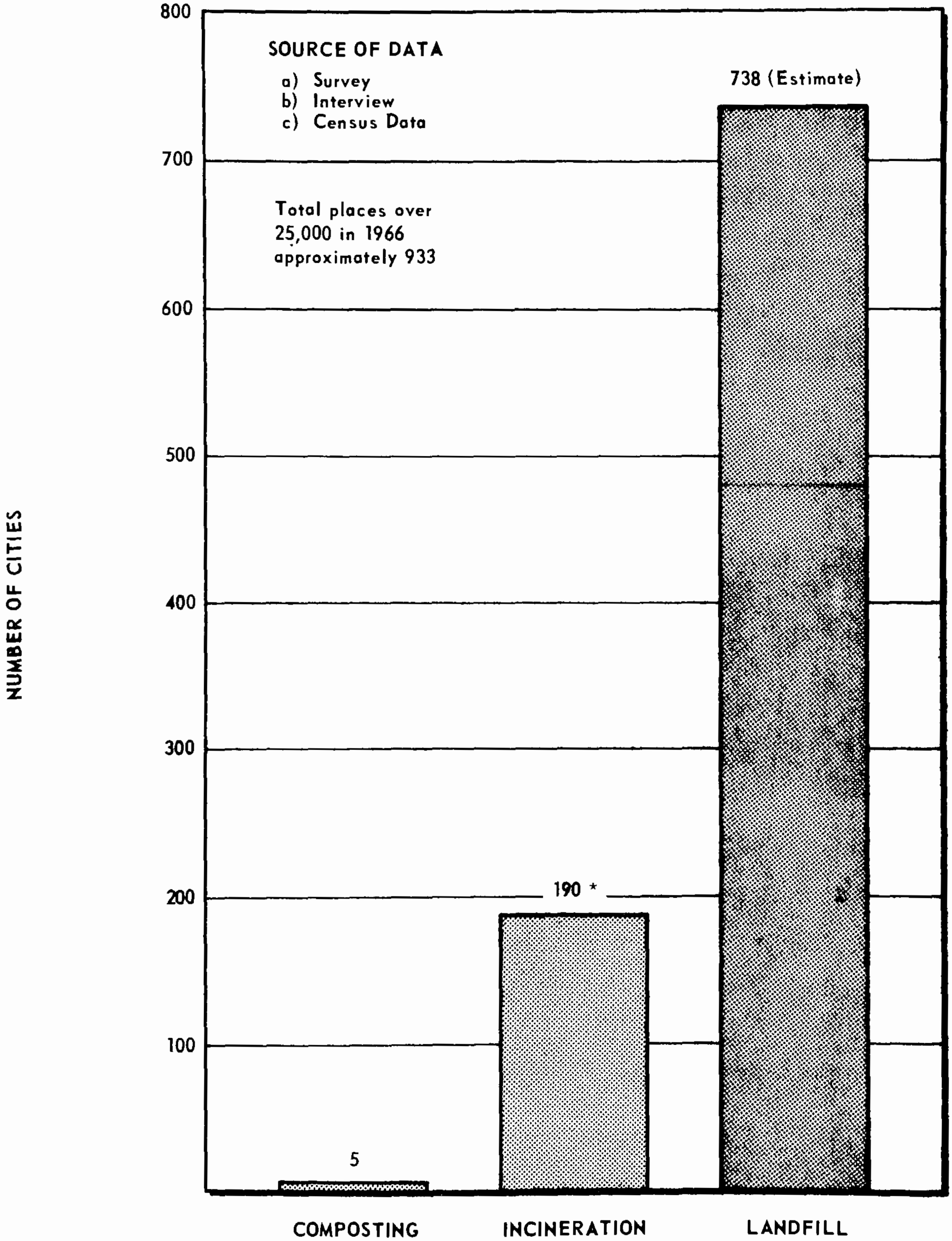
As previously discussed, disposal by landfill plays the most important part in national solid waste disposal practices. Consequently, it was determined that the number of years left in existing landfill sites and the distance one had to haul to these sites would be very significant. Figure 2, based on the total survey responses, shows that approximately one half of the communities using landfill have less than six years of life in their current sites and that they must either find other suitable landfill areas or change their method of waste disposal. Figure 3 illustrates that while in special cases long hauls are practical for the disposal of waste in landfill operations, approximately 50% of the communities haul less than five miles.

In Figures 4, 5 and 6, the cities (from fifty city interviews) have been classified by strata, with Strata A representing cities between 25,000 and 50,000; Strata B 50,000 to 100,000; Strata C 100,000 to 250,000; Strata D 250,000 to 500,000; Strata E 500,000 to 1,000,000 and Strata F over 1,000,000. This was done to see if there was any significance between the size of the town reporting and the kind of data it reported.

The figures show that there is a difference, with Figure 4 demonstrating that the smaller towns had more pounds per capita per day of installed incinerator capacity than did the larger communities, with Strata A showing 7.7 pounds per capita installed and Strata F showing 2.4 pounds per capita installed.

This does not mean that the larger communities incinerate a smaller percentage of their refuse. In fact, the reverse is true. The larger the

TYPE OF SOLID WASTE DISPOSAL
USED BY MUNICIPALITIES
OF OVER 25,000 POPULATION – 1966



* Some cities have more than one incinerator installed. There are a total of 250 incinerator plants in the U.S. Some incinerators handle refuse from several cities.

Figure 1

24185
LIBRARY
Environmental Control Administration
5555 Ridge Ave., Cincinnati, O. 45213

YEARS OF LIFE LEFT IN PRESENT LANDFILL SITE – 1966

Total Response – 397

Source of Data – Survey

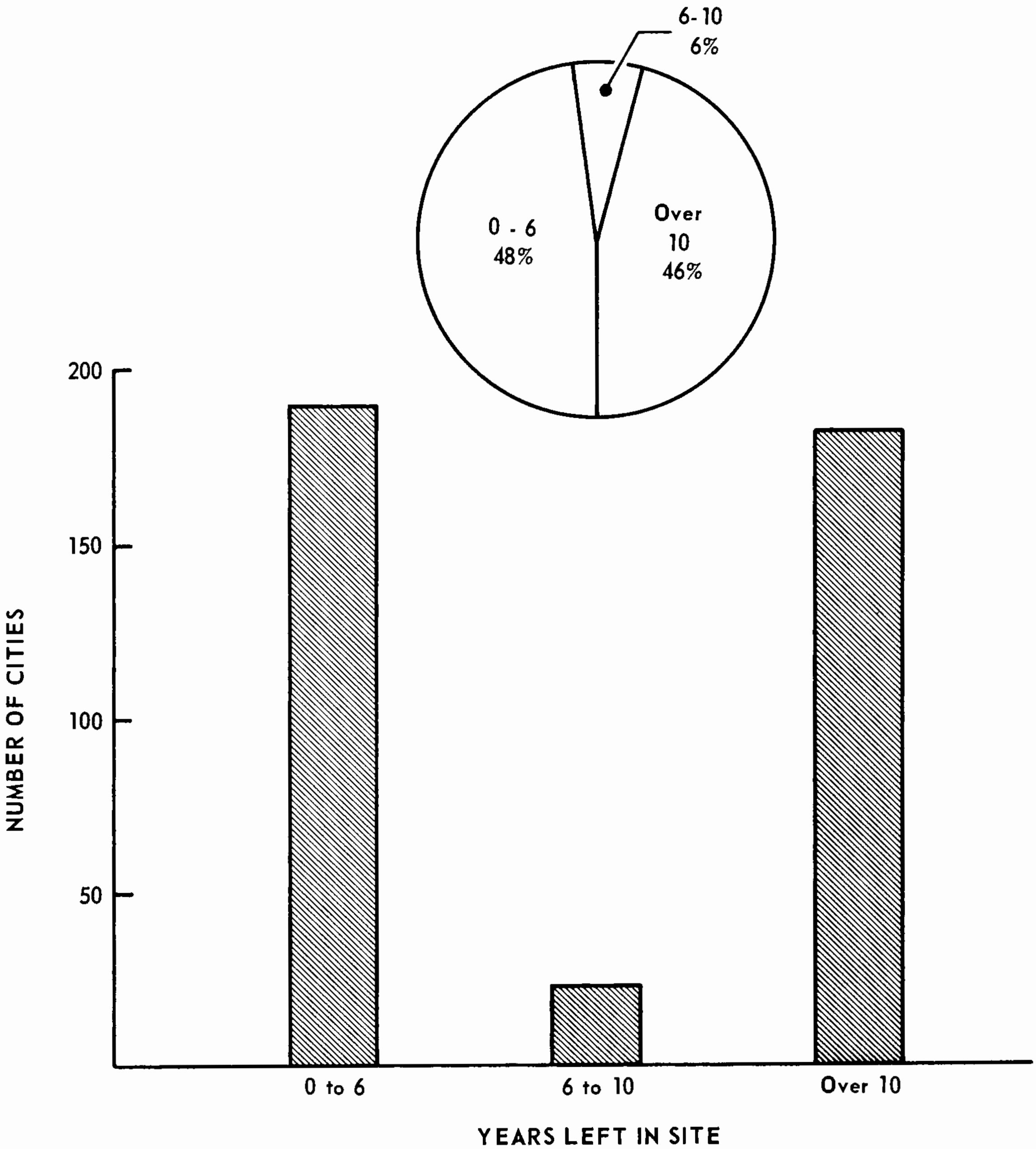


Figure 2

MILES TO DISPOSAL SITE – 1966

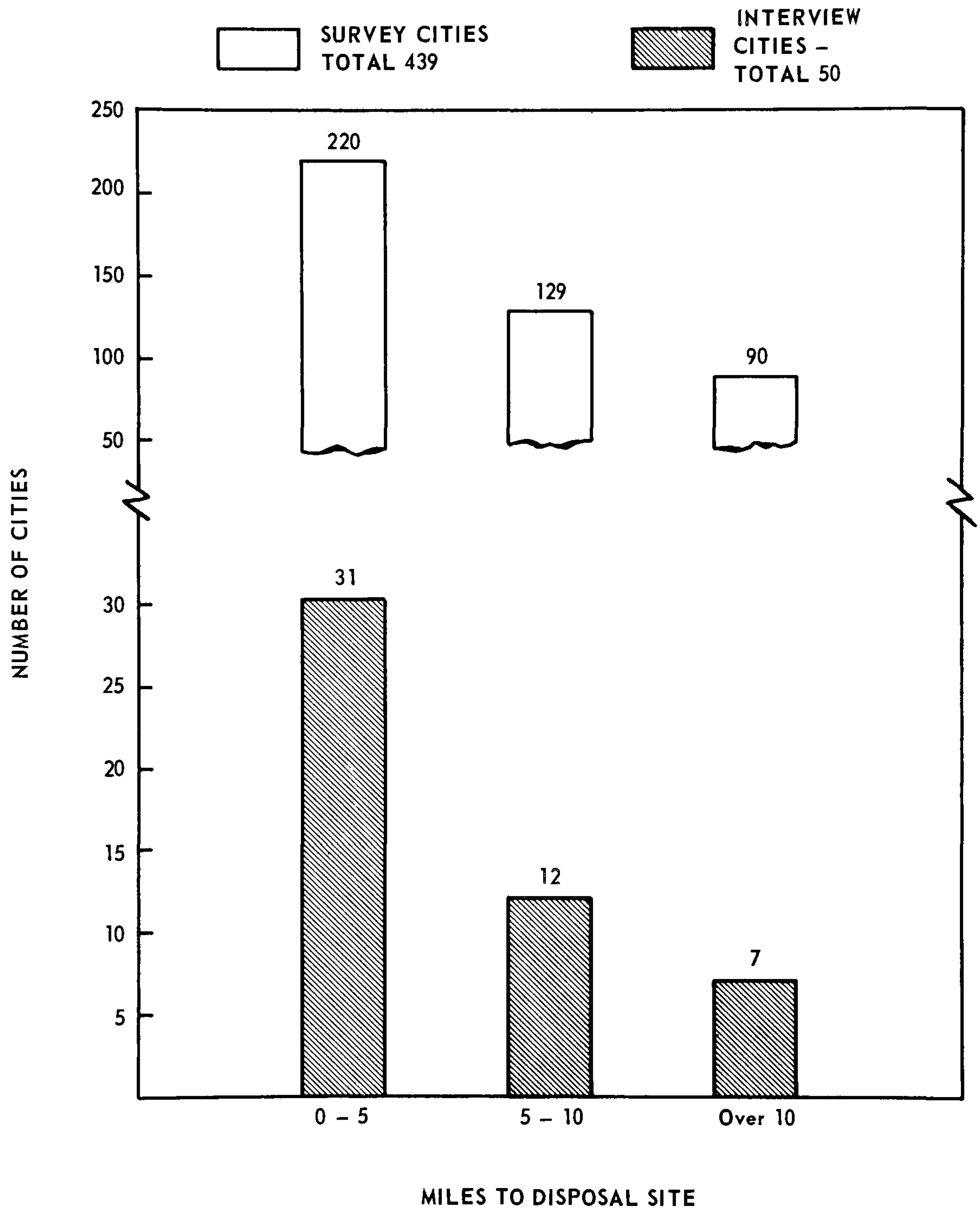


Figure 3

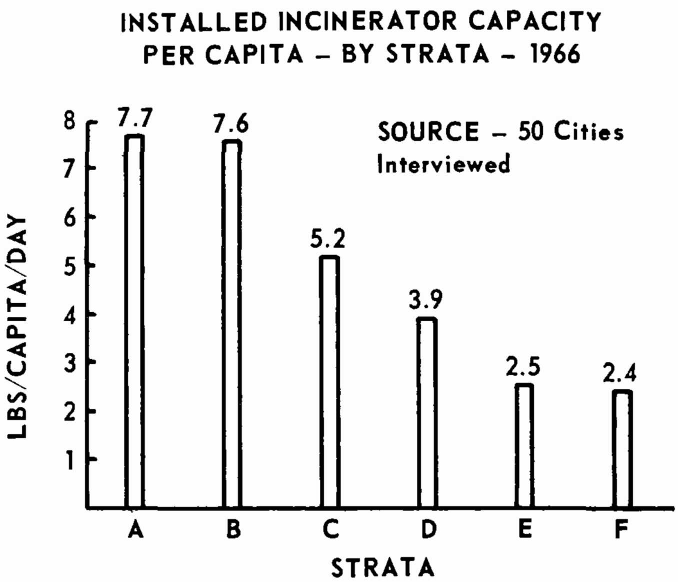


Figure 4

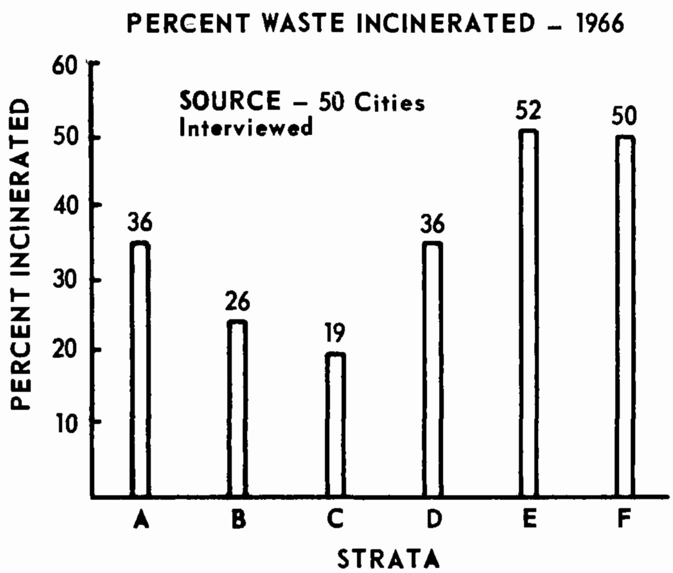


Figure 5

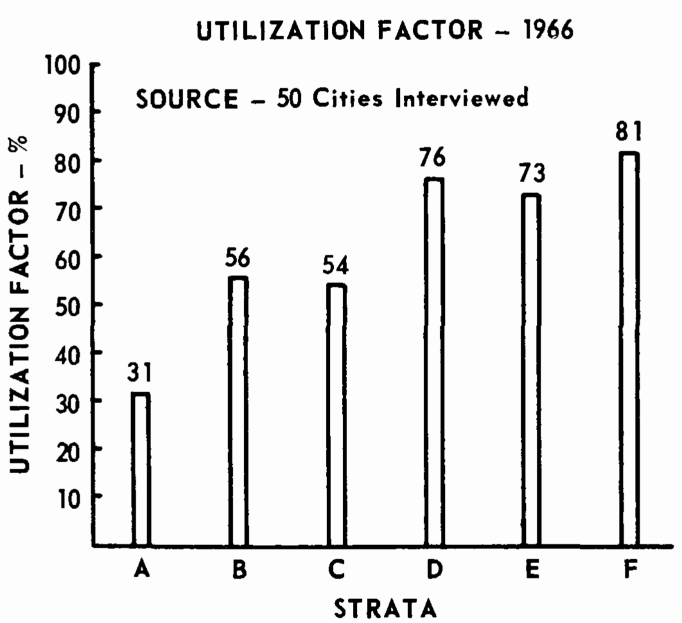


Figure 6

community, the larger the proportion of waste which is incinerated. The percentages shown in Figure 5 were determined from data obtained by personal interview of cognizant officials. Figure 6 shows that the larger cities utilize their incinerators to a greater extent than small cities. The utilization factor is calculated by dividing the number of hours the incinerator is operated by the total number of hours available in a seven day week. These high utilization factors are really close to 100% of available time since a large portion of the time remaining must be used for repairs and maintenance. Since the actual capacity of an incinerator can be significantly different from the "name plate" capacity (in this report all capacities are "name plate" capacities), and since the percent incinerated is an approximate value, the data shown in Figures 4, 5 and 6 should only be used to indicate qualitative trends. It should be noted that the data shown in the figures was obtained from 35 of the 50 cities which had incinerators.

Figure 7 presents the variation of average age of the incinerator with strata, and indicates that the larger cities have the oldest incinerators which may have to be replaced within the next ten year period. In addition, the larger cities, because they have high utilization factors, will require new incinerator capacity during this same period.

AVERAGE AGE OF INCINERATOR
FOR DIFFERENT STRATA – 1966

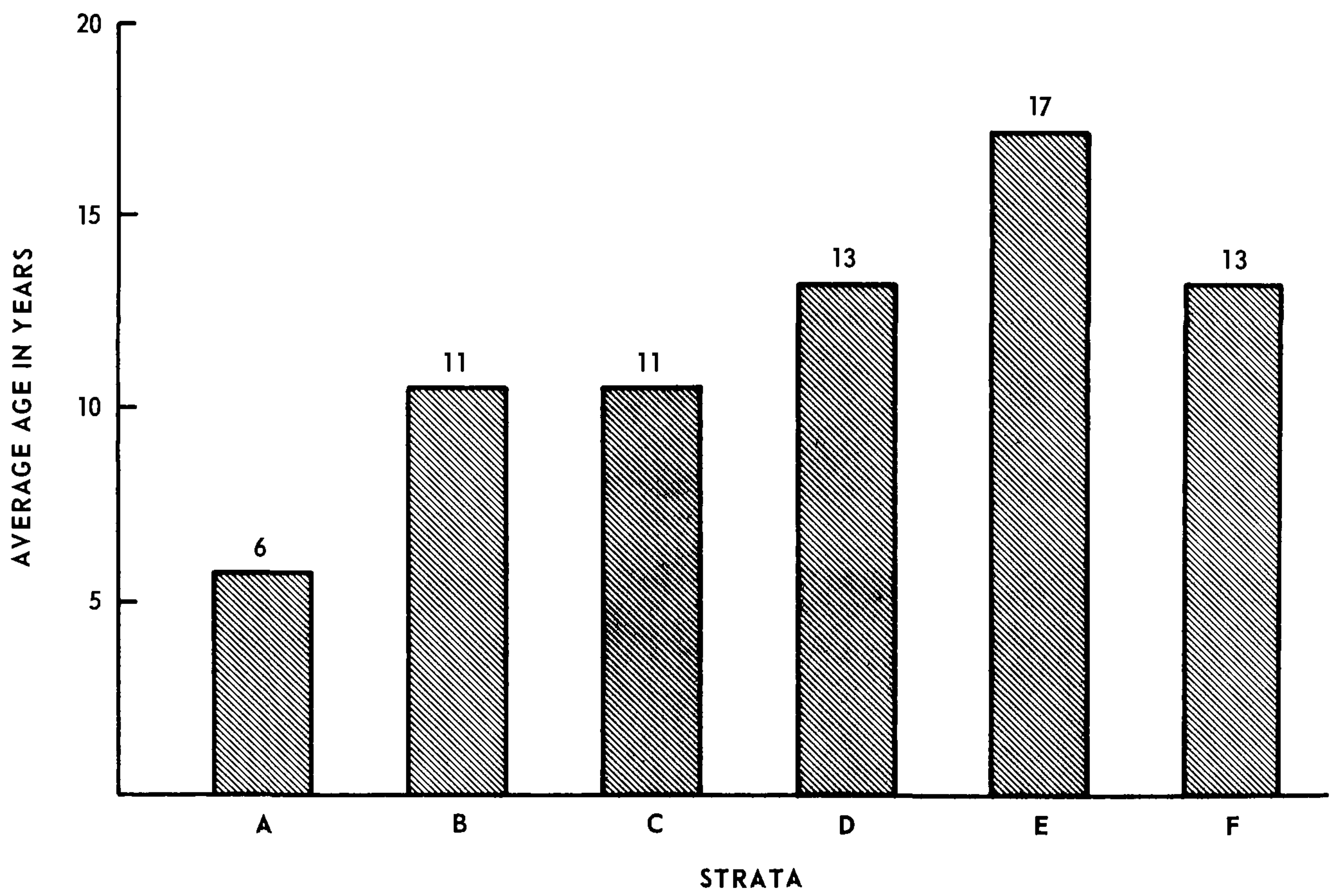


Figure 7

SECTION VIII

PLANNING GAP

Figure 8 indicates that a "planning gap" exists. This "planning gap" is defined as the additional amount of waste disposal facilities required (over and above that which is planned to be added) to handle the municipal solid waste streams. For example, in 1975, the thirty-five cities will have 42,000 tons per day of installed capacity in operation and approximately 20,000 tons per day of other capacity such as landfill. However, this total refuse stream will be 75,000 tons per day leaving a facilities planning gap of 13,000 tons per day.

The following assumptions were used in Figure 8.

1. The capacity in tons per day of refuse disposal facilities of any kind will remain constant for the life of that facility.

2. If the population increased between 1950 and 1960, the population will continue to increase at the same rate.

3. If the population decreased between 1950 and 1960, it will not decrease further, but will remain at the 1960 level.

4. The municipal refuse per capita was assumed to be 4.1 pounds per day and to increase at the rate of 2.5% per year. The figure of 2.5% per year increase was generated by averaging historical data obtained in several communities which had better than average historical records. A specific locality's growth rate may vary in some degree from this average figure.

5. Any community planning specific tonnages of increased capacity of any kind will have them in operation by 1975.

6. Any installation made prior to 1950 will not be in operation by 1975.

7. Any community which indicated a facility to be closed prior to 1975 that also indicated planning of a future facility would have a sufficient capacity in that site to deal with the waste disposal requirement in the year 1975. If a city did not so indicate, it was assumed they would not have the capacity.

Figure 9 breaks this total picture down into strata. For example, in the year 1975, with current planning, Strata F will have only 62% of the total capacity needed; Strata E will only have 75% of the total capacity needed; only Strata A will have excess capacity.

It is noted that only 28% of the fifty communities have planning bodies to cope with the solid waste problem; although the data indicates a great desire on the part of the municipal civil servants to participate in planning to alleviate this large problem. A further complication already

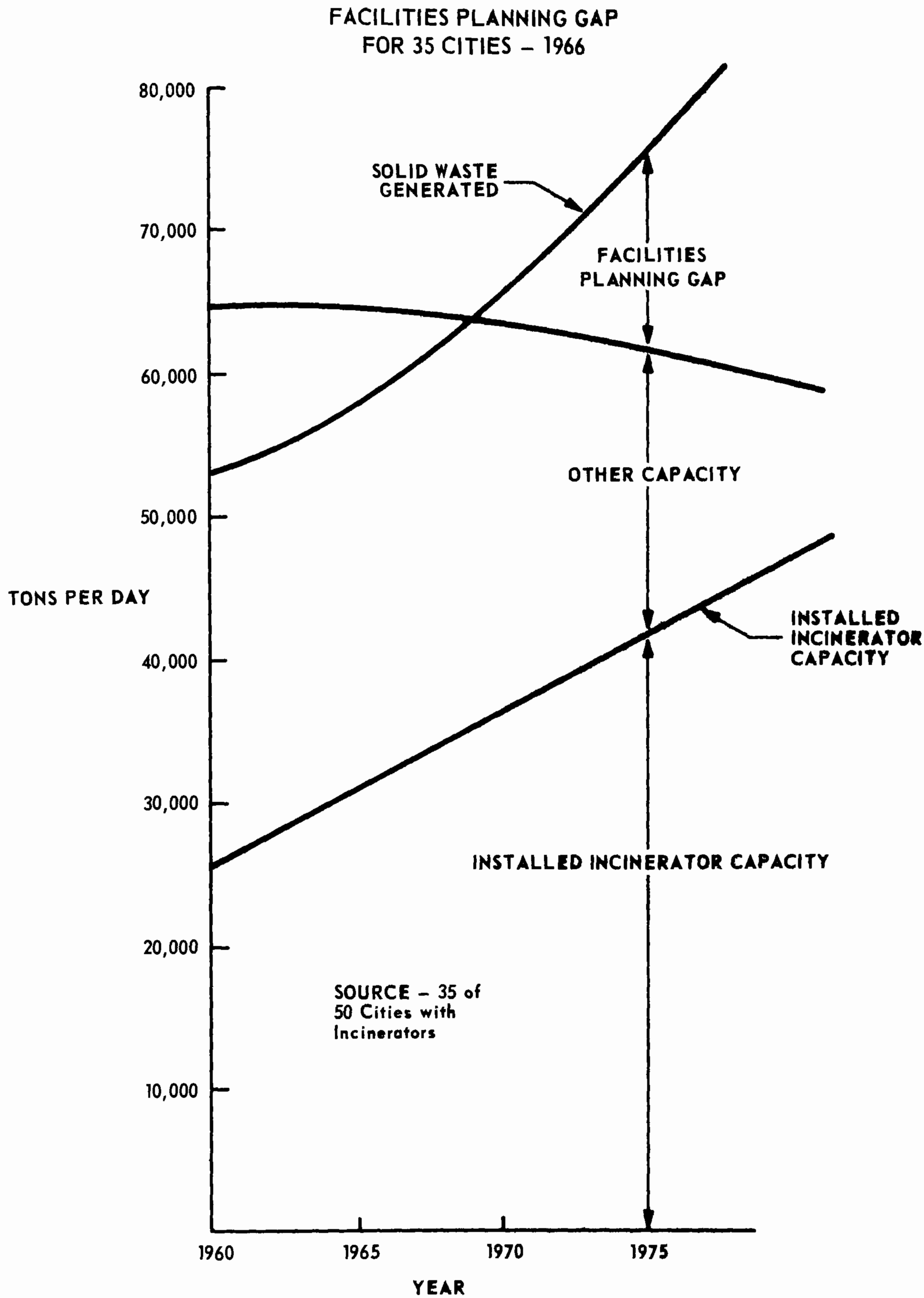

FACILITIES PLANNING GAP
FOR 35 CITIES – 1966
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
TONS PER DAY
SOLID WASTE
GENERATED
FACILITIES
PLANNING GAP
OTHER CAPACITY
INSTALLED
INCINERATOR
CAPACITY
INSTALLED INCINERATOR CAPACITY
SOURCE – 35 of
50 Cities with
Incinerators
1960
1965
1970
1975
YEAR

Figure 8

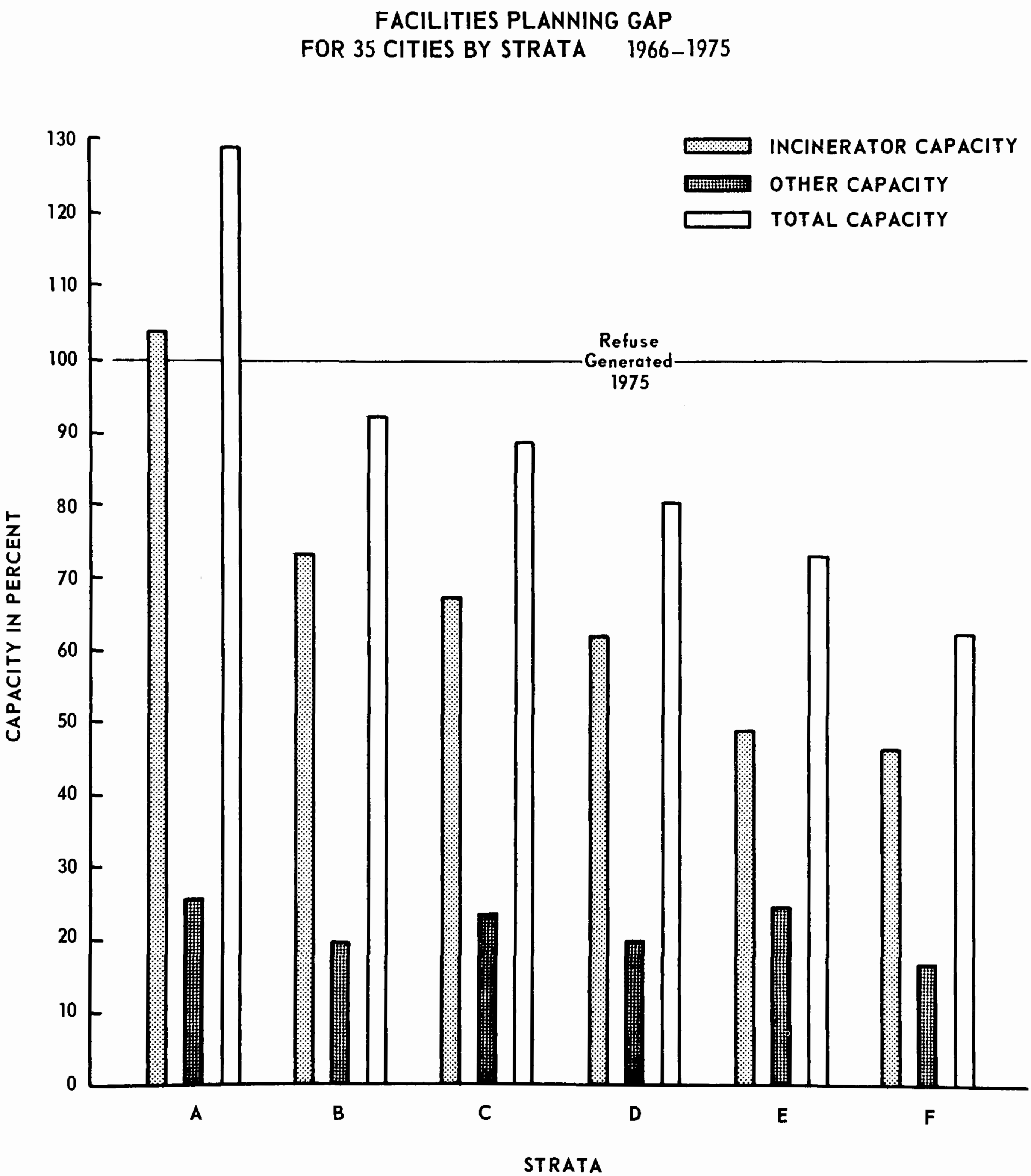

FACILITIES PLANNING GAP
FOR 35 CITIES BY STRATA 1966–1975
INCINERATOR CAPACITY
OTHER CAPACITY
TOTAL CAPACITY
CAPACITY IN PERCENT
0
10
20
30
40
50
60
70
80
90
100
110
120
130
Refuse
Generated
1975
A
B
C
D
E
F
STRATA

Figure 9

briefly mentioned is that nearly one half of the communities interviewed indicated that they will not handle any more industrial waste in the future. Yet, as the country continues to grow, industrial solid waste will grow and if the municipalities do not arrange for the handling of this material, industry must dispose of it. The magnitude of this problem will be discussed in more detail in the industrial inventory section of this study.

Throughout our interviews it was noted that a considerable awareness of the problems associated with solid waste disposal existed in the minds of the civil servants who were directly charged with the responsibilities in this area. Unfortunately, they also exhibited almost unanimously, a lack of confidence in the political bodies who were charged with the future planning and made comments such as -- "The only time we can get the Council to do any planning is when the problem is so big that even a blind voter could see it, and then it is too late".

In fact, we have already noted that a desire exists among civil servants, to form regional authorities to cope with these problems. Even though this feeling is expressed, however, in all of the cities interviewed we did not encounter either a municipality which had participated in a regional authority and had resigned from it or a municipality currently participating in an acting regional authority, although some were in the planning stages. In short, while everybody expresses the belief that regionalization would help, few, if any, are acting on this belief. There are, of course, certain notable exceptions, some of which are the Detroit region and Dade and Broward counties in Florida. The apparent obstacle in regionalization is the fear on the part of one political entity that it will surrender its authority to another political entity upon joining a region. For example, a small town does not want to feel that it will be swallowed by a large core city. This situation is further complicated by the fact that often the administration of the "core" city is one political party and the surrounding towns are of another political party. The natural dislike of having someone else's garbage in your town is, therefore, compounded by the political difference of the communities involved.

The very structure and traditions of the state's governmental organization may further hinder regionalization, particularly in those states such as the New England states where strong town governments exist at the expense of relatively weak county or larger regional organizations.

If the political facts of life do not allow for local regional planning, other alternatives may have to be sought. One of them could be state or federal regional planning bodies. Another solution might be private contractors who would, in effect, operate on a regional basis with the aid of state or federal planning bodies.

While the regionalization and planning picture is not as bright as it could be, continuing work is going on in the hope of improving all aspects of solid waste collection and disposal. Much of this work is sponsored by the Public Health Service and a substantial portion is being carried on by private industry with private funds.

SECTION IX

CENTRAL CITIES AND SATELLITE TOWNS

The following cities were interviewed in depth:

Baltimore, Maryland
Houston, Texas
Jersey City, New Jersey
Norwalk, Connecticut
Rome, New York

These cities have adequate records, incinerators (Baltimore, Houston, Jersey City and Norwalk), composting plants (Houston), landfill (Rome) and have various amounts of cross-flow between the central or core city to the satellite towns.

The trip reports which are presented in Appendices D, E, F, G, and H give a comprehensive view of the wide spectrum of solid waste problems facing the nation, and the various ways in which communities are solving them.

A summary of the five in-depth studies is presented in the following sections.

A. ORGANIZATION FOR DECISION

In all of the communities interviewed (with one minor variation) the political organization for decision regarding solid waste problems was similar. Essentially, the political organization consisted of an elected official commonly called the Mayor and a body of elected representatives called a Council, Board of Aldermen or Board of Supervisors.

Decisions as to changes, additions, expansion or contraction of solid waste disposal facilities had to be made by common agreement between the Mayor and supporting elected body. In practical application, it was determined that the individual in charge of solid waste (sometimes called Commissioner of Sanitation or Public Works) analyzed the specific municipality's needs and made recommendations to the Mayor based on engineering analyses. The Mayor then requested the funds as needed after modification of the engineering plans to conform to the political climate and pressures of the time. The elected body of city fathers then further modified the request, in so far as it was possible, to conform to the special interests of their constituents.

In one case, a third body, called the Board of Estimates, also reviewed request for expenditure of this nature. In another case, an "incinerator authority" was set up as a separate entity.

RECORDING OF DATA - MUNICIPALITIES

The degree of availability of recorded data was different from community to community. In those communities where there as yet was not a real problem in terms of unavailable land or high expense, records were often non-existent, at the worst consisting of the estimate of the man in charge of the disposal site as to quantity per week and at the best consisting of a daily weight of material processed through the waste reduction facility. Historical records were even more difficult to come by in the smaller communities, again reflecting a lack of interest or need of this type of data in the community at the present time. In general, the larger the community, the more sophisticated the records. Even in the best case, however, it was frankly admitted that some of the records would be inaccurate for several reasons including political favor for certain contractors using the facility to lack of attention to record keeping on anything other than a sampling basis. The best records were kept by those communities who charged for the use of their facility and had the most severe solid waste problems.

C. RECORDING OF DATA - INDUSTRY

It was found that industry was well informed in the main concerning its solid waste practices. In most cases, industry has to hire solid waste disposal contractors and this item of expense is large enough so that attention is paid to quantities of waste and historical trends. This does not mean that this information was always available. In some instances, industries were uncommunicative because of their fear of costly regulation or competitive knowledge that might be revealed by their waste figures.

The accuracy of the records, when the records were furnished, sometimes depended on the ability of the man in charge to estimate volume or weight of solid waste accumulations. However, in the larger industries, reasonably accurate records were found again because of the expense connected with the solid waste disposal problem.

D. RECORDING OF DATA - PRIVATE CONTRACTOR

These were by far the most difficult records to obtain. The private contracting business is very competitive and private contractors were hesitant to release information as to their volume of business because they felt their competitors would gain valuable commercial knowledge. Those contractors who were willing to talk were often hazy in their record keeping because of little need to have this information for their day-to-day business. The staff of the "Refuse Removal Journal" has been active in helping obtain the best figures available.

E. PERFORMANCE OF FACILITIES - SANITARY LAND FILL

Only one community had sanitary landfill operations that would probably meet the standards proposed by the Department of Health, Education and Welfare. In most cases, the landfill was far from sanitary. Very often open burning was taking place in these sites and in all cases, loose trash was free to blow about the area. There would be no problem for insects and rodents to thrive in any of these areas. In the one community which has a good procedure for sanitary landfill, other facilities exist which are not run properly -- some municipally operated and some privately operated.

F. PERFORMANCE OF FACILITIES - INCINERATION

In those communities using incineration, reduction of volume of solid waste disposed of in this fashion is acceptable. The burn-out of the ash, however, varies from very good to very poor. In the former case, a clean ash is observed with minute amounts of unburned material noted. In the latter case, whole sheets of newspapers, orange peels, etc. were noted in the incinerator residue in an unburned condition.

None of the incinerators had the more sophisticated air pollution devices and in one community during a temperature inversion, it was noted that an area surrounding the incinerator within a four mile radius was hazy with incinerator smoke and smelled of partially burned trash. Only one incinerator was cleaning its quench water of all putrescible matter by virtue of pumping this water to a nearby sewage plant for normal sewage treatment. The other incinerators were discharging their quench water directly, or after lagooning, to a stream and there is a possibility that some putrescible matter is finding its way into these streams.

G. ROLES OF THE MUNICIPALITY AND PRIVATE CONTRACTOR

In general, the municipal facilities for waste disposal are reserved for residential solid waste. However, some municipalities, either for a fee or free, process both commercial and industrial solid waste. In most communities, however, the commercial and industrial sources of solid waste must find other means of disposal.

A few industries chose to dispose of their waste on their own land or with their own waste reduction equipment. A large number, however, use the alternative of contracting with a private concern to remove the waste from their premises. These private contractors in many communities also service some residences. Many of the private contractors use private dump sites. Others use the municipal facility. If use of the municipal facility is permitted, the private contractor chooses the most economic disposal method.

In general, both the civil servants involved in the solid waste operations and the private contractors are knowledgeable, concerned people who are able to discuss intelligently their operations and problems. In fact, it can be said that in most cases, the private contractor is performing a service to the community without which the community would be unable to function. This is particularly true in the larger communities where land is at a premium. Very often the private contractor removes significant amounts of solid waste to areas outside the community. In this case, the private contractor is able to cross political boundaries while the core city itself would have difficulty in so doing.

H. CROSS-FLOW OF WASTE BETWEEN COMMUNITIES

The smaller communities apparently have little cross-flow of solid waste. What little there is is generally outward from the core city into the surrounding and more sparsely settled satellite towns. This is generally borne by private contracting vehicles. In the larger communities, however, the cross-flow of solid waste is either incinerated residue or unprocessed refuse. Direction of flow is universally out from the core city which has the most problems in terms of available land and in the main is carried by the private contractor because of his ability to cross political boundaries. Character of the waste is generally industrial and commercial primarily as most communities have some way to take care of the household waste generated by the taxpayers within their own boundaries. In several of the larger cities, however, this latter case is not necessarily a situation which will continue to exist as available land for non-combustibles and incinerator residue is fast being depleted.

I. INDUSTRIAL WASTE STREAM

The industrial waste stream is discussed in another section of this report. It is enough to say here that significant quantities of industrial waste exist in any industrialized community. Generally speaking, industry is willing to discuss this problem and has reasonably good records. Those industries which refuse to discuss the problem either were sensitive because of competitive information which might leak out by virtue of competitors knowing their solid waste stream or were afraid of expensive equipment necessitated by regulatory action similar to what is being encountered in the field of air and water pollution control.

J. UNOBTAINABLE INFORMATION

Under the sub-title "Recording of Data" we have discussed certain inaccuracies which may exist in the records which would contribute to the inaccuracy of any figures generated in this report. In addition, there are other gaps in the information which the scope of this contract does not permit us to fill. In spite of the best efforts of research, the role of private contractors is not completely defined. This is particularly true with regard to total tonnage collected and the breakdown of that tonnage into residential, commercial and industrial sources. In addition, there is lack of information about self-disposal which in many communities is significant. Other waste streams such as automobile hulks were beyond the scope of the contract. In addition, in the case where a community had an incinerator, bulky non-combustibles often went directly to the residue site in undetermined tonnage.

K. PLANNING

The preceding discussion would indicate that planning is needed, yet little is being done on a metropolitan area basis at the moment. Individual communities from time to time are encountered which have made an attempt to plan for the future, but little effective regional planning has been encountered.

In one area, the core city expects to run out of available land for residue in about five years. One satellite community is spending thousands of dollars per year in tolls to transport wastes and a neighboring community with thousands of acres of available land cannot be interested in joining a joint effort to attack the problem.

Many reasons are given for this, but it can be speculated that the underlying difficulty rests in fear of political dominance by the large core city and the emotional reaction against someone else's garbage in the local community.

One large community has had significant strides in the planning area forced on them by a crisis situation of their existing facilities. The plans are sophisticated and detailed, but again are not regional in scope.

SECTION X

REFERENCES

1. Stephenson, J. W. and A. S. Cafiero. Municipal Incinerator Design Practices and Trends. Proceedings of 1966 National Incinerator Conference. May 1966.

SECTION XI

APPENDIX A

WESTERN UNION QUESTIONNAIRE

1. What method is now used for the disposal of your municipal refuse at the present time?

a. Open dumping	___	e. Incineration	___
b. Open burning	___	f. Feed garbage to hogs	___
c. Sanitary landfill	___	g. Other (state)	___
d. Composting	___		___

2. If you dispose of the refuse by open dumping, open burning or sanitary landfill, what is the hauling distance from the center of the city to the disposal site?

   ________ miles

3. How long will you be able to use the present site?

   ________ years

4. If you dispose of the refuse by either incineration or composting, what is the total capacity of your facility on a 24 hour/day basis?

   ________ tons per 24 hour day

5. What percent of your refuse do you incinerate or compost?

   ________ %

6. When was your incinerator or composting plant installed?

   ________ year

7. How many hours per week is each incinerator operated?

   ________ hours per week

8. How many incinerators or composting plants, and of what size do you intend to install in the next two years?

   Size ________ tons per day

SECTION XI

APPENDIX B

SELECTION OF FIFTY CITIES FOR INTERVIEW

The primary objective was to select cities at random with waste reduction facilities. It was also desired to visit some cities with landfill, composting and mechanical compaction operations. The total number of cities surveyed was divided into strata according to population size as follows:

Strata A	25,000 - 50,000	population
Strata B	50,000 - 100,000	population
Strata C	100,000 - 250,000	population
Strata D	250,000 - 500,000	population
Strata E	500,000 - 1,000,000	population
Strata F	Over 1,000,000	population

From each strata, cities were selected for personal interview. For example, it was determined that we would visit fifteen cities in population Strata A. Five of the fifteen were chosen because they had landfill and composting operations. The remaining ten were chosen from the twenty-seven cities in the size range which the incinerator plant summary, given in Reference 1, indicated had incinerators. The sample was obtained by numbering the cities from one to twenty-seven in order as they appeared in the incinerator plant summary and selecting the ten by using a table of random numbers from that group.

Because of shifts in population from 1960, it was eventually determined that a total of sixteen cities fell in population Strata A. The following list of cities is segregated by population strata. Those cities which do not have an asterisk were chosen specifically to visit landfill and composting operations. Those cities with an asterisk were chosen by the random number method from the "ASME Proceedings of the 1966 Incinerator Conference" as described in the example above. The three cities with a double asterisk, enumerated in population Strata A, were chosen because they had either composting equipment and fell below the population strata of 25,000 or in the case of North Tonawanda, New York because it had a mechanical compactor and was in the 25,000 to 50,000 population range.

STRATA A:

Burlingame, California
** San Fernando, California
* Middletown, Connecticut
* Stratford, Connecticut
* West Haven, Connecticut
* Clearwater, Florida
** Largo, Florida
Highland Park, Illinois
* Bloomington, Indiana
* Framingham, Massachusetts
Mount Clemens, Michigan
Clarksdale, Mississippi
Farmington, New Mexico
* Hempstead, New York
** North Tonawanda, New York
* South Euclid, Ohio
* Abington, Pennsylvania
* Woonsocket, Rhode Island

STRATA B:

* Norwalk, Connecticut
* Pittsfield, Massachusetts
Rome, New York
* Euclid, Ohio
Altoona, Pennsylvania
* Alexandria, Virginia
* Charleston, West Virginia

STRATA C:

* Glendale, California
* Bridgeport, Connecticut
St. Petersburg, Florida
Camden, New Jersey
* Niagara Falls, New York
* Youngstown, Ohio
* Portsmouth, Virginia

STRATA D:

* Miami, Florida
* Atlanta, Georgia
* Indianapolis, Indiana
* Jersey City, New Jersey
* Norfolk, Virginia

STRATA E:

San Francisco, California
* Boston, Massachusetts
* Baltimore, Maryland
* Buffalo, New York
* Cleveland, Ohio
Pittsburgh, Pennsylvania
* Houston, Texas
Seattle, Washington
* Milwaukee, Wisconsin

STRATA F:

* Los Angeles, California
* Chicago, Illinois
* New York, New York
* Philadelphia, Pennsylvania

SECTION XI

APPENDIX C

H.E.W. INTERVIEWERS CHECK LIST OF QUESTIONS

* Questions will not be answered at the interview, but will be researched and recorded with interview information.

A. Western Union Survey - Validating Questions

1. What method is now used for the disposal of your municipal refuse at the present time? Check one:

   a. Open dumping ___
   b. Open burning ___
   c. Sanitary landfill ___
   d. Composting ___
   e. Incineration ___
   f. Feed garbage to hogs ___
   g. Other (state) __________
   ____

2. If you dispose of the refuse by open dumping, open burning or sanitary landfill, what is the hauling distance from the center of the city to the disposal site?

   __________ miles

3. How long will you be able to use the present site?

   __________ years

4. If you dispose of the refuse by either incineration or composting, what is the total capacity of your facility on a 24 hour/day basis?

   __________ tons per 24 hour day

5. What percent of your refuse do you incinerate or compost?

   __________ %

6. When was your incinerator or composting plant installed?

   __________ year

7. How many hours per week is each incinerator operated?

   __________ hours per week

8. How many incinerators or composting plants, and of what size do you intend to install in the next two years?

Size __________ tons per day

B. Mathematical Model Data Questions

1. Please complete the following table using date intervals as available from records kept by the community.

Dates	19__	19__	19__	19__
Tons per day in waste reduction facility				
Tons per day in other disposal facilities				

2. What percent of the total waste per day is municipal? __________%, industrial? ________%

3. What are the industrial wastes?

* 4. Population

Year						
Population						

5. Is it more difficult to find vacant land for location of waste disposal facilities?

6. Has the vacant land accessible to your community been materially reduced in recent years?

7. Will it be reduced in the next five years?

8. Would you please locate your facilities on this local map?

* 9. What figures are available concerning increase in wealth of the community?

10. Do you think your municipal facilities will handle more or less industrial waste in the future?

11. Do you have plans for joining with other communities to jointly solve your solid waste disposal problems?

12. Request a map showing collection or hauling routes with respect to location of waste reduction or disposal facilities.

C. <u>Technological - Economic Study Questions</u>

1. What are the operating costs of your facility?

2. What factors do you include in operating costs:

   Labor
   Depreciation
   Utilities
   Overhead
   Other

3. What improvements to your present installation are desired (required) to meet pollution standards -- i.e., scrubbers, precipitators, etc.?

4. What improvements to your present installation to lower operating costs are desired?

5. What operating standards would you want a new facility to meet with regard to pollution standards? Operating costs?

6. What was the installed date and cost of your facility?

7. Who was the design engineer of the facility?

8. Which manufacturers produced the components of the facility?

D. <u>Sampling System Questions</u>

1. Does your community, county or state have a solid waste planning commission? Do you currently plan to join any community to help with your mutual problems?

2. If a regional service of some kind were established to assist your community in planning, would you use it?

3. If you would use it, what kind of information would you like to receive? i.e., trends, kinds of refuse produced, change in type of refuse, projections when new facility needed, etc.

4. Would you be willing to submit periodic reports to the regional service and allow periodic visits by its survey teams?

5. If the regional service made recommendations for changes in your operations, would you follow them?

6. Would you be willing to participate in a pilot program of this nature?

7. What type of information do you have available on the different classes of refuse collected?

8. Does the classification vary depending on the area from which it is collected?

9. Is the information based on observation or do you actually sort the refuse and sample it? What equipment do you use for sampling?

E. Questions to Aid in Selecting Ten Metropolitan Areas

1. What type of records do you keep pertaining to your solid waste operations? e.g., tons per day handled, operating costs, number of complaints received, change in make-up of refuse, etc.

2. Have any studies been conducted of your communities and/or surrounding regions?

3. Do you have knowledge of industrial and municipal interaction of solid waste streams and facilities?

4. What information do you have on the significance of apartment house refuse to your total solid waste stream?

5. What is the average number of men employed full time in your collection, waste reduction, and/or landfill operation?

__________ men

F. Questions to Combine with the Above to Further Point Out Areas for Beneficial Research

1. When your present facilities are exhausted, how far will it be to the next site?

2. Are your present facility's surroundings industrial, commercial, or residential?

3. What acreage is allotted to your facility?

4. Do you have an abandoned solid waste facility?

5. If so, when was it abandoned, and why?

SECTION XI

APPENDIX D

BALTIMORE, MARYLAND

The metropolitan area of Baltimore was analyzed by personal interviews of cognizant people in the core city of Baltimore. A large private contractor in the area who operates in all three Governmental units was also interviewed. In addition, ten industries were contacted with varying degrees of success. The data obtained was analyzed to determine interaction of waste streams between the communities, and the amount per capita contributed by each segment of the metropolitan area such as residential, commercial and industrial sources. Historical trends were noted insofar as historical data was obtainable.

A. DISCUSSION OF THE DATA

It was determined that there is a significant flow of solid waste from the core city into the satellite communities and counties. This flow of waste is primarily commercial and industrial material which is handled by private contractors and deposited in private land fills outside of the core city boundaries. The figures for 1965 show approximately 2.4 pounds per capita of material flowing out from the core city to the surrounding areas. This figure has been increasing materially as the industrial development of the area continues. The residential solid waste is 2.8 pounds per capita per day, plus .4 pounds of bulky refuse. In 1960 the residential figure was 2.2 pounds per person per day. Baltimore city operates two incinerators, the old one which was constructed in 1933 has a capacity of 600 tons per day. This incinerator operates approximately 93% of the time available in a week, as does the new incinerator. The operating cost is $3.75 per ton, but this figure only includes its labor, utilities, etc., and does not include amortization, replacement reserves, or anything of that nature. The new incinerator was built in 1955 at a cost of $2,193,000. It has a capacity of 800 tons per day and an operating cost of $3.60 per ton. The primary reason for the city of Baltimore choosing incineration as a method of solid waste disposal was a lack of economical land. While there is still considerable vacant land in the Baltimore city area, there is simply no economically usable land available. The price per acre is very high, and the zoning restrictions are very tight for both residential and industrial land. Most of the available land is used for residential and commercial buildings.

There is very little self-disposal in the city of Baltimore. High-rise apartment buildings, however, do have incinerators. Approximately 35% operate in this fashion, the balance of the apartment houses use private contractors to collect the solid waste.

Water quenching is used for the ash, but it goes to the regular sewer and is treated as sewage would be treated and consequently, probably does not pollute surrounding natural waters.

Currently, the Baltimore city operation has a landfill within its boundaries where it takes non-combustible solid waste and incinerator residue. There is a maximum of five years left in this site at present rates of usage. Should the tempo of solid waste generation increase, the time left in the site will be reduced.

Adjoining Baltimore city to the north is Baltimore County, a completely separate Governmental body. Baltimore County is producing 3.1 pounds per capita per day of which 2.2 pounds per capita are residential solid waste. Another .7 pounds of commercial waste brings the value to 2.9 pounds per capita. Baltimore County used sanitary landfill as a method of solid waste disposal. It is currently operating three sites. At this time, no commercial or industrial material is permitted in the Baltimore County site. While there are literally thousands of acres available for land fill operation, the expense of land makes incineration very attractive to the sanitation officials, and they are seriously considering incineration at this time. The expense of the land today is $6,800 to $10,000 an acre for residential land, and as high as $2,500 per acre for swamp land.

At present, the Baltimore County authorities have closed one of their landfills because of capacity difficulties. They have been operating for the last several years by trucking the material through the harbor tunnel at a cost of $90,000 per year in tolls alone, and yet this operation is more economical than developing another landfill site with the cost of land and expense of condemnation proceedings, court fights, etc.

Twenty-five percent of the homes in Baltimore County probably use garbage disposal grinders. In addition, there is some private dumping by the more rural population. The Baltimore County authorities are very interested in a regional authority which would build new incinerators and make use of existing land for residue and non-combustible disposal. The authorities hope to combine with the authorities in Baltimore city and Anne Arundel County. The satellite area of Anne Arundel County excluding Annapolis, which has its own organization, is one of the fastest growing counties in the country. Currently, 55,000 homes are serviced by private contractors who receive their contracts from the county authorities. Another 15,000 homes are rural in nature and dispose of solid waste on their own property in their own fashion. The entire residential and industrial and commercial solid waste of the Anne Arundel County goes to private landfill. There is no municipal landfill at this time. Incineration or even county-operated landfill is not attractive to the Anne Arundel authorities at this time because they are purchasing private contractor service for their citizens at the rate of 15¢ per pick-up.

Throughout the county exists vacant land in the amount of approximately 100,000 acres. This land at this time is mostly unzoned and varies from swamp and ravine type to prime building land. The vacant land throughout the county is increasing in value rapidly because of the county's growth. The present calculated pounds per capita generation of residences is 1.8 pounds per day. No heavy industry currently appears in Anne Arundel County, but community authorities are making serious efforts to attract more industry and more residents to their county.

In addition, at this time, neither Baltimore city, Baltimore County nor Anne Arundel County permit commercial or industrial solid waste in municipally operated disposal sites, either incinerators or landfills. The private contractor, therefore, must have a private disposal site or this material will have no place to go. At the present time, it is felt that approximately 1,200 to 2,000 tons per day of commercial and industrial waste is collected by private contractors in the Baltimore area, from Baltimore city, Baltimore County and Anne Arundel County. From 800 to 1,200 tons are collected from Baltimore city and from 200 to 400 tons are collected from each of the counties.

A survey of industrial sources shows a varying degree of industries awareness and willingness to talk about the problems. It was noted that some companies had their own incinerators, some their own landfill sites and some open burning. Most of the plants (except for those located close to the center of the city) have sufficient land to engage in some self-disposal practices. In general, the companies did not keep any records as to amount of refuse being generated. If they did their own hauling, they usually knew how many truck loads a day were hauled away. However they did not know the capacity of the trucks or the amount of refuse in the trucks. If a private contractor did the hauling, they usually knew the size of their collection containers and how often they were emptied, but had no idea of the density of the material. A branch plant of a large corporation whose corporate management had purchased patent rights to a commercial incinerator and were currently evaluating it for possible installation at all their plants was best informed. Despite the opportunity for self-disposal, private contractors were used extensively by industry. These contractors carried waste beyond Baltimore city limits estimated at 1.2 pounds per capita per day.

SECTION XI

APPENDIX E

HOUSTON, TEXAS

A. GENERAL AND ECONOMIC DESCRIPTION OF THE STUDY AREA

The study area comprises Harris County, Texas which is Standard Metropolitan Statistical Area Number 078, Houston, Texas. The County ranks twelfth in the nation in population and the central city, Houston, containing a very high percentage of the County's population and economic activity ranks seventh among cities in the nation in population. Physiographically, the County is in the Gulf Coastal Plain characterized by very low topographical relief. The drainage is in rather sluggish incised streams, regionally called bayous. The major one is Buffalo Bayou, comprising the landward portion of the Houston Ship Channel which reaches fifty miles from the center of Houston to the Gulf of Mexico. This channel is lined with heavy industry, particularly chemical, petroleum and petrochemical, comprising one of the most highly industrialized areas in the nation. Despite the industrial activity in the satellite communities along the Ship Channel, the economic activity of the County in terms of number of establishments is largely concentrated in the city of Houston.

The climate is mild and rather humid, precipitation being about 46 inches, the January average temperature about 54° and July average temperature about 84°. The city has an average annual heating degree days below 65°F. of 1,278.

Despite the high concentration of industry, Harris County has over 60% of its area in farms. This is a characteristic of the "oasis economy" of the West and bears upon the solid waste problem. There are no counties in New Jersey, Connecticut or Massachusetts having 60% of their land in farms, and to reach such percentages in New York, one must look to the counties considered rural such as Cayuga, Chautauqua, Chenango, Cortland, etc. The value of farm land and buildings per acre, however, is of the same order as that in the states of New Jersey and Massachusetts.

The county is characterized by a very high growth rate. Among all urbanized areas having 1960 populations in excess of one million, Harris County had the highest 1950 - 1960 increase, 62.7%. Los Angeles was second with 62.3% (but Los Angeles of course has a population of 6 - 7 million). In addition to the core city of Houston, Harris County has 109 satellite communities.

Table 1 shows the distribution of these entities by population. Each of the communities constitutes a potential solid waste generating entity with a potential or real requirement for collection, disposition and disposal services.

TABLE 1

DISTRIBUTION OF COMMUNITIES IN HARRIS COUNTY

Population	No. of Communities
<100	32
100 - 300	22
300 - 1,000	18
1,000 - 3,000	20
3,000 - 10,000	11
10,000 - 30,000	4
30,000 - 100,000	1
938,219 (Houston)	1
Total	109

B. THE SOLID WASTE COLLECTION SYSTEM IN HARRIS COUNTY

Harris County has all of the waste generating elements -- residential, commercial (including apartment buildings and institutions), industrial (including mining and manufacturing), construction and agricultural. While collection itself is not within the scope of the present study, collection is a major element in disposition and may be taken as a convenient starting point.

The major single collection and disposition agency is, of course, the city of Houston. The city has an extensive collection system, from some 388,000 establishments, using 16 yard packers which average about four tons per load and operate six days per week. However, as in most cities, the municipal collection system does not handle all the solid waste. Wastes of certain types, e.g., industrial, are not collected by the municipal pick-up nor is waste generated in large quantities (greater than 2 - 30 gallon containers per collection) as from commercial establishments. These are served by the contract disposition agencies, of which there are several hundred serving the city itself, plus probably many more serving the county outside of the city. In 1966 there were issued 614 licenses to contract disposition agencies for dumping at the Holmes Road facility. About 300 of these are full time "professionals" and the remainder are part time one truck operations. About a dozen of these constitute "majors". In a few areas of the city, the municipality contracts with these agents for collection and disposition of the waste which is conventionally the municipality's responsibility in the city as a whole, namely the residential waste subject to municipal pick-up. The municipality does this because it finds it cheaper in these areas than in maintaining its own collection system.

In addition, Houston has an unusual arrangement for supplementing municipal collection by a device termed "sponsorships". The city provides only curb-side pick-up, but in certain areas the residents may wish to have door pick-up. The city encourages such areas to form committees or other types of associations which will take over the responsibility or for this supplemental collection. The agency contracts with a contract disposition agency to make the door pick-ups and assesses its members a charge to cover these costs. The city, thus freed of its collection responsibilities in that area rebates to the sponsoring agency 58¢ per month per housing unit. The difference in cost is made up by the fees charged by the sponsoring agency and the city saves the cost of collection in that area. The home owners' fees are of the order of $2.50 - $3.00 per month for the backdoor pick-up. The arrangement is beneficial to all parties, the city particularly avoiding additional capital investment for the equipment required to handle newly annexed areas. About 18,000 establishments are served under these sponsorships.

There is no overall trade association of the contract disposition agencies. This characteristic Houston has in common with many other areas of the country in which the contract disposition agencies have not yet recognized the advantages and desirability of strong trade associations. However, there have been in the recent past, at least three somewhat loosely organized groups. The most promising of these around which to build a future strong trade association is the Houston Containerized Refuse Haulers Association composed of a number of the major agencies. In the past, this group has presented the case for the contractors to municipal agencies and state and county control agencies. Another group is the North Harris County Garbage Association comprising a number of the contractors operating on the northern limits and outskirts of the city. This group is now inactive. A third group is the Acres Homes Betterment Committee comprising contractors operating north of Houston. Their major activity has been the provision of a dump for their use; the Acres Homes Betterment Committee Dump. These associations in their present stage seem to have largely ad hoc purposes and are galvanized into action to handle particular situations as they arise.

The difficulties of organizing a local or national trade association when there are so many part time practitioners are notorious. However, the times require it and this is particularly true of Harris County where half the solid waste in the city of Houston is collected and disposed by contractors and where the municipality has shown an unusual degree of initiative in conceiving, proposing and carrying out waste disposal practices.

C. REDUCTION AND DISPOSAL FACILITIES IN HARRIS COUNTY

As part of the study, an attempt was made to locate all non-private reduction and disposal facilities in Harris County. By non-private is meant those facilities which accept waste from producers or collectors other than the owner or operator of the facility.

Table 2 lists facilities categorized by ownership and service scope. This list does not purport to include every disposal facility in the county, but does result from information supplied by the knowledgeable persons interviewed during the three-day field campaign in the county. It also includes, of course, the information developed from the Phase I study of the city of Houston itself. It does not include the private facilities such as the private dumps of industrial establishments nor does it include private reduction facilities such as industrial incinerators. No doubt there are additional non-private facilities which could be located by a more extended search. In addition, it is known that there are numerous casual and clandestine dumps which are receiving non-private as well as private wastes presumably for the most part on a quite temporary basis.

While on the subject of small dumps, mention can be made of an unusual practice carried out in the areas just north of and adjacent to the city where a number of contractor and merchant dumps are located on the map. Many of the existing dumps there, including some of the larger ones, are located on land which was originally well below the present highway level and have been built up by dumping to as much as fifteen or twenty feet above the present highway level.

TABLE 2

REDUCTION AND DISPOSAL FACILITIES SERVING HARRIS COUNTY

	Tons Per Year	Acres	Life (Yrs.)
HOUSTON OWNED FACILITIES SERVING HOUSTON			
Patterson Street Incinerator	60,800	3.17	-
Kelley Street Incinerator	60,800	15.95	-
Velasco Street Incinerator	40,500	4.35	-
Holmes Road Incinerator	24,900	265	-
Holmes Road Facility	560,000	265	-
CONTRACTOR OWNED OR MERCHANT FACILITIES SERVING INDUSTRY AND OTHER COMMUNITIES			
Proler Steel Company Dump and Salvage			
Red Jones' Dump			
Granma's Dump	46,800	11	15
Marshall's Dump			
A. D. White's Trash Dump	2,000	6	10
Shepard's Trash Dump			
Buckingham's Dump			
Wylie's Dump	31,000	15	10
Alvin Ray's Selective Dump	2,000	10	15
Hall's Dump			
Washington's Dump			
Green's Bayou (Rice Hulls)			
Unnamed Dump (Near Crosby)			
Mansfield Road (Rice Hulls)	3,200	15	10
Tank Lake			
Ramsey's Dump			
Fall's Dump	--	15	-
GOVERNMENT OWNED FACILITIES SERVING OTHER COMMUNITIES			
Bellaire Sanitary Landfill	21,300	75	25
West University Place Sanitary Landfill	21,200	75	30
Galena Park Dump			
Pasadena Dump	53,250	11	-
La Porte Dump	8,200	3	8
Baytown Dump	36,100	30	10
Humble Dump			
Tom Ball Dump			
County Dump			
Webster Dump			
NASA Sanitary Landfill			
Ellington Air Force Base Sanitary Landfill			
Jersey Village Dump			
Katy Dump			

MERCHANT FACILITIES SERVING OTHER COMMUNITIES

Acres Homes Betterment Committee Dump

NEW FACILITIES PLANNED OR UNDER CONSTRUCTION IN HOUSTON'S PROGRAM	Tons Per Year	Acres	Life (Yrs.)
Lone Star Organics, Inc. Compost Plant	93,600		
United Compost Services, Inc. Compost Plant	93,600		
National Organics Compost Plant	93,600		
Wallace Industrial Contractors Incinerator	93,600		
New Holmes Road Incinerator	249,600		
New Unnamed Incinerator	187,200		
Reed Road Sanitary Landfill	111,000	89	5

The unusual practice constitutes an extension of this idea. Persons will purchase a small city lot as small as 50 x 100 feet and then will proceed to sell the very substance of the lot itself, namely the soil comprising it. Excavating machinery will be brought in and will excavate down to a depth of some 40 feet exactly on the lot lines, such that the lot comprises a pit with vertical sides 40 feet deep. The dirt is sold for construction fill and landscaping purposes elsewhere in the metropolitan area. The owner then has a garbage dump which he operates as a merchant dump until it is filled and sometimes until it is more than filled, standing high in the air with refuse. The entrepreneur owner has treated the lot not as real estate, but actually as a commodity, indeed twice -- once selling the substance of the lot itself as a commodity and then selling as another type of commodity the space created by selling the first. Since Houston has no zoning laws, there is nothing limiting this practice except the law of gravity which sets the angle of repose that can be reached by the final pile. Such things are going on in the midst of inhabited areas where there may actually be dwellings on each side of the ravished property. Several such sites were inspected all in various stages of excavation of the first commodity, and none as yet having received any of the second.

With that introduction to the periphery of the local practice, attention is now turned to the more normal municipal and merchant or contractor owned operations, recited in decreasing rank of the excellence of current performance. While the inspection was performed in 1967, the discussion will be confined to the operations prior to the placing on stream of the first of Houston's new operations, namely the composting plant. With that exception, the best run disposal facilities in the county are the sanitary landfills of Baytown, Bellaire and West University Place. These are very satisfactory operations, truly classifiable as sanitary landfills with no loose papers blowing around and with covering each day. The Bellaire and Baytown operations take care of all the community waste, other than industrial self-disposal, but West University Place handles only the municipal pick-up; the commercial collection going to Houston's Holmes Road facility. Ellington Air Force Base also operates a sanitary landfill, though this was not inspected.

The Holmes Road facility of the city of Houston has been in use for a considerable period and has borrowed its philosophy of life from the oil fields which surround it -- namely its anticipated future life is only a few months, but this has been the situation for at least five years. As a result, there is practically no cover left on the site and this must be hauled in from elsewhere. Under these circumstances, the operating personnel are performing valiantly in an attempt to maintain a sanitary landfill status.

The Government owned dumps which were inspected are checked in Table 6. The contractor owned or merchant dumps are operated with rudimentary engineering skill in placement and control, but none appear to have an intention of an earth cover even as a final stage. Most of them appear to have the plan of building up the deposit about the level of the surrounding land and the highway level. Most of these dumps, however, appear not to accept garbage, so the sanitation from the health and odor standpoint, is not as bad as it might be. Very little burning is practiced at the contractor owned and merchant dumps inspected.

While this recitation of the merchant and contractor dumps may sound sub-standard, these dumps serve a real economic purpose, in an interim period extending over many years in the past during which neither the city nor the county has been able to provide adequate disposal facilities for the community's wastes.

D. WASTE QUANTITIES

This study attempts to estimate the waste generation of the county, excluding that portion of the industrial waste which is self-disposed. The waste streams covered are as follows:

1. Wastes collected by municipalities which reach reduction or ultimate disposal almost exclusively in municipal facilities.

2. Wastes collected by contractors or handled by private generators which reach reduction or ultimate disposal in municipal facilities.

3. Wastes collected by contractors or having disposition by private parties which reach ultimate disposal in merchant or contractor owned facilities.

The difficulties of achieving this goal are forbidding, but they are of universal application and, therefore, their discussion is relegated to the more general portions of the overall project report.

The largest contributor to the total waste stream is, of course, the community comprising the city of Houston. The city, prior to the new plan, collects and disposes of 600 tons per day in its four incinerators and 900 tons per day to the Holmes Road facility. Contractors collect from the Houston community an amount equal to the city collection of which 900 tons per day goes to the Holmes Road facility and 600 tons per day goes elsewhere. The total for Houston facilities is, therefore, 3,000 tons per day or 935,000 tons per year; corrected for the known small amount to Holmes Road from West University Place this becomes 928,760. Probably this is not the only disposition from other communities in Holmes Road, but the study developed no information on these. The quantities going to the city facilities are measured (by loads) and studies had been made giving the average weight per load. Thus, the uncertain quantity so far is that taken to non-city facilities by contractors. An independent estimate of this based on a study made a few years ago is 500 tons per day. One of the major contractors was interviewed, yielding the information that 38% of the material handled by this contractor went to non-city facilities. If this is typical of the total contractor stream and the total amount handled by contractors is equal to that handled by the city, 1,500 tons per day, this would indicate 570 tons per day to non-city facilities. A fourth figure may be generated by summing the estimated daily tonnage to the merchant and contractor owned dumps immediately adjacent to the city.

There are fourteen of these known to be operating, not including the Proler Steel Company dump which takes incinerator residue. Of these, five have been inspected and estimated to take a total of 85,000 tons per year. If the remaining nine have the same average capability as the inspected five, the total would be 238,000 tons per year or 760 tons per day. When this is corrected for the estimated quantity from the enclave communities of Spring Valley, Hedwig, Hunters Creek, Piney Point, Bunker Hill and Hilshire Village known to now go to these dumps, the figure becomes 730 tons per day. From the four figures 600, 500, 570, and 730 tons per day, the average is 600 tons per day, which is the figure used.

By interviews of the municipalities and disposal facilities, there were developed for a number of communities the community waste generation excluding that having private disposition and disposal. These waste generation data varied from 1.75 to 9.54 pounds per capita per day.

It should be noted that the new communities surrounding the NASA installation in the southeast part of the county have not been included in the waste projections or in the 1966 populations. The reason is first that there is little chance of interaction with Houston, but more important, the economic and population development in these communities is so extreme as to defy numerical analysis when combined with the rest of the county. The NASA facility, having incidentally its own sanitary landfill, has generated around it a number of very rapidly growing residential communities -- Webster, Clear Lake City, etc. Five years ago, that entire area had no more than 5,000 population. Now it has 35,000 and by 1970 it is expected to have 250,000.

E. INTERACTION AMONG MUNICIPALITIES

De spite the predominant role of Houston and particularly with its dynamic new program for solid waste development, it is surprising that there is not more existing and planned interaction among the municipalities of the county. The only present interactions are that South Houston and Deer Park dispose in the Pasadena dump, the very small communities of Morgans Point, Shore Acres and Lomax dispose in the La Porte dump, and some contractor-collected waste from West University Place is disposed to the Holmes Road Facility of Houston. Two small communities, Crosby and Highlands, avail themselves of the county dump. There are some instances of communities disposing outside their own borders; for example, Bellaire and West University Place and the enclave communities of Spring Valley, Hedwig, etc. However, these do not actually involve interactions between Governmental units. The only known instances in which waste crosses county line is that for Baytown whose sanitary landfill is located just across the border in Chambers County, and that for Katy (which lies partly in Harris County) which uses a contractor leased dump in Waller County.

Not only is there little existing interaction between communities, but also very little is planned or encouraged. None of the municipalities interviewed indicated any desire to, in the future, utilize the facilities of or offer their own facilities to other municipalities. Even Houston with its dynamic program is confining itself entirely to its own wastes and making no provision for taking in some of its small neighbors.

F. HOUSTON'S SOLID WASTE PROGRAM

Except for the city of Houston, the remainder of the county is in general not in a critical condition regarding solid waste disposal. Many of the dumps and sanitary landfills have ten and fifteen and up to thirty years of remaining life, although the increase of population by that time will probably make it difficult to locate the next facilities as conveniently to the communities as the present ones. The exception is Pasadena which must immediately seek new disposal facilities. A few years ago, there were some preliminary discussions concerning a joint incinerator to be used by Pasadena, Deer Park, La Porte, other communities and possibly some of the industries. However, nothing came of that particular approach.

Some of the more progressive contractors and possibly through their association are considering close-in facilities. For example, one has studied the possible use of a small waste reduction facility. In addition, there had been some sporadic attempts in the past, mentioned in connection with the associations, to provide disposal facilities for the contractors serving the north part of Houston and the county north of Houston. This is the region not well served by the Houston city facilities of which only the Holmes facility is open to contractors.

With this quiscence and status quo in the rest of the county, all the more predominant in solid waste affairs in the county is what has been referred to in this report as "Houston's program for solid waste development". The next section is devoted to this program.

A study in 1964 conducted by Black and Veatch indicated the critical situation in the city's incinerators and the then Holmes Road facility. The four existing incinerators were not worth remodeling for future use. The exhaustion of the Holmes Road facility was recognized as was the poor placement of that facility -- the only one open to the contractors. The study recommended several new incinerators more strategically placed to serve the entire city, the details to depend upon a policy decision by the city as to the extent to which they would accept contractor dispositions.

In implementing these recommendations, Houston took several bold directions. This dynamic program has focused national interest in solid waste disposal on Houston and the outline of the program and many of its details have received extensive publicity. What will be reported here necessarily repeats some of this information.

First, Houston has under construction a new 800 ton per day incinerator on the Holmes Road site due to be completed September 1967. The first furnace will be put on test the latter part of May and the second in

June. All material into this plant will be weighed. Cans will be separated magnetically, crushed, hot washed and put in containers for sale as scrap metal. Two of the old incinerators will be shut down when the new incinerator is on stream. The city plans to permit contractor disposition if they use hydraulic type trucks. They plan to permit this use by the contractors for the same low prices as now charged for use of the Holmes Road facility, namely a $5/year license fee and 50¢/load for trucks greater than one ton and 25¢/load for trucks less than one ton if the material comes from within the city. If the material originates outside the city, the charges are $1 for over one ton and 50¢ for less than one ton. Obviously, these prices are much less than the costs of operating the incinerator and even lower than the costs of operating the present facility. However, the city considers that provision of disposal means is one of its public responsibilities. An attempt will be made to operate the new Holmes Road incinerator in a highly exemplary manner such that public education will be achieved and possibly public acceptance of incinerators at other locations of the city will result.

As an interim measure, the city opened the Reed Road sanitary landfill in the fall of 1966. This operates with the pit and ramp system building the ultimate level to about twelve feet above the original level. On inspection, the general appearance was very clean and workmanlike, although it happened that the day's deposit was not covered on the day of inspection. Excess cover from Reed Road is being used for cover at the Holmes Road facility. At present, Reed Road is taking city-collected garbage which would otherwise have gone to Holmes Road or the incinerators at a rate of 360 tons per day or 111,000 tons per year. Public acceptance of waste disposal facilities in Houston is poor and because of it, although the appearance of the Reed Road facility at present is very good, it is planned to build up the deposit first on the periphery of the area so as to form an enclosure keeping the remainder of the operation from open public view.

In addition to the 800 ton per day incinerator, Houston has also just let the engineering contracts for a second new incinerator, the size to be determined by the amount of bond funds available and probably about 600 tons per day. Among the decision factors leading to the new incinerators (rather than sanitary landfill) were lack of land within what was judged to be a reasonable haul distance, technical problems encountered with current land fill operations, and the sub-politics of locating sanitary landfill facilities.

Houston is not alone among cities planning new and constructing new incinerator facilities. The unusual element in Houston's approach is the concept of contracting with private companies for waste disposal. Houston has contracted with a private firm, associated with Wallace Industrial Contractors and Wallace Plumbing Company, to take 300 tons per day of waste and to dispose of it. The city will pay the contractor $3.50/ton of waste delivered, at which point the city will literally wash its hands of the refuse. The Wallace concern is planning to construct an incinerator of modern design and the city has offered the site of the Patterson Street incinerator for this purpose. The operation is permitted to take other wastes in addition to the city's as long as the city contract commitment is met.

However, the boldest portion of the dynamic program comprises three additional such "wash your hands" contracts with concerns who will build composting plants. In contrast with incineration, composting is a relatively untried reduction method in this country, notorious for its failures where it has been applied in municipal service in recent years. The failures have come about not so much through technical deficiencies, but through the failure to achieve the optimistic market for the product which was hoped for. By contracting this disposal service, the city is protected against monetary loss except insofar as it may furnish the land for the facilities. By contracting the city has brought to bear private entrepreneurial skills, a commendable goal being sought by a number of federal and business agencies in various fields.

If the private operators are successful in living up to their commitments, the city will have disposed of 900 tons per day of wastes (to the composting plants) wihtout any capital expenditure on its part, and at a per ton cost less than the probable operation costs alone of its own incinerator facilities. If such an approach could be of universal application, the municipal solid waste disposal practice in the nation would be much advanced. However, the marketing failure of recent U. S. composting plants indicates that success of future plants is uncertain and in light of that, Houston must be credited with a bold step in providing a more than full scale pilot exploration of the technical and economic possibilities. If the composting plants fail, Houston will find itself with 900 tons per day of wastes which the city will have to handle itself by other methods. Thus, the outcome of Houston's venturesomeness, unusual among municipalities, is to be awaited with eager interest.

Of the three composting operations, that of the Lone Star Organics Inc., a subsidiary of Metropolitan Waste Conversion Corporation, Barrington, Illinois is the most advanced in Houston. The contract arrangements with all three composting contractors are practically the same. The contractors agree to take 150 tons per day of waste, and the city, if requested, must deliver up to 300 tons per day averaged over six days. The contractor will handle the wastes completely after delivery. The contracts include a cost of living index factor to compensate for cost changes from January 1965 renewable each year. The city pays about $3.50 per ton for waste delivered and if the plants take more than 1,800 tons per week, the per ton rate drops for the excess. The Lone Star Organics Plant, locally known as Metro, was visited. The parent firm has operated a 50 ton per day pilot plant for three years at Largo, Florida in developing its patented process.

The Houston plant, designed for 300 tons per day is the largest so far designed. A slight difficulty has been experienced because of unloading facilities which proved inadequate for the service. The Houston city collection trucks work on an incentive basis such that any waiting time for unloading is a disadvantage to the men. In computing the delivery to the compost plants, an average of weight is made on each ten loads in order to project the remaining daily tonnage and loads required. The city routes its vehicles to the plant in accordance with this pre-arranged and constantly adjusted schedule. The city attempts to deliver most of the requirement for the week early in the week to avoid the possibility of having to increase the delivery rate by diverting trucks from distant points, etc. toward the end of the week. The first three days of the week are usually heavier in collections than the last two days.

The Metro plant is well constructed and well operated and the city is impressed with the caliber of performance. The flow line starts with a conveyor which carries the waste past ten salvage pickers. These operators segregate paper, cardboard, metal and rags. The paper and cardboard are remarkably clean and are baled for sale as scrap paper. Tramp metal is separated carefully prior to the hammermills and the tin cans are ground and delivered directly to the hopper railroad car for sale. In Houston there is no market for scrap aluminum and it is too expensive to salvage glass. The remaining material passes to hammermills where it is finely ground including the glass and then it is conveyed to the digestion vats. The digestion process in concrete troughs takes about six days and reaches 160 to 170°F. It is planned to add to the waste some thickened sludge from the city's activated sludge sewage treatment plants. The compost product after regrinding is gray and appears fibrous, having the characteristics of a ground papier-mache and contains 40 to 50% H_2O. The product is stored in outside piles where additional microbiological action continues to occur, generating some heat. The material inspected has a musty garbage-like odor at close range.

The product is to be sold to large landowners directly as mulch, to fertilizer manufacturers as filler and to the individual consumer. In Houston the material is selling in retail stores at 95¢/lb. bag. The yield from the average feed (75% dry matter, 25% H_2O) is approximately 9% metal, 4% non-combustible non-compostable residue, 1% textiles, 10% paper (range 4 - 15%) and 76% compost (at 40% moisture, 46% dry matter in compost and 30% H_2O). Questioned about the marketability of the product, the plant management indicated that the parent corporation has been successful in selling every pound of compost it has ever produced.

The Metro plant is now actually operating, but in the shakedown stage. It successfully passed the 300 ton per day for six days acceptance test, but is now running at less than this rate during the shakedown period.

The second compost contractor is United Compost Services Inc., a Houston based organization. This plant is not as far advanced into the operating stage as the Metro plant. On the day of the interviews, the plant had taken 160 tons, but the average tonnage is less than 100 tons per day at present. The plant is experiencing complaints from the citizens of the neighborhood in which it is located. These include some odor complaints.

The third compost contract is with National Organics Company (Norco), an Atlanta concern. They have not yet broken ground for the plant.

G. THE SUB-POLITICS OF SOLID WASTE DISPOSAL IN HARRIS COUNTY

By sub-politics or local politics, there is meant the interactions of municipal departments with each other, of municipalities and Governmental units with each other and of all of these with individual citizens, groups of citizens, Chambers of Commerce, newspapers, and other vehicles by which public opinion is translated into local action. In other cities it has been found that sub-politics is a major factor, sometimes a major obstacle in solid waste disposal. While the project did not make a thorough and intensive study of the behind-the-scenes sub-politics in Harris County, there does not appear to be a great deal of this in the city and county. This apparently results from the lack of interaction of solid waste disposal among the municipalities. Each municipality seems inclined to concern itself only with its own territory and problems and not to resort to combinations with other municipalities. Of course, in the city of Houston there was considerable controversy over the program involving new types of processes and new types of contractual arrangements. However, this did not seem to be a permanent obstacle to the program as evidenced by the rapidity by which it has so far been implemented.

Harris County has had for more than a decade an air and water pollution agency operating out of the County Health Department and this agency has brought down more than its share of sub-political controversy. In part, this stems from the fact that the County was, or has become, divided into two camps, one strongly for pollution control and one believing that pollution control to this extent is incompatible with industrial activity. The County has no laws under which effective pollution control can be achieved other than the general nuisance laws and this is highly handicapping to control. For solid waste disposal, it is, of course, air pollution control that is more deeply involved than water pollution control and from that standpoint whatever be the sub-politics the county and the city have done quite well in that little open burning is practiced on the non-private dumps. The four city incinerators are not equipped with sophisticated air pollution control devices and the extent to which they contribute or have been alleged to contribute to the overall air pollution problem which Houston faces was not determined by this study. However, the new Houston incinerators will have very high level air pollution control features, indeed intended to be exemplary in this regard and therefore, should not enter into the sub-politics.

The Federal Government agencies involved in solid waste and air pollution have not been a factor in Harris County. The state of Texas has had a Water Pollution Control Commission for several years and just recently has established an Air Pollution Control Commission which presumably will in the future begin to impinge upon air pollution problems in Harris County including those from solid waste if any. However, so far, these have not much affected the activity.

The Houston Chamber of Commerce is a very active group having participation by many of the industries in the industrial complex including those outside the city of Houston. As an example of the intensity of this group, its Industrial Committee about ten years ago sponsored out of its own funds contributed by the members an extensive air pollution survey of the entire city and county which cost several hundred thousand dollars. A follow-up to this survey was undertaken a few years ago. At one time in the past, a sub-committee of the Industrial Committee of the Chamber initiated some discussions concerning solid waste disposal in relation to the industrial and residential community. However, this was not very actively followed up and there has been no activity of the Committee in the past three years.

The preceding discussion has been in terms of seeking obstacles to efficient and acceptable solid waste disposal that might come through sub-politics. None have been shown in Harris County. However, sub-politics in addition to being a potential for obstacles, also is a potential for overcoming obstacles and accomplishing desirable ends. One of these desirable ends in solid waste disposal that can be accomplished by sub-politics activities is the education of the citizens and citizens groups and other members of the sub-political structure in the social acceptability and economic advantage of sanitary landfill and other forms of modern solid waste disposal.

It is true that Harris County has at least three exemplary sanitary landfills, but one of these is remote from Houston and the other two have not been played up in an education program. The operations which are readily viewable, namely the dumps north of town and the Holmes Road facility, do not at present offer good possibilities for an educational campaign. One of the difficulties is that there is nowhere in Houston a completed dump or sanitary landfill which has been converted into useful and desirable purposes. All of the dumps and fills with the exception of the completed South Houston dump are still in active operation or if they are abandoned, as some of the merchant dumps just north of the city, have been left unrestored. In other cities it is possible for the public to view completed dumps and landfills which have been converted to parks, recreational and industrial purposes. Even common dumps, which are not covered during the course of construction have been covered and made into park-like areas which the public can walk upon and in them recognize the future condition of active dumps and sanitary landfills.

It is not possible to do this in Harris County. It is not surprising, therefore, that there is public resistance to the location of sanitary landfills, or dumps as may be feared, or incinerators. It is particularly unfortunate that sub-politics has not been used in education toward sanitary landfills, for the city of Houston itself averages only about fifteen miles in diameter and for the most part has completed its radial freeways.

SECTION XI

APPENDIX F

JERSEY CITY, NEW JERSEY

A. DESCRIPTION OF METHOD:

The Jersey City, New Jersey area was analyzed by personal interview of cognizant people in and around Jersey City. Three major industries were contacted and their inputs to the waste stream defined. A representative private contractor was also interviewed. The data obtained was analyzed to determine interaction of waste streams between the communities, the amount per capita contributed by each segment of the metropolitan area such as residential, commercial and industrial inputs. Historical trends were noted insofar as historical data was obtainable. Jersey City is a heavily urbanized community which is surrounded in the main by similar communities.

B. DISCUSSION OF THE DATA:

It was determined that there is no apparent flow of solid waste into the core city of Jersey City. A flow of approximately 50 tons/day is being removed from Jersey City to private landfill operations outside the city by private contractors. The Jersey City Incinerator Authority operates its incinerator 24 hours a day, five days a week. This incinerator, which is actually made up of four 150 ton capacity furnaces, has a 600 ton/day capacity and was installed in 1957 at a cost of $2,500,000. Originally the furnaces were equipped with manually operated ash dumping grates and the standard stoking arms. In 1958, a hydraulic grate system and a new type of stoking arm was installed. These modifications allowed a gain of 2,750 pounds of refuse burned per hour per unit. During the last six months of 1958, they were able to incinerate 21% more than the design capacity of the incinerator. Table I shows the amount and origin of refuse incinerated from 1958 through 1965.

From the incinerator figures and population figures as furnished by the Jersey City Planning Board, the amount of residential and commercial waste per capita has increased from 2.44 pounds per capita in 1960 to 2.89 pounds per capita in 1965, which indicates an increase of .09 pounds per capita per year.

The Jersey City Planning Board which played a part in creating the Jersey City Incinerator Authority is now concentrating its efforts on other social and economic problems within the city. Jersey City reached its peak population in 1930 (316,715) -- it has been declining since then. In 1960, the population was 276,101. It is expected to decrease to approximately 266,000 in 1975. At that time, it is expected to take an upturn caused by the fulfillment of the city's long range planning. The water front area behind the City Hall is undergoing an urban renewal program and two high-rise apartment units have already been completed and are being rented. These apartment structures do not appear to be renting too rapidly. They are provided with mammoth parking lots which at the present are filled with broken bottles and other pieces of glass obviously tossed in by the juveniles of this otherwise densely populated lower income region. The Planning Board hopes to see 30,000 apartment type housing units built in this area with approximately 90,000 residents. The Planning Board visualizes a sort of bedroom community for New York City. They hope this influx of New Yorkers will help raise the current level of economic conditions in the city.

At the present time, there are 2,000 acres of vacant land in Jersey City, classified and valued as follows:

No. of Acres	Classification	Current Value
34	Residential B	$ 9,500 per acre
5	Business B	37,000 per acre
220	Commercial Light Mfg.	15,800 per acre
1,700	Industrial	10,000 per acre
67	Parks & Cemeteries	6,350 per acre

It is expected that most of this vacant land will be developed by 1985.

Industrial employment in Jersey City has fallen off considerably. In 1954, 562 industrial firms employed 40,829 or approximately 73 employees per establishment. In 1964, 503 industrial firms employed 28,388 or approximately 56 employees per establishment. A trend has developed in that the firms moving out of the city were larger employers than those moving in. It also is evident that the firms moving in do not require the higher grades of skilled labor. Thus, lower pay scales will be prevalent. At the present time, 44.4% of the city's labor force is employed outside of the city.

One or possibly the largest of the city's employers is a nationally known manufacturer of soap, detergents, etc. They employ 2,400 people and operate 49 weeks per year (2 week shut-down in July and 1 week shut-down in December). This industry does not contribute much in the way of process waste to the solid waste stream since most of the processes are chemical and process wastes are collected and reused. Corrugated cardboard and similar packaging materials are sold to a private scavenger who bundles and sells it. Office waste and general rubbish are collected by another private collector and taken at the rate of two truckloads a day to the Jersey City incinerator.

Another of the city's larger manufacturers manufactures tin cans and employs 1,800. They operate 52 weeks per year, two full shifts, and a partial third. They generate general plant rubbish at the rate of 18 tons per day. This rubbish is compacted in bins and hauled to a private dump in Pine Brook, New Jersey, approximately 25 miles

TABLE 1

SOLID WASTE DISPOSAL - JERSEY CITY

MUNICIPAL

Year	Tons Per Month Burn	Tons Per Month Non-Burn
1958	8,799	552
1959	8,230	116
1960	8,654	70
1961	NA	NA
1962	9,434	0
1963	9,335	0
1964	9,746	0
1965	9,165	0

PRIVATE CONTRACTORS

Year	Tons Per Month Burn	Tons Per Month Non-Burn
1958	393	84
1959	594	87
1960	448	64
1961	NA	NA
1962	1,061	276
1963	1,056	275
1964	521	NA
1965	968	0

INSTITUTIONS, HOSPITALS, SALVATION ARMY, ETC.

Year	Tons Per Month Burn	Tons Per Month Non-Burn
1958 to 1963	NA	NA
1963	NA	NA
1964	651	0
1965	306	0

from the plant. Approximately 30 cubic yards of broken pallets and lumber are removed every week by a private scavenger to an unknown destination.

The third industry was not as large as the other industries surveyed, it still has a relatively high rate of employment. This manufacturer produces iridescent lamps and employs 450. They operate 24 hours a day, five days a week with a three week shut-down in July. They generate approximately 10 tons of refuse a day. Besides the general office, shipping, cafeteria type waste, a considerable amount of process waste in the form of broken glass is generated. A private scavenger hauls away two truckloads of this refuse a day to a private dump outside the city.

Other cities in the area were surveyed to determine if any interaction existed. In Hoboken, a minimum amount of information was available. Private contractors handle all collecting and disposal requirements. At the present time, this city of approximately 48,000 people is generating 600 tons a week of residential and commercial refuse, or approximately 3.0 pounds per capita per day. This figure compares with the basic figure of 4.4 pounds per capita per day obtained in Jersey City. As the cities are adjacent to one another and are basically of the same economic makeup, the correlation of these figures is readily understandable and would indicate no cross flows. All of Hoboken's refuse is removed to private dumps outside of the city.

The city of Hackensack, while not adjacent to Jersey City, is in close proximity to it. Because very complete records of refuse disposal were available, this city was also surveyed.

The Hackensack incinerator was built in 1927 at a cost of $90,000. It has a rated capacity of 100 tons a day and operates ten hours a day, six days a week. The city of Hackensack completed a "garbage collection and incinerator study" in May of 1966. This study clearly points out the needs of this city of 35,000 people. Basically, the present incinerator is operating on a day-to-day basis. It is constantly under repair and cannot operate too much longer. There is no vacant land within the city, the closest being 7 1/2 miles away.

A city supervised, privately owned landfill area is currently being used. This area was originally five acres -- 2 1/2 acres have been filled in and it is expected that in another five years, this site will be closed. There are approximately 15 apartment houses which have their own incinerators within the city limits. It has been estimated that the population of Hackensack, which decreased in the period from 1950 to 1960, is on the increase and will double within the next 20 years.

The refuse processed at the incinerator has increased from 12,383 tons in 1952 to 18,685 tons in 1965. At times during this period, the incinerator has been operated at 30% above its rated capacity. Both city and private contractors collect refuse in the city. Due to the limited capacity of the incinerator, only 40% of the total garbage and refuse collected in 1965 was incinerated. This type of refuse represents 60% of the total refuse generated by the city. Wood, bulk trash, logs, etc. are not presented to the incinerator. Residential and commercial refuse amounts to approximately 4.2 pounds per capita per day in Hackensack. Industrial refuse amounts to 1.7 pounds per capita. It is predicted that this figure will be fairly constant as the city's population increases. There is no indication of any refuse being collected elsewhere and brought to the city, but several private collectors are hauling refuse to private dumps outside the city.

SECTION XI

APPENDIX G

NORWALK, CONNECTICUT

A. DESCRIPTION OF METHOD

The Norwalk, Connecticut metropolitan area was analyzed by personal interview of cognizant people in Norwalk. The three satellite towns of Westport, Weston and Wilton were also interviewed. Four major industries were contacted and their inputs to the waste stream defined. A representative private contractor was interviewed as was the Director of the South Western Planning Region. The data obtained was analyzed to determine interaction of waste streams between the communities, the amount per capita contributed by each segment of the metropolitan area such as residential, commercial and industrial inputs. Historical trends were noted in so far as historical data was obtainable. Norwalk is an industrialized community, but also a suburb of New York City. It has its own suburbs which range from no industry to light industry.

B. DISCUSSION OF THE DATA

It was determined that there was no apparent flow of solid waste from the core city of Norwalk into the satellite communities. The Norwalk figures for 1965-1966 were running at approximately 240 tons per day burned in a five day week or 4.1 pounds per capita generated over a seven day week. In 1958 the amount burned was only 120 tons per day on a five day week basis. No per capita figure is able to be calculated because it is known that an indeterminate amount of refuse now being burned in an incinerator in those days went directly to a landfill.

The 4.1 figure consists of residential, commercial and industrial waste. The residential and commercial figure alone is approximately 3.0 pounds per capita. This material is handled by two incinerators in the city of Norwalk. The old plant which was constructed in 1940 and remodeled in 1952, operates eight hours a day and is rated at 150 tons. The new plant was built in 1962 at a cost of $1,050,000 and was rated at 360 tons and operates 14 hours a day. Operating cost of the incinerator and dump without amortization is $3.46 per ton.

Incineration was chosen as a waste reduction method for the city of Norwalk, primarily because land was becoming both scarce and expensive. At this time, this was the overwhelming factor in the selection of incineration rather than some alternate waste disposal method.

The anti-pollution equipment used in the new Norwalk incinerator consists only of a water wetted baffle chamber. It is not known how much water was used but that the effluent water is treated in a clarifier and recycled. The waste water is dumped in the harbor. It was stated that the incinerator was operating satisfactorily from an air pollution standpoint, except when heavy industrial charges of rubber and like materials were charged. They have no plans now for further air pollution equipment.

The surrounding towns have no waste reduction facilities per se, but use various grades of sanitary landfill varying from an open dump to a sanitary landfill operation.

The town of Wilton at the time of the interview had no landfill in its boundaries and was using a dump in the neighboring community of Weston to dispose of the 91 1/2 tons or 2.4 pounds per capita generated.

The town of Weston was also using this facility (which is in Weston) to dispose of its 45 tons per week or roughly 2.1 pounds per capita. This facility is a privately owned facility and is a dump not a sanitary land fill. Because of new state regulations, the town of Weston may take over the operation of this dump and run it in a sanitary manner. The town of Wilton would not be permitted to use it under these circumstances. This situation has been anticipated by Wilton and acreage within their community boundaries was obtained for the landfill.

At present an injunction exists against the city using this land for its intended purpose. The injunction was obtained by residents near the proposed site. This situation will be discussed further in a later part of this report.

The town of Westport conducts a landfill operation which is not in accord with the standards normally used to designate a sanitary landfill. Its per capita refuse is 2.7 pounds generated.

In the core city of Norwalk, only 80 acres remain which could be considered as available for refuse disposal. This land is shore land and is marshy. It would have to be considered very poor with serious building limitations. This land, however, may not remain available for the purpose of refuse disposal as conservationists are interested in preserving it for its value to migratory water fowl, Norwalk being on one of the major Canadian duck and geese flyways. On the other extreme, the town of Westport has approximately 1,500 acres of vacant land. The neighboring residents of any proposed new land fill area are the primary obstacles to the selection of land. This will be further noted under the discussion of the Wilton situation.

It is interesting to note that the communities of Weston and Wilton, which are strictly residential in nature having no industry and a very minimum amount of commercial activities within their boundaries, generate from 2.1 to 2.4 pounds per capita.

Westport, which is a town which has commercial activity, reflects this in the pounds per capita generated by having a 2.7 pounds per capita figure. Norwalk with heavy commercial activities shows 3 pounds per capita for residential and commercial refuse and a total of 4.1 pounds per capita when industry is included. It is entirely possible also that some of the satellite towns' refuse finds its way to the Norwalk facility which is free for private contractors who pick up refuse in Norwalk.

It is known, particularly in the case of Norwalk, that certain elements of solid waste are not noted in these figures. No weights are available on bulky non-combustible items which go directly to the Norwalk residue dump. A collection of this type material is made in alternate halves of the town every other week. The trucks are busy all day and the volume is substantial. In addition, some salvage of the material and cardboard is going on and there is no information as to the quantity of this waste stream. There is also no information available at this time on the amount of refuse which is disposed of at its source.

Four major manufacturing firms were interviewed in the Norwalk core city to determine their contribution to the waste stream of the community. An instrument firm was determined to be generating five tons per day. Two apparel manufacturers had an average of 1.75 tons per day. A large food concern generated 2.5 tons per day.

Little inter-community planning is noticeable in the Norwalk area. The South Western Planning Region was interviewed to see what, if any, action had been taken toward regionalization or planning. This region which comprises Greenwich, Stamford, New Canaan, Darien, Norwalk, Wilton, Weston and Westport was established under the Enabling Act of the State Legislature. Membership in this planning region is voluntary and not all of the towns listed are actually members. It was stated that some towns join the planning region and drop off and rejoin again.

The Planning Region Agency has issued only two reports -- one on population and one on land use. They ran last year, in addition, a refuse disposal inventory. Responses were received from Westport, Greenwich, Darien and Stamford. Little effective regionalized planning has been accomplished at this time.

A private contractor was interviewed to give us a picture of the private collection in the Norwalk area. He stated that for the most part all waste collected in Norwalk went into Norwalk's disposal facilities since there was no charge for dumping other than the normal license fee. He estimated that private collections handle one third to one half of the residential and commercial collection within the city, and 100% of the industrial collection except where self-disposal by industrial plants was the case. There are five big private collectors that handle Norwalk's refuse.

If a truck partially loaded from another community continues its route in Norwalk, there is no doubt that the foreign waste is disposed of in Norwalk. No special practice is made of this, but it does happen.

The contractor confirmed that there is no major outflow of Norwalk's generated waste to disposal sites beyond the city. There are two salvage operations in the city -- one who handles metal and one who handles paper and metal. In general, salvage does not seem to be a big item other than for cardboard salvage from some industrial plants. It appears that there is not a strong economic justification for much sorting and salvage of waste collected.

Another large collector also confirmed that very little if any of Norwalk's refuse was being deposited outside of the city. He also confirmed the figures and impressions reported in the Wilton and Weston collection and disposal systems.

The Chamber of Commerce staff in Norwalk indicated that there was little community interest in the problem except if rates were adjusted upward or a landfill is proposed in their neighborhood. The interest that exists then apparently is one of protest.

Earlier in this report we discussed the Wilton situation where the community was forewarned that their current disposal site would be eliminated. The community then took action to obtain another site which the citizens proceeded to make unavailable by means of a restraining injunction. The private contractors servicing the community recognized that at this time they could not legally take Wilton waste into any of the surrounding communities, making their job an almost impossible one. They consequently notified their customers of their intention to no longer collect in the Wilton community after January 1st of 1967.

The following article reprinted in its entirety appeared in the January 3rd "New York Times" and is, in a real sense, the type of problem that the nation faces, depicted on a far smaller scale.

NEW YORK TIMES - JANUARY 3, 1967

"REFUSE DISPOSAL WORRIES WILTON"

Connecticut Aides to Meet With Town on Problem -- Pickups are Halted

WILTON, Conn., Jan. 3 - No garbage is being collected in the town and its 12,000 inhabitants are getting worried.

Householders are burning paper in their backyards and fireplaces and piling other refuse in their garbage cans while waiting for town officials to solve the disposal problem.

Dr. Henry Appelbaum, the community's director of public health, is to meet here tomorrow with state health officials to decide whether to declare a health emergency.

The garbage is piling up because the three private carting companies that service the town have no place to get rid of it.

The town's problems began early last year when the State General Assembly passed a law forbidding the dumping of garbage in open land and the burning of it in open pits. It gave communities a year to make other arrangements.

Until today, Wilton's refuse had been carted to an open pit owned by Anson Morton in neighboring Weston. When the new law was passed, Mr. Morton told the town to take its garbage elsewhere. He gave Wilton several time extensions and then set today as the deadline.

"WOODLAND ACQUIRED"

In anticipation of the new law, the town purchased 70 acres of woodland about a year and a half ago for general municipal purposes. It then built a road to the site and set aside two acres for use as garbage landfill.

Residents of the area near the projected landfill brought suit against the town. In November, Superior Court Judge Anthony J. Armentano granted them a permanent injunction forbidding the town to use land for garbage disposal under penalty of a $2,500 fine.

Last week, Dr. Appelbaum wrote a letter to First Selectman Vincent J. Tito suggesting that the town declare a state of health emergency. Mr. Tito said that was a function of Dr. Appelbaum, the health director. Dr. Appelbaum then set up tomorrow's meeting with state authorities.

Worried Wilton inhabitants were calling town officials and The Wilton Bulletin, the local weekly newspaper, today for guidance.

"I tell them to do their best for themselves until a solution is found," David Gearhart, the newspaper's editor, said. "I'm sure some solution will be found. It better be soon."

SECTION XI

APPENDIX H

ROME, NEW YORK

A. DESCRIPTION OF METHOD

The Rome, New York metropolitan area was analyzed by personal interview of cognizant people. Highway and dump superintendents in the surrounding towns were also interviewed. In addition, we interviewed the secretary of the Chamber of Commerce and two major industries. The waste disposal practices of Griffiss Air Force Base were determined for their influence on the waste streams in the Rome area. A representative private contractor was also interviewed.

The data was analyzed to determine interaction of waste streams between the communities, the amount per capita contributed by each segment of the metropolitan area such as residential, commercial and industrial inputs. Historical trends were noted as far as historical records were obtainable.

B. DISCUSSION OF THE DATA

It was determined that there was little flow of solid waste between communities, though what there was, was more prevalent between the rural suburbs as compared to a flow from the core city to the suburbs. The pounds per capita of solid waste for the core city of Rome was determined to be approximately 3.0 pounds per capita including commercial and residential waste. Approximately 50% of this figure was collected by municipal trucks from the central core city -- the balance was collected by private contractors in the outer city. It was impossible to obtain historical tonnage data. However, it is interesting to note some actual expense figures presented in Table

Year	Waste Disposal Expense	
1946	\$ 43,000 + \$10,000 private contractor	
1960	\$ 88,900	
1965	\$108,264	
1966	\$110,545	
1967	\$120,377	(BUDGETED EXPENSE)

The pounds per capita figure of 3.0 pounds does not include industrial waste. The waste is disposed of in a landfill site which is rented at a nominal cost per month from a private owner. Most of the solid waste is left uncovered for significant periods of time and some fires are permitted to burn in the landfill area from time to time. In the winter time almost no effort is made to cover refuse. Landfill is the chosen method for the area solely on the basis of economics.

Land is plentiful and cheap. At least 1,500 acres exist which could be used as land fill sites. This land is zoned all the way from being suitable for mobile homes to 15,000 to 20,000 square foot residential building lots and varies from prime flat high land suitable for residential development to farm land ranging from good grazing pasture to swampy marsh. All of this land is within two to three miles of the center of the Rome area.

There is a definite interaction of industrial waste with the Rome facility with two major manufacturers disposing of 30,000 pounds per day each in the landfill. The military installation, however, is kept separate from the Rome facility and runs a land fill which is no more sanitary than the one described for the city of Rome. An indeterminate amount of waste is disposed of in this facility in addition to 152,000 pounds of metal which is sold every year. A small amount of garbage amounting to approximately 750 pounds per day is sold to a private contractor for feeding to hogs.

The private contractor who was interviewed indicated that there was negligible cross flow between communities. The contractor also indicated that each community was serviced by private contractors who were able to use the community facility economically and while some cross flow might occur by virtue of a route which started in one community and ended in another, there was no major practice of this.

The Chamber of Commerce staff in the core city of Rome indicated that industry was satisfied with the current operation of being able to use the city facility and that there was not much self disposal by industry. There was a great deal of self disposal by residents. It was the opinion of the Chamber of Commerce staff that better economy could be achieved with the initiation of transfer stations within the city where residents would be required to bring their refuse for trucking by the city to the landfill. The Chamber of Commerce staff also indicated that there were many complaints about the landfill from residents in the surrounding area. The complaints indicated that the landfill was continually smoking from the fires going on and that the roads in the area were dirty by virtue of refuse blowing off the open trucks of private contractors and industry.

The surrounding towns are best described by the example of the town of Lee, New York.

The town of Lee, a small semi-rural community, maintains its own dump which is open from 2 - 7 p.m. on Tuesday, Thursday and Friday and on Saturday from 8 to 5. The dump is about five acres in size and is being utilized in a rather ingenious manner. Twice a year a long trench about 15 feet deep and 10 feet wide is excavated and the refuse is dumped under supervision in progressive areas along this pit. The refuse is burned in the pit and subsequently covered with fill from the excavation. In this manner, a clean and orderly dump is maintained and the life is estimated as twenty years or more. In fact, it is probable that some of the early areas may be retrenched and utilized in a similar manner when the site is filled.

A great many of the people in town carry their own refuse to the dump. There is only one contractor operating who utilizes a small packer truck about 16 or 17 yards in capacity. This contractor picks up in town six days a week, usually two loads a day and on the day when the dump is closed he disposes of refuse on his own farm.

It is thought that there is some cross flow of the refuse between Rome outer city and Lee, but it is believed that the amount is negligible. This operation seems to be satisfactory for this belt type city and indeed the villages of Taberg in the town of Annsville and Westernville in the town of Western have adopted exactly the same disposal methods within their town boundaries. These towns are small and the town official (called the supervisor) works on other jobs and is not available generally for supervision and information on refuse problems.

As an estimate, some 35 yards per day average are picked up by a private collector in the town of Lee, six days a week. This is probably equivalent to about 1,200 pounds per day. It should be noted that this represents only a fraction of the total waste generated within the town since most of the people dispose of their own refuse. As noted above, an exactly similar situation exists in other small surrounding towns.

PART 3

MATHEMATICAL MODEL

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TABLE OF CONTENTS

SECTION I

INTRODUCTION TO MATHEMATICAL MODELING

A. METHOD OF APPROACH

This section of the report describes mathematical methods to estimate solid waste production and installed waste reduction capacity in 1975. Two mathematical models are presented. The first, a national model, uses data collected from the forty-eight continental states to predict installed waste reduction capacity in each of these states in 1975. The second, a model of the state of Connecticut, uses data generated in a "transportation" study to predict installed waste reduction capacity and municipal and industrial solid waste production in Connecticut in 1975. Many states are presently developing "transportation" studies for their highway programs, and may be able to use the concepts presented in this report to develop their own mathematical models for solid waste planning purposes.

B. MATHEMATICAL MODELING

Mathematical models are mathematical equations which use one or more known variables to predict one or more unknown variables. The equations mathematically represent past trends and can be extrapolated to the future assuming past trends continue.

The mathematical models developed utilized linear regression techniques. Linear regression analysis is a statistical technique used to determine the mathematical relationship between a dependent variable (Y) and a set of independent variables (X_1, X_2, ... X_n). An equation of the form

$$Y = a_o + a_1X_1 + a_2X_2 + \dots + a_nX_n \pm ts_y$$

is obtained when linear regression analysis has been applied to a set of data. The numerical values of the a's are such that the sum of the squares of the vertical distances between the data points and the straight line representing the equation is minimized. The ts_y in the above equation is a mathematical representation of these vertical distances.

The standard deviation, σ_y, is a measure of the spread of the data about the mean of the Y's. There is a 68% chance that a random value of Y will fall within σ_y of the mean of the Y's. The standard error of the estimate, s_y, is a measure of the spread of the data about the linear regression line. When t = 1, there is a 68% chance that a random value of Y will fall within $\pm s_y$ of the value predicted by the line. Where t = 2, there is a 95% chance that a random value of Y will fall within $\pm 2s_y$ of the value predicted by the line.

The correlation coefficient, R, is a measure of how well the equation represents the data. R is defined so that $100R^2$ equals the percent of the variability of Y that is accounted for by the relationship with the X's. In mathematical form:

$$R = \sqrt{1 - \frac{S_Y^2}{\sigma Y^2}}$$

For this study Combustion Engineering used a regression analysis computer program that provided the ability to consider non-linear as well as linear relationships. This additional capability allowed for a more exact analysis of solid waste reduction capacity needs. The computer program also selected the best combination of variables; all variables which had coefficients with confidence of less than 95% were eliminated from the equation. In other words, all regression equations predicted in this report are given with 95% confidence.

While regression analysis is a valuable tool for mathematical model building, consideration must be given to the possible misuse of it. The use of regression analysis can result in invalid predictions because of the assumption of non-existing cause and effect relationships For example, we do get an extremely high linear correlation by considering the increase in alcohol consumption with the increase in teachers' salaries. It is recognized that no cause and effect relationship exists in this example. The example illustrates two changes in our environment with no real relationship. The above example is to emphasize the need for "common sense" judgements in gathering input information for any computer analysis of sets of interrelated variables. In addition, the use of regression equations to predict the future implies that the historical relationship between the variables will remain constant over time; i.e., the coefficients a_0, a_1 ... etc., will remain constant. Any changes in these relationships and, hence, in the constants will introduce errors into the predicting equation.

SECTION II

NATIONAL MODEL

A. MODEL CONCEPT

This section discusses the data used for the national waste reduction model and how this data was combined into a set of variables which was used in linear regression analysis. Linear regression analysis resulted in two equations, a complex one and a simplified one. These equations were then used to project national solid waste capacities for 1975 by state. The complex model involves several physical quantities as independent variables whereas the simplified model uses only two physical quantities as independent variables.

B. DESCRIPTION OF VARIABLES

Tables 1 to 6 and Figure 1 summarize the statistical information gathered on installed waste reduction facilities in the United States. The information was collected in three ways: (1) Combustion Engineering personnel personally interviewed officials in fifty cities, (2) a telephone survey of approximately six hundred cities was conducted by the Western Union Telegraph Company using the questionnaire in Appendix A and (3) telephone interviews were made with personnel of the State Health Departments to verify Western Union responses.

Due to the nature of the personal interview and the experience of the interviewers, the statistical data gathered by Combustion Engineering personnel was assumed to be correct. The Chi square test was used to test the significance of the results and a linear correlation analysis was performed to determine the relative accuracy of the data. The correlation coefficient of personal interview data with Western Union data was .97. A comparison of the data gathered by the three methods revealed exact agreement in the responses of two-thirds of those cities which reported waste reduction facilities. The standard error of the mean installed capacity was approximately 16.5% in a town, with a much lower percentage error on a per state basis of approximately 8%. Since state values were obtained by adding up the values for each city, the resulting error in the state value is equal to the square root of the sum of the squares of errors in the city data. The Western Union data was combined with the other data to provide the dependent variable, tons of installed waste reduction capacity by state.

The choice of the independent variables was based upon the assumption that solid waste reduction capacity was primarily dependent upon two factors: (1) amount of refuse generated and (2) amount of land available for land fill. The first factor was based on the assumption that solid waste reduction capacity, when installed, is directly dependent on the amount of waste produced. The second factor was used to determine when waste reduction is required. It is well known that while land fill which is the primary alternative to waste reduction is relatively inexpensive to operate, it is also relatively extravagant of land. Incineration reduces the bulk volume of the solid waste by about 80%, accounting for significant land savings. Consequently, areas with little

TABLE 1

STATISTICAL SUMMARY OF SURVEY DATA
FOR NATIONAL MATHEMATICAL MODEL

State	% of Population Greater than 50,000 Sampled* (See Note 1)	% of Population Between 25,000 & 50,000 Sampled* (See Note 1)	Number of Replies From Cities Greater than 50,000	Number of Replies Received Between 25,000 and 50,000
Alabama	100.0	***	6	0
Arizona	100.0	***	2	0
Arkansas	100.0	***	3	0
California **	94.0	83.5	38	47
Colorado	100.0	***	3	0
Connectciut **	100.0	100.0	10	16
Delaware **	100.0	****	1	0
Florida **	95.9	***	9	0
Georgia **	80.7	***	4	0
Idaho	****	***	0	0
Illinois **	98.9	73.4	14	22
Indiana **	95.9	75.9	8	8
Iowa	100.0	***	7	0
Kansas	100.0	***	3	0
Kentucky	100.0	***	3	0
Louisiana **	100.0	***	5	0
Maine	100.0	***	1	0
Maryland	100.0	82.9	5	5
Massachusetts	90.4	88.7	17	25
Michigan **	92.9	88.3	17	17

STATISTICAL SUMMARY OF SURVEY DATA
FOR NATIONAL MATHEMATICAL MODEL

Minnesota	100.0	***	4	0
Mississippi **	100.0	***	1	0
Missouri **	100.0	***	6	0
Montana	100.0	***	2	0
Nebraska	100.0	***	2	0
Nevada	100.0	***	2	0
New Hampshire	100.0	***	1	0
New Jersey **	93.0	94.4	15	31
New Mexico	100.0	***	1	0
New York **	96.9	79.5	15	20
North Carolina **	100.0	***	7	0
North Dakota	****	***	0	0
Ohio **	95.1	91.3	15	20
Oklahoma **	100.0	***	3	0
Oregon	100.0	***	2	0
Pennsylvania **	97.2	100.0	19	20
Rhode Island **	100.0	100.0	4	3
South Carolina **	100.0	***	3	0
South Dakota	100.0	***	1	0
Tennessee **	100.0	***	4	0
Texas **	98.4	***	20	0
Utah	100.0	***	2	0
Vermont	****	***	0	0
Virginia	83.5	100.0	7	3
Washington	100.0	***	3	0

STATISTICAL SUMMARY OF SURVEY DATA
FOR NATIONAL MATHEMATICAL MODEL

West Virginia **	100.0	100.0	3	4
Wisconsin **	92.7	92.9	6	10
Wyoming	****	***	0	0
			304	251

NOTE:

Cities were placed in one or the other strata by population existing in city as recorded by 1960 census.

Note 1 -- Represents total population sampled as a percentage of total population in all cities in this population range.

* Sampled by Western Union and personal interview.
** State Health Department contacted by telephone for further verification of state totals.
*** Cities between 25,000 and 50,000 were surveyed only in the states listed in technical protocol.
**** State has no cities in this strata.

TABLE 2

SUMMARY OF INSTALLED WASTE REDUCTION CAPACITY 1966 IN OPERATION

State	Installed Capacity lbs/day/person, Cities Larger than 25,000 Less than 50,00	Installed Capacity lbs/day/person, Cities Larger than 50,000	Total Installed Capacity for Cities*** (1966) Tons/Day
Alabama	*	0.0	0
Arizona	*	0.0	0
Arkansas	*	0.0	0
California	0.0	0.0	0
Colorado	*	0.0	0
Connecticut	3.3	9.4	4960
Delaware	*	0.0	0
Florida	4.6	6.3	5320
Georgia	0.9	3.5	1855
Idaho	**	**	0
Illinois	0.0	1.7	3960
Indiana	1.9	0.6	835
Iowa	*	0.0	0
Kansas	*	0.1	35
Kentucky	*	5.3	1350
Louisiana	*	3.7	1940
Maine	*	0.0	0
Maryland	0.0	4.3	2574
Massachusetts	2.8	2.8	4690
Michigan	2.5	1.7	3550

<u>SUMMARY OF INSTALLED WASTE REDUCTION CAPACITY 1966 IN OPERATION</u> (2)

Minnesota	*	0.5	225
Mississippi	1.1	0.0	144
Missouri	*	1.3	1000
Montana	*	0.0	0
Nebraska	*	0.0	0
Nevada	**	1.7	100
New Hampshire	*	2.8	125
New Jersey	1.1	0.9	1424
New Mexico	*	0.0	0
New York	8.1	2.8	21042
North Carolina	*	0.0	0
North Dakota	*	**	0
Ohio	1.1	2.2	4840
Oklahoma	*	0.0	0
Oregon	*	0.3	60
Pennsylvania	2.9	2.7	6325
Rhode Island	3.8	2.7	865
South Carolina	*	0.0	0
South Dakota	*	0.0	0
Tennessee	*	0.0	0
Texas	*	0.4	924
Utah	*	2.3	300
Vermont	*	**	0
Virginia	0.0	2.7	1710
Washington	*	0.0	0

SUMMARY OF INSTALLED WASTE REDUCTION CAPACITY 1966 IN OPERATION (3)

West Virginia	0.0	2.7	300
Wisconsin	3.6	3.0	2625
Wyoming	*	**	0
TOTAL			73078 tons/day

NOTE:

Cities were placed in one or the other strata by population existing in city as recorded by 1965 census.

* Cities between 25,000 and 50,000 were surveyed only in the states listed in technical protocol.

** State had no cities in this strata.

*** Capacity was obtained by projecting Western Union and personal data to include entire state population. This total state capacity was reviewed with state health officials in selected states.

TABLE 3

INCINERATORS IN THE UNITED STATES
OPERATING IN 1966

State	City	Capacity Tons Per 24 Hr. Day	Date Installed
CONNECTICUT	Greenwich	200	1938
Installed Operating Capacity	Darien	60	1941
4,960 tons/day	New London	120	1941
	Stamford	225	1942
	Derby	60	1951
	Waterbury	300	1951
	Hartford	600	1952
	New Britain	300	1954
	New Canaan	50	1955
	East Hartford	200	1956
	West Hartford	350	1957
	Bridgeport	300	1958
	Stamford	125	1959
	Bridgeport	200	1960
	Greenwich	250	1961
	Norwalk	360	1962
	New Haven	720	1963
	Stratford	240	1963
	West Haven	300	1966
DISTRICT OF COLUMBIA	Washington	500	1932
Installed Operating Capacity	Washington	500	1955
1,500 tons/day	Washington	500	1962
FLORIDA	Orlando	200	1942
Installed Operating Capacity	Jacksonville	120	1945
5,320 tons/day	Jacksonville	350	1949
	Miami	900	1951
	Hollywood	450	1952
	Jacksonville	350	1952
	Ft. Lauderdale	250	1954
	Coral Gables	300	1957
	Miami	300	1960
	Broward County	600	1964
	Orlando	250	1964
	Clearwater	300	1964
	Ft. Lauderdale	450	1966
	St. Petersburg	500	1966
GEORGIA	Athens	75	1939
Installed Operating Capacity	Atlanta	330	1939
1,855 tons/day	Atlanta	350	1951
	Atlanta	500	1963
	DeKalb County	600	1964

State	City	Capacity Tons Per 24 Hr. Day	Date Installed
ILLINOIS Installed Operating Capacity 3,960 tons/day	Aurora	40	1947
	Evanston	180	1955
	Cicero	500	1956
	Chicago	720	1956
	Chicago	1200	1959
	Chicago	1200	1963
	Skokie	120	---
INDIANA Installed Operating Capacity 835 tons/day	Indianapolis	450	1954
	New Albany	285	1959
	Bloomington	100	1964
KANSAS Installed Operating Capacity 35 tons/day	Dodge City	35	1965
KENTUCKY Installed Operating Capacity 1,350 tons/day	Lexington	200	1957
	Louisville	750	1957
	Louisville	250	1965
	Lexington	150	1966
LOUISIANA Installed Operating Capacity 1,940 tons/day	Jefferson Parish	90	1948
	Jefferson Parish	100	1950
	Shreveport	350	1951
	New Orleans	400	1958
	New Orleans	400	1962
	New Orleans	200	1963
	Jefferson Parish	400	1964
MARYLAND Installed Operating Capacity 2,574 tons/day	Baltimore	600	1933
	Salisbury	124	1933
	Baltimore	800	1956
	Montgomery County	1050	1965
MASSACHUSETTS Installed Operating Capacity 4,690 tons/day	Cambridge	150	1938
	Holyoke	225	1947
	Fall River	20	1948
	Brookline	300	1952
	Lawrence	300	1952
	Newton	180	1954
	Worcester	250	1954
	Framingham	200	1955
	New Bedford	240	1957
	Marblehead	90	1958
	Belmont	150	1959
	Boston	750	1959
	Waltham	150	1959
	Somerville	300	1960
	Wellesley	150	1960
	Dedham	100	1961
	Winchester	100	1961

State	City	Capacity Tons Per 24 Hr. Day	Date Installed
MASSACHUSETTS (cont.)	Salem	235	1962
Installed Operating Capacity	Watertown	100	1963
4,690 tons/day	Lowell	400	1964
	Weymouth	300	1965
MICHIGAN	Hamtramck	200	1957
Installed Operating Capacity	Detroit	600	1958
3,550 tons/day	Detroit	600	1958
	Detroit	400	1958
	Detroit	400	1958
	Garden City	10	1960
	River Rouge	50	1961
	Trenton	100	1963
	S.E. Oakland County	600	1963
	Central Wayne County	500	1964
	Ecorse	90	1954
MINNESOTA	Minneapolis	225	1939
Installed Operating Capacity			
225 tons/day			
MISSISSIPPI	Picayune	144	1966
Installed Operating Capacity			
144 tons/day			
MISSOURI	St. Louis	500	1950
Installed Operating Capacity	St. Louis	500	1958
1,000 tons/day			
NEVADA	Las Vegas	100	
Installed Operating Capacity			
100 tons/day			
NEW HAMPSHIRE	Manchester	125	1937
Installed Operating Capacity			
125 tons/day			
NEW JERSEY	Hamilton Township	100	1925
Installed Operating Capacity	Hackensack	100	1927
1,424 tons/day	Red Bank	60	1930
	Spring Lake	30	1930
	Perth Amboy	90	1930
	Atlantic City	94	1931
	Princeton	100	1954
	Jersey City	600	1957
	Ewing	250	1965
NEW YORK	Buffalo	400	1927
Installed Operating Capacity	Elmira	100	1929
21,042 tons/day	Middletown	50	1929
	New Rochelle	150	1929

State	City	Capacity Tons Per 24 Hr. Day	Date Installed
NEW YORK (cont.) Installed Operating Capacity 21,042 tons/day	Schenectady	165	1932
	Glen Cove	100	1938
	Larchmont	120	1939
	New Rochelle	250	1939
	New York	2840	Prior to 1945
	Babylon	90	1946
	Cheektowaga N.W.	150	1946
	Amsterdam	120	1947
	Corning	80	1947
	Tonawanda	90	1948
	Lackawana	100	1949
	Mount Vernon	600	1949
	West Seneca	60	1949
	Tonawanda	90	1950
	North Tonawanda	72	1951
	Port Chester	120	1951
	Yonkers	450	1951
	Hempstead	700	1952
	Long Beach	200	1952
	Harrison	150	1953
	New York	1000	1953
	Buffalo	300	1954
	New York	1000	1954
	Huntington	150	1955
	Rochester	450	1955
	Babylon	300	1956
	Binghamton	300	1956
	Niagara Falls	240	1956
	Rochester	450	1956
	White Plains	400	1956
	New York	660	1957
	Oyster Bay	500	1957
	Tonawanda	80	1957
	Huntington	150	1958
	New York	1000	1959
	New York	1000	1959
	Rye	150	1959
	Scarsdale	150	1959
	Freeport	150	1960
	New York	1000	1961
	East Rochester	200	1962
	New York	1000	1962
	Valley Stream	200	1962
	Garden City	175	1963
	Beacon	100	1964
	Canajoharie	50	1964
	Hempstead	650	1965
	Huntington	150	1965
	Newburg	240	1965
	Oyster Bay	500	1965
	Rampo	200	1965
	Plainview	900	1966

State	City	Capacity Tons Per 24 Hr. Day	Date Installed
OHIO Installed Operating Capacity 4,840 tons/day	Cincinnati	400	1933
	Cleveland	900	1936
	Dayton	200	1940
	Youngstown	300	1945
	Barberton	65	1948
	Cleveland Heights	150	1948
	Lakewood	100	1951
	Cincinnati	500	1954
	South Euclid	100	1954
	Maple Heights	150	1955
	Euclid	300	1956
	Parma	225	1957
	Cleveland	500	1961
	Sharonville	300	1961
	Norwood	150	1961
	Cincinnati	500	1965
OREGON Installed Operating Capacity 60 tons/day	Portland	60	1932
PENNSYLVANIA Installed Operating Capacity 6,325 tons/day	Johnstown	55	1920
	Allentown	150+	1929
	Erie	225+	1930
	Lower Merion	80+	1938
	Philadelphia	600	1938
	Pittsburgh	400	1939
	Meadville	80	1949
	West Mifflen	40+	1949
	Ambridge	150	1950
	Philadelphia	200	1950
	Philadelphia	300	1950
	Bloomsburg	60	1952
	Red Lion	60	1954
	Philadelphia	300	1954
	Abington	200+	1955
	Philadelphia	250	1955
	Philadelphia	300	1955
	Philadelphia	600	1956
	Cheltenham	100	1958
	Whitemarsh	300	1959
	Bradford	200	1960
	Delaware County	300+	1960
	Philadelphia	600	1960
	Delaware County	300+	1961
	Delaware County	300+	1962
	Penn Hills	175	1962
RHODE ISLAND Installed Operating Capacity 865 tons/day	Newport	100	1937
	Warwick	45	1946
	Providence	160	1948

State	City	Capacity Tons Per 24 Hr. Day	Date Installed
RHODE ISLAND (cont.)	Woonsocket	160	1960
Installed Operating Capacity	Pawtucket	400	1964
865 tons/day			
TEXAS	Laredo	24	1925
Installed Operating Capacity	Houston	200	1947
924 tons/day	Houston	200	1949
	Houston	200	1954
	Amarillo	300	1966
UTAH	Ogden	300	1966
Installed Operating Capacity			
300 tons/day			
VIRGINIA	Norfolk	360	1946
Installed Operating Capacity	Arlington County	300	1949
1,710 tons/day	Alexandria	200	1954
	Arlington County	300	1955
	Portsmouth	350	1963
	Roanoke	200	1964
WEST VIRGINIA	Charleston	300	1964
Installed Operating Capacity			
300 tons/day			
WISCONSIN	Racine	120	1929
Installed Operating Capacity	Oshkosh	100	1929
2,625 tons/day	Whitefish Bay	40	1929
	Kenosha	120	1936
	Green Bay	60	1946
	Fond du Lac	90	1950
	Kenosha	120	1951
	Milwaukee	300	1952
	Milwaukee	300	1954
	Racine	60	1954
	West Allis	100	1954
	Racine	60	1958
	Wauwatosa	105	1959
	De Pere	75	1961
	Nekoosa	60	1963
	Sheboygan	240	1964
	Port Washington	75	1965
	De Pere	150	1966
	Green Bay	450	1966
TOTAL U. S.		74,578 tons/day	

TABLE 4

DISTRIBUTION OF INCINERATORS OPERATING IN 1966

State	Number of Towns	Number of County Incinerators	Number of Plants
Connecticut	16		19
District of Columbia	1		3
Florida	9	1	14
Georgia	3		5
Illinois	5		7
Indiana	3		3
Kansas	1		1
Kentucky	2		4
Louisiana	2	1	7
Maryland	2	1	4
Massachusetts	21		21
Michigan	7	1	11
Minnesota	1		1
Mississippi	1		1
Missouri	1		2
Nevada	1		1
New Hampshire	1		1
New Jersey	9		9
New York	40		60
Ohio	13		16
Oregon	1		1
Pennsylvania	17	1	26
Rhode Island	5		5
Texas	3		5
Utah	1		1
Virginia	5		6
West Virginia	1		1
Wisconsin	13		19
Total	185	5	254

TABLE 5 (a)

INSTALLED INCINERATOR CAPACITY IN THE UNITED STATES
OPERATING IN 1966

Year	Number of Incinerators	Total Capacity
1950	90	22,932
1960	205	57,044
1966	254	74,578

TABLE 5 (b)

AVERAGE SIZE OF INCINERATORS
CONTINUING TO OPERATE IN 1966

Year Installed	Number Installed*	Tons/Day	Average Size Tons/Day	Max. Size Tons/Day
Prior to 1950	74	15,252	206	900
1950-1959	102	34,022	334	1,200
1960-1966	78	25,304	324	1,200
Total	254	74,578		

* This is a breakdown of the 254 incinerators installed prior to 1967 that are still in operation in 1966.

TABLE 6

COMPOSTING PLANTS IN OPERATION IN THE UNITED STATES

JUNE 1967

	Tons/Day
Altoona, Pennsylvania	20 to 45
St. Petersburg, Florida	105
Houston, Texas (1)	300
Mobile, Alabama	200
Boulder, Colorado (2)	100
	725 to 745 tons/day of refuse

---

(1) In June, 1967 Houston was operating one plant and another had been constructed (400 tons per day) which was not operating due to contract problems.

(2) The plant had been shut down temporarily due to bad weather when the city was contacted.

GEOGRAPHIC DISTRIBUTION OF WASTE REDUCTION FACILITIES IN OPERATION - 1966

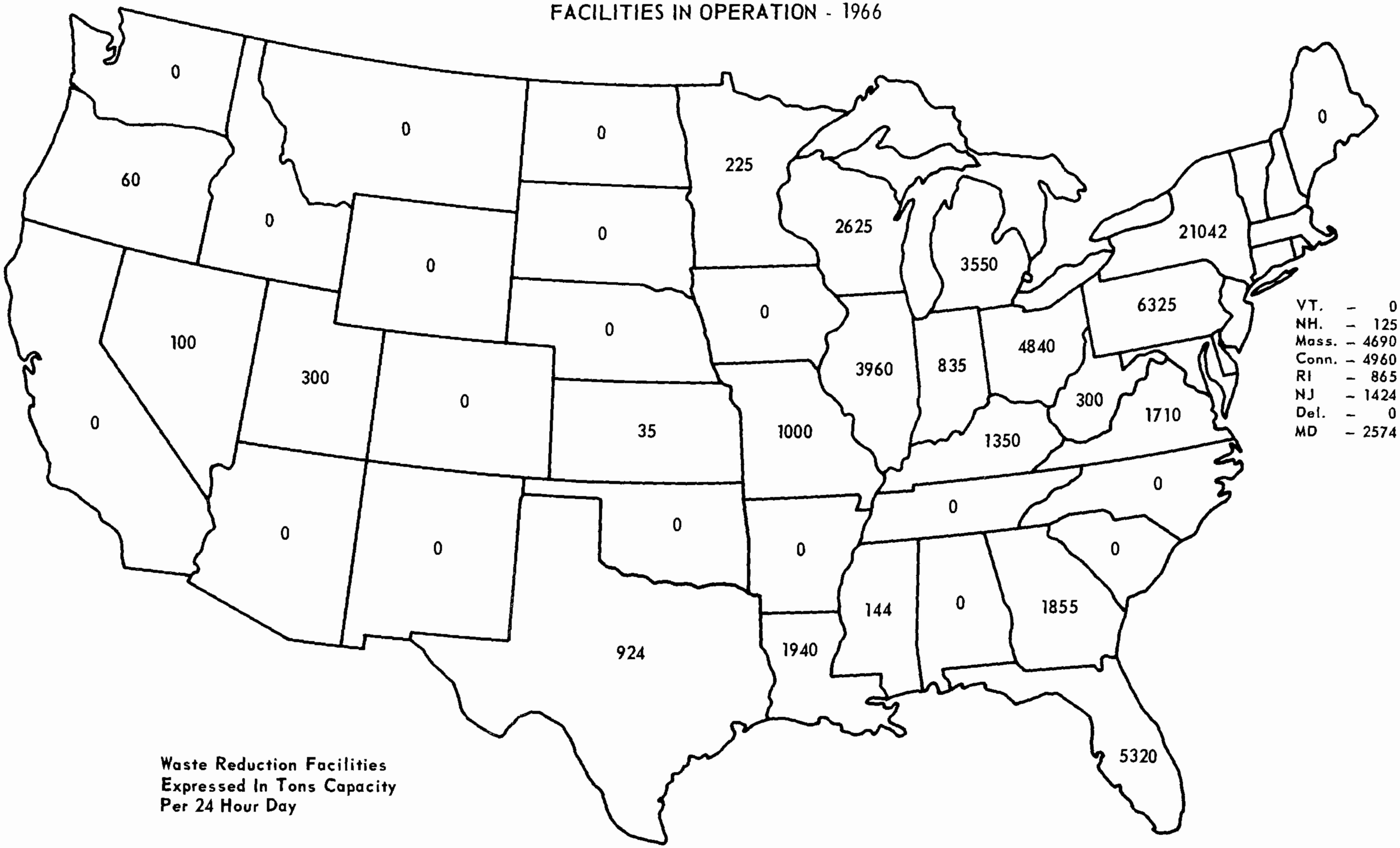

Figure 1

vacant land might choose to use the more expensive disposal method.

The variables used were:

Variable	Why Selected	The Variable is an Indicator of the Following Factors
1. Population	More people means more waste	Municipal waste generation
2. Population density (people per square mile)	Best variable with data available	Vacant land
3. Value added by manufacturer	Manufacturing is a source of solid waste	Industrial waste generation
4. Total Sales	Economic activity affects amount of solid waste	Total waste generation
5. Year	Per capita solid wastes and other factors change with time	Growth in total waste generation per capita and other factors which change with time

Other variables such as urban population, urban land, urban population density, state land area, and a variable measuring the competition between cities for land were investigated. However, these variables were found to have either negligible correlations with solid waste reduction capacity or they duplicated the correlation found with the five variables used in the final model.

In the development of the model, the variables mentioned above were combined to provide a more meaningful explanation of solid waste reduction capacity. For example, population density as a measure of vacant land would indicate when waste reduction equipment should be installed, but would not also indicate the size of this equipment necessarily. Population as a measure of the waste produced does indicate the size of equipment when it is necessary. These two factors combined, therefore, are a better factor than both taken independently. Another, but less obvious interaction was discovered in value added by manufacture and total sales. Consequently, these factors, in addition to being considered independently, were combined to form a new factor which allows for the interaction. Data for the independent variables was obtained.[1 to 8]

Table 7 shows the correlation between dependent and independent variables. For example, the intersection of row 2 and column 4 contains the correlation coefficient of variables 2 and 4. Likewise, the number at the intersection of row 4 and column 2 is the same number because it is a measure of the correlation of the same two variables 4 and 2. Therefore, the matrix shown in Table 7 is symmetrical about the diagonal denoted by the unity coefficients. If variable 2 was plotted against variable 4, it would have a correlation coefficient of .77. However, it should be noted that when several variables are used, multiple regression analysis can result in a regression coefficient larger than any of the individual correlation coefficients shown in Table 7.

TABLE 7

NATIONAL MATHEMATICAL MODEL CORRELATION MATRIX

Variable	1*	2	3	4	5	6	7	8	9	10	Y	Variable
1	1.00	.91	.84	.81	.80	.72	.78	.81	.71	.09	.76	1
2	.91	1.00	.99	.77	.80	.71	.86	.80	.86	.09	.91	2
3	.84	.99	1.00	.72	.77	.67	.86	.76	.90	.09	.93	3
4	.81	.77	.72	1.00	.99	.90	.93	.99	.83	.25	.72	4
5	.80	.80	.77	.99	1.00	.86	.97	.97	.90	.25	.77	5
6	.72	.71	.67	.90	.86	1.00	.84	.94	.74	.24	.70	6
7	.78	.86	.86	.93	.97	.84	1.00	.95	.97	.22	.87	7
8	.81	.80	.76	.99	.97	.94	.95	1.00	.86	.24	.76	8
9	.71	.86	.90	.83	.90	.74	.97	.86	1.00	.21	.90	9
10	.09	.09	.09	.25	.25	.24	.22	.24	.21	1.00	.24	10
Y	.76	.91	.93	.72	.77	.70	.87	.76	.90	.24	1.00	Y

* Numbers refer to the following list of variables:

X_1 = Population x Population density x 10^{-6}

1 $X_1^{.5}$

2 $X_1^{1.5}$

3 X_1^{2}

4 X_2 = Value added by manufacturer \$ x 10^{-6}

5 $X_2^{1.5}$

X_3 = Total Sales \$ x 10^{-6}

6 $X_3^{.5}$

7 $X_4 = X_2 X_3$

8 $X_4^{.5}$

9 $X_4^{1.5}$

10 X_5 = Year

Y = Tons of installed capacity per 24 hour day.

C. PROJECTIONS OF NATIONAL INSTALLED WASTE REDUCTION CAPACITY TO 1975

Equations 1 and 2 can be used to predict the solid waste reduction capacity of the nation by state in 1975. The complex model, Equation 1, used five independent variables and achieved a multiple correlation coefficient of .98 with a standard error of estimate of 899 tons. The correlation of .98 means that these variables explain (.98 x .98) 96 percent of the variability in the installed capacities of the states.

Although the simplified model, Equation 2, used only two independent variables, a multiple correlation coefficient of .96 with a standard error of 1,165 tons was achieved. This simpler model accounts for (.96 x .96) 92 percent of the variability of the installed capacities of the states.

COMPLEX EQUATION FOR NATIONAL MODEL

Eq. 1) $$Y = 145138 + 143.585X_1^{.5} - .0932X_1^{1.5} - .0013X_1^{2} + 7374X_2 - 1284X_2^{1.5} + 9406X_3^{.5} + 464X_4 - 9318X_4^{.5} - 8.423X_4^{1.5} + 69.855X_5$$

WHERE:

Y = tons of installed capacity per 24 hour day
X_1 = population x population density x 10^{-6} = $\frac{(\text{people})^2}{\text{sq. mile}} \times 10^{-6}$
X_2 = value added by manufacture \$ x 10^{-6}
X_3 = total sales \$ x 10^{-9}
X_4 = $X_2 X_3$
X_5 = year

Standard Error of Estimate = 899 tons
Multiple Correlation R = .98
Number of Observations = 54

SIMPLIFIED EQUATION FOR NATIONAL MODEL

Eq. 2) $$Y = -1598X_1 10^{6} - 5.6X_1 + 275.96X_1^{.5} + 8.6X10^{-4}X_1^{2} + 80.54X_5$$

WHERE:

Y = tons of installed capacity per 24 hour day
X_1 = population x population density x 10^{-6}
X_5 = year

Standard Error of Estimate = 1,165 tons
Multiple Correlation R = .96
Number of Observations = 54

Figure 2 is a graphical representation of the simplified equation for 1950, 1960, 1966 and 1975. An inspection of the data indicated that the regression line fits the data well at high values of X_1. The equation has a smooth transition from these high values to zero, and because of this smooth transition an X_1 value of 400 and below does not fit the data well. Consequently, the equation was not used to predict installed capacity in states whose X_1 value was below 400 in 1975.

The simplified rather than complex equation was employed as the basis for projection of installed waste reduction capacity in 1975 because projections of some of the variables used in the complex model were not available for 1975.

A differential shift method (Equation 3, Table 8) was used to project installed capacity by state to 1975. Some states' waste reduction capacity is greater and others less than anticipated by the model (Equation 2), and it was assumed that the relative position of each state to the curve would be the same in 1975. For example, if a state had a waste reduction capacity greater than that which the model predicts for 1966, it would have a waste reduction capacity greater than the model predicts in 1975.

Three values are presented in Table 8 for the installed waste reduction capacity in 1975. The first two values are presented in tabular form for each state. These results were obtained from the substitution of the highest and lowest values of the Bureau of Census population projections for each state in 1975[7] into Equation 3, given at the top of Table 8. The resulting national installed capacity using the high population figure yields 125,000 tons per day, the low population figure yields 107,000 tons per day. A straight line engineering projection shown in Figure 3 yielded a value of 104,550 tons per day.

Two exceptions to the above method were the projections made for California and New Jersey. California in recent years has shut down all operating waste reduction plants because these plants did not have air pollution control equipment to meet requirements of the state. With the improvement of air pollution control devices, California might start reinstalling waste reduction plants, and consequently, the highest projection of the model is presented. It is also conceivable that the present trend of zero waste reduction plants will continue and, consequently, the low projection for California is zero.

The mathematical model was not used to predict the installed waste reduction capacity in New Jersey in 1975 due to the land characteristics of the state. New Jersey has more low, flat, marshy land in relation to its total land area than other states. This land is ideally suited for land fill operations. Also, this land is in close proximity to the larger cities and provides the most economic type of refuse disposal available. However, New Jersey is both densely populated and has little total land area -- two factors which would usually indicate the need for waste reduction facilities.

The values presented in Table 8 for New Jersey are engineering estimates. As long as the land can continue to be used for this purpose, large increases in waste reduction capacity cannot be expected. It is interesting to note that if New Jersey was similar to other states, it would have from 16,500 to 24,000 tons per day installed in 1975 -- an unrealistic expectation in light of their present solid waste disposal practices.

TONS OF INSTALLED WASTE REDUCTION CAPACITY DETERMINED FROM NATIONAL MATHEMATICAL MODEL

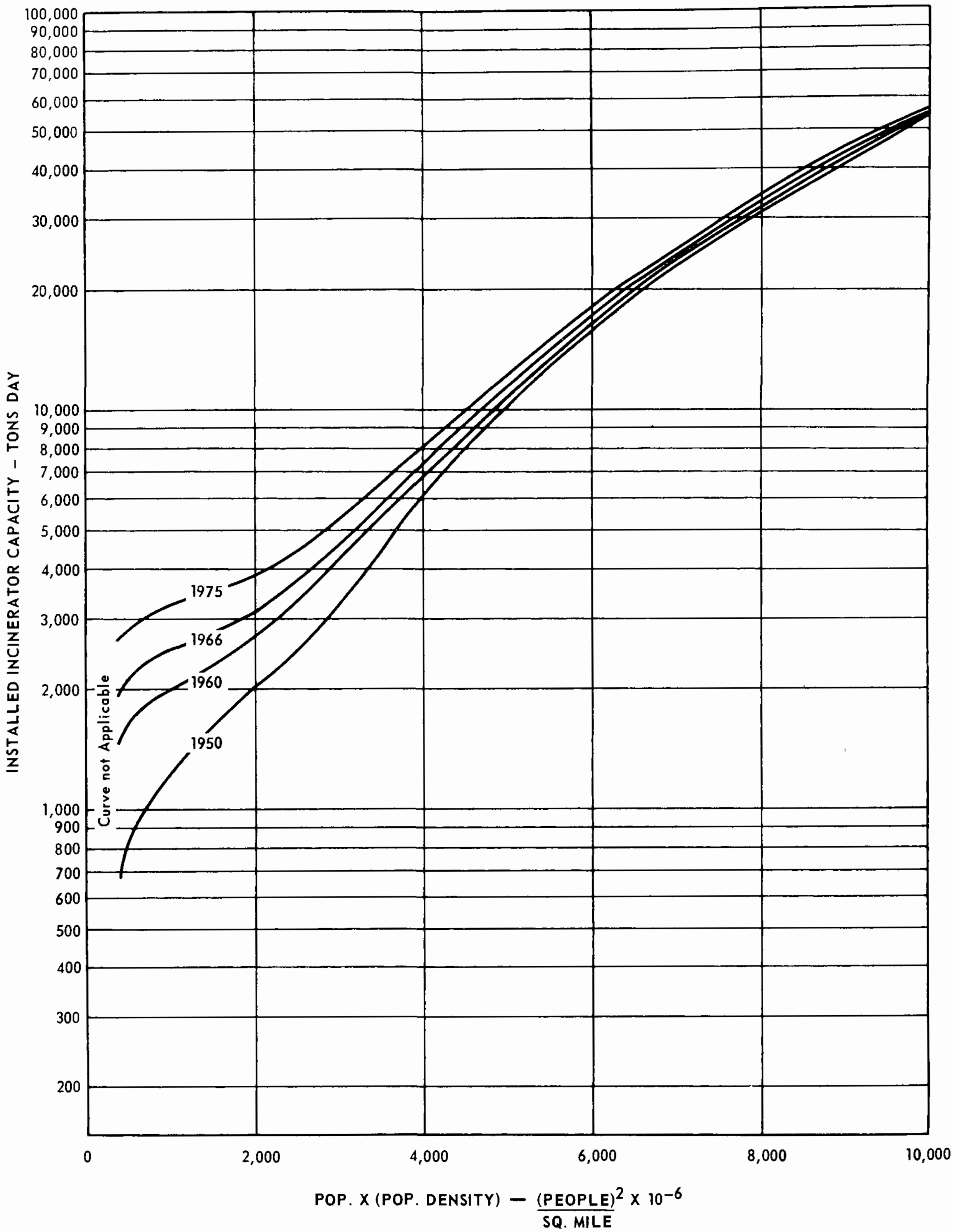

Figure 2

TABLE 8

INSTALLED WASTE REDUCTION CAPACITY FOR 1975
BASED ON PROJECTIONS OF NATIONAL WASTE REDUCTION MODEL

Eq. 3)

$$Y_{75} = 733.50 - 5.60(X_{75} - X_{66}) + 275.96(X_{75}^{.5} - X_{66}^{.5}) + 8.6 \times 10^{-4}(X_{75}^{2} - X_{66}^{2}) + Y_{66}$$

WHERE:

Y = installed capacity
X = population x population density x 10^{-6}
Subscripts define year to which variables applied

NOTE:

Equation applies only when X>400
When X≯400, Y_{75} assumed = Y_{66}

	Y TONS/DAY		X POP. x P.D. x 10^{-6}	
	HIGH	LOW	HIGH	LOW
Alabama	1,250	1,150	305.1	280.8
Arkansas	0	0	89.3	81.4
Arizona	0	0	46.2	38.8
California	7,300	0	3,783.4	3,351.6
Colorado	0	0	5.7	5.2
Connecticut	6,300	6,100	2,281.3	2,101.9
Delaware	0	0	194.4	177.0
Florida	6,350	6,250	1,239.4	1,050.6
Georgia	2,900	2,800	435.0	402.8
Idaho	0	0	7.3	7.0
Illinois	5,350	5,100	2,617.7	2,454.5
Indiana	1,650	1,650	852.5	794.5
Iowa	0	0	157.9	141.6
Kansas	35	35	70.3	64.5
Kentucky	2,300	2,200	302.2	270.2
Louisiana	2,950	2,900	393.9	366.3
Maine	0	0	38.6	34.6
Maryland	3,650	3,550	1,869.6	1,703.6
Massachusetts	8,800	7,500	4,640.3	4,311.2
Michigan	4,400	4,300	1,537.0	1,405.6

	Y TONS/DAY HIGH	LOW	X POP. x P.D. x 10^{-6} HIGH	LOW
Minnesota	225	225	209.2	193.0
Mississippi	144	144	150.2	134.4
Missouri	1,850	1,800	340.6	313.5
Montana	0	0	4.1	3.9
Nebraska	0	0	34.0	30.8
Nevada	100	100	2.1	2.0
New Hampshire	125	125	66.8	61.3
New Jersey	2,250	2,125	8,665.5	7,948.5
New Mexico	0	0	14.8	12.9
New York	39,300	33,200	8,624.2	92.9
North Carolina	900	850	630.7	576.3
North Dakota	0	0	7.1	6.0
Ohio	6,900	6,350	3,405.9	3,190.4
Oklahoma	0	0	105.6	96.1
Oregon	60	60	47.5	43.8
Pennsylvania	8,000	7,350	3,483.6	3,210.9
Rhode Island	1,700	1,600	921.8	849.4
South Carolina	1,000	950	286.6	268.3
South Dakota	0	0	7.9	6.7
Tennessee	1,000	900	444.8	411.4
Texas	1,900	1,850	583.3	537.3
Utah	300	300	19.1	17.1
Vermont	0	0	23.6	22.2
Virginia	2,650	2,650	665.8	624.1
Washington	0	0	181.7	169.2
West Virginia	300	300	142.8	123.0
Wisconsin	3,550	3,500	414.7	381.0
Wyoming	0	0	1.6	1.2
	125,489	107,914		

Engineering Projection - 104,550 tons

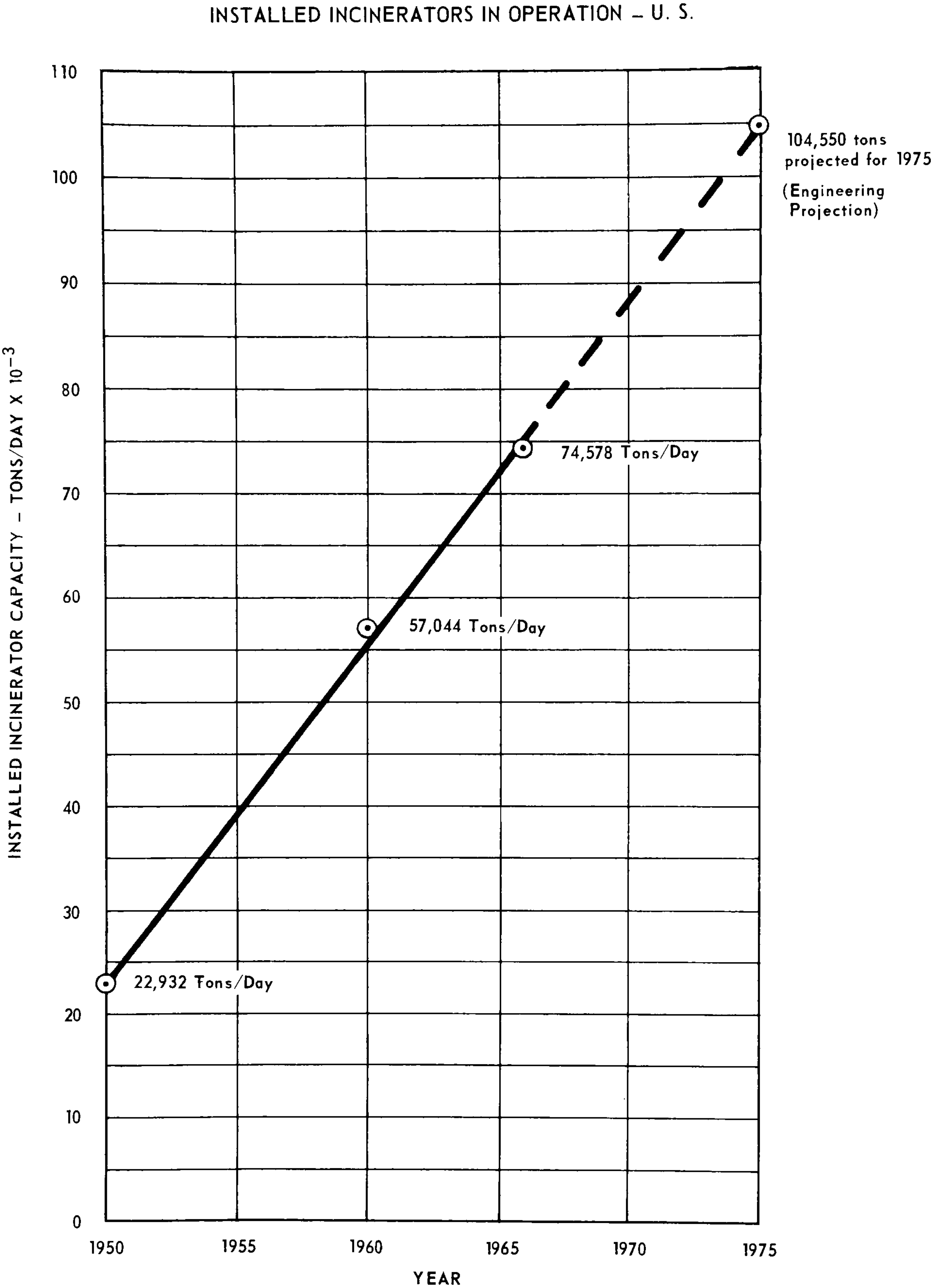
INSTALLED INCINERATORS IN OPERATION – U. S.
INSTALLED INCINERATOR CAPACITY – TONS/DAY X 10^{-3}
0
10
20
30
40
50
60
70
80
90
100
110
1950
1955
1960
1965
1970
1975
YEAR
22,932 Tons/Day
57,044 Tons/Day
74,578 Tons/Day
104,550 tons projected for 1975
(Engineering Projection)

Figure 3

SECTION III

CONNECTICUT MODELS

A. MODEL CONCEPT

The Connecticut waste reduction models are shown in relation to other planning models in Figure 4. The chronological development of these models is illustrated in Figure 4. Model 1 can be any national projection of economic activity. The one shown in Figure 4 was developed by the National Planning Association. Models 2 and 3, shown in Figure 4, were developed by the state of Connecticut for its planning needs. These models can be developed by other states for highway planning and other municipal planning activites. The Connecticut solid waste models, Model 4, were developed by Combustion Engineering during the present study.

Connecticut's land usage study (Model 3, Figure 4) complied with the Federal regulation that all towns of over 5,000 people in a state must undertake a land usage study in order that the state be eligible for the 90 percent Federal aid in road building projects. The use of the Connecticut land usage study as a basis for developing the Connecticut waste reduction model can serve as an example for other states wishing to model their own solid waste reduction needs. The data necessary for the variables used in the state's model should readily be available from its own land usage study.

Model 3, Connecticut's land usage study[11], distributed the state total of several economic variables such as population and manufacturing employment to each of the 169 Connecticut towns. This was done through the use of a method called differential shift analysis. The change in an economic variable of a sub-region is assumed to consist of two factors. The first factor, called the proportional shift, allows for the change of this variable as a percentage of the change of the entire state. The second factor allows for the differential shift between the sub-region and the state. That is, this second factor allows for the difference in the growth rates of the entire state and the individual towns.

The Connecticut land use model was formulated as a set of simultaneous equations, each equation describing one sector of the economy. The equations mathematically formulated the interplay between transportation facilities in and leading to a town and the presence of people in the town. The tendency of people to settle near transportation facilities and the tendency of highways to be built near people were described mathematically. These equations were solved with a computer and the results were used by Combustion Engineering as inputs to the waste reduction and waste production models described in detail in this report.

THE INFORMATION SOURCES OF THE CONNECTICUT REDUCTION CAPACITY MODEL

MODEL 1

National Planning Association Reports on Industrial Employment[9]

↓ Future Employment by S.I.C. Code

MODEL 2

Connecticut "Socio-Economic Growth Model" by Connecticut Interregional Planning Program[10]

Regression analysis on past trends and an economic input-output model for Connecticut were used to predict population and employment levels and outputs to the industrial and service sectors to the year 2000.

↓ Employment and Population for Connecticut in 1960, 1970, 1980, 1990, 2000.

MODEL 3

"A Model for Allocating Economic Activities into Sub-Areas in a State"[11]

Prepared for the Connecticut Interregional Planning Program (CIPP) by Alan M. Voorhees & Associates, Inc.

A mathematical model ("Transportation Study") developed by linear regression techniques allocated Connecticut's residential and industrial population into each of the 169 towns for 1960, 1970, 1980, 1990, and 2000.

↓ Vacant Land, Population and Employment (manufacturing, retail, service and others) by towns for 1960, 1970, 1980, 1990, and 2000.

MODEL 4

Connecticut Solid Waste Models (This Report)

The waste generation per capita and per employee by S.I.C. Code were determined from the municipal and industrial solid waste inventories. By means of linear regression, the waste reduction capacity of Connecticut towns was correlated with the data of the CIPP study. The resulting mathematical model was used to project installed waste reduction capacity by county to 1975. Municipal and industrial waste production were also estimated.

↓ Municipal Waste, Industrial Waste and Incineration Capacity in 1975.

Figure 4

B. DESCRIPTION OF VARIABLES

The data for one of the dependent variables, tons of installed capacity per day per town, comes from Table 3. The data for the other dependent variable, tons of solid waste reduced per week per town, comes from Reference 13. Connecticut's incinerators are not utilized to capacity. For example, the town of Greenwich with a rated capacity of 450 tons per day or 3,150 tons per week reduces only 720 tons of solid waste per week. The data on the utilization of Connecticut incinerators was incorporated into the Connecticut utilization model. Typical utilization data is provided in Table 9. Using this utilization data, a new variable, Y", tons of solid waste reduced per week, was developed. This new dependent variable was used with the variables of the Connecticut capacity model to form the Connecticut utilization model.

The independent variables for these models are similar to the variables described previously. It was again assumed that solid waste reduction capacity was primarily dependent upon two factors: (1) amount of refuse generated and (2) amount of land available for land fill.

The variables used in the Connecticut models were:

Variable	Why Selected	The Variable is an Indication of the Following Factor
1. Population	More people means more waste	Municipal waste generation
2. Total possible population (based on zoning laws)	Measures residential land available	Vacant land
3. Manufacturing employment	Industry is a source of solid waste and also indicates general economic activity which is associated with solid waste production	Industrial waste generation
4. Total possible manufacturing employment	Measures industrial land available	Vacant land
5. Vacant land		Vacant land

The data for these independent variables was found in References 10 and 11. Table 9 presents a typical summary of county data.

TABLE 9

TYPICAL SUMMARY OF COUNTY DATA 1966
OBTAINED FROM CONNECTICUT TRANSPORTATION STUDY[11]

FAIRFIELD COUNTY

Town	Population	Total Possible Population	Mfg. Population	Total Possible Mfg. Population	Tons/Day Installed	Tons/Week Reduced
Bethel	9,731	28,117	873	1,795	0	0
Bridgeport	157,685	158,309	33,684	36,871	500	1,662.5
Brookfield	6,664	32,894	342	7,932	0	0
Danbury	46,200	103,902	9,106	20,924	0	0
Darien	21,411	27,395	215	215	60	200.0
Easten	4,728	11,453	0	0	0	0
Fairfield	50,481	71,992	2,852	4,950	0	0
Greenwich	57,885	68,279	4,573	4,573	450	720.0
Monroe	9,241	33,987	536	829	0	0
New Canaan	19,440	25,682	226	255	50	117.0
New Fairfield	4,578	26,308	5	5	0	0
Newton	12,639	60,151	2,344	5,393	0	0
Norwalk	71,856	96,618	14,245	25,622	360	1,055.0
Redding	5,320	16,242	370	424	0	0
Ridgefield	13,500	42,547	206	2,568	0	0
Shelton	20,142	58,483	3,910	8,414	0	0
Sherman	1,029	17,557	3	3	0	0
Stamford	104,643	123,056	17,584	19,658	350	1,380.0
Stratford	50,195	60,408	2,660	18,487	240	800.0
Trumbull	26,322	47,297	305	1,546	0	0
Weston	5,507	11,524	0	0	0	0
Westport	27,656	35,561	391	391	0	0
Wilton	11,833	21,389	575	2,534	0	0
	738,686	1,179,151	95,005	163,389	2,010	5,934.5

Total possible population was generated by the land allocation model[11] from a consideration of the town zoning laws and the suitability of this land to support population on the basis of slope and soil characteristics. Total possible manufacturing employment was similarly generated from land zoned for industrial purposes.

In the development of the models, the variables mentioned above were combined to provide a more meaningful explanation of solid waste reduction capacity. For example, the ratio of population to total possible population saturation would indicate when waste reduction equipment should be installed. However, it would not also indicate the size of this equipment necessary. Population as a measure of the waste produced does indicate the size of equipment when it is necessary. These two factors combined, therefore, are a better factor than both taken independently. Manufacturing employment and total possible manufacturing were similarly combined. Since some towns are completely residential and total possible manufacturing is zero, a "one" was added in the denominator to prevent the variable from becoming indeterminate.

As shown in Tables 10 and 11, land in Connecticut is characterized by class and is described by land characteristics by the Connecticut Interregional Planning Association. Land zoning is prescribed by town governments. The land characteristics depend upon the soil and slope of the terrain. It may be possible to develop a relationship between the number of solid waste disposal sites and the type of land on which they are built. However, the data summarized in Tables 12 and 13 indicate that Connecticut towns have in the past and can in the future use any type of land for waste disposal sites. For this reason, the variable "vacant land" included all the unused land in a town rather than land of special soil, slope, or zone characteristics.

Data such as that shown in Table 14 was available for all Connecticut towns for 1960, but not for 1966 and 1975. To determine the non-industrial vacant land in 1966 and 1975, the 1960 non-industrial vacant land figure was changed by an amount proportional to the change in population for the town. That is:

$$\frac{(\text{Vacant Land})_{66} - (\text{Vacant Land})_{60}}{(\text{Vacant Land})_{60}} = -\left[\frac{\text{Population}_{66} - \text{Population}_{60}}{(\text{Total Possible Population})_{60}}\right]$$

and

$$\frac{(\text{Vacant Land})_{75} - (\text{Vacant Land})_{60}}{(\text{Vacant Land})_{60}} = -\left[\frac{\text{Population}_{75} - \text{Population}_{60}}{(\text{Total Possible Population})_{60}}\right]$$

TABLE 10[12]

ZONE CLASSES IN CONECTICUT

Zone	
Ind.	Industrial
1	Residential lots up to 4,999 square feet
2	Residential lots 5,000 square feet to 19,999 square feet
3	Residential lots 20,000 square feet to 39,999 square feet
4	Residential lots 40,000 square feet and over
Spec.	Specially zoned for such purposes as recreation and flood plain zoning
Com.	Commercial

TABLE 11 (a)[13]

LAND CLASSES IN CONNECTICUT

Soil Class #1 -- Excellent for building purposes
Soil Class #2 -- Good - Fair for building purposes
Soil Class #3 -- Poor for building purposes
Soil Class #4 -- Very Poor for building purposes
Soil Class #1A is a modification of Soil Class #1

TABLE 11 (b)

Soil Class	0% 5%	10%	15%	20%	20%+
4	5	5	5	5	5
3	4	4	4	4	5
2	2	2	2	2	2
1A	1	2	3	4	5
1	1				

TABLE 12

NUMBER OF WASTE DISPOSAL SITES BY ZONE FOR CONNECTICUT IN 1966

Zone	Number of Sites
Industrial	35
1	0
2	13
3	17
4	67
Special	7
Commercial	4
	143

TABLE 13

NUMBER OF WASTE DISPOSAL SITES BY LAND CLASS FOR CONNECTICUT

Land Class	Number of Sites
1	29
2	32
3	5
4	27
5	50
	143

TABLE 14[10]

TYPICAL SUMMARY OF VACANT LAND DATA

Bethel - 1960

Vacant Land in Acres

	LAND CLASS					
	1	2	3	4	5	Total
Zone						
Residential 1	0	0	0	0	0	0
Residential 2	207	68	8	95	184	562
Residential 3	269	515	67	165	397	1,413
Residential 4	1,032	1,083	608	1,731	2,002	6,456
Commercial	18	21	0	0	6	45
Industrial	96	15	14	65	246	436
Other	0	0	0	0	0	0
Total	1,622	1,702	697	2,056	2,835	8,912

to determine the amount of industrial vacant land for 1960 and 1975. The manufacturing employment figures were used in a manner similar to that for non-industrial land.

Table 15 shows the relationship among the dependent and independent variables of the Connecticut capacity model. Table 16 shows the relationship among the dependent and independent variables of the Connecticut utilization model.

C. PROJECTIONS OF INSTALLED WASTE REDUCTION CAPACITY TO 1975

Equations 4 and 5 model the solid waste reduction capacity of Connecticut by town. One hundred sixty-nine observations were used to generate each equation. The first equation uses three independent variables and achieves a multiple correlation coefficient of .95 with a standard error of 34.3 tons per day. Thus, 90 percent (95 x .95) of the variability of the installed capacities of Connecticut towns is accounted for by this model.

Although the simplified model uses only one independent variable, it does almost as well as the complex model. A multiple correlation coefficient of .94 is achieved with a standard error of 37.6 tons per day. Thus, this simple model accounts for 88 percent (.94 x .94) of the variability of the installed capacities of Connecticut towns.

Table 17 presents a compilation of the Connecticut model 1975 projections in terms of tonnage per county rather than tonnage per town. This is due to the difficulty of accounting for the political decisions involved in the installation of solid waste reduction equipment. For example, one of two towns, each needing 30 tons of waste reduction capacity, may decide to build a 60 ton unit while the other town may continue with land fill disposal. Neither town should actually build the needed 30 ton unit because about 60 tons is the size of the smallest economically feasible size of waste reduction equipment. Thus, the difficulty of quantifying political decisions and the economic limitations on waste reduction equipment size resulted in the decision to express the data on a per county basis. The county data was obtained by summing the town data for each county. Typical county data is shown in Table 9 for the county of Fairfield. The 68 percent confidence level for both models is approximately ±200 tons per day for the state.

Figure 5 represents the relationship between Y' and X_6. The effect of time, i.e. year, was not evaluated in this study. The relationship consequently represents one time period (1966). To improve the projective ability of this model with time, consideration should be made of increases in per capita waste generation and the change in ratio of industrial to municipal waste handled by Connecticut towns. For example, the values of Y would have to increase by about 25 percent in 1975 over the values indicated to account for a 2.5 percent compounded annual increase in waste generation.

It will be noticed that the graph levels off at 600 tons per day because a Connecticut town with a value of X_6 that corresponds to a Y equal to

TABLE 15

CONNECTICUT MATHEMATICAL
CAPACITY MODEL CORRELATION MATRIX

Variable	1*	2	3	4	5	6	7	8	Y'	Variable
1	1.00	.82	.74	.81	.67	.40	.39	.36	.82	1
2	.82	1.00	.99	.85	.83	.07	.10	.11	.90	2
3	.74	.99	1.00	.80	.83	.01	.03	.05	.86	3
4	.81	.85	.80	1.00	.92	.18	.19	.18	.81	4
5	.67	.83	.83	.92	1.00	.03	.04	.05	.72	5
6	.40	.07	.01	.18	.03	1.00	.98	.93	.12	6
7	.39	.10	.03	.19	.04	.98	1.00	.98	.16	7
8	.36	.11	.05	.18	.05	.93	.98	1.00	.19	8
Y'	.82	.90	.86	.81	.72	.12	.16	.19	1.00	Y'

* Numbers refer to the following list of variables

$X_6 = \frac{\text{Population}^2}{\text{Total Possible Population}} \times 10^{-3}$

1 $X_6^{.5}$

2 $X_6^{1.5}$

3 X_6^{2}

4 $X_7 = \frac{(\text{Manufacturing Employment})^2}{\text{Total Possible Manufacturing Employment} + 1}$

5 X_7^{2}

6 $X_8 = \text{Vacant Land} \times (X_6)^{1/2}$

7 $X_8^{1.5}$

8 X_8^{2}

Y' = Tons of installed capacity, per 24 hour day

TABLE 16

CONNECTICUT MATHEMATICAL UTILIZATION MODEL
CORRELATION MATRIX

Variable	1*	2	3	4	5	6	7	8	9	Y"	Variable
1	1.00	.97	.93	.85	.20	.20	.22	.22	.83	.94	1
2	.97	1.00	.99	.86	.83	.07	.10	.11	.84	.94	2
3	.93	.99	1.00	.84	.83	.01	.10	.05	.82	.90	3
4	.85	.80	.84	1.00	.98	.09	.10	.10	.93	.85	4
5	.80	.83	.83	.98	1.00	.03	.04	.05	.90	.79	5
6	.20	.07	.01	.09	.03	1.00	.98	.93	.05	.10	6
7	.22	.10	.10	.10	.04	.98	1.00	.98	.05	.13	7
8	.22	.11	.05	.10	.05	.93	.98	1.00	.06	.15	8
9	.83	.84	.82	.93	.90	.05	.05	.06	1.00	.84	9
Y"	.94	.94	.90	.85	.79	.10	.13	.15	.84	1.00	Y"

* Numbers refer to the following list of variables

1 $X_6 = \frac{\text{Population}^2}{\text{(Total Possible Population)}} \times 10^{-3}$

2 $X_6^{1.5}$

3 X_6^{2}

$X_7 = \frac{\text{(Manufacturing Population)}^2}{\text{(Total Possible Manufacturing Population)}}$

4 $X_7^{1.5}$

5 X_7^{2}

6 X_8 = Vacant Land x $(X_6)^{1/2}$

7 $X_8^{1.5}$

8 X_8^{2}

$X_9 = \frac{\text{(Manufacturing Population) x Population}}{\text{(Total Possible Population)}}$

9 $X_9^{1.5}$

Y" = Tons of solid waste reduced per week per town

COMPLEX CONNECTICUT CAPACITY MODEL

Eq. 4) $$Y' = -21.8095 - 13.629X_6^{.5} + 1.35389X_6^{1.5} - .0759122X_6^2 + 6.00175 \times 10^{-3}X_7 - 3.053 \times 10^{-7}X_7^2 + .0116033X_8 - 9.84902 \times 10^{-5}X_8^{1.5} + 2.06190 \times 10^{-7}X_8^2$$

WHERE:

Y' = tons installed capacity per day per town

$$X_6 = \frac{\text{population}^2 \text{ (town)} \times 10^{-3}}{\text{total possible population (town)}}$$

$$X_7 = \frac{\text{manufacturing employment}^2 \text{ (town)}}{\text{total possible manufacturing employment (town)} + 1}$$

$$X_8 = \text{vacant land (acres-town)} \sqrt{\frac{\text{population}^2 \text{ (town)} \times 10^{-3}}{\text{total possible population (town)}}}$$

Correlation Coefficient R = .95
Standard Error of Estimate = 34.3 tons per day
Number of Observations = 169

SIMPLIFIED CONNECTICUT CAPACITY MODEL

Eq. 5) $$Y' = 3.13757 - 6.5456X_6 + 2.3710X_6^{1.5} - .123466X_6^2$$

WHERE:

Y' = tons installed capacity per day per town

$$X_6 = \frac{\text{population}^2 \text{ (town)} \times 10^{-3}}{\text{total possible population (town)}}$$

Correlation Coefficient R = .94
Standard Error of Estimate = 37.6 tons per day
Number of Observations = 169

TONS/DAY OF INSTALLED INCINERATOR CAPACITY DETERMINED FROM CONNECTICUT MODEL

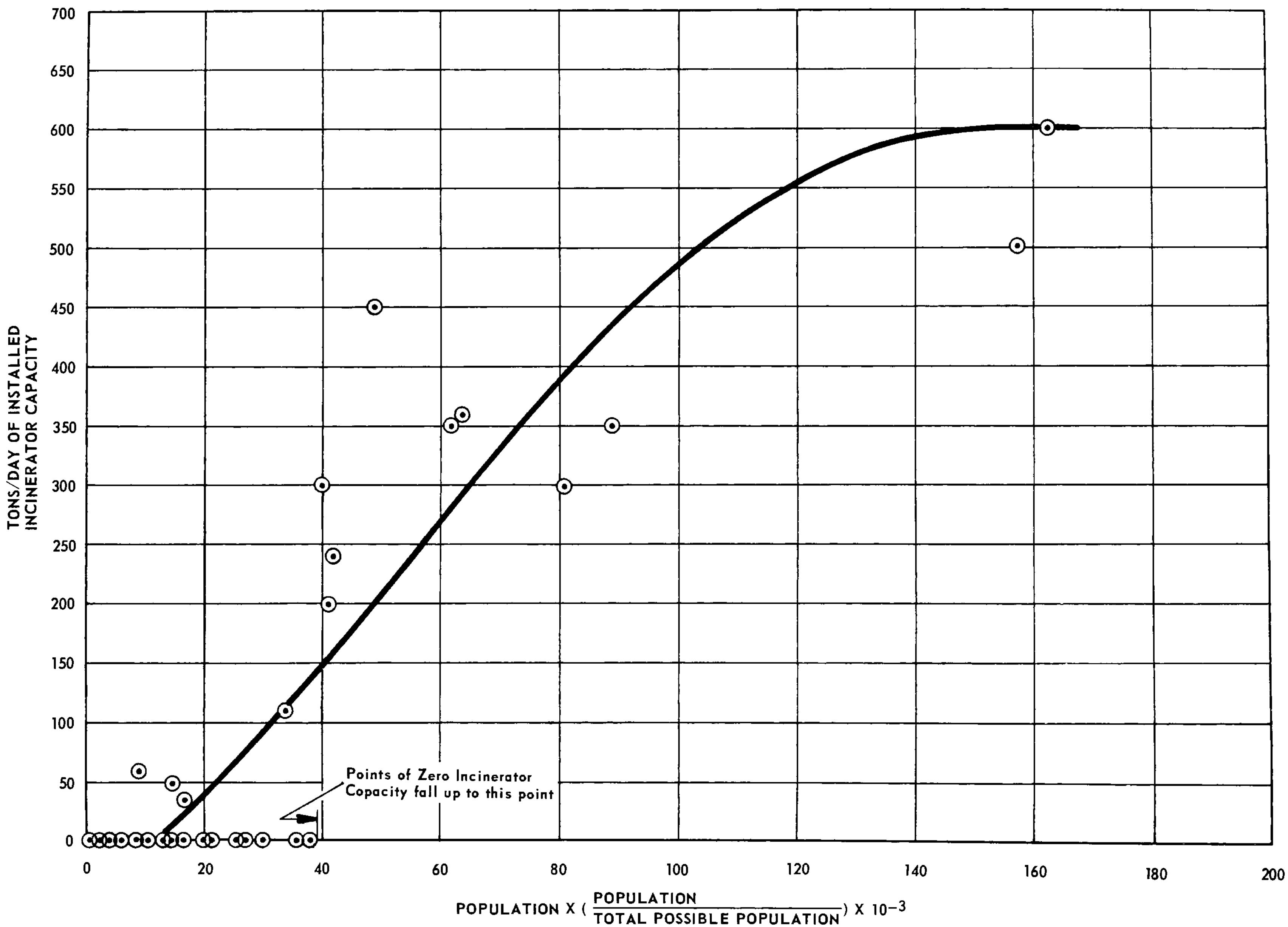

Figure 5

TABLE 17

CONNECTICUT SOLID WASTE REDUCTION CAPACITY BY COUNTY

TONS OF INSTALLED CAPACITY PER 24 HOUR DAY

County	1966 Actual	1975 Eq. (4)	1975 Eq. (5)
Fairfield	2,010	2,425	2,525
Hartford	1,450	2,200	2,025
Litchfield	0	0	0
Middlesex	0	50	50
New Haven	1,380	1,950	1,875
New London	120	175	175
Tolland	0	50	0
Windham	0	0	0
TOTAL	4,960	6,850	6,650

NOTE: The model also assumes no increase in pounds per capita. If 2 1/2 percent per year applies to all types of refuse in Connecticut, the values shown above for 1975 would be increased by approximately 25 percent -- assuming all equipment runs at same utilization factor. In addition, a larger portion of the industrial solid waste stream was handled in municipal facilities. Installed capacity would increase even further.

600 is probably saturated. That is, the population of the town is about equal to the total possible population. Thus, solid waste reduction needs will probably increase due to increased waste per capita or due to municipalities handling a larger share of the industrial solid waste stream.

D. PROJECTIONS OF UTILIZED WASTE REDUCTION CAPACITY TO 1975

Equations 5 and 6 model the utilized solid waste reduction of Connecticut by town. One hundred sixty-nine observations were used to generate each equation. The first equation uses four independent variables and achieves a multiple correlation coefficient of .97 with a standard error of 74.1 tons per week. Thus (.97 x .97) 94 percent of the variability of the utilized capacities of Connecticut towns is accounted for by this model. The correlation coefficient and standard error of the utilization model as compared to the correlation coefficient (.95) and standard error (34.3 tons per day) of the capacity model indicate that the utilization model is the better model. The utilization model removes one additional unknown from the models previously described. That is, that a town can have 500 tons per day installed capacity and operate it eight hours to provide the same burning as a 250 ton per day plant operating sixteen hours a day.

The simplified utilization model does almost as well as the complex model although only one independent variable was used. A multiple correlation coefficient of .96 is achieved with a standard error of 85.9 tons per week. Thus this simple model accounts for (.96 x .96) 92 percent of the variability of the utilized capacities of Connecticut towns.

Table 18 presents a compilation of the Connecticut utilization model 1975 projections in terms of tonnage per county. The county data was obtained by summing the town data for each county. Typical county data is shown in Table 9 for the county of Fairfield. The 68 percent confidence level for both models is approximately ±1,100 tons per week for the state.

E. MUNICIPAL AND INDUSTRIAL WASTE PRODUCTION FOR CONNECTICUT TO 1975

Tables 19 to 22 present the estimated 1965 and the projected 1975 values of municipal and industrial wastes for Connecticut counties. The 1975 municipal waste figures were computed from the 1965 per capita waste figures and the 2.5 percent compounded growth rate obtained from the municipal inventory section of this report. The 1975 municipal per capita waste figures were then multiplied by the 1975 population figures.[10] The table showing industrial wastes is taken from the industrial inventory portion of this report. The calculations involved and the method used for the 1975 industrial waste projections can also be found in the industrial inventory section.

COMPLEX CONNECTICUT UTILIZATION MODEL

Eq. 6) $Y'' = 35.587 - 19.9571X_6 + 6.05086X_6^{1.5} - .290490X_6^{2} + .400826 \times 10^{-3}X_7^{1.5} - .253287 \times 10^{-5}X_7^{2} + .016324X_8 - .133483 \times 10^{-3}X_8^{1.5} + .271533 \times 10^{-6}X_8^{2} + .464890 \times 10^{-4}X_9^{1.5}$

WHERE:

Y'' = tons of solid waste reduced per week per town

$X_6 = \dfrac{\text{population}^2 \text{ (town)} \times 10^{-3}}{\text{total possible population (town)}}$

$X_7 = \dfrac{\text{manufacturing employment}^2 \text{ (town)}}{\text{total possible manufacturing employment (town)} + 1}$

$X_8 = \text{vacant land (acres - town)} \sqrt{\dfrac{\text{population}^2 \text{ (town)} \times 10^{-3}}{\text{total possible population (town)}}}$

$X_9 = \text{manufacturing population (town)} \times \dfrac{\text{population (town)}}{\text{total possible population (town)}}$

Correlation Coefficient = .97
Standard Error of Estimate = 74.1 tons per week
Number of observations = 169

SIMPLIFIED CONNECTICUT UTILIZATION MODEL

Eq. 7) $Y'' = 13.400 - 21.9399X_6 + 7.18692X_6^{1.5} - .359355X_6^{2}$

WHERE:

Y'' = tons of solid waste reduced per week per town

$X_6 = \dfrac{\text{population}^2 \text{ (town)}}{\text{total possible population (town)}}$

Correlation Coefficient = .96
Standard Error of Estimate = 85.9 tons per week
Number of Observations = 169

TABLE 18

CONNECTICUT SOLID WASTE REDUCTION
UTILIZED CAPACITY OF COUNTY

County	Tons of Utilized Capacity Per Week 1966 Actual	1975 Eq. (6)	1975 Eq. (7)
Fairfield	5,934.5	6,559.5	7,201.6
Hartford	4,631.5	5,765.0	5,731.4
Litchfield	0	0	0
Middlesex	0	0	0
New Haven	3,070.5	4,972.7	5,230.7
New London	240.0	430.6	484.8
Tolland	0	0	0
Windham	0	0	0
TOTAL	13,876.5	17,727.8	18,648.5

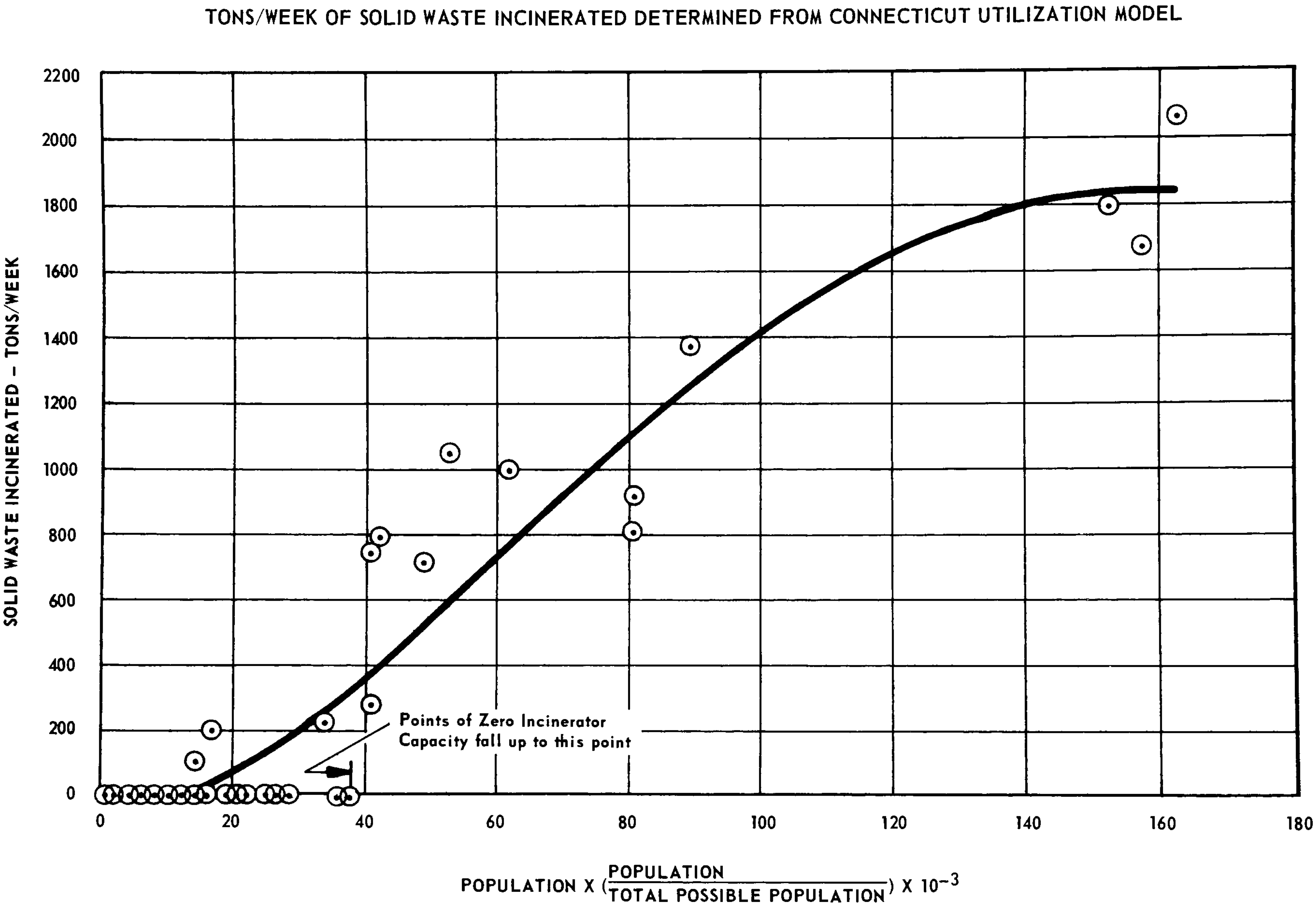
TONS/WEEK OF SOLID WASTE INCINERATED DETERMINED FROM CONNECTICUT UTILIZATION MODEL
SOLID WASTE INCINERATED - TONS/WEEK
2200
2000
1800
1600
1400
1200
1000
800
600
400
200
0
0
20
40
60
80
100
120
140
160
180
Points of Zero Incinerator Capacity fall up to this point
POPULATION X (POPULATION / TOTAL POSSIBLE POPULATION) X 10^-3

Figure 6

TABLE 19

MUNICIPAL WASTE FOR DISPOSAL IN CONNECTICUT BY COUNTY FOR 1965

Pounds per Capita per Day	
Residential	2.4
Bulky	.3
Commercial**	1.4
	4.1

** Commercial waste is 1.4 pounds per urban capita per day. Connecticut population is about 80 percent urban and therefore a figure of 1.1 pounds per capita per day was used in the calculations.

County	Population (1965)	Residential MPY**	Bulky MPY**	Commercial MPY**	Total MPY**
Fairfield	730,100	630	80	293	1,003
Hartford	762,500	662	84	306	1,052
Litchfield	131,100	114	14	53	181
Middlesex	99,700	87	11	40	138
New Haven	719,700	625	79	289	993
New London	207,700	180	23	83	286
Tolland	82,400	72	9	33	114
Windham	75,800	66	8	30	104
TOTAL	2,809,000	2,436	308	1,127	3,871

** Million pounds per year

TABLE 20

MUNICIPAL WASTE FOR DISPOSAL IN CONNECTICUT BY COUNTY FOR 1975

	Lbs./Capita/Day
Residential	3.07
Bulky	.38
Commercial	1.81**
	5.26*

* Based on a compounded growth rate of 2.5 percent per year.

** Commercial waste is 1.8 pounds per urban capita per day.
Connecticut population is about 80 percent urban and therefore a figure of 1.4 pounds per capita per day was used in the calculations.

County	Population (1975)	Residential MPY***	Bulky MPY***	Commercial MPY***	Total
Fairfield	861,910	965	121	453	1,539
Hartford	901,120	1,012	126	474	1,612
Litchfield	157,129	171	22	83	276
Middlesex	149,791	168	21	79	268
New Haven	846,323	950	119	445	1,514
New London	260,803	292	37	137	466
Tolland	112,432	126	16	59	201
Windham	93,454	105	13	49	167
TOTAL	3,382,962	3,789	475	1,779	6,043

*** Million pounds per year

TABLE 21

INDUSTRIAL WASTE FOR DISPOSAL IN CONNECTICUT BY COUNTY FOR 1965

County	Manufacturing Employment	Manufacturing Solid Waste (MPY)*	Total Employment	Total** Industrial Solid Waste (MPY)*
Fairfield	105,153	485	251,318	1,010
Hartford	129,670	502	363,291	1,047
Litchfield	16,519	76	36,570	169
Middlesex	11,856	80	35,354	156
New Haven	95,677	538	275,334	1,035
New London	36,145	142	75,873	285
Tolland	3,221	16	17,731	72
Windham	15,013	81	24,906	138
TOTAL	413,254	1,920	1,080,377	3,912

* Million Pounds Per Year

** Includes manufacturing solid waste. Non-manufacturing industrial solid waste comes from demolition and supermarkets. For Fairfield County manufacturing solid waste equals 485 million pounds per year, demolition and supermarkets waste is 525 million pounds per year, and the total manufacturing and non-manufacturing industrial solid waste is 1,010 million pounds per year. Based on national averages, approximately 55 percent of industrial solid wastes is disposed of in industrial sites.

TABLE 22

INDUSTRIAL WASTE FOR DISPOSAL IN CONNECTICUT BY COUNTY FOR 1975

County	Manufacturing Employment	Manufacturing Solid Waste (MPY)*	Total Employment	Total** Industrial Solid Waste (MPY)*
Fairfield	112,830	513	280,378	1,091
Hartford	169,092	671	442,267	1,312
Litchfield	17,353	77	47,445	187
Middlesex	16,820	102	50,746	212
New Haven	125,524	644	335,454	1,247
New London	39,431	160	98,504	347
Tolland	7,205	32	27,841	100
Windham	14,150	84	30,634	151
TOTAL	502,405	2,283	1,313,269	4,647

* Million Pounds Per Year

** Includes manufacturing solid waste. Non-manufacturing industrial solid waste comes from demolition and supermarkets. For Fairfield County manufacturing solid waste equals 485 million pounds per year, demolition and supermarkets waste is 525 million pounds per year, and the total manufacturing and non-manufacturing industrial solid waste is 1,010 million pounds per year. Based on national averages, approximately 55 percent of industrial solid wastes is disposed of in industrial sites.

SECTION IV

REFERENCES

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SECTION V

APPENDIX A

WESTERN UNION QUESTIONNAIRE FOR

DEPT. OF HEALTH, EDUCATION AND WELFARE

Name ____

Title ____

City ____

Good day, this is Western Union calling. We are conducting a survey for Combustion Engineering, Inc. under contract for the United States Department of Health, Education and Welfare. The H.E.W. contract number is P 86-66 163.

1. What method is now used for the disposal of your municipal refuse at the present time? Check one:

   A. Open dumping
   B. Open burning
   C. Sanitary land fill
   D. Composting
   E. Incineration
   F. Feed garbage to hogs
   G. Other (state)

2. If you dispose of the refuse by open dumping, open burning or sanitary land fill, what is the hauling distance from the center of the city to the disposal site?

   ____________________ miles

3. How long will you be able to use the present site?

   ____________________ years

4. If you dispose of the refuse by either incineration or composting, what is the total capacity of your facility on a 24 hour/day basis?

   ________________________ tons per 24 hour day

5. What percentage of your refuse do you incinerate or compost?

   ____________ %

6. When was your incinerator or composting plant installed?

   ____________________ year

7. How many hours per week is each incinerator operated?

______________________________ hours per week

8. How many incinerators or composting plants and of what size do you intend to install in the next two years?

Size ______________________________________ Tons per day

industrial inventory
(volume ii)

TECHNICAL - ECONOMIC STUDY OF SOLID WASTE DISPOSAL NEEDS AND PRACTICES

VOLUME II - INDUSTRIAL INVENTORY

Conducted for the Public Health Service
under Contract #Ph 86-66-163

Prepared by

Dr. L. Koenig
Louis Koenig Research
San Antonio, Texas

Wensley Barker, Jr.
Senior Product Analyst
Product Diversification Department

COMBUSTION ENGINEERING, INC.
WINDSOR, CONNECTICUT

November 1, 1967

TABLE OF CONTENTS

SECTION I

INTRODUCTION

The material presented in this report is part of a technical - economic study of solid waste disposal needs and practices conducted under contract Ph 86-66-163, with the Department of Health, Education and Welfare. The total study is reported in four volumes:

Volume I	-	Municipal Inventory
Volume II	-	Industrial Inventory
Volume III	-	Information System
Volume IV	-	Technical Over-View

This report presents the Industrial Inventory. It is based on interviews of 320 plants in twenty-four selected industries and presents an inventory of the amount of waste for disposal generated by each of these industries, its disposal, and an estimate of the quantity of such waste in 1975. Excluded from this inventory by direction of the contracting agency were such sources of waste as: agricultural waste, mining and primary metals manufacturing wastes, and wastes from institutions.

This report was prepared by Dr. Louis Koenig, Louis Koenig Research, San Antonio, Texas and Wensley Barker, Jr., Product Diversification Department. Mr. Ralph J. Black was Project Director for the Public Health Service; Mr. Elliot D. Ranard was Program Manager for Combustion Engineering, Inc.

SECTION II

SUMMARY

A. METHOD

In twenty-four S.I.C. Codes, mostly manufacturing, there were conducted 169 plant interviews to determine waste production, disposition and disposal. In addition, there were available the results of prior interviews, similarly directed, such that the total number of interviews utilized in this study was 320. The locations of most of these interviews are spotted on the map, Figure 1.

In some codes, waste/product ratios were determined which, when multiplied by the total 1965 production, projected the waste of each code subject to ultimate disposal. For most codes, a waste/employee ratio in terms of thousands of pounds a year per employee (Kpye) was obtained. The Kpye values for any code showed a dispersion, but for practically all codes, this dispersion was log-normal and by a mathematical manipulation, the average Kpye for the population of establishments in the code could be estimated.

The interviews also developed the fraction of total waste which was utilized in some way, either given away, sold or utilized as a by-product, so that by subtraction the Kpye corresponding to the waste requiring ultimate disposal could be obtained. In a few cases where the fraction of the waste utilized was large, the Kpye's were adjusted to provide Kpye's with respect to the waste requiring ultimate disposal.

The data for disposition were combined to show the frequency of disposition agent, whether self, contract, or municipal pick-up; the ultimate disposal type, whether open dump, dump and burn, sanitary land fill, tepee burn or incineration; and the ownership of the ultimate disposal facility, whether self, contractor owned, merchant or municipal.

By means of change ratios (the ratio of physical production estimated for 1975 to physical production for 1965) there were predicted the 1975 wastes for ultimate disposal, adjusted where possible by recognizable trends expected to be experienced in this decade.

B. WASTE QUANTITIES, PROJECTED CODES

The statistics, projections and predictions for the twenty-four codes are shown in Table I. (Also in Table I are the "non-projected" codes mentioned later in this summary.) The λ mean Kpye signifies the average Kpye, for the code, computed by the mathematical technique described. The column headed "Waste Ratio Other Than λ Mean" describes the waste/product or other ratios used where Kpye was not used. The 68 percent confidence interval represents, mostly for Kpye's, the range within which there is a 68 percent probability that the true mean of the population lies The estimated 1965 waste for disposal is shown in units of million pounds

LOCATION OF INDUSTRIAL INTERVIEWS

NUMBERS, INDICATE TOTAL INTERVIEWS IN ONE CITY OR ITS METROPOLITAN AREA

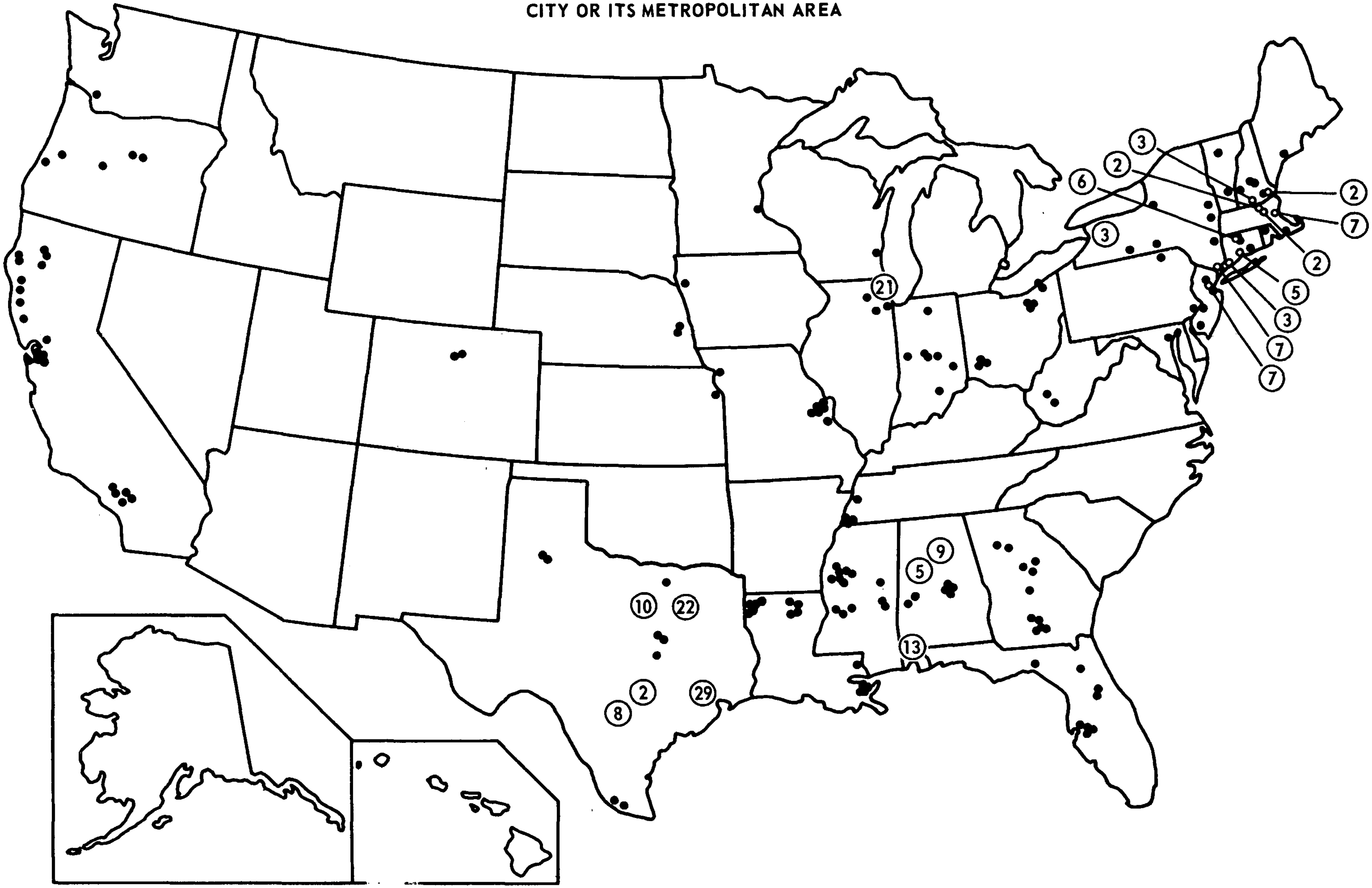


Figure 1

TABLE I

SUMMARY OF WASTE RATIOS, PROJECTIONS AND PREDICTIONS

PROJECTED

S.I.C. Code Interviewed	Industry	Number of Interviews	λ Mean Kpye, Projected on	Other Waste Ratios Projected On	68% Confidence Level	Quantity, Waste For Disposal, Million/Lb/Yr. 1965 Est.	1975 Red.	Projected On Codes	Total Employees Projected On	Waste For Disposal, Kpye
MANUFACTURING										
20	Food	14	11.2		6.7-20	10,584	14,076	20, ex. 11, 13, 15, 43, 44, 51, 61, 95	982,220	10.8
201	Meats	19		lbs/head	1490-2400(4)	1,650	2,400	2011, 2013	225,000(2)	7.3
221, 2, 3, 5, 7, 9	Textile Mill Products	10	3.88		2.64-5.70	1,706	2,132	22, ex. 226, 8	677,600	2.52
231, 2, 3, 4	Apparel & Related Products	9	.792		.554-1.13	696	1,037	23, ex. 235, 7	1,238,354	.562
244	Wooden Containers	15	125		91-172	2,470	2,190	244, 42, 43, 45	29,737	85
2421	Saw Mills	30		lbs/board feet		65,600	23,000(5)	242	236,910(2)	277
2431	Mill Work	9	16.3		11-23	570	890	2431	65,919	8.65
25, ex. 14, 15, 22, 42, 91	Wooden Furniture	16	14.6		8.1-26.2	3,090	5,170	2511, 12, 19, 21, 253, 41, 99	268,736	11.5
26, ex. 2611	Paper	29	19.4		15.5-24.4	9,950	14,700	26, ex. 2611	570,000	17.5
2732, 275, 276	Printing & Publishing	10	51.4		29.4-90	2,318	3,222	2732, 275, ex. <250 emp., 276	140,900	16.5
281, 282, 2895	Chemicals	13	281: .47		.33-.61	113	4,900	281, 282, 2895, 287	281: 240,500	.47
			Other: 12.6		7.6-21	2,512			Other: 199,400	12.6
285	Paints	8	5.25		3.6-7.7	324	390	285	62,000	5.3
2952	Asphalt Roofing	8	82.5		51-133	1,148	1,538	2952	14,300	80.5
301, 306	Rubber	13	11.9		6.7-21.3	2,900	3,900	30, ex. 307	247,000	11.9
311	Tanning	7	19.4		9.0-42	598	670	311	30,800	19.4
321, 322	Glass	7	111		72-150	2,680	3,936	321	23,000	93.21
			6.3		3.1-9.3			322	95,000	5.28
3411	Metal Cans	3	18.1		16.6-19.7	183	258	3411	53,745	3.40
342, 3, 4, 351, 2, 3, 4, 6	Fabricated Metal Products & Machine Except Electrical	18	6		4.58-7.86	6,020	8,758	34, ex. 3411, ex. 345, 6, 7, 8, 9 & 35	20,056,286	2.93
361, 2, 3, 5, 6, 7, 9	Electrical Machinery	20	2.75		2.18-3.46	2,760	4,968	36, ex. 364	1,327,581	2.08
371, 372	Auto & Aircraft	9	2.34		1.4-4.0	2,910	3,660	371, 372	1,361,144	2.14
Total 20 Manufacturing Code Groups		267				120,782	101,795		10,146,132	11.9
Total 19 Manufacturing Code Groups (Except Saw Mills)		237				55,182	78,795		9,909,222	5.56
NON-MANUFACTURING										
0712	Cotton Ginning	13		lbs/bale		1,572(1)	1,665	0712	>25,000(2, 3)	<63
1795	Demolition	16		lbs/capita SMSA's		38,100	44,300	1795	8,449(2)	4510
4731	Stockyards (incl. Auction)	11		34 lb/cattle equivalent	24-48	779	779(7)	4731 & Auction Yards	>3,000(2, 6)	<260
5411	Super Markets	13			29-57	20,310	26,400	5411 (>19 emp.)	568,000	35.7
Total Non-Manufacturing						60,761	73,144			16.9
Total 24 Codes Manufacturing & Non-Manufacturing						181,543	174,939		10,750,581	11.0
Total 23 Codes Manufacturing & Non-Manufacturing (Except Saw Mills)						115,943	151,939		10,513,671	

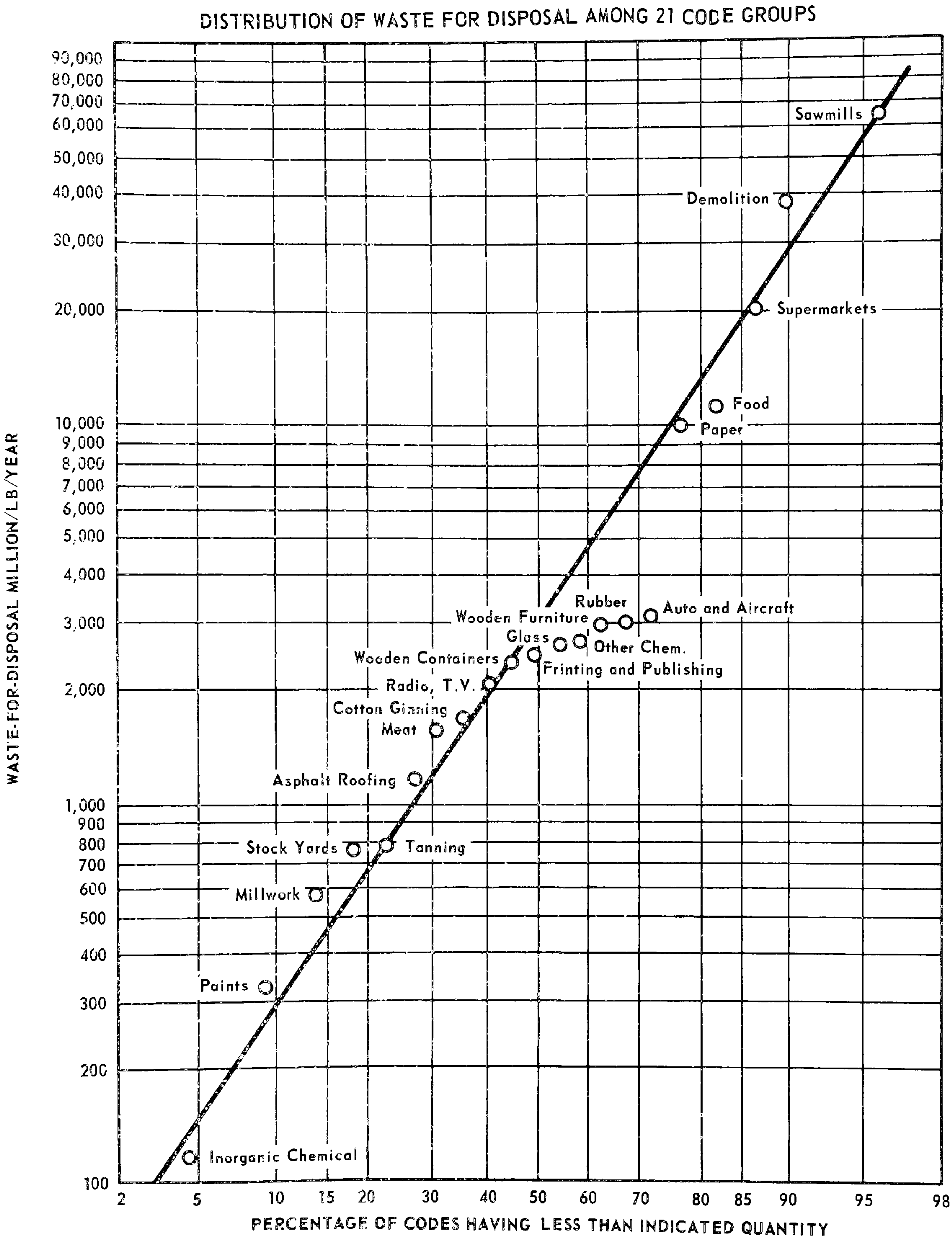
TABLE I

SUMMARY OF WASTE RATIOS, PROJECTIONS AND PREDICTIONS

NON-PROJECTED

S.I.C. Code Interviewed	Industry	Number of Interviews	λ Mean Kpye, Projected on	Other Waste Ratios Projected on	68% Confidence Interval	Quantity, Waste For Disposal, Mill/Lb/Yr 1965 Est.	1975 Red.	Projected On Codes	Total Employees Projected On	Waste For Disposal Kpye
19	Ordinance & Accessories					711	876	19	242,942	2.93
2015	Poultry	5				0	0	2015	65,349	0
2043	Cereal	2				392	514	2043	11,665	33.6
2044	Rice	10(8)		20% x Hulls		285	373	2044	4,321	66
2051	Bakeries	3				1,349	1,767	2051	226,298	5.96
2061	Sugar	11(9)				0	0	2061	9,657	0
2095	Coffee	3				0	0	2095	14,012	0
21	Tobacco					813	967	21	75,243	10.8
226, 8	Textile, Residual Codes					452	565	226, 8	179,728	2.52
235, 7	Apparel, Residual Codes					23	34	235, 7	41,270	.562
241	Logging					0	0	241	79,135	0
2432	Veneer & Plywood	4				0	0	2432	67,778	0
2433, 249	Pre-fab Homes & n.e.c. Wood					7,467	9,767	2433, 249	85,801	87.0
2514, 15, 22, 42, 91	Metal Furniture					787	1,314	2514, 15, 22, 42, 91	110,381	7.13
2611	Pulp Mills					239	348	2611	13,720	17.5
291, 2, 31, 4, 7, 8, 9, 275 (<250)	Printing Publishing Residual					12,903	17,870	271, 2, 31, 4, 7, 8, 9, 275 <250	784,485	16.5
28, ex. 281, 2, 95, 5	Chemical Residual Ex. Paints					3,099	5,795	283, 284, 289 x 2895 + 286	245,927	12.6
307	Plastic Products					2,027	3,359	307	170,315	11.9
31, ex. 311	Leather Ex. Tanning					5,727	6,523	31, ex. 311	295,185	19.4
32, ex. 321, 2, 3	Stone Clay Products					2,097	3,028	32, ex. 321, 2, 3	418,775	5.01
323	Glass Products					138	199	323	25,987	5.28
33	Primary Metals					3,503	4,442	33	1,151,851	3.04
345, 6, 7, 8, 9	Fabricated Metal, Residual Codes					1,457	2,054	345, 6, 7, 8, 9	497,720	2.93
364	Lighting & Wiring Devices					287	517	364	138,186	2.08
37, ex 371, 2	Transportation Equipment, Residual					569	717	37, ex. 371, 2	266,453	2.14
38	Instruments & Related Products					1,665	2,734	38	310,537	5.36
39	Miscellaneous Manufacturing					1,696	2,474	39	369,608	4.59
Total Non-Projected		38				47,686	66,237		5,902,329	8.1
PROJECTED AND NON-PROJECTED										
Total All Manufacturing Codes						168,468	168,032		16,048,461	10.5
Total All Manufacturing Codes Ex. Saw Mills						102,868	145,032		15,811,551	6.5
Total All Codes Manufacturing & Non-Manufacturing		358				229,229	241,176		16,652,910	13.8
Total All Codes Manufacturing Ex. Saw Mills						163,629	218,176		16,416,000	9.96

(1) 1962 to 1963 season.
(2) Employees associated with code. Projection not on employee basis.
(3) At greater than five employees per establishment.
(4) On 1965 estimate.
(5) Assuming all sawdust and shavings sold in 1975.
(6) At greater than two employees per auction yard.
(7) Inserted same as 1965 to achieve a total.
(8) Waste computed at 20 percent of the rice hulls.
(9) Kpye not obtained from these interviews, but from postcard survey of 37 establishments



DISTRIBUTION OF WASTE FOR DISPOSAL AMONG 21 CODE GROUPS
WASTE-FOR-DISPOSAL MILLION/LB/YEAR
PERCENTAGE OF CODES HAVING LESS THAN INDICATED QUANTITY
Sawmills
Demolition
Supermarkets
Food
Paper
Rubber
Auto and Aircraft
Wooden Furniture
Glass
Other Chem.
Wooden Containers
Printing and Publishing
Radio, T.V.
Cotton Ginning
Meat
Asphalt Roofing
Stock Yards
Tanning
Millwork
Paints
Inorganic Chemical
90,000
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
900
800
700
600
500
400
300
200
100
2
5
10
15
20
30
40
50
60
70
80
85
90
95
98

Figure 2

DISTRIBUTION OF WASTE FOR DISPOSAL: EMPLOYEE RATIOS IN 21 CODE GROUPS

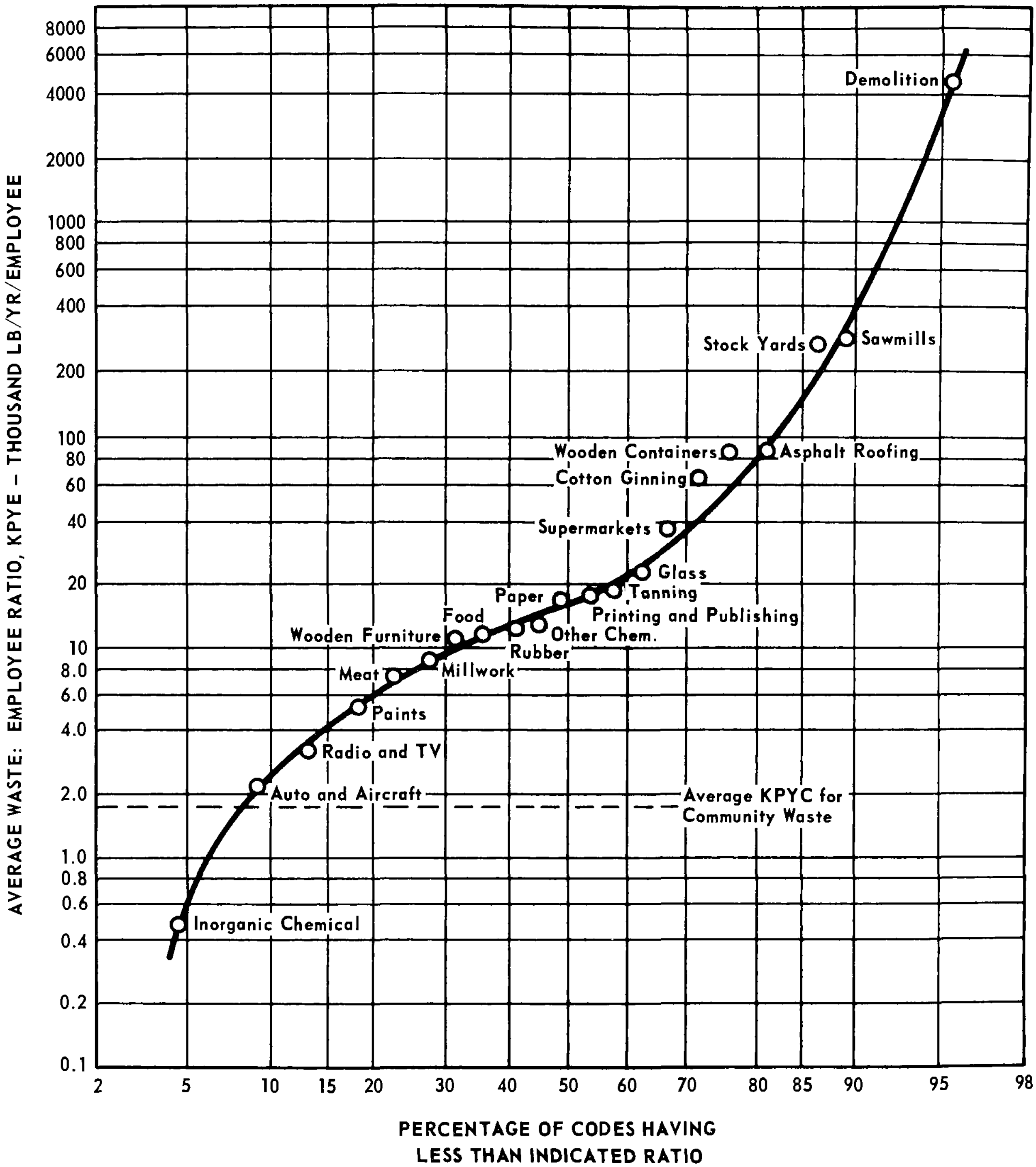


Figure 3

The average Kpye's for various code groupings are also instructive. For the nineteen manufacturing codes (ex. saw mills), the average Kpye is 5.56. Some of the codes which have individual Kpye's below this average happen to have large numbers of employees. With saw mills included, the twenty manufacturing codes have an average Kpye of 11.0. This arises from the fact that the Kpye for saw mills is exceptionally high, in fact, almost fifty times as high as the average of the rest. When the four non-manufacturing codes are added, the average Kpye becomes 16.9. This occurs because two of the added non-manufacturing codes have high Kpye's and also high mpy's. When saw mills is withdrawn from the twenty-four code group, the Kpye for the remainder falls to 11.0, again reflecting the high mpy and high Kpye of saw mills.

C. DISPOSITION-DISPOSAL QUANTITIES, PROJECTED CODES

The general level of accuracy of the waste for disposal quantities is indicated by the confidence intervals shown in Table I. The accuracy, for disposition-disposal patterns and for utilization achieved, is of a considerably lower order primarily because the disposition sample is not nearly large enough to cover the known degree of geographical, political and economic dispersity in the population which has a direct bearing on disposition-disposal patterns. The quantities of scrap and waste, defined as all solid material generated not appearing in the primary product, and thus the utilization achieved of this scrap and waste also has the deficiency that the project was not primarily directed at this objective and it is likely that substantial scrap and waste quantities have missed. Nevertheless, pending a more thorough investigation, the results are presented for their value.

The total scrap and waste generated in the twenty-four code groups is 350,500 million pounds per year, of which the major portion is from saw mills. The total for the twenty-three code groups excluding sawmills is 157,900. The degree of utilization achieved, measured by the fraction of the scrap and waste which finds utilization is 48% for the twenty-four code groups, and 27% for the twenty-three code groups. This reflects not only the high contribution of saw mill, the total scrap and waste, but also the high utilization achieved in the saw mill industry, 66%. Other high achievements are cotton ginning, 59%; wooden containers, 50%; mill work, 47%; auto and aircraft, 50%; stockyards, 60%; and printing and publishing, 68%. Utilizations of over 50% are also achieved by fabricated metal products and machinery (except electrical)

The remainder of this section concerns the waste for disposal, namely the 181,500 million pounds per year for the twenty-four code group or the 115,900 for the twenty-three code group. By disposition agent, about half of this is handled at the establishment site by the generator and an additional one-quarter is handled by the generator by hauling off the plant site. Contract disposition accounts for 21% and municipal pick-up for 3%. When saw mills are excluded, about one-fifth is handled at the site, two-fifths by the generator by hauling off the plant site, and one-third by contract.

As to type of ultimate disposal facility, incinerators and burners are about equal with dumps, each around 40%, other modes being of small importance. With saw mills excluded, dump is the major mode with 57%, incinerator or burner and sanitary land fill having considerably smaller percentages. This again indicates the importance of burning as a disposal method for saw mills.

As to ownership of the ultimate disposal or reduction facilities, private ownership is predominant with 50% followed by municipal with about 36%. With saw mills excluded, the private ownership falls to 22% and municipal becomes the major mode with 56%.

The portions of the total industrial waste for disposal, which are not included in the quantity of solid waste developed by the municipal portions of this project, are those that find disposition in self owned ultimate disposal facilities. For the 24 codes this quantity is about 91,200 million pounds and for the twenty-three codes, 25,700. The major ultimate disposal type, among self owned facilities, is incinerator or burner handling 76% of the waste for disposal in self owned facilities, followed by dump 18%, with other modes of very minor importance. Excluding saw mills, the incinerator or burner still maintains predominance with 62% and dumps become 25%, open burning gaining some in relative importance.

D. WASTE QUANTITIES AND DISPOSITION-DISPOSAL PATTERN, NON-PROJECTED CODES

The number of manufacturing employees, on which the projections previously summarized are based, is 10,146,000. There remain about 5,900,000 employees who are contributing to manufacturing waste for disposal, but which are not covered in the wastes summarized in the projected codes. An attempt was made to estimate the quantities of wastes generated by these 5.9 million employees, based in part on prior non-project knowledge of the Kpye's for certain codes, and in part by assignments of Kpye's to non-projected codes according to similarities between non-projected codes and the already studied projected codes. The results of this work are contained on Page 2 of Table I showing a total of 47,686 million pounds per year estimated for 1965 and 66,237 estimated for 1975 from these non-projected codes. The accuracy of this figure, of course, is of a lower order than that for the projected codes, and for that reason it is presented separately so that the reader may make his own judgment.

The last four rows in Table I present the data for the projected and non-projected codes combined; that is, for all manufacturing codes plus the four non-manufacturing codes covered.

The total 1965 waste for disposal is 229,229 million pounds per year, or except saw mills, 163,629. Waste from manufacturing codes makes up 168,468 million pounds per year of the former and 120,868 million pounds per year of the latter. For all manufacturing codes, the average Kpye is 10.5, or except saw mills, 6.5.

The disposition disposal pattern and distribution, when non-projected codes are included, is practically the same as that for the projected codes only, discussed in the previous section. For example, about two-thirds of industrial waste collected by contractors is taken to municipal owned ultimate disposal or reduction facilities and about one-third is handled in contract owned or merchant facilities.

E. SPECIAL WASTE TYPES

A study was made of certain special waste types from the interview data. General plant trash averages about 1.3 Kpye. Codes 34, 35 and 36 are prominent generators of metal wastes, most of which does not find its way into the waste for disposal stream. In these codes, the metal waste is of the order of 60% of the total scrap and waste.

F. WASTE FOR DISPOSAL BY STATE

The same general method, used to project waste for disposal for the United States, was used, with some modifications, to project waste for disposal for each of the fifty states and the District of Columbia. For all codes covered, the top states are New York with 22,580 million pounds per year (in 1965) followed by California, Pennsylvania, Illinois and Ohio, in that order, Ohio having 11,470 million pounds per year. With saw mills excluded, the same five states are in the top five, but California falls somewhat in rank.

The ranking is different when measured in terms of waste generation intensity per capita, the Kpyc ratio (thousand pounds of waste for disposal per year per capita of total resident population, 1965). The highest states are, in general, the lumbering states which do not have much manufacturing (i.e. much population). Oregon leads with a Kpyc of 5.39, compared to the U. S. average of 1.18. The Great Basin states, having little lumbering and little manufacturing, are the lowest, Nevada with .38, Utah with .47. The industrialized states of the Northeast are close to the national average, New York for example, having 1.25 and Pennsylvania having 1.26. The national average figure of 1.18 corresponds to 3.2 pounds per capita per calendar day.

Corresponding to the national average for projected plus non-projected codes of 6.50 for the Kpye for manufacturing (ex. saw mills), the comparable state Kpye's range from 4.6 to 15.4 with a median of 7.4. The study was undertaken to determine whether the variations in S.I.C. Code profiles among the states might be small enough to allow the use of a single Kpye figure applied against all employees in manufacturing, except saw mills, short cutting the code by code method. The results showed that the S.I.C. Code profiles do vary appreciably and the code by code method must be used for projection.

G. WASTE QUANTITIES IN CONNECTICUT COUNTIES

The same approach further modified, and further generalized to include projected and unprojected codes in a single Kpye was applied to project the waste for disposal for the individual counties for Connecticut for 1965 and to predict these for 1975.

In 1965, Hartford County makes the largest contribution with 1,047 million pounds per year (manufacturing and non-manufacturing) followed closely by New Haven and Fairfield. This ranking is maintained in 1975. The highest percentage growth in the period is for Tolland with 44% and Middlesex with 40%. The Kpye's in individual counties, manufacturing codes only, range from 3.87 to 6.76, the eight county Connecticut average being 4.65.

SECTION III

CONCLUSIONS

A. It has been found that the dispersions of waste quantity per employee for nearly all of the industries studied were log-normally distributed. This being so, it was possible to calculate from a small number of samples the mean waste quantity/employee for the industry as a whole and therefore, to predict with satisfactory accuracy the total waste production of the industry.

B. The waste for disposal generated by the industries in the twenty-four projected codes was calculated to be 181,500 million pounds per year in 1965. This is based upon an employee population of 10,146,000. The non-projected codes within those industries represent an employee population of 5,900,000 and the waste generated by this segment of the industrial population was estimated and added to the previous figure giving a total industrial waste figure for the twenty-four codes of 229,229 million pounds per year.

C. The dispersion - disposal results are known with somewhat less accuracy than the waste quantity figures, but it is significant that within the twenty-four codes studied, 48 percent of the waste is utilized in some manner. If saw mills, which have a high waste utilization factor are excluded, only 27 percent of the waste is utilized in the remaining industries.

D. Fifty percent of the industrial waste surveyed was disposed in private facilities with 36 percent going to municipal facilities. If saw mills, which are a large generator of waste are excluded, 22 percent of the industrial waste goes to private facilities and 56 percent to municipal faciliites. Forty percent of this waste is burned in either incinerators or by open burning. Forty percent is disposed of in dumps. Again excluding saw mills, 57 percent of this industrial waste goes to dumps. These figures indicate that the same pressures of decreasing land availability and air pollution regulations which have been noted in the municipal section of this report will be felt by disposers of industrial waste and the problem will become more acute with time.

E. This industrial inventory has shown that a large percentage of industrial waste is of a uniform character and is independent of the industry involved. This waste consists of shipping waste, plant trash, and office waste.

F. Two industries, food and chemicals, are characterized by process wastes which are peculiar to the process involved. Determination of the character and quantities of this waste would require further detailed study.

G. It will be noted that the largest producers of waste are those industries in the wood and wood products categories, S.I.C. Code 24. While a great deal of utilization of these wastes exists in these industries, it is apparent that the problem of disposal of this tremendous quantity of sawdust, shavings, etc. without resulting air pollution is increasing.

H. Many industries such as paper mills are presently disposing of large quantities of waste in a liquid form to streams and sewers. The pressures of stream anti-pollution regulations will require in the future that this waste be captured and disposed of by other means such as land fill, incineration, etc.

SECTION IV

RECOMMENDATIONS FOR FUTURE ACTIVITY

A. It is recommended that industries such as foods and chemicals, which have process wastes which are peculiar to the process involved, be studied in detail to define further the waste disposal problems and practices in these industries.

B. It is recommended that consideration be given to the development of an incinerator suitable for burning sawdust and wood wastes in an air suspension and with suitable air cleaning devices to prevent air pollution.

C. It is recommended that an incinerator be developed which would be suitable for burning the semi-liquid wastes in sludge form which are now being disposed of in streams.

D. Many industries have process waste which has a high Btu content and represents a disposal problem. It is recommended that preparation and blending systems be developed to take wastes such as asphalt, rubber, plastic and so forth and prepare them for blending with municipal waste in municipal facilities. A cooperative arrangement between municipal waste disposal facilities and small local industries, which generate this type of waste, appears to be the most efficient way to dispose of these materials.

E. It is recommended that the development of a system for separation and preparation of combustible demolition wastes be encouraged to permit incineration of these wastes.

SECTION V

SURVEY METHOD AND PROCEDURE

A. SELECTION OF INDUSTRIES

Prior to the present contract, Combustion Engineering and Louis Koenig Research conducted investigations of industry waste generation of a large number of industries. This previous data was used to select the industries which are the largest generators of solid waste. Specifically excluded were mining wastes, petroleum industry wastes and junked automobiles which are under the cognizance of the Department of the Interior. Also excluded were agricultural wastes and institutional wastes.

As a first approximation, industries so selected were chosen to represent potential disposal problems. This previous data was used only for this selection of industries. The data generated during the interviews conducted under the H.E.W. program was used to estimate total waste production of the industries selected. The industries listed below were approved by the Department of Health, Education and Welfare for evaluation.

- Saw Mills
- Super Markets
- Cotton Ginning
- Demolition
- Paper
- Foods
- Wooden Containers
- Wood Furniture & Fixtures
- Auto & Aircraft Manufacture
- Meat Packing
- Chemicals
- Stock Yards
- Paints
- Electrical Machinery
- Rubber
- Glass
- Asphalt Roofing
- Mill Work
- Tanning
- Printing & Publishing
- Textiles
- Apparel
- Fabricated Metal Products
- Machinery (except electrical)

B. SELECTION OF PLANTS

Within each of the twenty-four selected industries an analysis of the number of establishments versus the number of employees per establishment was made using census data, to determine the plant size pattern of the industry. Selections of plant sizes to represent small, medium and large establishments in this industry were made and six specific plants, to be interviewed in each of the twenty industries, were chosen. These selections, made to present a cross-section of size and geographic location within the industry, were chosen from the plant and product directory published by "Fortune" in 1966[1] and the state directories of manufacturing establishments.

C. DATA COLLECTION

Personal interviews were made in each of the 169 plants selected. An interview check list previously approved by the Department of Health, Education and Welfare, a sample of which is contained in Appendix A, was used by the interviewer to insure the uniformity of information obtained. Most of the information required was readily obtained.

It was found that, in general, it was preferable for the interviewer to contact the plant manager or plant engineer to obtain the information desired. In most of the large plants, information as to the character of waste, quantities produced and disposal problems was readily available. In the smaller plants, the stated quantities usually represent on-the-spot estimates by the plant personnel responsible.

During interviews of some of the industries, it was not too difficult to obtain information on solid waste generation and disposal once the interviewer established that this was his principal interest; however, extreme reluctance to discuss liquid waste was noted. This is obviously indicative of problems in this area and fear of regulation in advance of acceptable disposal methods.

Computations on waste quantities were made subsequently using the interview data supplemented by additional information and estimates as to bulk densities, units of measurement, etc. In some cases, new data were generated on the spot. Measurements, for example of truck body sizes, container sizes, etc. were made when the interviewee could not state them of his own knowledge. In other cases, interviewees were asked if they would make special measurements subsequent to the interview. For example, several interviewees conducted experiments on bulk densities of their wastes and forwarded the information later.

Where necessary, interviews were followed up by phone calls in order to clarify questionable points or obtain information later found to be needed.

All of the codes covered in this study had previously been studied in a somewhat similar manner under various proprietary research projects of Combustion Engineering. Indeed, as previously noted, the selection of these codes had been based on the information thus developed. From these prior studies there were available additional interviews in most of the codes studied, and it was possible for the most part to incorporate these interviews in the basic data of the present study. The prior interviews had been conducted for somewhat different purposes and did not conform in all of their information to that in the present interviews.

In addition, some of the prior projects had conducted postcard surveys to determine disposition patterns in certain codes. The results of these postcard disposition surveys were incorporated in the present study where applicable. The postcard information comprised only the mode of disposition and ultimate disposal of the waste and gave percentages of the total waste, unspecified as to type, which was handled by the various disposition and disposal modes.

A word about the units used, in the computations, is in order. For waste quantities the unit used herein is thousand pounds per year of waste (Kpy). This quantity says nothing about the number of pounds per month, per week, per day, or per hour, but simply totals for whatever number of hours, days, weeks or months per year that the waste is produced. For the waste/employee ratio, there is used thousands of pounds per year per employee (Kpye). The Kpye is the number which when multiplied by the total number of employees in the establishment will produce the total amount of waste produced annually. This Kpye says nothing about the number of hours which each employee must put in producing that quantity of waste. In some establishments he may put in 261 days per year, in others 312, etc. Presumably, if it be assumed that the waste production per employee hour is constant then the dispersion in employee hours per year is responsible for some of the dispersion in the Kpye's.

To determine whether there was a trend in waste/employee ratio or waste/product ratios with establishment size, the ratios were plotted on log-log paper against the number of employees. In most cases, it was obvious that there was no trend with size. In those cases, which were not obvious, a regression line was computed and the significance of the difference between the slope of the line and a slope of zero was determined by standard statistical techniques.

D. PROJECTIONS FOR TOTAL QUANTITIES AND PATTERNS

The total quantity of waste generated in a code was obtained by multiplying the average Kpye by the number of employees in that code, or group of sub-codes. The number of employees in each S.I.C. Code was taken from Reference 2 which gives employment in March 1964. The employment data were for 1964 and the interview data generating waste quantities, Kpy, were obtained during 1966. It would not have been feasible, with the interviewing methods used, to develop the quantities of wastes for 1965 or 1964 since it was difficult enough as it was to generate quantity figures arising out of the recent past at the time of the interview. If S.I.C. Codes are in general expanding, this means that the number of employees is increasing each year and also the amount of waste generated is increasing. If that be the case, then the 1966 waste used in the computations would be too high for 1965 conditions and the 1964 employees used in the computations would be too low. Overall, the waste/employee ratio would be too high compared to the true 1965 ratio. However, with dispersion such as found in the basic data it is highly unlikely that any significant differences in the projections would have been found if both the waste generated and the number of employees had been for the 1965 period.

In certain codes, for special reasons, pertaining thereto, the waste/employee method was not used, but the waste/product ratio or other waste ratio was used as being superior.

From the total quantity thus projected, there was subtracted the waste and by-product not entering the waste stream of interest, namely that sold, given away, or utilized for fuel or otherwise.

While the waste/employee ratio was preferable, as described for projecting the current waste, the future trend of the waste/employee ratio is not predictable and therefore, it becomes an insecure basis for projecting the 1975 waste. For the purpose, it was assumed rather that the waste/product ratio would reamin about the same during the next ten years, except in special codes where the trends were contradictory to this. There was available a set of change ratios, being the ratio of the 1975 estimated physical production to the 1965 physical production, in each code.[3]

The change ratios for physical production were used to adjust the current total waste to the estimated 1975 waste. For meat packing and stockyards, the trends indicated that the waste/product ratio might change greatly in the next ten years and projections by the change ratio method are insecure. Special projections, not using the change ratios, were also applied for cotton ginning and for demolition.

Under the disposition and disposal section of each code chapter there are given the tallies which describe the disposition agent, the ultimate disposal facility ownership and the ultimate disposal type. While the information is given for each code, there is, in general, no reason why the code should control the disposition and disposal pattern in those aspects. If it is found that in six out of eight interviews the waste goes to a city sanitary land fill, this very likely means that in six out of eight interviews the establishments were located in cities that had sanitary land fills. If they had been located in cities having incinerators, six out of the eight might have gone to an incinerator. Likewise, whether the waste is self hauled, contractor hauled or enjoys city pick-up is certainly no characteristic of code, but merely reflects the economics of a particular situation in which the interviewed establishments found themselves. Accordingly, unless there is some overwhelming trend for which a physical reason can be assigned, these disposition and disposal patterns by code have little significance. However, taken all together, they do represent frequencies for disposition and disposal patterns and the general tally reported was undertaken with this purpose.

E. PREFATORY NOTE ON STRUCTURE DEFECTS IN THIS REPORT

This report contains some defects in structure which are residual from the prescribed method of conducting the project. It may benefit the reader to have the project sequence in mind if he should notice these defects. Stage one of the project comprised the survey of twenty codes and the preparation of a report thereon. The original objective was to be concerned only with waste for disposal and the report touched upon other portions of scrap and waste only insofar as was necessary to statistically manipulate the data. When this report was in the final stages, it was requested to incorporate therein the scrap and waste and the fraction utilized. The main body of this subsidiary work is contained in "General Disposition Disposal Patterns", Section VII, but this also required some modifications in the individual code chapters. There are some defects residual in this supplementation.

The second stage of the project was originally designed to make a deeper study of some of the original twenty codes. Instead, the second stage was recast to cover the extension to five additional codes, and a projection of waste totals for "non-projected" codes. This contradiction, of projecting non-projected codes, comes about because the basic data obtained for certain 4-digit codes were projected to total waste quantities by using the employees in these interviewed codes and those in certain closely related codes whose waste/employee ratios could confidently be expected to equal those for the interviewed codes. There remained a number of 4-digit codes, and the employees in them, for which the waste was not projected. These constituted the non-projected codes.

It was then decided to attempt to project the total waste production for the nation and also for the fifty states individually. This required that waste production be projected for the codes previously not projected. This is the substance of "projections of non-projected codes". The work on the non-projected codes is reported in a separate chapter and the data thereon are presented separately in the summary in order that the reader may distinguish between relatively secure projections and those which are based on less secure assumptions concerning waste/employee ratios.

SECTION VI

SURVEY RESULTS

A. SAW MILLS AND PLANING MILLS

1. THE INDUSTRY

S.I.C. Code 242, saw mills and planing mills, includes general saw mills and planing mills 2421, hardwood dimension and flooring mills 2426, and special products saw mills not elsewhere classified 2429. It specifically does not include logging except where the logging is conducted in direct combination with the saw mill and reported as such. The waste figures to be used and generated exclude the logging waste and cover only the waste generated between the delivery of the log to the mill and the shipping of the dressed finished lumber. Saw mills are also operated in connection with wooden container manufacture and certain other industries in the lumber and wood products code, but these are not covered in Code 242. Hardwood dimension is hardwood cut to prespecified dimensions for "remanufacture" into other wood products. Hardwood flooring mills are saw mills which proceed a little further into "remanufacturing" in milling the typical flooring board shape from the rough dried lumber blanks rather than putting the rough lumber through the planing mill to produce lumber.

The overall operations, with respect to waste production of most saw mills can be represented by some path on the flow sheet, Figure 4. Some saw mills may start with the cants, but the typical saw mill starts with the log. This may be debarked, producing the bark waste and yielding a debarked log. The debarked log is usually made into a cant; that is, a squared-up log, by sawing the rounded slabs off the four sides. The waste from this operation is the slabs and edges. As will be described, there is a market for wood chips in the pulp industry and, therefore, it is common to chip up the slabs to produce these saleable chips. Because of this outlet, another route may be followed in which the debarked logs are squared-up directly by chipping rather than going through the slabbing operation. When a debarker is not used, the slabs and edges contain the bark. Sawing the slabs and also sawing the cants themselves produces green sawdust and yields rough green lumber. At this point, the lumber leaves the saw mill proper.

Typically, the rough lumber is dried either in a heated kiln or in the air to produce dried rough lumber. This dried rough lumber is the feed to the planing mill, although in some instances, green rough lumber may be sent through the planing mill without drying. The rough lumber is put through the planing mill, producing dry shavings and yielding finished lumber. Saws in the planing mill trim the finished lumber to length and also there may occasionally be some resawing; that is, making thinner or narrower wood out of the original rough lumber. This operation produces dry sawdust, dry shavings, and mill trim and ends.

FLOW SHEET FOR SAW MILLS

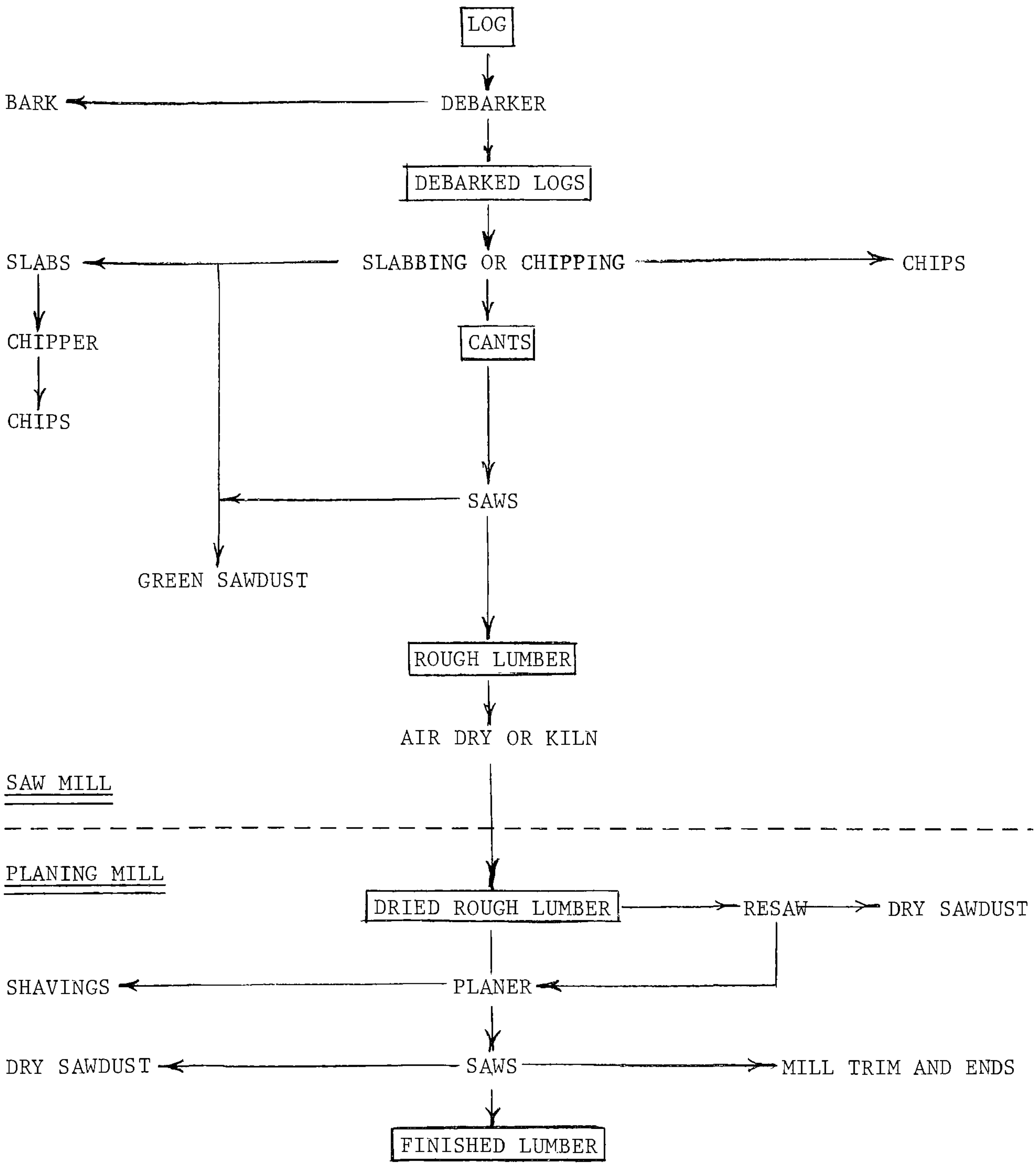


Figure 4

An important distinction is to be made between green waste and dry waste since green waste is potentially utilizable for pulp. However, dry waste is not generally acceptable by the pulp mills.

While veneer and plywood plants were not specifically studied, their operations do bear upon some of the statistics to be presented. A plywood plant starts with logs which may be debarked, but which more typically are not. The log, usually eight feet long, is placed in a lathe and turned down to become cylindrical. The wood and bark removed in this operation is called "round up". It corresponds to the bark and slabs produced in saw mills. The log is then peeled down in the lathe, producing veneer, which corresponds to the rough lumber of the saw mill. In this operation there is no sawdust, but there is a residue comprising "a core" four to eight inches in diameter, too small to peel further on the lathe. Some plywood mills make eight foot studs from these cores by a sawing operation. Others chip them for saleable chips.

The wet veneer is then dried, laminated into plywood by gluing and the plywood sheets squared-up by sawing. This corresponds to the planing mill operation and produces dry sawdust and trim but no shavings.

The industry is sectionalized with production as shown in Table II taken from Reference 4.

The first column, roundwood products total, refers to the quantity of logs taken from the forest and delivered to the manufacturing plants. There is also a wood quantity representing logging residues and the total of these two is the saw timber harvested. In addition to sawlogs, roundwood is also used for veneer, for pulpwood, for fuel wood and for miscellaneous industrial wood products. The last two are very small in the total. Pulpwood amounts to 16% of the total and the wastes from pulpwood have been accounted for in this study in the paper industry. However, some of the general statistics to be used include the wastes from pulpwood, as do they also for veneer manufacture. Veneer manufacture probably has waste/product ratio not much different from that for saw mills, so the use of waste/product ratios for total roundwood products as a substitute for waste/product ratios for sawlogs alone is admissible if the allowable error is of the order of 10% (pulpwood does have bark waste which in sawmills amounts to something of the order of one-third and one-fourth the total waste).

The waste/product ratios for roundwood products total can be expected to be something of the order of 12% lower than for saw mills alone because of this inclusion. However, as will be seen, a 12% error is allowable considering the accuracy of the other information.

2. INTERVIEWS

The saw mill code had been studied in prior Combustion Engineering products and yielded 21 interviews in the South and in Oregon and Washington. The interviews for the present project, therefore, we

TABLE II

1962 Billion BF International 1/4 Inch Board Rule

	Roundwood Products Total	Sawlogs	Veneer	Pulpwood	Misc. Ind.	Fuel Wood
North	5.732	3.393	.240	1.335	.423	.341
South	41.608	9.396	.751	3.244	.835	.328
Rocky Mt.	3.714	3.438	.131	.096	.048	.001
Pacific Coast	21.521	14.790	3.898	2.491	.257	.084
Total	72.575	31.017	5.020	7.166	1.563	.754

concentrated in California in order to cover the remainder of the West. As the interviews progressed, it was found that contrary to the situation in the South where quantities were fairly well available, the disposition in California was such that little record was kept of waste quantities. In an effort to overcome this deficiency of quantitative data, nine interviews were conducted rather than six. The total number of interviews from which the conclusions in the present study are drawn then are thirty plus two literature references on overall waste quantities for the West and one literature reference comprising a detailed waste study for twenty-nine Douglas fir mills and one ponderosa pine mill in the West.[5]

3. UNITS OF MEASUREMENT

The uses to which lumber is put make of prime importance the linear dimensions of the piece. For this reason, the units of measurement used in the saw mill industry are associated with linear dimensions, and tend to neglect product and raw material weights. This is extremely harassing for a study of waste generation and the conclusions of this study must suffer from that.

The unit of measurement for lumber is the board foot, defined as the equivalent of a board 12 inches wide, 1 inch thick and 1 foot long. A 1 x 8 board, 18 feet long by this definition contains 12 board feet, which is the equivalent in volume of 1 cubic foot. However, such a board 1 x 8 x 18 at no time in the whole history of its manufacture is associated with or finds itself having the dimensions of a piece of wood containing a volume of 1 cubic foot. As finished dressed lumber, this piece would contain only 0.875 cubic feet. As rough lumber, it would contain something of the order of 1.2 cubic feet, and in the original Douglas fir log from which it might have come, it would have been associated with about 2.2 cubic feet of log.

Indeed, on first approaching the saw mill industry, one welcomes the conclusion that the industry has no waste since from a thousand board feet of log it produces a thousand board feet of rough lumber, and this in turn yields a thousand board feet of dressed lumber. The reason for this is that the "log scales" used to measure the quantity in a log is intended to measure the amount of lumber that can be produced from the log under conventional mill practices. Such measurement conventions result in the startling performance that the yield from raw material can be greater than 100%. What this means is that measured by the log scale the log is claimed to contain say 1,000 board feet, but by careful planning and saw mill operation the operator may be able to produce 1,150 board feet out of it. His yield therefore is 115%.

There are at least a half dozen log scales, in which the ratio between cubic feet in the log and board foot measure varies, and of course, this relation varies with the diameter of the log within each scale. In addition to these difficulties, the weights of a given volume of log vary with the type of wood (having different densities, measured as grams of oven dry wood per cc of green wood volume), and with the moisture content (measured as grams of water per gram of oven dry wood). Means are provided (Reference 6) whereby the weight of round timbers in lbs./cf can be determined if one knows the species, the diameter and the thickness of the sap wood.

In addition to the difficulties arising from units of measurement of the lumber and the log itself, there are further difficulties introduced by subsidiary units of measurement used for some of the waste products. The cord, for example, used to measure the quantity of pulp wood has with the introduction of chips for pulp been translated to measure quantities of chips. In this use the cord has several values. Another unit of measurement is called simply the "unit". At least half a dozen different values for the "unit" were revealed during the course of the interviews.

A development which has gained momentum in the South holds out some hope that eventually quantity data in the saw mill industry may come in a form more useful to waste and utilization studies such as this one.

In the South it is well advanced to sell chips to paper mills. The paper mill purchases the chips by weight (and moisture content) and both producer and purchaser must then pay attention to the weight, rather than the board feet of the chips. This leads to a higher frequency of recording the quantity data on chip production, and also to a greater accuracy in the measurement of it (when once one has determined the units of the "unit"). When slabs and edgings instead of being sold as chips were simply burned for fuel or burned as a waste there was no record kept of the quantity. With the imminence of utilizing other saw mill waste products for industrial purposes, and therefore their entrance as articles of commerce, the tendency to take and record weights is increasing. Indeed, some mills actually now purchase logs by weight. This is referred to as the "weight scale" in distinction to the "log scale". Such establishments are able to provide information on the pounds/nominal board foot for the log, the bark, the chips, the rough lumber, the shavings and the finished lumber. Since the national statistical figures are in terms of nominal board feet of production which is approximately equal to the nominal board feet in the log, such a pbf (pounds/board foot) measure becomes directly useful in waste studies. Unfortunately, some of the interviews and all of the studies reported in the literature to which reference was made provide data only in terms of the volume per cent of the log going into the various waste streams. Thus, a conversion is necessary in order to use both types of information.

4. WASTE QUANTITIES

The waste data for the mills in the three Pacific Coast states come from eight individual interviews, two sets of literature data on overall averages, and the detailed Voorhees study (Reference 5) on twenty-nine Douglas fir mills and eleven ponderosa pine mills. Some of these data sources provided information on combinations of the basic streams, for example, on bark and sawdust together. The dry sawdust is very small in quantity compared to green sawdust, so sawdust figures usually encompass both and are approximately the quantity of green sawdust. In such cases, the bark and sawdust where combined, were separated in the proportions found from the average of other data sources where they had been separated.

In order to make the two sets of data, volume basis and weight basis, comparable it was easier with the information at hand to convert the pbf figures to volume per cent figures rather than the reverse. To do this required a knowledge of the pounds of log per nominal board foot. The Voorhees studies gave the nbf/cf (nominal board feet per cubic foot) in the log as 5.45 for Douglas fir and 5.75 for ponderosa pine. From Reference 6, log densities were computed for both woods based on proportions, thought to be reasonable, of 50% sap wood in Douglas fir and 36% sap wood in ponderosa pine. From the nbf/cf it was then possible to compute lbs./nbf in the log (pounds/nominal board foot). These averaged 8.1 lbs./nbf, range ±10%. This figure was used to compute volume per cent from pbf (pounds/board foot) figures for the green waste streams. The values obtained for shavings and for mill trim and planer ends were adjusted to represent dry weights rather than wet weights by multiplying the pbf on the green basis by 35/45 which is approximately the pcf (pounds per cubic foot) of dry wood and the pcf of green wood.

When the interview average was compared with the Douglas fir and ponderosa pine averages, it was found that the volume per cent figures for bark, sawdust and for shavings were in close correspondence. However, for chips the interview average was 25.2 volume per cent while the corresponding figure, for slabs and edgings, for the mills averaged 11.3% with an additional 4.7% for mill trim and planer ends not identified as such in the interviews. This discrepancy remains unexplained in the data, but it was handled as follows. The sum of the identified waste streams averaged 50.7% and the mill trim and planer ends averaged over the three sets was 3.1%. The difference between the 50.7 and the sum of the averages for mill trim and planer ends, shavings, sawdust and bark was 16.2% and this was taken as the chosen figure for slabs and edgings or chips.

No literature reports or prior detailed studies were available for the Southern saw mill industry, and accordingly the results are based only on the eight interviews supplying quantitative data, mostly in the pbf form. Where the data were in the volume per cent form, the conversion was based on the 41 pcf for dry wood and 57 pcf for green wood characteristic of long leaf yellow pine.

The results of the above described series of computations are shown in Table III. The Pacific Coast data was taken as applying to both Pacific Coast and Rocky Mountain regions here called Western. The Southern data was considered as applying to both Southern and Northern regions here called Eastern.

There was some discrepancy in the data regarding the pbf for the original log in the Southern region. When the average pounds per nominal board foot figures for each waste stream including that for

TABLE III

WASTE/PRODUCT AND OTHER RATIOS

WESTERN AND EASTERN SAW MILLS

	Volume %		Pound/Board Foot		Other Ratios	
	East	West	East	West	East	West
Bark	20.0	12.2	2.40	0.99		
Sawdust	18.0	13.0	2.13	1.05		
Slabs or Chips	20.0	16.2	2.44	1.31		
Shavings	8.5	6.2	.78	.39		
Mill Trim	0	3.1	0	.19		
Total Waste	66.5	50.7	7.75	3.93		
Original Log	100.0	100.0	12.00	8.10		
Nominal Board Foot/Cubic Foot in Log						5.50
Pound/Cubic Foot of Log					53.00	41.00
Nominal Board Foot/Cubic Foot in Finished Lumber						10.70
Bark & Sawdust (Volume) %					1.11	.94
Shavings/Sawdust (Volume) %					.47	.48
Slabs or Chips Sawdust (Volume) %					1.11	1.25

the finished lumber were totaled, they came to the 12.0 pbf shown. However, three interviews provided direct data on log weights and these three averaged 15.3 pbf. But even these three individual interviews did not total to the stated log weight when all itemized waste streams were summed. The discrepancy is unexplained.

It may be considered notable that the original log has 12.0 pbf in the East and only 8.1 in the West. Two factors contribute to this. One is that the pcf density of Southern pine wood is greater than that of Douglas fir and ponderosa pine characteristic of the Western lumbering. The other is that since the diameters are smaller in the South than in the West the fraction of waste is greater in the South than in the West, and accordingly, the number of cubic feet required for one nominal board foot is greater in the South than in the West. The projection of the total quantity of waste for the two sections will be taken up when the disposition has been explored.

5. DISPOSITION AND DISPOSAL

The disposition modes of both Eastern and Western wastes were developed by computing the average percentage of each waste stream going to the various disposition modes; in other words:

$$100 \frac{\sum_{1}^{k} \left(\frac{\text{pounds waste type i to disposition mode j}}{\text{pounds waste type i}} \right)_k}{n_k}$$

where:

i = bark, sawdust, etc.

j = fuel, sold, TP, etc.

k = individual establishment

n_k = number of establishments

This summation and averaging was performed for ten Southern interviews and for fifteen Pacific Coast interviews with the results shown in Table IV. In addition, forty-six Southern postcard responses provided disposition and disposal data on the total waste at each saw mill. This postcard data did not provide disposition and disposal separately for each waste stream and could be used only in computing the last row of Table IV.

The 1964 distribution of sawlog production was 34.4 billion bf, but the distribution by region was not readily available. This was approximated by using the regional proportions from 1962 from Reference 4. This gave 14.4 bbfy (billion board feet per year) for the East (South plus North) and 20.1 bbfy for the West (Pacific Coast plus Rocky Mountain). If it be assumed that disposition mode is

West / East

TABLE IV

PERCENT OF EACH WASTE TYPE HAVING EACH DISPOSITION

	SOLD	FUEL	GIVE AWAY	TEPEE	SELF DUMP	NOT SELF DUMP	OPEN BURN
Bark	22 / 0	27 / 10	0 / 0	51 / 48	0 / 25	0 / 0	0 / 17
Chips or Slabs	80 / 100	10 / 0	0 / 0	10 / 0	0 / 0	0 / 0	0 / 0
Sawdust	18 / 10	45 / 35	0 / 12	37 / 16	0 / 17	0 / 0	0 / 10
Shavings	25 / 10	42 / 35	0 / 12	33 / 16	0 / 17	0 / 0	0 / 10
Cut-Offs	67 / 0	0 / 0	0 / 0	33 / 0	0 / 0	0 / 0	0 / 0
Total Waste Including Chips*	41 / 31	28 / 30	0 / 1.9	31 / 26	0 / 8	0 / .5**	0 / 1.6

* Weighed according to average proportions in waste.

** Not self dump occurred only in the postcard responses for which we did not have data on separate waste streams.

independent of establishment size, and that the sample is representative of the population then the disposition of total waste in the two regions follows the percentages totaled in Table V. On this basis, the non-sold, non-fuel, non-give away waste; that is the waste of interest to the present project, becomes shown in Table , 41,000 million pounds per year for the East and 24,500 million pounds per year for the West. In the East about 3/4 of this is burned in tepee burners.

TABLE V

WASTE DISPOSITION

	East	West
Non-sold, non-fuel, non-give away, MPY (1964)	41,000	24,500
% Tepee	73.6	100
% Self Dump	20.6	
% Open Burning	4.3	
% Non-Self Dump	1.5	

In the West, the interview sample indicates that it is all burned in tepees.

It is of interest to compare these figures with those of Reference 4, (Timber Trends) which was the result of an intensive study conducted by the U. S. Forest Study and the State Forest Surveys and which has been conducted at various intervals in the past. This work separates waste types into coarse and fine, coarse being slabs, edgings, chips and other material suitable for chipping while fine comprises sawdust, shavings, and other material not suitable for chipping for pulp manufacture. If it be taken that the nbf/cf in log is 5.6 in both West and East, then the figures provided by Reference 4 for total used and unused waste from all roundwood products as compared with total production of all roundwood products would indicate a volume percentage of waste of 36.3 for the East and 31.6 for the West. These may be compared with the figures from Table III of 66.5% for the East and 50.7 for the West. This discrepancy remains unresolved.

Based on the values given for the unused portion of the waste, Reference 4 adjusted to 1964, projects 24,600 million pounds per year for the East compared to the 41,000 million pounds per year of this study. Furthermore, this study projects that the 41,000 million pounds per year is entirely from the fine wastes since in the South at least it was found that all the chippable material was being sold for pulp. It is possible that some of the discrepancy may arise from coarse material unsold for pulp in the North as distinct from the South. The comparison with the results for the West is better. Reference 4 projects to 21,700 million pounds per year, adjusted to 1964, compared with 24,500 from this study.

6. TRENDS

The trends in waste disposition in the saw mill industry are so strong as to virtually defy projection of condition to 1975. Despite the large quantity of unused waste still available and low recovery of lumber from the log, the present condition already represents a great advance over that of ten and twenty years ago. These advances are still continuing. One of them was about to break upon the South virtually at the time of the interviews. In the past, pulp mills had not accepted sawdust and other fine residues because of their short fiber length. Recently improved pulping processes have allowed the retention of a longer fiber length from the conventional materials roundwood and on chips and this allows the incorporation of sawdust and shavings into the mix. Beginning in the fall of 1966, contracts were being activated among the Southern mills to dispose of sawdust as well as chips to the pulp mills. Since all the chips are now being sold to the pulp mills and since nationally wood chips provide only about 22% of the pulp requirements, it seems quite clear that in the South where pulp mills exist in proximity with saw mills there will be an opportunity to sell all the shavings and sawdust as well as the chips for pulp. When that is done, the shavings and sawdust now used for fuel will have to be replaced by bark with the result that the only waste then left will be 1.19 pbf of bark. If this switch should occur completely in the immediate future such that the total production of lumber is still applicable, it would change the 41,000 million pounds per year of unused wastes to only 17,000 million pounds per year, all of which would be bark. The growth factor to 1975 applied to this 17,000 million pounds per year generates 23,000 million pounds per year as the projected Eastern waste in 1975, assuming that all chips, shavings and sawdust will be sold for pulp.

In the West the situation is quite complicated. Western mills succeed in using a greater percentage of their waste for fuel, and in selling it. All forms of the waste are already sold. The interviews and the general literature seem to give the impression that sale of chips was not so successful in the West because of the lack of pulp mills to take them. However, the actual interview data does not substantiate this since 80% of the chips are sold. A vigorous prospect for taking more saw mill waste is particle board which can take shavings and other hogged-down wood. Since the pulp market is far from being saturated with wood residues as raw material and since the demand for paper is increasing rapidly, it seems possible that eventually the West will equal the East in the utilization not only of chips but also of sawdust and shavings for pulp and particle board. If that should occur, however, there would actually not be enough bark now unused to replace the sawdust and shavings now used for fuel. The result would be that, if this could be achieved, there would be no unused wastes in the Western saw mill industry. It is admitted that this statement is based only on total quantities and does not take into account the necessity for achieving the same balance in each individual mill. However, it does represent what the trend might be.

Incidentally, with respect to use for fuel there is an additional distinction between Eastern and Western mills. In the East, particularly in the South, natural gas is available and comparatively cheap so that wood waste has a relatively low value for fuel. In the West, however, gas is not cheap and the displacement of wood waste by gas for fuel would be accompanied by a substantial increase in the expense. Therefore, Western mills are not likely to divert wood waste now used for fuel to other utilizations unless these show a considerable profit. However, this is not of particular concern to the particular study since the wood waste now used for fuel does not enter the waste stream of interest anyway, i.e. to be disposed.

Another development of direct interest to solid waste disposal is the quite remarkable law passed by the state of Oregon, outlawing tepee burners for wood waste because of the air pollution involved. Since tepee burners are quite standard for disposal of wood waste, this constitutes a drastic step for an economy so heavy in lumbering. Existing tepee burners are allowed to continue operation, but no new ones may be installed. If such a law is passed in the other Western states, it would, of course, greatly accelerate the trend to utilization rather than ultimate disposal.

7. SCOPE OF THIS STUDY

All of the codes covered in the present study are covered in a quite cursory way, originally intended to be limited to only half a dozen interviews in each code and a general description of the waste types and problems. This condition is common to all codes and is mentioned in the introductory material. However, it is given particular mention in this chapter because of the existence of the extensive investigation and report constituting Reference 4. This report was produced by acknowledged experts and practitioners in the field of forestry and lumbering aided by the state forestry departments who are in close touch with the situations in their individual states. While the details of the survey method and the data handling are not fully stated in the report, it is obvious that a great deal of work has gone into the study and the results should be authoritative. The present study produces figures which in some cases differ from those in Reference 4, but this does not by any means indicate that the authors contradict the more extensive study. It is quite possible that the Timber Trends study already has data in a form which might be recomputed for the purposes of the present investigation.

In the other direction, possibly some of the needs and deficiencies as brought out in the manipulations of the present study may be useful in making some provision for such information explicitly in future surveys for the Timber Trends series.

SECTION VI

SURVEY RESULTS

B. SUPER MARKETS

1. CODES AND INTERVIEWS

The super markets interviewed were part of the retail grocery S.I.C. Code 5411, but the interviews and projections were limited to establishments having twenty or more employees. Such establishments have about 568,000 employees or one half the total number of employees in all retail grocery stores. Twelve interviews were available, six from this project and six from previous projects.

2. WASTE TYPES

The meat wastes from super markets were practically all sold and thus do not enter into the waste stream. The two types of wastes in the stream were shipping wastes, almost entirely cardboard boxes, and produce and sweepings. The cardboard averaged 75% of the waste.

3. WASTE QUANTITIES

There was no trend of the Kpye (thousand pounds waste/employee/year) with number of employees. The ten available Kpye's were log-normally distributed with a median of 25 and a σ ratio attributable to the population of 2.64. If the entire population of 16,000 establishments with greater than 20 employees had these characteristics, the average Kpye would be 40.7 and the 68% confidence interval is from 29 to 57. Applied to the 568,000 employees, this produces 23,000 million pounds per year of waste. The general disposition - disposal study indicated that about 12% of this was given away, sold or flushed to the sewer, leaving 20,310 million pounds per year as waste for disposal, and in 1975, 26,400 million pounds per year.

4. DISPOSITION AND DISPOSAL

This was analyzed separately for the cardboard and the produce. The disposition of cardboard was six contract, two give away, one sold directly by the store, two incinerated at the store and two city pick-up. The ultimate disposal means was three sold, four dump, two incineration, one sanitary land fill and one unidentified. The agencies were six city, two private and one contractor owned.

The produce disposition was five by contract, one give away and in two cases it was being flushed to the sewer. The ultimate disposal was three to the city dump, two city land fill and the two to the sewer. The equipment used was trucks, packers and containerized vehicles. Haul distances were of the order of four miles, but one establishment was hauling twenty-seven miles one way.

5. TRENDS

A definite trend was indicated toward a lower waste/product ratio. Several establishments predicted that prepackaged food and better preparation and preservation would significantly reduce the amount of waste.

SECTION VI

SURVEY RESULTS

C. COTTON GINNING

1. THE INDUSTRY

The cotton ginning industry has a number of unusual features. The industry is, of course, confined to the cotton growing states in the South divided into four regions -- the West: California, Arizona, New Mexico and Nevada with about 20% of the production; the Southwest: Texas, Oklahoma and Kansas with about 35% of the production; the Delta states: Missouri, Arkansas, Tennessee, Mississippi, Louisiana, Illinois and Kentucky with 33%; and the Southeast: Virginia, North Carolina, South Carolina, Georgia, Florida and Alabama with 12%. The leading state is Texas with 4,700 thousand bales in the 1962 — 1963 season, the major area being in the High Plains and a lesser producing center in the Rio Grande Valley. The next state is California with about 1,900 thousand bales, followed by Mississippi with about 1,700 thousand bales, and Arkansas with about 1,500 thousand.[7]

In the 1961 — 1962 season, there were about 5,400 gins in the nation and the number has been decreasing each year. In 1964, it had been reduced by about 200 gins.[8] The total bales ginned in the 1962 to 1963 season was about 15 million and thus, the average gin had a production of about 2,700 bales. The distribution of gins by bales ginned is approximately log-normal (a little less skewed) with a median of about 2,150 bales/year and a σ ratio of about 2.2.

Compared to other industries, the cotton ginning industry suffers from a very low utilization factor on its equipment. In the first place, cotton ginning is a seasonal operation limited to about twelve weeks during the year in any one locality. The ginning season may start as early as August 1st and end as late as January 15th, according to the local climate. Incidentally, this means that the waste production in any one location is concentrated in the twelve week season. The time utilization of the plant is very low. The average hours per year operated for nine gins in the interviews was 1,120 hours out of the possible 8,766 hours in the year, about a 12.7% utilization of time. Furthermore, not all of this time in operation is time in production. It is not possible to call in a shift for less than eight hours, so that when the cotton deliveries to the gin are not enough to correspond to a fully day's production, the gin is not producing during each operating hour. Furthermore, about an hour is consumed in starting up and another hour in shutting down for cleaning. In addition, breakdowns and delays due to poor weather further cut into the production schedule. In nine of the interviews, the average production rate was about six bales per operating hour compared with an average capability in normal operation of about fifteen bales per producing hour. Putting in the allowance for two hours per 24 hours for cleaning, this corresponds to a utilization factor of about 5.5% on the total capability of the equipment. Since the investment for a modern gin is of the order of $15,000 per bale per hour of capability, it is evident that the cotton ginning industry operates with a quite different philosophy of capital than does most manufacturing industry.

2. SUB-CODES AND INTERVIEWS

Cotton ginning comprises sub-code 0712. Thirteen interviews were available, conducted in Mississippi, Louisiana, and Texas and, in addition, disposition information was obtained from three responses to our postcard survey for Louisiana and Mississippi.

3. WASTE TYPE

The type of waste as well as the quantity thereof varies with the method of harvesting the cotton. The classical method of harvesting, picking off the seed cotton by hand, produces the least waste and this waste consists of portions of the boll and occasional leaf parts. Machine picked cotton is produced by mechanical adaptation of this hand picking method and it may contain more leaf and a little stem. Hand snapping comprises snapping off the stem and the boll without attempting to pick out the cotton itself. This, of course, produces additional waste components of stems and leaves. In machine stripping, the plant is run through mechanical elements that strip off some side branches, the leaves, stems, etc. Finally in machine scrapping, the field is gone over a second or third time, producing more trash.

The cotton delivered to the gin contains all of these above mentioned elements as foreign matter plus the seed. In the ginning process the cotton fiber itself is separated from the foreign matter and from the seed. Some cotton fiber remains in the waste. When the ginned cotton is further processed through a lint cleaner, some small pieces of cotton occur as a waste to that operation. These are called motes. If they are thus separated they are usually baled and sold for felting material, etc. and thus are not considered in the waste stream in this study. The quantity in any case is small compared to typical waste, something of the order of 12 to 15 lbs./500 lb - bale of ginned cotton. The remaining material is the "gin trash".

Its composition varies depending on the type of harvesting. With some methods there may be as much as 500 lbs. of dirt (i.e. soil) per bale so that the overall gin trash would be about 50% mineral and 50% vegetable. Of the vegetable material itself in machine stripped trash the moisture content would typically run about 8% if the harvesting is done before a frost and within ten days after a frost would have fallen to 4% or less. Where defoliants are used and the material is somewhat green, the moisture content may be 20 to 30%. The bulk density is very low. With a small amount of dirt, it is of the order of 5 lbs./cu. ft.

4. WASTE QUANTITIES

The weight of gin waste per nominal 500 pound bale of cotton depends upon the method of picking. The weight of such a cotton bale plus the seed associated with it is of the order of 1350 to 1450 pounds. The difference between this weight and the total weight of cotton delivered to the gin per bale produced represents the gin waste. In the 1962 to 1963 season, the national averages of these gin wastes per bale were:

Hand Picked	25 pounds
Hand Snapped	560 pounds
Machine Picked	110 pounds
Machine Stripped	770 pounds
Machine Scrapped	1,050 pounds

These weights, resulting from national statistics to be described below, were approximately confirmed during the individual interviews.

The method used to project the total gin waste of the nation was as follows. The U. S. Department of Agriculture supplies annual data[9] on the number of bales ginned in each state, the percentage of the total harvested by each of five methods in each state, and the weight of raw cotton delivered to the gin per nominal 500 pound bale for each harvesting method in each state. These figures were manipulated as follows. From a number of sources, it was indicated that the typical weight of gin waste in hand picked cotton was about 25 pounds per bale. By subtracting 25 pounds from the weight of cotton delivered to the gin per bale in each state, there was obtained a figure corresponding to the weight of cotton plus seed for each state.

In one state the weight of raw cotton delivered to the gin per bale was lower for machine picked than for hand picked and the 25 pound procedure was applied to machine picked in that state. Subtracting this base weight of cotton plus seed from the weights per bale for each method of harvesting for each state then produced a set of data on the gin trash per bale for each method of harvesting for each state. This weight per bale, multiplied by the number of bales ginned in each state produced the total gin waste for each state. This totaled 3,836 million pounds per year for 1962 to 1963. Using the disposal pattern described in the next section, the waste for disposal is 1,572 million pounds per year; 1,432 million pounds per year of it is burned.

The procedure for projecting the 1975 gin waste was as follows. There are available back to at least the 1949 to 1950 season, similar figures on the percentage of the cotton crop mechanically harvested in each state. A time series was plotted of this percentage for each state and it was found that by 1975 all states will have 100% machine harvesting. At present, machine harvesting comprises almost completely machine picking in all states except Texas and Oklahoma in which machine stripping is more prominent. Therefore, it was taken that in 1975 all states except Texas and Oklahoma will have 100% machine picking and Texas and Oklahoma will have 100% machine stripping.

To obtain the 1975 forecast for bales ginned in each state, a time series was used starting about 1950 and an extrapolation was made. It was quite general that there will be little trend in bales ginned to 1975 judged by the performance of each state in the past fifteen years. The gin waste per bale figures for 1975 were multiplied by the projected gins baled for 1975 and summed to a projected total of 4,036 million pounds per year of gin waste in 1975. The disposal pattern of 1965 - 1966, assuming that it is maintained, would indicate waste-for-disposal at 1,665 million pounds per year.

5. DISPOSITION AND DISPOSAL

The disposal of gin waste is a major problem for the industry and is being made more critical by the action of federal and certain state regulatory agencies who are moving to control air pollution from the common disposal method of burning. Because of this factor of state regulation, which naturally varies from state to state and because of the inherent geographical differences affecting waste disposal, this subject warrants a full scale study in itself and cannot well be covered as one among twenty industries in this preliminary survey. Indeed, a number of such studies have been made and there is considerable activity on the part of the ginners, the ginners associations, the regulatory agencies, and equipment manufacturers, as well as the experiment stations and the U. S. Department of Agriculture.

Because the problem is so difficult, ginners who are able to sell or give away the waste may be considered fortunate. In one of the thirteen interviews and postcards, the gin waste was sold for a nominal price of $1.50 - $2.50 a ton to growers who incorporated the material in the soil as an organic amendment. In two other cases, some or all of the gin trash was given away for the same purpose, one of these being to the farm of the gin owner. One gin was considering a commercial operation in which the waste would be pelletized and fortified for cattle feed being a complete feed including roughage.

Since there have been no really likely suggestions for economic utilization of the waste, it would seem that the best disposal at present would be as a soil conditioner. However, there are some objections even to this. One interviewed gin would welcome such a use, but refrained from exploiting it because it would involve storing the waste while waiting for the farmers to come and get it at their leisure, and presumably well after the ginning season. In the Mississippi Delta region use as a soil amendment is not practiced, partly because they have there a campaign to eradicate weeds from the cotton fields and the return of the waste to the fields would interfere with this program. Storage of the waste is not desirable since because of its low bulk density a large space is required and because of its low real specific gravity it is easily blown around the countryside by the wind.

For the same reason, it has some disadvantages as a soil amendment since in order to be maintained on the field it must be plowed in. This has led to some experiments being conducted by some interviewed gins in composting the waste in pits to reduce its volume and increase its density and resistance to wind blowing.

For the most part then, the ginner is on his own in the disposition and disposal of the waste and this is indicated in the interviews. In one of the twelve interviews the ultimate disposal was to a city owned dump. In the remaining eleven it was to a self-owned burner or incinerator. Gin trash, fresh from the gin, is readily burnable. However, its low bulk density requires a high volume of the fire bed and its low actual specific gravity requires low velocities in the overhead space to avoid blowing the burning material and ash out the stack.

Numerous devices for accomplishing this burning have found favor in the ginning industry, on the basis, one gathers from interviewing the field, of being the lesser of other possible evils. Cheapness is a primary consideration, and there are probably very, very few sophisticated incinerators specifically designed to avoid air pollution in the industry. None were found in the interviews. Among types of burners encountered were tepee burners, jug burners (masonry structures with a stack on top which looks like a wine jug), and simple pits in the open surrounded by a corrugated iron fence. There are signs of considerable activity at the grass roots level to develop superior burners, but so far none of the regular equipment companies supplying this market seem to be interested. Presumably a likely type of manufacturer for such incineration equipment would be the cotton ginning equipment manufacturers who have the close contact with the market, followed by the incinerator manufacturers themselves, or possibly in conjunction therewith.

Air pollution results from chemicals used on the cotton for growing and harvesting purposes. Arsenic containing insecticides appear in the waste and arsenic compounds, being volatile, issue in the flue gas as a fume. These poisonous fumes carried downwind can be an actual health hazard and it is for this reason that the health departments and air pollution control departments of some states are vitally concerned. In the Mississippi Delta it is not the usual practice to use arsenic compounds for boll weevil control. Instead, methylparathionate is used to the extent of about 85% and Sevin about 15%. These are evanescent materials which even applied on the plant last only a few hours. Malathion is not used to any extent because it is more expensive than these. With such growing practices, presumably the hazardous type of air pollution would not occur. However, on the Texas High Plains, arsenic compounds are commonly used and the air pollution situation there is mounting.

The foregoing provides some illustration of why the cotton gin waste problem is so complicated, depending as it does so much on the technological, geographical and climatological aspects of the growing, the harvesting, and even the merchandising of the cotton.

There recently became available[10] an extensive survey comprising a 100% sample of the cotton gins in the nation during the 1965 - 1966 season indicating the per cent of gins in each state which burn their wastes, which return the waste to the land, and which have other disposition modes. The 100% sample can be used in obtaining an accurate figure for cotton gin waste for disposal. To each of the state totals for total gin waste there was applied the three percentages from the 100% sample, thus giving the Kpy the waste burned, returned to the land, and having other disposition for each state. The overall national average for the United States was 37.3% burned, 59.0% returned to land, and 3.7% other disposition. The figures given in the quantity section of this chapter result from that computation. A separate study from project data indicated that the disposition pattern for motes was quite similar to the above with the percentage returned to land becoming percentage sold. Motes averaged, in the sample, 8.5% of the total waste.

The quantitative changes in the disposition pattern by 1975 cannot be predicted, but if there is no change in disposition pattern in each state, a similar procedure projects that the disposition of the 1975 waste would be 37.8% burned, 58.4% returned to the land and 3.8% other disposition. If one must hazard a guess as to the qualitative changes in disposition pattern by 1975, it would be that the pressure on air pollution control will substantially reduce the amount burned and increase the amount returned to land and to other disposition modes.

6. TRENDS

Something of the expected trends have already been made evident through the 1975 projection method used. There is an increasing trend to machine harvesting already evident from the historical data. Another trend to be provided for, though not explored here, is the use of defoliants prior to harvesting. This affects both the composition and quantity of the gin waste. Trends in gins baled as shown by the state statistics are not great. However, within smaller regions than defined by state boundaries extensive changes may occur. Based on the interviews in the Rio Grande Valley of Texas, it may be expected that the cotton production of the Valley will decrease markedly in the next ten years. Overlying the entire trend picture are the inroads on cotton made by the synthetic fibers and the inroads on domestic cotton made by imported cotton. These subjects are considered beyond the scope of the preliminary exploration.

In the interviews, various technological changes were mentioned as bearing on the waste trend, but it was not possible to integrate these into a total picture. It is quite certain that the productivity (product/employee ratio) will increase in ginning due to the continuing introduction of automatic machinery. Even the method of planting can affect the waste picture. For example, in one area it was thought that broadcast seeding (in distinction to row seeding) would become major. This would increase the difficulty of weed control and work against use of the waste as soil amendment. Likewise, it would increase the incidence of machine stripping which would increase the waste per bale. In some areas a machine (the Rood) scavenges the cotton dropped to the ground during the regular harvesting. This machine will have a very high waste per bale ratio because of the dirt picked up with the cotton. Another development in just the opposite direction is the Logan machine, now being manufactured by one of the ginning equipment companies which cleans the cotton in the field. This, of course, would greatly reduce the waste per bale ratio. In disposal, the most likely trend is that the fraction burned will decrease as a result of the pressure of air pollution control.

SECTION VI

SURVEY RESULTS

D. DEMOLITION

1. THE INDUSTRY

The general method for demolition was to interview one of the more prominent wrecking companies in the city to obtain answers to the general questions on waste disposal. The quantity of waste developed in this interview was converted to Kpy and the interviewees estimate of the percentage of the total business which he had was used to project the total for the city. Care was taken to determine the boundaries of the territory served. If we were fortunate enough to choose one of the larger wreckers in the city, he was asked to name a few of the next larger ones. Then the next largest was approached for a brief interview to confirm the general questions as to disposition, disposal, etc. and similar questions were put concerning the waste quantity and per cent of the total business enjoyed. This served as a check on the prior projection. The population of the area served was projected to 1966 by multiplying the percentage increase 1950 to 1960 by the 1960 census population, giving a projected increase for 1960 to 1970. Six-tenths of this was taken as the projected increase, 1960 to 1966 and added to the 1960 census figure to obtain 1966 estimate. The Kpy was divided by this 1966 population to develop a waste ratio in units of thousand pounds per year per capita (Kpyc).

The following example is given to show the nature of the computations in detail. The confirmation between the two interviewees came out better than for most cities interviewed. Wrecker C stated he did 80 to 90% of the business in the city. He estimated his waste in two categories, Type One consisted of lumber, stucco, wire, etc. from demolition of frame buildings of which he produced 250 thirty cubic yard cans per month. These "cans" were hauled away on trailers and in connection with a study of a larger size can, he had recently determined that 15 tons could be hauled in a can 8 x 8 x 30 feet. This computes to 68 cubic yards (cy) per can or a bulk density of 0.442 thousand pounds per cubic yard (Kp/cy). The other type of waste, Type Two, was from brick and masonry buildings and this produced about 1.5 loads per 1,000 brick handled at about 4.5 cy/load. This computes to 6.75 cy/Kbrick and further discussion produced an overall estimate of 6 to 10 cy/Kbrick. An average of 7.0 was taken. In addition to this, there was a quantity equivalent to about one-third of this from small non-brick buildings. This waste was of a masonry rubble type and the interviewee confirmed a figure which had been obtained from one of the municipal interviews (Los Angeles) of a bulk density of about 1.8 Kp/cy. The waste generation of Wrecker C computed from these data is described in Table VI.

TABLE VI

WASTE GENERATION OF WRECKER C

	Kpy	% Wt. Basis	cy/yr.	% Bulk Basis	kp/cy
Type One Lumber Stucco Wire	39,700	20	90,000	94	.442
Type Two	16,800	30	9,300	6	1.800
	56,500		99,300		0.569

A subsequent interview with Wrecker R stated by Wrecker C to be the Number 2 operator indicated that in previous years Wrecker R had enjoyed 45 to 50% of the business, but that in the past year or so they had only done 10% of the total city business. This amounted to 45 to 50 cy/day on a five day week basis. He also confirmed that Wrecker C did indeed handle upwards of 90% of the total business. A bulk density was not obtained in this confirmatory interview, but for computation, it was taken that bulk density of the overall waste of Wrecker R was the same as that of Wrecker C, namely 0.57 KP/cy. At 45 cy/day this computes to 6,660 Kpy which happens to be just 10.6% of the city total as computed from the data supplied by Wrecker C.

When this total city Kpy was divided by the estimated 1966 population, there was obtained a waste/population ratio which conformed well with the geographic pattern of the other waste population ratios for other cities.

2. WASTE TYPES

Demolition waste may be divided into two waste classes. Frame houses produce a waste comprising wood, stucco, metal lathe, etc. which is generally regarded as a combustible waste though not conventionally incinerateable. The bulk density of this material is of the order of 350 to 450 lbs./cy. In a recent set of experiments exploring the use of an 8' x 8' x 30' container for demolition described as lumber, stucco and wire, the cans were found to hold about 15 tons. This computes to 442 lbs./cy. However, a 22' can could contain only 6 tons, a bulk density of 230 lbs./cy. The difference lies in the fact that the 30' can is big enough to take the large pieces of lumber lying flat, while the smaller can accepts them only at an angle, thus wasting space. Another interview provided a bulk density of 328 lbs./cy in 55 yard trucks. This type of waste contains two-thirds to three-quarters combustible matter, i.e. wood, roofing, etc. The term "combustible" is applied to this waste as a whole when it is necessary to segregate types of wastes in order to assess charges at land fills, etc.

The second type of waste is termed "non-combustible" and is indeed non-combustible, consisting of bricks, masonry, rock, concrete, rubble, etc. resulting from the demolition of masonry buildings and of the foundations and slab floors of frame buildings. Weighing experiments on such waste show very high bulk densities, some as high as 1,800 lbs./cy.

The ratio between the two types of demolition waste varies greatly, depending on the type of construction which is typical of the city. In the one city already cited as an example, the non-combustible portion was only about 10% of the total. In another city where brick and masonry construction is common, the non-combustible was 80% of the total.

The quantities of total demolition waste computed as above from seven interviews for the six cities were:

City	Pounds Per Year Per Capita (not kilopounds)
Milwaukee	230
New Orleans	62
Ft. Worth	12
Dallas	22
Houston	173
New York	Data Not Available

In addition, similar data were available from prior projects on seven cities geographically spread from border to border and coast to coast. On the basis of these twelve data points, assignment of round number pyc's (pounds per year per capita) was made to each of the 48 states and these pyc's were assigned to each SMSA (Standard Metropolitan Statistical Area) in the state. If the SMSA or SCA (Standard Consolidated Area) lay in two states with different pyc's, it was assigned to the state with the larger pyc. These pyc's were then applied to the 1966 and 1975 estimates of the populations of the SMSA's or SCA's and the products summed over all areas.

Thus, projected in round numbers, the 1966 demolition waste is 38,100 million pounds per year and the 1975 waste assuming no trend in pyc's in the interval is 44,300 million pounds per year.

3. DISPOSITION AND DISPOSAL

Disposition of demolition waste is almost entirely by the demolition contractor himself, and indeed is an integral part of the demolition operation. In thirteen interviews conducted over the past several years, only one instance was found in which a demolition establishment occasionally used contract disposition. Truck sizes used in disposition run from 4 1/2 to 55 cubic yards. The container system is also used in 10 and 52 cubic yard sizes and in one experimental development in a 68 cy size. The haul distance, of course, varies with the location of the demolition job, but in general does not average less than ten miles and in some cities up to forty miles. The round trip time may be anywhere between forty-five minutes and four hours.

Salvage used to be an important part of the disposition and disposal picture for demolition waste. However, with the increasing cost and scarcity of semi-skilled labor and the increasing cost of insurance (for the warehousing phase of salvage), salvage has passed out of the picture in highly industrialized regions and southern cities are just now going through the transition to the non-salvage style of demolition. As an example, in one city it formerly took a six man crew one and one half weeks to demolish with salvage a five room house. Abandonment of this method was forced by labor conditions and it now takes only one day to demolish a similar house by machine methods. The machine method consists of using a clamshell derrick which literally demolishes the house by taking bites out of it and depositing the bites in the waiting trucks. This trend is greatly increasing the waste generation in those cities in the transition, but it is believed that this transition is about over for the bulk of the cities in which demolition is occurring.

Air pollution ordinances are also overtaking the demolition industry. Formerly it was the practice to "clam shell" a building, depositing the combustible waste on an adjacent vacant lot where it was burned on the site. Pollution or safety ordinances are forcing abandonment of this practice. In one northern city the banning of open burning has forced demolition contractors to haul waste as much as forty miles for disposal. This has doubled the cost of demolishing frame houses. In another city there is no ban on open burning, but there is an ordinance prohibiting burning within 200 feet of a structure which effectively prevents burning of demolition waste on site. In one city, where air pollution is acknowledged to be a problem which must be faced in the near future, one of the interviewed demolition contractors had considered incineration, but decided against it on the basis that in his opinion air pollution ordinances would prohibit incineration within two years.

Ultimate disposal is almost entirely in dumps or sanitary land fills. The Type Two waste is acceptable at any dump and thus is associated with the shorter haul distances. In addition, Type Two waste has value as fill at various points in the metropolitan areas at which leveling and construction is planned. It is more difficult to arrange ultimate disposal for the Type One waste due to the combustible material and to the bulky nature of the waste. Practically all the disposal is in dumps or sanitary land fills, but in one city it has been the practice to barge some out to sea. Open burning of demolition waste on open dumps is rapidly on the way out. The ultimate disposal facility may be operated by the municipality, by the demolition contractor himself (private as defined), or as a merchant facility. Among fifteen interview responses, the incidence was seven municipal, four merchant, two not self (merchant or municipal not determined) and two private. In other words, only one in seven was private.

4. TRENDS

It is obvious from the interviews that the demolition industry faces a major problem in waste disposal. The disposal of the masonry rubble Type Two waste is not difficult since it can be used for clean fill which is always needed in a metropolitan area. The problem is with the "combustible" Type One waste. Not only are the haul distances to existing dumps becoming too great, but also existing dumps and sanitary land fills are becoming more restrictive on the inclusion of the large pieces of wood generated by demolition. Furthermore, this type of waste contains many bulky items such as pipe, bathtubs, sinks, etc. plus a considerable amount of non-combustible material such as wire, stucco, plaster and this makes it difficult for incineration. Segregation of the bulky items and the non-combustibles from the Type One waste is out of the question because of labor costs which indeed even prevent the salvage of these items and the wood itself as saleable materials.

Incineration seems to be the only possibility of a solution to the problem, but required is the development of a specialized incinerator to handle such wastes. In several interviews there was mentioned the desirability of a portable incinerator which would satisfy air pollution requirements, handle the waste type and also be movable from one demolition site to another. This seems to be an opportunity for needed research and development.

There does not seem to be anything in the general economic trend which would reduce the amount of demolition per capita in the next ten years. The quantity of waste will probably increase somewhat in those cities which now have a comparatively low waste per capita ratio, since it is in general in these cities that the transition is in progress from hand demolition to machine demolition. This transition has already occurred in the region of the country where most of the demolition occurs, and thus the overall effect will not be large. The industry faces a major problem in finding dump or land fill sites which are close to the work. It will undoubtedly be impossible to locate these and haul distances will increase substantially. Attempts are underway (some confidentially revealed during the interview campaign) to develop better methods of handling and segregating the Type One waste and of incinerating it.

The demolition industry is one of the few industries that does not have a national trade association. Such an association through its activities and through the pooling of techniques and experiences would probably be very helpful in this phase of the industry's problems.

SECTION VI

SURVEY RESULTS

E. PAPER

1. SUB-CODES AND INTERVIEWS

S.I.C. Code 2611 comprises pulp mills not associated with paper mills. There are only about fifty of these in the nation, and it was felt that their solid waste production would be relatively small, so this code was not interviewed or included in the projections. The remaining sub-codes of interest, together with the number of employees and the number of interviews, are as follows:

Code	Description	Employees	Interviews
2621	Paper mill ex. building paper	133,000	6
2631	Paperboard mills	67,000	11
264	Paper & paperboard products	166,000	5
2651, 2, 3	Paperboard boxes		7
2654, 5	Corrugated and fiber boxes, sanitary food containers		2
265	(All Sub-Codes)	191,000	9
266	Building paper and board	12,000	1

Six interviews were conducted on the current project, but a total of twenty-six other establishments were available from previous interviews in a total of twenty-nine interviews.

2. WASTE TYPES

Some paperboard mills start with logs as raw material, but some start with waste paper. Those that start with logs and the paper mills which quite universally start with logs, have waste bark which is used for fuel. In general, in paper making and paper converting operations, the waste paper itself can be repulped or is saleable as paper scrap. However, in manufacturing certain kinds of paper the waste is not saleable. These include wet-strength papers, coated papers, waxed papers such as from sanitary food containers, paper products containing metal inserts such as juice cans, and treated paper of various kinds. Establishments handling these kinds of papers have more waste than those handling papers which can be repulped or sold. Paper establishments have plant trash and shipping wastes.

The wastes contain some metal from staples used in box manufacture, from metal strapping comprising a portion of the shipping waste, and the metal portions of metal insert containers.

3. WASTE QUANTITIES

There was no trend of KPYe's with size. In earlier work there seemed to be some reason, based on the technology of the sub-codes, for separately considering certain paper sub-codes. Accordingly in the present study the 32 available Kpye's were analyzed in five groups comprising the sub-codes 2621, 2631, 264, 2651, 2 and 3, and 2654, 5. The log normal distributions of these had similar σ ratios. Group 2651, 2 and 3 had the lowest mean and the groups comprising 2621, 2624, and 2654, 5 had means relatively close together and high. A test was run for the significance of the difference of the 2651, 2 and 3 mean from the means of the three high groups, with the result that there was no significant difference at the 5% level. The remaining group being between these two it was concluded that the code could just as well be represented by a single distribution. This log normal distribution of 32 Kpye's had a median of 8.64 and a σ ratio of 3.55. If this is characteristic of the population of about 5,000 establishments, the average Kpye would be 19.4 and the 68% confidence interval thereon would be from 15.5 to 24.4.

As will be shown in the distribution section, it is estimated that 10.6% of the total waste constitutes that utilized for fuel or sold. Thus, only 89.4% of this total is subject to ultimate disposal as a waste and the corresponding average Kpye is 17.3.

A corresponding figure was computed by another route primarily to test whether the dispersion might not be better if the Kpye's were computed in terms of the non-fuel non-sold waste. These numbers may be used, however, to project another figure for the average, which, if the population had those statistical characteristics, would be 16.1, a close check with the 17.3 obtained via the total waste and disposition route. This average applied against the total number of employees in the paper code excluding pulp mills 2611, projects to 9,950 million pounds per year in 1965. With the growth factors this predicts 14,700 million pounds per year in 1975.

4. DISPOSITION AND DISPOSAL

Disposition was by Dumpsters, dump truck and front end loaders. Haul distances average three miles with a maximum of seven in the interviews. Out of the thirty-two establishments, four sold some or all of their waste and two utilized some for fuel. Among these six, the average percentage used for fuel or sold was 78.5%. If this disposition mode is independent of size and the sample is representative for disposition, the fraction of the total waste sold or used for fuel would be 14.7%. Of the remaining disposition situations, including the postcard responses, thirty were by self, thirteen by contract, one by city pickup and two unknown. The ultimate disposal facility ownership was twenty-three self, thirteen city, eleven not self, but unknown. The disposal method was twenty-five dump, four sanitary land fill, three open burning, seven incineration and nine unknown.

5. TRENDS

A few plants indicated they were attempting to reclaim more fiber, but since fiber (as sludge from settlers) was a very small amount of the total waste, this cannot bring about any trend. No other trends were evident from the interviews.

SURVEY RESULTS

F. FOODS

1. SUB-CODES AND INTERVIEWS

Previous studies had been made in the food sub-codes of cereal preparations, poultry processing, rice milling, bakeries, sugar, coffee and meat packing. Meat packing appears as a separate chapter in the present report. The other sub-codes treated separately had such small amounts of total waste that they were not chosen for industry coverage in this report. The food industry is highly heterogeneous and it would be impossible to cover every sub-code in it. The seven interviews were in sub-codes 2033 canned fruits and vegetables, 2021 butter, 4 ice cream, 5 dairy products, 2082 beer and 2099 miscellaneous food specialties. The projection was based on all food sub-codes excluding the seven sub-codes mentioned in the first sentence above. This group has 1,030,011 employees which is about one-third less than the number of employees in the entire two-digit code.

2. WASTE TYPES

The waste types were plant trash, shipping wastes, and process wastes characteristic of each product process. Where distinguishable, the process was about two-thirds of the total. The shipping wastes included cardboard boxes and metal cans.

3. WASTE QUANTITIES

The waste quantities were based only on the six Kpye's available from the seven interviews in the current project. There was no trend with employment size and there were not enough interviews in any one sub-code to make distinctions between sub-codes. Kpye's were log-normally distributed with a median of 6.0 and a σ ratio of 3.17. If these are the characteristics of the population of 27,000 establishments, the mean Kpye would be 11.6 and the 68% confidence interval from 6.7 to 20. Applied against the number of employees in the projected sub-codes (excluding the seven mentioned) this gives 11,346 million pounds per year. Adjusted by the results of the disposition and disposal analysis, the waste for disposal is 10,584 million pounds per year. At a growth factor of 1.33, this projects to 14,076 million pounds per year in 1975.

4. DISPOSITION AND DISPOSAL

The disposition and disposal data described here arises from the seven interviews on this project plus seven additional interviews from earlier projects. Disposition is by truck, dump truck and containerized trucks, five self, nine contract and one city. The ultimate disposal method was five dump, three incinerator and three sanitary land fill and four uncertain, probably dumps. Ownership of the ultimate disposal facility was three self, four city and one not self.

5. TRENDS

The interviewees did not expect any trends in waste/product or waste/employee ratios.

SECTION VI

SURVEY RESULTS

G. WOODEN CONTAINERS

1. SUB-CODES AND INTERVIEWS

The sub-codes making up 244, Wooden Containers, together with the number of employees and the number of interviews available are as follows:

Code	Description	Employees	Interviews
2441	Nailed wooden boxes and shook	13,653	8
2442	Wirebound boxes and crates	9,713	6
2443	Veneer and plywood containers (except boxes)	3,498	0
2445	Cooperage	2,872	1

An industry very similar to the wooden container industry, i.e. starting from the same raw material, comprising very similar operations and having quite comparable waste quantities, is the manufacture of wooden pallets. Some of the establishments interviewed manufactured pallets along with wooden containers of various types.

There is considerable heterogeneity in the industry which actually is not reflected in the observed dispersion of Kpye's among the codes. Basic to the lumber and wood products industry is the distinction between those establishments which start from logs as raw material, and those which start from lumber already manufactured from logs. Both types of establishments are found in the sub-codes of 244. Using 2442, wirebound boxes and crates as an example, a typical establishment is a combination of a saw mill, a veneer mill, and a box assembly plant. The saw mill produces the cleats for the ends of the veneer boxes. The veneer mill produces the veneer for the sides and the box assembly plant assembles these two items into the finished box. All establishments interviewed had the veneer mill, but some of them did not have the cleat mill, purchasing cleats from another source. A typical ratio of mbf (million board feet) feeding the cleat plant to mbf feeding veneer plant is about 0.7.

As a result of the interviews and a subsidiary postcard survey there were available twenty-eight productivity figures for establishments in Code 244, in terms of Kbfye (thousand board feet per year per employee). These productivity ratios were log-normally distributed with a median of forty-two Kbfye and a σ ratio of 1.81. The productivity is about one-fourth that in saw mills.

2. WASTE TYPES

The waste from wooden container manufacture is similar to saw mill waste but includes more dry wood from the veneer mill and the box plant. The saw mill portion, of course, produces wastes entirely similar to lumber manufacture in saw mills. The veneer plant portion has waste characteristic of veneer production. Round-up waste (green wood) occurs in the first cuts on the rotary lathe rounding up the log cylindrical with the lathe axis. It includes both bark and the outside layers of wood. The residual cylindrical core, also green wood, may appear as a waste directly. However, it is not uncommon to use these cores as raw material for manufacturing 2 x 4's (studs) and quite common to chip the core or the residual from stud manufacture into chips for sale to pulp and paper mills. The waste cuttings from manufacturing the siding elements from the raw veneer are dry wood. In addition, the box assembly portion of the plant produces reject boxes, etc.

3. WASTE QUANTITIES

As will be indicated from the disposition survey, it is almost universal to sell chips from wooden box manufacture for pulping. Accordingly, the chips described as wastes have been eliminated from the waste stream computations hereafter. There is no trend of Kpye with sub-code or with employee size.

The fifteen Kpye's are log-normally distributed except for the lowest three which occur at lower Kpye's than corresponds to their percentile levels. The median is 66 Kpye and the σ ratio 3.18. If these are the characteristics of the population of 904 establishments in the projected codes the average Kpye would be 125 and the 68% confidence interval from 91 to 172. Applied against the total of some 29,000 employees in the projected codes this gives 3,717 million pounds per year for the non-chip waste. However, the disposition and disposal study showed that a certain fraction of the interviewed establishments are able to dispose of some or all of the non-chip waste without cost to themselves, i.e. either by giving it away or by using it for fuel. Portions thus handled do not enter into the industrial waste stream and when this correction is made the projected non-chip waste for which free disposition is not available becomes 2,380 million pounds per year. In the disposition - disposal analysis, a new Kpye including chips was used against which was applied the pattern including chips. The result was 2,470 million pounds per year which was chosen. Applying the growth factor (which for this industry is less than 1.0), this becomes 2,190 million pounds per year projected for 1975.

4. DISPOSITION AND DISPOSAL

For the disposition study there are available data of two different types which were first considered independently. One of these is the information from the fifteen interviews and the other is information from a postcard disposition survey previously made comprising twenty-five responses. Of the fifteen interviews, seven incinerate all their waste and one open burns all his waste. These eight comprise 53% of the establishments. Four out of fifteen, or 27%, dispose of all of their waste without cost to themselves by giving away or use for fuel. The wastes of these establishments therefore, do not enter into the industrial waste problem. Three out of fifteen, or 20%, dispose of about 50% of their waste without cost to themselves and the other 50% they incinerate. These data refer to numbers of establishments, but if it be assumed that these ratios are independent of establishment size (measured by total waste production), then these percentages likewise become the percentages applicable to the disposition of the waste produced. With this assumption, these data indicate that 37% of the waste is disposed of without cost to the producer and thus does not enter into the industrial waste problem while 63% of it requries an expenditure for disposition and disposal.

Similar information is available from the postcard survey. The check between the two sets of data is quite good. Three out of the twenty-five (compare three out of fifteen) have more than one type of disposition and in each case, half was disposed of without cost to the producer and half by disposition involving expenditure. Thirty-two per cent of the waste was disposed without cost to the producers (compared 37%). Sixty-eight per cent (compare 63%) incurred a cost.

Since these results are in conformity with each other, the data may be combined whereupon, based on the assumption above, it may be projected that about 30% of the non-chip waste find free disposition (nearly always for fuel). About 58% are disposed with some expense to the producer, nearly all burning in some form and mostly by tepee burner. The remaining 12% is about half free disposition and half not free. In summary, 70% of the establishments have a waste problem and among these establishments, about 8% of the waste is disposed of wihtout cost to the producer. Over all, about 36% of the waste finds free disposition and the remaining 64% constitutes an expense to the producer.

In all cases, the disposition is by self for the non-sold non-fuel, non-give away waste. It is to be noted specifically that no instances of contract disposition or city pickup were found. The ownership of the ultimate disposal facility was in each case the producer, and the type as qualitatively indicated above.

5. TRENDS

No evidence of any general trends were observed in waste/product or waste/employee ratio. However, as has been described in the saw mill chapter, it is imminent, in the South at least, that sawdust is to become utilizable for pulp. If this is the case for saw mills, it will very likely also be the case for wooden container manufacture starting from logs, since these also sell chips to the pulp mills. Unfortunately, an exact quantification of the fraction of wooden container waste which is sawdust is not available to the project, but such approximate data as are available suggest that sawdust may be of the order of 30 to 40% of the non-chip waste. Accordingly, if sawdust becomes saleable to pulp mills, the total waste will be reduced by this amount.

SECTION VI

SURVEY RESULTS

H. WOOD FURNITURE AND FIXTURES

1. SUB-CODES AND INTERVIEWS

The sub-codes involving wood furniture, together with number of employees and number of interviews incorporated in this chapter, are as follows:

Code	Description	Employees	Interviews
2511	Household ex. upholstered	141,000	7
2512	Household, upholstered	69,000	5
2519	Household (not elsewhere classified)	2,000	0
2521	Office	6,000	1
2531	Public building	18,000	1
2541	Partitions, fixtures	23,000	2
2599	N.E.C. (not elsewhere classified)	8,000	0

Of the sixteen interviews, six were on this project and ten were available from previous projects.

2. WASTE TYPES

The types of waste occurring are plant trash, shipping waste and process waste. The process waste consists of sawdust, shavings and wood scrap, upholstery materials, oily rags, styrofoam, sandpaper and abrasives. No data were available on the various proportions of these.

3. WASTE QUANTITIES

The twelve Kpye's are log-normally distributed with a median of 3.0 and a σ ratio taken as corresponding to the population of 6.0. There is no trend in Kpye with sub-code or employee size. If this is the characteristic of the entire population of 6,800 establishments, the average Kpye would be 14.6 and the 68% interval from 8.1 to 26.2 Kpye.

A certain portion of the waste is used as fuel, sold or given away, in other words, it is disposed of without cost to the producer, and therefore, not considered as entering a waste stream. The general disposition - disposal study gave the waste entering the final waste stream as 79% of the total waste represented by the Kpye's. Applied to the total number of employees, this gives 3,090 million pounds per year of waste in the ultimate waste stream. The physical production ratio to 1975 is 1.67, thus projecting the 1965 waste quantity at 5,170 million pounds per year.

4. DISPOSITION AND DISPOSAL

The data given following, includes both the ultimate waste stream and the 18% disposed fuel, sold, or given away. Disposition was by truck, thirteen self, two contract, one city, three fuel, three sold and three give away. Ultimate disposal was seven incineration, six dumps, one sanitary land fill and one open burning. Ultimate disposal facility ownership was seven private, being the incinerators and nine city.

5. TRENDS

There is no major trend in waste/product ratio. One establishment indicated that more of the sawdust would find a useful outlet in particle board and composition board and one establishment indicated that there was trend in shipping waste away from wood and to cardboard.

SECTION VI

SURVEY RESULTS

I. AUTO AND AIRCRAFT MANUFACTURE

1. SUB-CODES AND INTERVIEWS

The sub-codes covered in this chapter are 371, motor vehicles and motor vehicle equipment with 620,000 employees and 372, aircraft and parts with 740,000 employees. The interviews were drawn from sub-codes 3711, 3712, 3714, 3721, 3722 and 3729. Six interviews came from the present project and two were available from prior projects. Three interviews were in Code 371, four in 372 and one in both codes.

2. WASTE TYPES

The major types of waste are plant trash and shipping wastes, the latter containing considerable wood. Only four out of the eight interviews had any process waste and the percentage of these wastes in the total was very small.

3. WASTE QUANTITIES

The Kpye (thousand pounds of waste/year/employee) for the eight interviews showed no differences between the two three-digit codes and tested statistically at the 5% level of significance showed no significance to the correlation with number of employees. The Kpye figures were log-normally distributed with a median of 0.90 and a σ ratio taken to correspond to the population of 4.0. If this is the characteristic of the entire population of some 4,000 establishments, the average Kpye would be 2.34 and the 68% interval from 1.4 to 4.0 Kpye. Applied against 1,361,000 employees in these two three-digit codes, this projects the total waste to 3,180 million pounds per year. The general disposition - disposal study indicates that about 8% of waste is given away, so that waste-for-disposal is currently 2,910 million pounds per year, and in 1975, 3,660 million pounds per year.

4. DISPOSITION AND DISPOSAL

Of the eleven disposition situations, six were by contract, four private and one by city. Metal scraps and shavings were generally sold, but no major portion of the waste was sold for salvage. Equipment used in disposition ranged widely from three cubic yard gondolas to fifty-five cubic yard trailers and compactor trucks. Haul distance was one to five miles except that the haul distance of one establishment to the municipal incinerator was thirteen miles.

Disposal was three incinerators, three dumps, one dump and burn, two sanitary land fill and one unidentified. The disposal agencies were six city, two self and two contractor owned.

5. TRENDS

Generally, no trends in waste/employee or waste/product ratios were evident.

SURVEY RESULTS

J. MEAT PACKING

1. SUB-CODE AND INTERVIEWS

In 1964 there were 1,368 meat packers, defined as firms purchasing for slaughter more than 1,000 head of cattle or 2,000 head of all livestock.[11]

The number of meat packing establishments (strictly reporting units) in 1964 was 2,831,[2] but not all meat packing establishments conduct slaughter. In Code 2011, there were 177,000 employees and in Code 2013, sausages and other prepared meats, there were an additional 48,000.

Seven interviews with establishments in 2011 and 2013 were conducted during this project and eight additional interviews plus earlier published information were available from earlier studies.

2. WASTE TYPES

The interviews confirmed the almost literal truth of the old statement that slaughter houses utilize every part of the animal except the squeal. True, slaughter houses generate considerable quantities of waste comprising paunch manure or stomach contents. The only part of the animal not utilized, and observed in only two interviews, was hog hair for hog slaughtering operations. The meat packing plants not engaged in slaughtering, produced only plant trash and shipping wastes from packaging lines. Those conducting slaughtering presumably produce these types of wastes also, but interviews with such establishments concentrated so much on the paunch manure and stomach contents problem that not much quantitative data was obtained. The paunch manure consists of undigested and partly digested food typically hay and stomach juices obtained from the four stomachs or paunches of cattle and calves. This material has a high water content, about 85%, and also a high fat content. Placed outdoors on a pile and allowed to drain a bit, it will burn with a greasy persistent flame even when it is obviously wet.

From hogs the material is better described as stomach contents and consists largely of undigested corn. All other wastes from packing plants are either liquids or are customarily flushed with water and removed via sewers.

3. WASTE QUANTITIES

As implied in the previous section, meat packing establishments that do not conduct slaughtering operations have only a very small amount of waste. The six interviewed establishments in this category had only 1.5 Kpye average, which is only one-tenth of the average Kpye for meat packing houses conducting slaughtering operations.

For the paunch manure some of the interviews and some published data provided pounds of paunch manure per head for certain types of animals. The averages of the available figures showed a cattle - hog ratio of 7.46:1. Two interviews were with packing plants handling both hogs and cattle for which only the total paunch manure was known. Using the 7.46:1 ratio on both these establishments produced two additional lbs./animal ratios. The result was five ratios for cattle, five for hogs, one only for sheep, and for calves only a single estimate that paunch manure for calves was one-third that for cattle. The cattle and hogs lbs./head figures were each log-normally distributed with medians of 38 and 5.1 lbs./head respectively, σ ratios of 2.89 and 1.88 (coincidentally, this ratio is also 7.46). If these were characteristics of the entire population of about 1,400 packing plants in the nation, the respective averages, lbs./head, would be 76 and 6.3. With calves at 22 lbs./head and sheep at 6, these averages applied against the total number of head of each of the four types slaughtered in 1964. This produces 2,613 million pounds per year of paunch manure and stomach contents of which 71% is contributed by the cattle.

It is difficult to compute the true confidence limits since involved is the confidence limit on a summation, the components of which are log-normally distributed. However, if the confidence limits of the total are the same as that for cattle, the 68% confidence interval would be from 1,490 to 2,400 million pounds per year. The true confidence interval is narrower than this.

Some earlier studies have indicated a productivity for meat packing of 770 head (mixed types) per year per employee. From this ratio, a corresponding average Kpye may be computed as about 15.

As will be discussed in the disposition section, it is estimated that only about 50% of the produced paunch manure and stomach contents enter the solid waste stream of interest. This would be 1,300 million pounds per year of paunch manure and stomach contents. In addition, presumably all establishments have the same waste/employee ratio for the non-paunch manure wastes as do the interviewed establishments conducting slaughtering, namely 1.5 Kpye. This amounts to another 350 million pounds per year of which the disposition - disposal study shows 100% is waste for disposal, for a total of 1,650 million pounds per year from the meat packing industry. With the assigned growth factor this becomes 2,400 million pounds per year in 1975. However, this last figure is highly uncertain as will be discussed under the section on trends.

4. DISPOSITION AND DISPOSAL

The disposal of paunch manure and stomach contents from slaughtering is a major waste problem of the meat packing industry, and the industry is engaging in considerable activity on a number of fronts. This activity cannot be adequately covered by the number and itinerary of interviews available for this study. Among suggestions ranging from mere ideas to commercial realities, for handling paunch manure and stomach contents are:

a. Dehydrate and use as animal feed.

b. Dehydrate for soil conditioner.

c. Solvent extraction of the grease for sale and utilization of the residue for feed or soil amendment.

d. Incineration of the 85% moisture material.

It is clear that with this degree of commercial interest and development, predictions about the future of this meat packing industry waste must be considered highly uncertain.

Nine interviews mentioned the disposition of paunch manure and stomach contents waste. Two establishments flushed the stomach contents waste to the city sewer. A group of establishments comprising another single interview also flushed the material to a common sewer, but the sewer fed a common disposal facility which wet screened the waste and burned the material remaining on the screen, i.e. the solids, in an open burning pile. The material passing the screen goes to a settler, the overflow going to the city sewer and the underflow being lagooned. Judged from the comments of interviews on the general disposition of paunch manure and stomach contents, it is likely that the frequency of these materials discharged to the city sewer system is greater than the simple interview frequencies would indicate. However, such disposition removes the material from the scope of the present study.

The high liquid content of the original waste and the ease of disposition to the sewer or some water course when this is not prohibited by ordinances suggests that it is probably not uncommon that paunch manure and stomach contents be wet screened leaving only the material not passing the screen for disposition by the producer. This was the case with one establishment interviewed and probably also the case in three other interviews for which it was not possible to determine whether the paunch manure was screened or not.

In the six cases where there remained solid waste to be disposed of, either raw paunch manure and stomach contents or screenings therefrom five of the establishments hauled the material themselves and one used contract disposition.

In two cases, the ultimate disposal was in the city land fill, and in two other cases, to an unidentified city disposal facility.

It will be recognized that with the paunch manure and stomach contents waste from the meat packing industry, it has been more difficult than in any of the other codes studied to distinguish between solid waste and liquid or liquid-borne wastes. This difficulty has been accentuated because of the diversity of disposition and disposal methods which are in use and which bear on this distinction.

Of the eight cases of disposition of paunch manure and stomach contents in five it is known whether the material is screened or not. Of these five, two establishments disposed of all the waste, two disposed of none of it (as solids) and one handles whatever fraction of the waste remains on the screen.

Assuming that 50% of the original waste appears as the screening, and that the small sample of five is representative of the frequencies of occurrence in population and that the disposition mode is independent of establishment size, then one half of the total paunch manure and stomach contents generated will actually appear as a solid waste to be disposed of.

In six interviews, waste other than paunch manure and stomach contents is listed, three of these establishments having slaughtering and three having no slaughtering. For these wastes which are plant trash, shipping waste and in one case pen waste, disposition is four self and two contract. In two cases, the material was incinerated by the producer and in two cases, disposed of in a city sanitary land fill and a city dump.

5. TRENDS

No quantitative trends in waste/product or waste/employee ratio were evident from the interviews. However, the ferment of activity and development in the handling of paunch manure and stomach contents clearly indicates that some trend is to be expected in a direction to decrease the quantity of these wastes which must be handled by a solid waste disposal facility -- if they are at all successful. To adequately assess these trends would require a much more comprehensive study of the various methods being proposed and a prediction of their merits and competitive positions.

In the other direction, it is quite likely that water pollution control measures will gradually prohibit the discharge of paunch manure or material passing the screens into water courses as is now done where this is allowed. It is not likely that the discharge of the material passing the screens into city sewer systems will be prohibited since there is no pollution involved and the material is of the type that can be handled by a conventional sewage system plant, possibly at some additional expense which presumably will be negotiated Short of flushing the total waste to a water course, this is probably the most economic disposition that the producer can make and presumably will be favored unless some of the utilization methods being proposed should develop profitable values.

SECTION VI

SURVEY RESULTS

K. CHEMICALS

1. SUB-CODES AND INTERVIEWS

The sub-codes and approximate number of employees in the codes are:

Code	Description	Employees
281	Industrial organic & inorganic chemicals	240,000
282	Fibers, plastics	148,000
283	Drugs	94,000
284	Cleaning and toilet goods	86,000
285	Paints	62,000
287	Agricultural chemicals	49,000
289	Miscellaneous, including 2895 carbon black	62,000 2,300

There were available six interviews conducted under this project and seven contributed from prior project work as follows:

Code	This Project	Prior Projects
281	2	3
282	2	3
284	1	
287	1	0
2895	0	1

After studying the interview data it was decided to drop the one interview in 284 from further consideration because it was a plant manufacturing both detergents and food items. Code 285, paints, is not considered here because it constitutes one of the separate codes being studied under this project.

2. WASTE TYPES

The chemical industry is highly heterogeneous with respect to wastes and probably cannot satisfactorily be projected even by a sample of thirteen. The process wastes are highly specific to each manufactured product. The major quantity of process waste in the interviews was a liquid waste and thus not covered in the present project. It was not uncommon to incinerate combustible liquid wastes in a pit incinerator. Other disposal methods encountered for liquid wastes included dumping at sea and injection underground. Four out of the thirteen establishments had no process waste.

3. WASTE QUANTITIES

There was a distinct difference in Kpye level between the three Code 281 establishments and the remainder of the establishments supplying data. The distribution of the waste/employee ratio for this code was neither normal nor log-normal. The mean was 0.47 Kpye and the estimated standard deviation of the population 0.17. The corresponding 68% confidence interval for the mean of the population is $\pm$0.14 which means that there is a 68% probability that the true mean of the population lies in the band 0.47 $\pm$ 0.14. This mean applied to the total 1965 employment (240,509) in the code gives 113 million pounds per year as the waste generation. The estimated 1975 waste total is 211 million pounds per year for this code.

As with the 281 code, the Kpye's for the other codes combined showed no trend with number of employees. The distribution was log-normal with a median of 7.3 Kpye and a σ ratio of 2.88. If these are the characteristics of the entire population of 3,875 such establishments, the expected average for this population is 12.6 Kpye (the actual average of the sample was 10.4). Applied against the approximately 200,000 employees in the projected codes (282, 287, 2895), this gives 2,520 million pounds per year for 1966 and 4,700 million pounds per year for 1975. These data may be manipulated to provide the 68% confidence limit on the mean of the logs of the population of Kpye. When the adjustment is made for the arithmetic average, the 68% confidence limits for this become 7.6-21, centered of course on 21.6. This signifies that there is a 68% probability that the true mean of the population lies in the interval between 7.6 and 21.

4. WASTE QUANTITIES

Over an average for all establishments interviewed, the solid process waste amounted to about 20% and the plant trash and shipping wastes about 80%.

5. DISPOSITION AND DISPOSAL

Private disposition is the major mode in the chemical industry. In the sample, eleven dispositions were private and only two by contract. The haul distance was of the order of one to four miles.

Private disposal is not uncommon, there being in the interview eight private disposal operations as against five municipal. Of the private ultimate disposals, four were dump and burn, one dump and three incineration. Two other establishments had special incinerators for particular process wastes which constituted special problems and occurred only in very small amounts. The city disposal facilities were four sanitary land fills and one dump.

6. TRENDS

One interview indicated no trend in the waste/product or waste employee ratio, but three anticipated a reduction in waste/product ratio. One of these was impelled by state air pollution regulations, one because of transfer to bulk shipments using less packages, and one which had a particularly bad process waste problem is considering changing the product which would reduce the waste.

SECTION VI

SURVEY RESULTS

L. STOCKYARDS

1. THE INDUSTRY

Stockyards have the S.I.C. classification 4731. In 1963 there were 54 "public terminal markets" assignable to this code. They handled about 15 million cattle, 2 million calves, 22 million hogs and 6 million sheep; a total of about 22 million "animal units" on the conventional basis that one cattle equals three calves, four hogs and ten sheep.[11, 12]

The terminal markets are log-normally distributed by size with a median of 250,000 animal units.

So far as waste production is concerned, the stockyards provide a holding place for animals in the process of sale or transfer. Most of the animals are moved out within 24 hours of the time of arrival, sometimes as little as ten to twelve hours, depending on the customs at the various markets. Animals to be sold as feeders and stockers may remain in the yards for longer periods of time, up to several days.

In addition to the fifty odd terminal markets there were in 1962 1,725 "auction markets". While the business transaction which occurs differs from terminal markets, the physical handling involving waste production is quite similar.

The animals pass through the auction market and are held for a period of time similar to that in terminal markets. In auction markets, however, it is typical to have auction sales only one or a relatively few times per week as compared with the continuous operation of a terminal market. Since the retention time is the same, the waste production per animal should be the same in auction markets as terminal markets. In 1962 auction markets handled about 36 million animal units. The markets are log-normally distributed by animal units handled with a median of about 25,000. However, auction markets appear to be classified in the standard industrial classification in Code 0719, Agricultural Services, n.e.c.

The thirteen interviews available comprised some of the largest terminal markets in the nation and included two small auction markets

2. WASTE TYPES

The waste streams encountered in stockyards are these:

a. Pen waste -- the material which collects in the pens, composed of animal manure, plus bedding if it is used, plus hay fed to the animals which is wasted and drops to the ground.

b. Truck cleanings -- material similar to pen waste cleaned from the trucks delivering the cattle to the yards.

c. Lumber -- from pen rehabilitation.

d. Plant trash -- from offices and particularly from hotels and cafeterias operated by larger stockyards and office wastes from tenants in the levestock exchange building.

e. Concrete and masonry -- from repair of pen and alley bottoms.

The pen waste always contains spilled hay, but some yards do not actually purchase bedding. Depending upon the amount of bedding and also upon the amount of time that elapses between the time of production and the time the waste enters the pertinent waste stream -- in other words depending on the time in storage piles -- the moisture content of the pen waste may vary widely from as high as 80% to as low as 20%. The bulk density varies accordingly, both with the dryness and with the amount of bedding. (The term bedding henceforth will refer to both straw purchased as such and also the spilled hay which becomes bedding.)

Four rough measures of bulk density, moisture content unknown, one of them specifically measured on a few trucks by the stockyard specifically for this project were 450, 890, 1,300 and 1,888 lbs./cy (pcy).

3. <u>WASTE QUANTITIES</u>

The fraction of concrete and masonry rubble in the total waste is minute. The one interview in which there was a quantitative measure gave 0.1% in the total waste.

The quantity of lumber from pen rehabilitation was estimated from the amount of lumber purchased per year, none of it going into new construction, but all replacing worn out pens, etc. This waste stream is also small in relation to the total. The average of seven interviews gave 1.5% of the total waste.

The amount of hotel and cafeteria waste and plant trash was available in only three interviews, the average percentage of the total wastes being 0.8%.

It is clear, therefore, that the great bulk of stockyard waste is the pen waste including the truck cleanings. Data were available from four interviews for computing the percentage of truck cleanings in the pen waste. These percentages were close together and average 9%.

The typical contribution of the various components to total stockyard wastes on the above basis is as follows.

Pen Waste	97.6%
(including truck cleanings	(9.0%)
Hotel and Plant Trash	0.8%
Lumber	1.5%
Concrete and Masonry	0.1%
	100.0%

It is seen that so far as quantity projections are concerned, one need deal only with the pen waste.

In previous Combustion Engineering studies on this subject, the evidence indicated that "northern" yards used bedding in the pens while "southern" yards used none. The interviews under the present project have added to this information and modified it. In the first place, it was learned that considerable quantities of hay are spilled in any stockyard and this effectively becomes bedding so far as the waste composition is measured. Estimates were that from one-quarter to one-third of the hay fed is spilled and becomes part of the bedding. Only three quantitative figures were available on spilled hay and these were from 1.5 to 15% spilled hay in the pen waste. All of these interviews were from yards that purchased straw or other material for bedding and the ratio of estimated spilled hay to total bedding (purchased plus spilled hay) was .17, .56 and .92. While these figures leave the quantitative situation unclear, they do clarify the fact that every yard does have bedding type material in the pen waste whether they purchase bedding specifically for this purpose or not.

Quantitatively, the percentage of spilled hay in the pen waste is at least 2%, and this must apply both to "northern" and to "southern" yards.

An exploration was undertaken to determine the extent of the differences between "northern" and "southern" yards and the line of demarkation between them. The percentage of bedding material in pen waste (including spilled hay estimates) ran from a low of not less than the above 2% for yards stating they did not buy bedding to as high as 15.3%. An attempt was made to correlate the per cent bedding in pen waste according to how cold it was (heating degree days) and how wet it was (average annual precipitation). The results were not very definitive, but if any results are to be stated, they would be that the bedding percentage tends to be high, around 15%, where it is dry and cold and also where it is hot and wet. It tends to be low where it is hot and dry. No yards were interviewed in regions that could be called cold and wet. It seemed technically sound that where the climate is either wet or cold there will be a tendency to use bedding. Presumably, if operating practices are such that large quantities of feed hay are spilled, such yards in these regions will be able to get by without purchasing bedding.

The exploration of the boundary between purchasing bedding and not purchasing bedding was made with the anticipation of dividing the yards into two groups -- those with bedding and those without bedding in order to improve the accuracy of the total pen waste projection. However, the above figures indicate that the amount of bedding in pen waste is not likely to be more than 15% under any circumstances and therefore, considering the other inaccuracies of the projection, such a separation need not be made.

The previous figures have shown that it is not warranted to consider the other waste stream separately, so that it is concluded to deal from this point on with the total stockyard waste including all components. There remains the relation of this waste to the size of the operation. In most of the other codes, the waste/employee ratio is used because employee data are available while production data are not. However, for stockyards the production data is indeed more readily available than the employee data since the U. S. Department of Agriculture has regularly, for many years, kept and published statistics on the number of animals of each type handled by each stockyard. Furthermore, in this case it is quite clear that the total waste production is better related to the animals passing through the stockyard than it is to the employees who handle them. However, stockyards differ not only in the total number of head handled, but also in the numbers of head of each type, the major types being cattle, calves, hogs and sheep. Required is some equivalence ratio which will express the waste produced by one type in ratio to that produced by the same number of head of another type.

Four different measures for this weighing were considered, in all cases expressing the other three types in terms of equivalent cattle. First, it might be considered that the amount of pen waste generated and thus for our purposes the amount of total stockyard waste generated would be proportional to the weight of the animal. The data on weights of animals passing through the stockyards are not directly available, but there are available data on the average live weights of livestock slaughtered by type.[2] Second, there are available similar equivalences in the "animal unit" measure used in describing stockyard operations. A third measure would be the relative content of each animal in feed in the process of digestion, thus the relative weights of paunch manure and stomach contents. Using such weights implies that the number of passages of food through each type animal at the time of its stay in the yards is approximately equal.

Weighting factors based on these three weight units were as follows, and the adjusted weighting factors used were developed from these three.

	Conventional	Slaughtered Live Weight	Paunch Manure and Stomach Content	Chosen Weight
Cattle	1	1	1	1.0
Calves	.33	.22	.33*	.27
Hogs	.25	.23	.093	.19
Sheep	.10	.096	.090	.095

* Developed fron conventional measures and, therefore, not used.

A fourth measure which was considered, particularly prior to the determination that bedding contents were not major, is the amount of pen space occupied by each animal on the assumption that bedding depth for each type is approximately constant and thus the amount of bedding would be proportional to the pen space. Pen space recommendations are available from the U. S. Department of Agriculture and actual space practices were obtained for two of the stockyards interviewed.[13]

An adjusted average of these gives the equivalents:

Cattle	1.0
Calves	.71
Hogs	.30
Sheep	.27

With these assignments there were computed waste/product ratios for each of the eight interviewed yards providing data on total waste. The units were lbs./cattle equivalent. Also, as a check, there were computed waste/product ratios in terms of absolute numbers of head of all kinds handled, in other words, with the weight of each type being 1.0. These waste/product ratios of course had a dispersion. All three were log-normally distributed, and were almost identical in σ ratio, being 2.39. The lbs./cattle equivalent, weight basis, data were then studied for correlation with cattle equivalents handled and showed no trend with size.

The study of this code was exceptional in that since there are only fifty-four stockyards (1963) and the interviews have covered eight from among the larger of these. It actually happens that already contained in the interview sample is more than half of the total animals handled by all stockyards, specifically having 58% of the cattle, 34% of the calves, 61% of the hogs, 44% of the sheep and 57% of all head. This means that the projection need be only for the remaining forty-six stockyards handling 43% of the total.

If the non-interviewed forty-six stockyards have the statistical characteristics described above for the interviewed yards, the average lbs./cattle equivalent would be 34 and the 68% confidence interval on this average would be from 24 to 48.

The cattle handled by the forty-six yards in 1963 comes to 8.66 million cattle equivalent on the 1.0, 0.27, 0.19, 0.095 weighting basis. At the average waste/product ratio this gives 295 million pounds per year for the forty-six and the actual total of the eight interviewed yards is 414 million pounds per year. Thus, the total projected waste currently is 709 million pounds per year.

If it be assumed that reinterview of the eight stockyards would produce the same total waste quantities, then the dispersion in this part of the total projection is zero and the dispersion of the lbs./cattle equivalent applies only to the projected portion. On that basis, the 68% confidence level for the 709 million pounds per year would be from 623 to 830 million pounds per year.

In addition, the 1,725 auction markets handle approximately 36 million animal units annually (1962). As previously mentioned, the animal unit is computed on a weighting basis of 1.0, 0.33, 0.25, 0.10 which does not differ greatly considering the degree of approximation from the cattle equivalent weighting ratios used for pen waste. If the 34 lbs./cattle equivalent applies to this production, and there is no evidence that it should be any different, the total auction market to waste would be 1,210 million pounds per year with a 68% confidence interval from 860 to 1,710. The total livestock market waste would be 1,919 million pounds per year with a 68% confidence interval from 1,480 to 2,540. That these are not the waste figures with which this study is concerned is explained in the next section.

4. DISPOSITION AND DISPOSAL

The disposition of the pen waste and the non-pen waste will be considered separately, the pen waste, of course, being by far the major portion of the total. The modes of disposition of pen waste as determined from the interviews may conveniently be divided into three categories.

Some waste is sold for a nominal price or given away directly for use on farm land as fertilizer. Some stockyards allow individual farmers to take fertilizer from the disposal site or a storage site directly. Two stockyards have been highly successful in encouraging a commercialization of this operation in which the pen waste, after curing in a pile after about six months, is hauled by merchant operators to farmers in the area. The stockyard provides a crane and an operator for loading and charges the merchant $1 per load. The operation started through off-season use of the gravel trucks, but more recently several operators have developed large manure trucks incorporating spreaders with which they spread the material directly on the farmer's field. The average distance transported by the merchant haulers is about twenty-five miles. The charge made to the farmers by the merchanized operators is $2 per ton for the first twenty miles plus 10¢ a ton a mile thereafter with the scale dropping to 5¢ per ton a mile beyond a certain distance. The maximum distance hauled is as high as sixty miles. The gravel truck operators who simply dump the material in the field for later spreading charge $2 per ton for distances up to thirty miles.

The stockyards engaging in this operation have been very successfully disposing of their pen waste to a useful purpose and are to be commended in the solution. There are some restrictions on the universal application of this solution. It is necessary that the stockyard be located in an area given to the type of farming which can use the fertilizer. It happens that the two stockyards in question are in the middle of a corn and wheat raising region where such application of fertilizer is practical. The stockyards with the assistance of the State Agricultural Experiment Station have promoted this use of the fertilizer by demonstrating the effectiveness in increasing yields, showing that weed seeds are not viable in the product, etc., and one stockyard itself engages in a continuing publicity campaign in farmer's magazines and newspapers stressing the practice. If a stockyard, however, is located say in a dairying region where it is not practical to utilize the fertilizer on pastures, then this solution would not be available to them.

With the major stockyard engaging in this practice there still remain a few difficulties. It is necessary to be scrupulous in avoiding extraneous trash in the pen waste. Thus, it is necessary to constantly be alert to keep wire, concrete, can, etc. out of the pen waste. The operation has been successful for ten years or more because of unusually favorable weather conditions which allow the operators to get into the pile and spread in the fields. If there should be a prolonged wet spell during the winter months, it would not be possible to move the pen waste in that season. Finally, it must be considered unfortunate, against such an exemplary operation, that the general public in the city in which the yard is located still find objection to this disposition method. The objection comes because of the practice of storing the pen waste in piles for curing and composting for a six month period operating from one pile while waste is being accumulated on another. This makes the waste much more easily handled by the operators and the curing process is responsible for the killing of the weed seeds. The raw waste loses about 30% of its weight in the process. This in itself is not of importance, but the community complains about the storage piles which happen to be not far from a new expressway entrance to the city.

A second mode of disposition is to sell or give away the waste for processing into fertilizer. This is typically done by an organization separate from the stockyard although it may be owned or controlled by the stockyard. One yard transfers the waste to an outside processor who composts it. The more common practice however, is dehydration, which incidentally stockyard operators are likely to term "incineration". The processing establishment may be on the stockyard ground or the yard may haul pen waste to the processing plant at another location. On the average, it takes four tons of pen waste to produce one ton of processed fertilizer. The bagged fertilizer may be sold under the yard's own brand or under other proprietary brand names. If the waste is sold for this purpose, the return is only nominal.

For processing into fertilizer, it is desired to have as little bedding, i.e. straw and hay, as possible in the raw material. Therefore, where there is a heavy use of straw or heavy spillage of hay resulting in considerable bedding components processing to fertilizer by dehydration is contra-indicated. Yards, therefore, attempt to select for dehydration that portion of the pen waste containing the least bedding, and to dispose otherwise of the heavy bedding material. Yards disposing by dehydration make efforts to keep the hay and bedding out of the waste for this purpose. Where this is unavoidable due to practical or conventional considerations, it is indicated to compost the waste rather than to dehydrate it as the means for processing into fertilizer.

The third disposition mode is to haul the pen waste to a dump sometimes located at the yards, in other cases some distance away. In this study it is considered that this third mode of disposition is the only one by which the pen waste enters the waste stream of interest to this study, since the other two modes now successfully dispose of it by utilization and without a great deal of cost to the producers. One interviewed establishment in this third disposition mode provides a logical problem for the researcher since he could give the material away to farmers, who presumably would be willing to take all of it, but the responsible authority at the yard is of the belief that the material has value and should be paid for. Since he has adequate storage area to handle it, the material is now being stored at the yards. This establishment incidentally formerly operated a dehydration plant but found it, in his particular circumstance, unprofitable and therefore, put it in stand-by.

In eleven of the interviews, it was possible to establish what percentage of the pen waste went to each of the three modes of disposition. Table VII shows these percentages and gives the average of all, each being considered of equal weight. If this sample is representative of all yards and if the mode of disposition is not a function of animals handled yearly, then the averages given in the last column of Table would be the percentages of total pen waste going to the three modes. This would be 30% to processing for fertilizer, 30% given away to farmers, and 40% remaining a problem. This summation counts the establishment which could give away its waste, but is now storing it as in the third disposition mode, i.e. constituting a problem.

TABLE VII

DISPOSITION MODES

PEN WASTE

Mode (Eastablishment)	% of Establishment's Total Pen Waste											Average of 11, %
	A	B	C	D	E	F	G	H	I	J	K	
Sell or give away for processing into fertilizer		100			96.5				40	100		30
Give away to farmers for fertilizer			100		3.5	6.3	100	100			25	30
To dump or storage; in general, constitutes a disposal problem now	100			100		93.7			60		75	40

These numbers might be applied to the total waste in the manner used for other codes in this study, but in this case as for total quantities it is possible to improve upon the confidence interval by taking advantage of the fact that we already have information on the disposition modes for more than half of the waste produced. There are available nine interviews for which the quantities going to the three modes are known and two interviews providing percentages on dispositions from two other yards for which the total quantities are known. It is possible to project the total waste of these two yards by taking their cattle equivalents handled and multiplying by the most probable value of the waste/product ratio, namely the median 26.2 lbs./cattle equivalent. This produces dispositions for the eleven yards as follows:

	Million lbs./yr.	Percent
Processed	114	25.9
Farmers	138	31.4
Problem	187	42.7
TOTAL		100%

The total waste accounted for here for which the disposition mode is known is about 62% of the total waste estimated for all yards. The incidence figures from Table VII thus are to be applied only to the residual of 269 million pounds per year. When this is done, and the two sets of figures combined, the projection shows that of the total pen waste of the fifty-four terminal stockyards amounting to 709 million pounds per year, 195 million pounds per year or 27.5% is sold or given away for processing into fertilizer, 219 million pounds per year or 30.8% is sold or given away to farmers for direct application as fertilizer, and 296 million pounds per year or 41.7% becomes a waste, subject to ultimate disposal and is therefore the waste of interest to the present study. The 68% confidence interval on this 296 million pounds per year is from 265 to 340.

The disposition study and computations, having been obtained almost solely from terminal stockyards, apply only to the terminal stockyard waste. It is quite possible that the disposition modes for the auction yards, since they in general are only one-tenth the size of the terminal yards, might be quite different. There is no way of determining this without an interview campaign among the auction yards. However, if the results should be that the disposition modes of the auction yards are the same as for the sample terminal yards (Table VII) then of total waste of the terminal yards and the auction yards amounting to 1,919 million pounds per year, 29.1% or 558 million pounds per year would be sold or given away for processing in fertilizer, 30.3% or 582 million pounds per year would be sold or given away to farmers for direct application as fertilizer, and 40.6% or 779 million pounds per year would become the waste subject to ultimate disposal and thus, of interest to the present study. The 68% confidence interval of this 779 million pounds per year could be computed as before, but in view of the large uncertainty of the application of the terminal yard disposition mode to the auction yards, this seems unwarranted.

Incidental to the above in two establishments the waste from the hog house was flushed to the sewer and thus, becomes a waterborne outside the province of this study.

The non-pen waste, comprising an average of only 2%, of the total waste, was disposed of in the six pertinent interviews once in a self owned incinerator, once in a self owned tepee burner, three cases of open burning self owned, one self owned dump and one contract hauling to city sanitary land fill.

5. TRENDS

Evident from the interviews was a general trend to seek a greater degree of utilization of the pen waste, to avoid pollution of water courses or from open burning, and to solve problems arising from running out of dumping space. (The anti-pollution sentiments were, however, not universal in the interviews.) This trend will, of course, reduce the quantity of waste for ultimate disposal and presumably will ameliorate the problems connected with ultimate disposal. However, it is not capable of quantification.

In particular, the trend for total waste from stockyards contains complications beyond the capabilities of the present study. The total number of cattle handled will presumably increase during the next ten years along with the increase of population in a way which probably has been quantified. However, this quantification is not important to the present study because of the large uncertainty in other factors.

Some of the interviews revealed that the decentralized auction markets were taking an increasing share of the animals handled. In part, this comes about through the introduction of truck transportation of livestock, replacing the former high concentration of rail handling. The terminal markets were set up primarily as concentration points for rail shipments of cattle and the historical figures for almost any stockyard will show the extreme deterioration of the rail hauling aspect and its replacement by truck deliveries. If truck delivery is the practice, then it becomes efficient from the standpoint of handling, to decentralize the market into smaller markets. But smaller markets cannot support the merchandizing structure of the large terminal markets and thus, tend to become auction markets.

There are numerous advantages and disadvantages of such a trend judged from the overall standpoint of merchandizing, price computation, etc., but this study is concerned only with the fact of its existence. Measured by the purchases of livestock by packers (and packers purchase about 80% of all of the total head passing through the terminal stockyards), the terminal markets share of total packers purchases has fallen between 1960 and 1964 from 45.8% to 36.5% in cattle, 25.4% to 18.8% in calves, from 30.3% to 23.8% in hogs and from 35.4% to 28.6% in sheep. This suggests that the terminal markets will not share proportionally in the growth of the livestock handling industry in the next ten years, unless some radical reversal occurs.

The share lost by the terminal stockyards has been taken up in part by the auction yards and in part by direct sales and country dealers. If auction markets do indeed have the same waste/product ratio as terminal markets, then the pen waste generation "lost" by the terminal markets will be in part replaced by an increase in the auction markets. But whether the direct sales and country dealer sales is to increase in the future at the expense of the auction markets is uncertain and it seems unwarranted to venture a prediction without a deeper study. Furthermore, as previously mentioned, the interviews do not allow a description of the modes of disposition for the auction markets, and since this is essential to a projection of the solid waste of interest to this study, the subject is still further removed for quantification.

SECTION VI

SURVEY RESULTS

M. PAINTS

1. SUB-CODES AND INTERVIEWS

Paints and allied products, Code 285, is divided into paints, varnishes, lacquers and enamels, Code 2851, and putty, calking compounds, etc., Code 2852. The bulk of the employees, of course, is in 2851 and all eight available interviews were in that code. The projection, however, is on the entire Code 285, having approximately 62,000 employees.

2. WASTE TYPES

Three of the eight establishments interviewed had mentioned solvents as a waste, but these being liquids are not included in the study. The interviewed establishments had plant trash and shipping waste and some of them separately listed process waste consisting of contaminated pigment bags, tars and semi-solids. Where separately listed, these process wastes comprised about 30% of the total.

3. WASTE QUANTITIES

The eight Kpye's were log-normally distributed with a median of 4.5 and a σ ratio of 2.04. The trend with number of employees is not significant at the 5% level. If these are the characteristics of the entire population of 1,725 establishments, the average Kpye would be 5.25 and the 68% confidence interval from 3.6 to 7.7. Applied against the total number of employees, this gives 324 million pounds per year, and with a growth factor of 1.22, 394 million pounds per year in 1975.

4. DISPOSITION AND DISPOSAL

Disposition is by truck or Dumpster, five waste streams being handled by self and seven by contract. The ultimate disposal type is two dump, two sanitary land fill, two open burning and two incinerators. The ownership of the ultimate disposal facility is three self, two contractor owned and two city owned.

5. TRENDS

No trends affecting the waste picture were evident.

SECTION VI

SURVEY RESULTS

N. ELECTRICAL MACHINERY

1. SUB-CODES AND INTERVIEWS

The interviewed sub-codes were as follows:

Code	Description	Employees	Interviews
361	Electric transmission and distribution equipment		5
362	Industrial apparatus		4
363	Household appliances		1
365	Radio and TV		2
366	Communication equipment		1
367	Electronic components		3
369	Miscellaneous		1
		1,327,581	

The remaining uninterviewed three-digit code which was non-projected is Code 364, Lighting and Wiring Equipment, with 138,186 employees.

Of the total of eighteen interviews, thirteen were obtained in the present project and the remaining five came from previous work.

2. WASTE TYPES

In addition to plant trash and shipping waste, the latter sometimes including styrofoam, the process wastes included metal scrap, rubber, plastic and a small amount of wire scrap. The quantity of wire scrap coming from radio and TV manufacture was decreasing due to the increasing use of printed circuits.

3. WASTE QUANTITIES

The eighteen Kpye's showed no trend with employee size or with four-digit sub-code. The Kpye's for scrap and waste were log-normally distributed within the tolerance set for that characteristic, but the deviations therefrom were such that a slightly better fit was obtained by an arithmetic normal distribution. Computed by both methods, the mpy for the arithmetic distribution was about 12% less than that for the log normal. Because of the weight of evidence of the other codes for the log normality of Kpye's, it was judged that the distribution of the population in Code 36 would also be log normal despite the fact that for the particular sample the arithmetic normal was a slightly better fit. On this basis, the median was 1.80 Kpye and the σ ratio 2.49. If this is the characteristic of the entire population of 9,500 establishments, the average Kpye would be 2.75 and the 68% confidence interval thereon from 2.2 to 3.5. Applied against the number of employees in the projected code, this gives 3,651 mpy scrap and waste in 1965.

The disposition - disposal analysis in Section V indicates that 24.4% of the scrap and waste is utilized, thus leaving 2,760 mpy as waste for disposal. A 1.8 growth factor gives 4,960 mpy waste for disposal for 1975.

4. TRENDS

No trends in production practices over the next ten years were anticipated which would alter the waste/product ratio.

SECTION VI

SURVEY RESULTS

O. RUBBER

1. SUB-CODES AND INTERVIEWS

Code 30 is titled "Rubber and Miscellaneous Plastics Products". The sub-codes, together with the number of employees therein are:

Code	Description	Employees
301	Tires and tubes	86,000
302	Footwear	29,000
303	Reclaimed rubber	2,000
306	Fabricated rubber products (n.e.c.)	131,000
307	Miscellaneous plastics products	170,000

Despite its inclusion in Code 30, industry 307 is not strictly a rubber handling industry and, therefore, was excluded from the survey.

Four interviews were conducted in 306 and two in 301. Two Kpye figures were obtained from studies conducted in 1949 by R. H. Stellwaegen. In addition, four interviews were made available from a prior Combustion Engineering project.

2. WASTE TYPES

In general, the rubber establishments had plant trash and some shipping waste. Most also had process waste. The process wastes are of two types: (1) rubber and rubber trimmings, etc. and (2) solvents and pigments.

The rubber waste is difficult to incinerate partly because of its high BTU content, and partly because of the high temperature necessary to avoid smoke. Two interviewed establishments had abandoned incinerators because of poor air pollution performance and as indicated in the disposal section, only one establishment is operating an incinerator for disposal and that on only 3% of its waste for the purpose of reclaiming the metal in the waste product. Apparently, if rubber is mixed with general municipal rubbish for incineration, satisfactory performance can be obtained. Thus, the one plant for which incineration was the ultimate disposal for a major portion of its process waste, accomplished this incineration by mixing it with other municipal waste.

In 1949, a study was made under the auspices of Akron, Ohio Chamber of Commerce by Robert H. Stellwaegen. This comprised an analysis of the problem of disposal of Akron municipal wastes, together with the wastes of the five major rubber companies located there. The characteristics of the rubber wastes cited below are those from that report.

The average proximate composition of rubber wastes generated is 75% C, 10.5% H, 2.5% S, and 12% ash, which computes to a heating value of 17,570 BTU/lb. of rubber. Scrap rubber from tire manufacture will comprise 60% treads and 40% carcasses, giving overall 68% rubber and 32% fabric with a heating value of 13,480 BTU/lb. of scrap. Beads may be incinerated separately to recover the contained metal. They comprise about 15% metal and 85% rubber and fabric in the proportions described above. If precleaned, the bead material is 98% metal. The liquid type waste, solvents, oils, pigments, etc. comprise 29% oil and grease at 18,500 BTU/lb., 47% solvents at 18,000 BTU/lb., and 25% cements, latex, etc. at 17,600 BTU/lb. Overall, the process type waste from these five major plants was made up of 46% rubber scrap, 45% beads, and 9% solvents, pigments, etc.

The report data indicates that of the total waste produced by the rubber establishments, 48% was process waste and 52% was non-process waste, i.e. plant trash and shipping waste.

3. WASTE QUANTITIES

For the interviews from this project there was no trend of Kpye with number of employees, and the Kpye level was higher but not significantly higher than the level from prior projects. The values for Code 306 were not significantly different from the other points.

The eight Kpye points were log-normally distributed with a median of 3.9 Kpye and a σ ratio of 4.62. If this distribution were characteristic of the universe of 1,368 rubber plants, the average waste/employee ratio for these 1,368 plants would be 11.9 Kpye which corresponds to a waste generation of about 2,900 million pounds per year for the 247,000 employees represented. The confidence interval on the mean is 6.7 to 21.3.

An interesting analysis was made possible by the availability of waste/employee ratios for three identical plants in 1949 through the Stellwaegen report and in 1964 through previous work done by Combustion Engineering. It was found that despite considerable changes in employment in these three plants the waste/employee ratios changed very little. If this constancy of the waste/employee ratio over the fifteen year period is characteristic of the rubber industry as a whole, then it may be inferred that the waste/product ratio in the same period has decreased markedly; for in the period

1950 to 1963, employment in the tires and tubes segment of the industry has declined by about 13% while production has increased by 68%. With a constant waste/employee ratio, this requires that the waste/product ratio has declined by some 50% in the period. These statements are only roughly quantitative and are drawn only from the tires and tube segment of the industry. However, there appears to be enough information to suggest considerable caution in projecting 1975 waste via the waste/product ratio which is proposed for this study. Since three of these individual establishments showed a constancy over the period in the waste/employee ratio, it was assumed that the other two plants also had this constancy and that for that reason the 1949 Stellwaegen report data could be used in the present analysis. In the absence of further substantiating data, the projected waste for disposal in 1975 was obtained by multiplying by the predicted production gain for the whole code over the time period.

4. DISPOSITION AND DISPOSAL

In the eleven available interviews the disposition for seven was by contract and for four by self. Within this code there does not appear to be any trend to one or the other type of disposition, either with number of employees or with Kpy (thousand pounds per year). Only a few interviews of the total provided information on the types of disposition equipment, but in those cases, this was trucks or container loading truck. Haul distances in the interview were short, averaging about three miles with a maximum of seven one way.

Out of sixteen disposal situations in the eleven interviews, only one waste stream constituting a major portion of an establishment's waste was incinerated. Oddly enough, this incineration was in the municipal incinerator, while at the same time the pallets, wood boxes and shipping waste were hauled to a dump. Another establishment used incineration, but only on 17% of its total waste comprising paper, lumber, etc. A third establishment incinerated 3% of its waste specifically to reclaim the metal in the fabricated items. All the rest of the disposal situations were to dumps or sanitary land fills about equally divided. One establishment dumped a small portion of its waste, consisting of solvents and pigments, into an abandoned mine.

The ownership of the ultimate disposal facilities were three self (i.e. private), seven municipal, one not self, n.e.c., and one contractor owned.

5. TRENDS

The interviews did not produce any direct statements concerning trends in the industry which might affect waste generation and disposal. However, as described in a previous section, the constancy of the waste/employee ratios for three plants requires that the waste/product ratio has decreased markedly over the past fifteen years. A continued decrease in the next ten years is, therefore, possible.

Rubber waste has a high BTU content and except at a very high temperature produces a smoky flame. This produces problems in incineration. Of this problem waste, the generation per employee is almost ten times what the employee generates in municipal refuse as a private citizen. In a typical city the number of rubber employees is probably quite small and the problem therefore is not great. In one city, Akron, there is a notable concentration of rubber establishments, presumably a corresponding high percentage of total employment generating rubber process waste, and a consequent high proportion of rubber process waste in the overall community wastes. Indeed, in the Stellwaegen report the wastes from the five major rubber establishments were estimated at 38% of the total community waste.

SECTION VI

SURVEY RESULTS

P. GLASS

1. SUB-CODES AND INTERVIEWS

The interviews covered the sub-codes 321, Flat Glass - 23,000 employees and 322, Glass and Glassware Pressed or Blown - 95,000 employees. These sub-codes comprise the manufacturers of glass products from glass produced in the same establishment. The interviews on this project included five establishments in 322 and one in 321, being a plate glass establishment. Also available was an interview from a prior project in 321 in the window glass category.

2. WASTE TYPES

For both sub-codes there can be distinguished two types of waste: Type 1 is combustible and comprises plant trash, shipping waste, sawdust and paper cardboard. Type 2 is non-combustible and comprises process waste, glass cullet, defective batch material, and plaster and abrasives from the polishing of glass, and defective product. The Type 2 wastes will contain only a small percentage of combustible material. If the content of grinding and polishing materials is high, it may contain considerable moisture.

3. WASTE QUANTITIES

Within each sub-code there was no trend of waste/employee ratios with number of employees, but there was a distinct difference in Kpye level between the two codes.

In the 321 code the one interview from this project happened to be of a plate glass manufacturer and such establishments have appreciable quantities of Type 2 waste arising from the grinding and polishing operations. The second interview obtained from a previous project was a window glass manufacturer, presumably not having these grinding and polishing wastes. However, the Type 2 waste quantity in that interview had not been obtained since it was not within the purpose of the previous project. In order to provide data useful for the present project, there was computed the Kpye for the plate glass plant, Type 2 wastes <u>excluding</u> the grinding and polishing waste, and this Kpye was assigned as the Type 2 waste of the window glass plant, of which it then comprised of the order of 50% of the total waste. With this adjustment, the two waste/employee ratios had an arithmetic mean of 111 Kpye. The actual numbers were 92 for the window glass plant adjusted and 131 for the plate glass plant. To be consistent with the remainder of the data here presented, the estimated arithmetic standard deviation of the population based on this sample of two is 28 Kpye and the 68% confidence limit of the mean is 39; thus it may be anticipated that 68% of the population of such plants will have a Kpye in the band 111 ± 39. This assumes that establishments in this code are equally distributed between plate glass establishments and flat glass establishments, an assumption which is probably not correct, but not resolvable with the information available at this state of the project. The percentage of Type 1 waste in the total for the 321 sample percentage was 8% for the plate glass plant and 50% for the window glass plant.

For the 321 code, the percentage of Type 1 waste in the total waste for five samples was 42%, 12% and three cases with a very low percentage. From these data an estimating figure for the entire glass industry projected would be of the order of 10 to 20% Type 1 waste.

For the 322 code the distribution of Kpye's was neither normal nor log-normal and actually was even more skewed than a log-normal curve. The arithmetic mean of the five values is 6.3 Kpye. The estimated arithmetic standard deviation of the population is 6.0 and the 68% confidence interval of the above mean is 6.0 ± 3.2. This means that 68% of the population values are estimated to lie in the band between 3.1 and 9.3 Kpye.

Applied to the total employees in each code separately, these yield 2,600 million pounds per year for Code 321 and 600 million pounds per year for 322. The disposition - disposal study indicates that about 16% of this waste finds other disposition so that the waste for disposal is 2,680 million pounds per year currently and 3,936 million pounds per year in 1975.

4. DISPOSITION AND DISPOSAL

One establishment was putting its process waste in the sewer, but intended to discontinue the practice shortly. The remaining dispositions for the Type 2 waste were three self and two contract, and for the Type 1 waste, three self, one contract and one sold. The hauling was performed with Dumpsters and dump trucks.

The disposal means for Type 1 waste comprised three private disposal facilities at the establishments, two tepee burners and one open burning. For Type 2 waste, the disposal consisted of two city sanitary land fills, one private dump, one merchant dump and one unspecified dump.

5. TRENDS

Several establishments indicated that they were in rapid growth. There is no indication that the waste/product ratio will change in the future.

A recent development in plate glass manufacture is the float process whereby the molten glass is cast on a liquid surface instead of on a solid table. This will not change the waste/product ratio, but it will greatly decrease the number of employees and thus, if the float process takes over in plate glass manufacture, the waste/employee ratio in that segment of the industry will increase and will no longer be the same as that in the window glass segment.

SECTION VI

SURVEY RESULTS

Q. ASPHALT ROOFING

1. SUB-CODES AND INTERVIEWS

Prior information was available indicating that in asphalt roofing manufacturing, Code 2952, the waste/employee ratio was very high and the disposal presented difficulties. The code has 14,300 employees and eight interviews were conducted.

2. WASTE TYPES

The wastes consist of scrap roofing, machine break, trimmings, damaged roofing rolls, felt and roofing granules. Because of its physical form (in sheets) and weight, the scrap material is difficult to handle. In addition, in an incinerator it burns with a hot, smoky flame and has a very high ash content because of the granules. Open burning produces dense smoke.

3. WASTE QUANTITIES

The eight Kpye's showed no trend with size and were log-normally distributed with a median of 55 Kpye and a σ ratio of 3.24. If these are characteristics of the entire population of 231 establishments, the average Kpye would be 82.5, and the 68% confidence interval would range from 51 to 133. Applied against the total number of employees, this gives 1,180 million pounds per year. But the disposition - disposal study shows a small percentage used for fuel and the waste for disposal becomes 1,148 million pounds per year, and with a growth factor of 1.34, 1,538 million pounds per year in 1975.

4. DISPOSITION AND DISPOSAL

Disposition was by truck and dump truck -- four self, three contract and one unknown. Two establishments hauled about five miles. One establishment was able to sell or give away a very small portion of the waste for use in paving driveways, parking lots, etc. Ultimate disposal was five dumps, two sanitary land fills and one unknown; ownership of the ultimate disposal facility being five private, one city and two unknown.

5. TRENDS

The disposal of these wastes is a real problem to the industry and indications were that an incinerator which would handle them would be welcome. One roofing manufacturer at one time had an incinerator and used the recovered heat in the asphalt stills. There was no evidence of any trends in waste/product ratio.

SECTION VI

SURVEY RESULTS

R. MILL WORK

1. SUB-CODES AND INTERVIEWS

Mill work comprises Code 2431 with about 66,000 employees. The raw material for the industry is typically finished lumber manufactured by a saw mill and already seasoned. Nine interviews were available, all in Code 2431, with some subsidiary production in 2511 (cabinets) and 2433 (prefabricated houses) and an interview available from an earlier project in Code 2433 indicated that the Kpye is of the same order as the Kpye for mill work and accordingly, no bias is expected from the one combination interview.

2. WASTE TYPES

The wastes in addition to plant and office trash comprise dry wood in the form of sawdust, shavings and wood scraps. Two establishments, manufacturing windows, also had shipping wastes comprising the cartons and boxes in which the glass is received.

3. WASTE QUANTITIES

As will be shown in the disposition section, a considerable fraction of mill work waste is sold. A similar statement can be made about saw mill waste and wooden container waste and in those cases, the quantity sold is subtracted from the total waste before computing the Kpye's. This will not be done with mill work wastes for the following reason. The fraction of saw mill waste which is chips is relatively constant among establishments and it is almost universal to sell 100% of these chips. Thus, the waste stream of interest is that excluding chips and the Kpye excluding chips will project this stream of interest. However, with mill work wastes, although about half of the establishments sell some of their wastes, the fraction sold is quite variable, ranging in the actual interviews from 29 to 91% of the total wastes. This means that even if the Kpye's for total waste were identical for each establishment interviewed, the Kpye's for the non-sold waste would have a dispersion. In other words, excluding a variable component increases the dispersion of the resulting Kpye's. It is desirable to achieve the maximum constancy of the Kpye's unaffected by the random practices of disposition. Only if the disposition practices are not random, but are constant, or are relatively constant and simply described, then it may be preferable to deal with some residual portion of the waste.

On this basis, the nine Kpye's show no trend with employee size, are log-normally distributed, and have a median of 10.3 and a σ ratio of 2.62. If this is characteristic of the population of 3,430 reporting units (approximately equal to establishments), the average Kpye would be 16.3 and the 58% confidence interval from 11 to 23.

Applied to the total employees in 2431, this gives 1,072 million pounds per year for the total waste. As will be shown in the disposition section, the waste disposed of without cost to the producer is estimated at about 47% and thus, only 53% of the above total enters into the waste stream of interest. This is 570 million pounds per year at present and with a growth factor of 1.56, projects to 886 million pounds per year in 1975.

4. DISPOSITION AND DISPOSAL

Six of the nine interviewed establishments sold some of the wastes and in five of these, it was the sawdust that was sold. One establishment shipped it 800 miles. The average percentage of their wastes sold by these six is 58%. Two establishments out of nine used some waste for fuel, in both cases scrap wood and plant trash. The average of their wastes so used was 16%.

Two establishments gave away shavings, wood blocks and some sawdust. The average percentage of their wastes thus given away was 20%.

If each establishment be given an equal weight, which amounts to assuming that this is a random sample of all establishments and that there is no trend of disposition method with size, these data would indicate that 39% of total mill work wastes are sold, about 4% are used for fuel and another 4% are given away. Thus, a total of 47% is disposed of without cost to the producer and, therefore, does not enter into the industrial waste stream of interest to this project.

Of the remaining eleven disposition situations, five were self, three contractor and three city pickup.

The disposition equipment was small and large trucks and dump trucks, one haul distance being as much as ten miles.

The method of ultimate disposal was five dump, one open burning, one sanitary land fill, two incineration and two unknown. The ultimate disposal facility was owned by two self, six city and three not self.

5. TRENDS

No trends in waste/product or waste/employee ratio were evident.

SECTION VI

SURVEY RESULTS

S. TANNING

1. THE INDUSTRY

Leather tanning and finishing constitutes one sub-code 3111 in Code 31, "Leather and Leather Products". It has 516 establishments and 30,800 employees. The six interviews from this project and one available from a prior project included one establishment engaged in curing hides which is strictly in Code 2011, "Meat Packing". However, this was an independent operation not involving meat packing as such and since the Kpye was median to the Code 27 interviews, it was included as a leather tanning industry. The pattern of the tanning industry is that the animal goes to the packer, who produces the hide. About 80% of the production of hides goes to a hide dealer who brine cures and rough fleshes them, commonly selling this waste to a rendering plant. The hide, still bearing the hair, goes to the tannery where it is tanned. About 20% of the production by-passes the hide dealer and goes directly from packer to tannery.

2. WASTE TYPES

Waste types included plant trash, sawdust and shavings, wet trimmings, hair and fleshings and dry trimmings, hair and fleshings. The dry trimmings, hair and fleshings were sold in all interviews, and are not contained in the Kpye figures given. In one establishment the wet trimmings, hair and fleshings comprised 13% of the total waste and the dry trimmings, hair and fleshings comprise about one-tenth this amount.

3. WASTE QUANTITIES

The distribution of Kpye's, eliminating the small amount used as fuel in two interviews, is log-normal with a median of 5.1 and a σ ratio taken to correspond to the population of 5.7. This gives a 68% confidence interval for the deviation ratio of $2.17^{\pm 1}$. If this is the characteristic of the entire population of 516 establishments, the average Kpye would be 19.4 and the 68% interval from 9.0 to 42 Kpye. Applied against the 30,800 employees in the four-digit code, this yields 598 million pounds per year. At a physical growth ratio of 1.12, the projected waste for 1975 is 670 million pounds per year.

4. DISPOSITION AND DISPOSAL

Disposition is by truck, six private, five contract. The two cases of use of a small percentage for fuel are not included. The ultimate disposal type is ten dump and one incinerator and the ultimate disposal facility ownership is three private, seven city and one merchant.

5. TRENDS

There was no indication of any trends in waste/employee or waste/product ratio.

SECTION VI

SURVEY RESULTS

T. PRINTING AND PUBLISHING

1. SUB-CODES AND INTERVIEWS

Code 27, "Printing and Publishing", is complicated by the fact that about half of the total employees occur in the three sub-codes which comprise both printing and publishing, namely 2711, 2721 and 2731. In these sub-codes it is not possible from data available to the project to determine what fraction of the employees are in the publishing phase (i.e. the intangible operation) and what percentage in the printing phase which would produce the waste. In newspaper printing and publishing, the printing employees are well in the minority. Accordingly, it may be expected that the Kpye for these three codes would be substantially less than the Kpye for the rest of the industry. Since there was no way to quantify this, the three codes were not used in the projection.

The remaining codes involved in printing, together with a number of employees, are:

Code	Description	Employees
2732	Book Printing	37,700
275	Commercial Printing	303,900
276	Manifold Business Forms	26,000

The interviews on this project were three in 2751, one in 2732, one in 276 and one in 271 which turned out to be a small newspaper. From previous projects there was one in 2732 and three in combined operations 2732 and 275.

2. WASTE TYPES

It is characteristic of the industry that most of the actual process waste, i.e. waste paper, is reclaimed. Only three out of ten interviews had non-sold process wastes. However, when process wastes were found, they constituted the major portion of the total waste, averaging 92%. The remaining wastes were plant trash, shipping wastes, ink and glue and non-saleable paper. It is typical that the non-saleable paper is that which is coated, impregnated, or otherwise made non-reclaimable.

3. WASTE QUANTITIES

Of the three out of ten having non-sold reclaimable paper scrap, one had only a small portion of this scrap not sold, and the other two did not provide Kpye data. Accordingly, the Kpye's were computed on the non-sold portion which means that they were almost entirely the "remaining wastes" mentioned in the previous paragraph.

There was no trend of these waste/employee ratios with size of establishment or among different sub-codes. The Kpye's were log-normally distributed with a median of 1.85 Kpye and a σ ratio, taken to correspond to the population, of 3.68. If this is characteristic of the entire population of some 18,500 establishments, the average Kpye would be 4.53 and a 68% confidence interval from 2.7 to 7.6 Kpye. Applied against the total number of employees in Codes 2732, 275 and 276, this gives 1,660 million pounds per year of waste for disposal.

When the more thorough general investigation of disposition and disposal was made, it was recognized that the sold reclaimable paper constituted a very large portion of the scrap and waste, and therefore, the two establishments that did not sell this reclaimable paper might, through the projection, considerably increase the quantity of waste for disposal. Accordingly, a new set of Kpye's was computed taking all scrap and waste, both the reclaimable paper sold and unsold and the remaining wastes. For these, the median Kpye was 21.0, the σ ratio 3.68 (the same as for the other), and this would give an average Kpye of 51.4 with a 68% confidence interval from 29.4 to 90 Kpye.

Applied against the total number of employees in 2732, 275 and 276, this gives 18,500 million pounds per year of scrap and waste. The general disposition - disposal study in Section V indicates that 32% of the scrap and waste is waste for disposal and this gives 5,920 million pounds per year as waste for disposal. This is over 3.5 times as much as the waste for disposal projected on the basis of the other Kpye's and indicates that the reclaimable but not sold paper from the two plants out of ten, i.e. from a projected 20% of the population, would greatly overbalance the small quantity of "remaining" waste, plant trash, etc. from the other 80% of the population. The quantities are such as to check this conclusion, but it still must be presented with great reservation because the difference 1,660 and 5,920 comes about through the operation of the disposition - disposal pattern which is believed anyway to be quite insecure. Of the two plants responsible, one is known to be a large plant and the other is thought to be a large plant, so that the unusual characteristic of not selling reclaimable paper cannot be attributed to a small size of plant. It happens that both of these plants are located in relatively small communities where possibly the economics of the market dictate against sale of reclaimable paper. However, there is no way to resolve this uneasy feeling about the larger number and with the above reservation, it will be accepted.

However, it also happens that none of the Code 275 interviews, job printing shops, were in establishment of less than 250 employees while about 75% of total employees in job printing shops are in such small establishments. For this reason, it was not felt warranted to extrapolate the Kpye relation to low number of employees even though it showed no trend at a high number of employees. Accordingly, a separate projection was made in which the employees in Code 275 establishments having less than 250 employees were eliminated. This reduces the 18,500 million pounds per year to 7,243 and the 5,920 million pounds per year to 2,318. The physical production growth factor to 1975 is 1.39 and this projects the 1975 waste production of the three codes to 8,250 million pounds per year and of the three codes with the small job printing shops eliminated to 3,222 million pounds per year.

4. DISPOSITION AND DISPOSAL

Disposition was by trucks and compactor trucks, three self, five contractor and one city pickup. Ultimate disposal was three incinerators (self owned), one open burning, one sanitary land fill, three dumps and one unknown. The ownership of the ultimate disposal facility was three self (the incinerators), three contractor owned, two city and one unknown.

5. TRENDS

No trends in waste/employee or waste/product were revealed.

SECTION VI

SURVEY RESULTS

U. TEXTILES

1. SUB-CODES AND INTERVIEWS

S.I.C. Code 22, "Textile Mill Products", comprises nine three-digit sub-codes from which interviews were obtained in six as follows:

Code	Description	Employees	Interviews
221	Weaving mills, cotton	208,820	2
222	Weaving mills, synthetics	86,785	2
223	Weaving mills, wool	45,528	1
225	Knitting mills	208,724	1
227	Floor covering mills	35,848	1
229	Miscellaneous	66, 001	3

The remaining three sub-codes in the two digit code are:

224	Narrow fabric mills	24,811
226	Textile finishing, ex. wool	73,129
228	Yarn and thread mills	106,599

Sub-code 224 was included among the projected codes because there did not seem to be any reason by which it differed from the interviewed codes. However, sub-codes 226 and 228 were judged to be sufficiently different in the physical processing involved so that it was not so secure that they shared the same Kpye with the others. The number of employees in the projected codes is 677,600, some 79% of the total employees in the two-digit code.

2. WASTE TYPES

The waste types included plant trash, shipping waste including some metal baling ties, and process waste including cloth, yarn, sweepings, cones etc. Not all establishments had process waste and those that did have it did not show a particularly high Kpye compared to the others. Process waste varied from 10% to 60% of the total wastes in any establishments where they occurred.

3. WASTE QUANTITIES

Among the ten Kpye's there was no trend with employee size and no indication of any variation with the interviewed sub-codes except that the Kpye's for 229, miscellaneous, were on the high side. No physical reason could be attached to this and, therefore, these Kpye's were included in the distribution with the others. The Kpye's were log-normally distributed with a median of 2.11 Kpye and a σ ratio of 3.03. If these are the characteristics of the population of some 7,000 establishments, the mean Kpye would be 3.88 and a 68% confidence interval from 2.6 to 5.7. Applied against the number of employees in projected codes, this gives 2,629 million pounds per year for scrap and waste.

The disposition - disposal analysis, Section V, indicates that the waste for disposal is some 65% of scrap and waste, practically all the remainder being sold. This gives 1,706 million pounds per year for waste for disposal and at a growth factor of 1.25, 2,132 million pounds per year waste for disposal in 1975.

4. TRENDS

None of the interviews foresaw any trends in waste/product ratio in the next ten years.

SECTION VI

SURVEY RESULTS

V. APPAREL

1. SUB-CODES AND INTERVIEWS

S.I.C. Code 23, "Apparel and Related Products", is comprised of nine three-digit sub-codes from which interviews were conducted in four as follows:

Code	Description	Employees	Interviews
231	Men's and boys' suits and coats	120,457	1
232	Men's and boys' furnishings	307,876	4
233	Women's outwear	407,748	3
234	Women's undergarments	113,633	1

Three of the remaining codes were considered similar enough in processing to be included in the projected codes as follows:

236	Children's outwear	77,865
238	Miscellaneous apparel and accessories	60,948
239	Fabricated textiles, n.e.c.	148,225

The total employees in projected sub-codes are 1,238,354, some 97% of the total in the two-digit code from which there remains as unprojected codes:

235	Hats, caps, millinery	33,204
237	Fur goods	8,066

2. WASTE TYPES

In addition to plant trash and some shipping waste, seven out of the nine interviews showed some process waste comprising rags, cloth scraps, cuttings, etc. For those that had process scrap, these average 43% of total scrap and waste, about two-thirds of this scrap being sold.

3. WASTE QUANTITIES

The seven Kpye's showed no trend with employee size and no reason for distinguishing among codes interviewed. The Kpye's were log-normally distributed with a median of 0.51 Kpye and a σ ratio of 2.61

If these are the characteristics of the population of 26,261 establishments, the mean Kpye would be 0.79 and the 68% confidence interval ranges from 0.55 to 1.13. Applied against the indicated number of employees in projected codes, this gives a scrap and waste for projected codes of 981 million pounds per year.

The disposition - disposal analysis in Section V indicates that 29% of the scrap and waste is utilized, leaving 696 million pounds per year as waste for disposal. With an indicated growth factor of 1.49, this becomes 1,037 million pounds per year in 1975.

4. TRENDS

None of the interviews saw any trends in production pattern which would alter the waste/product ratio in the next ten years.

SECTION VI

SURVEY RESULTS

W. FABRICATED METAL PRODUCTS AND MACHINERY EXCEPT ELECTRICAL

1. SUB-CODES AND INTERVIEWS

These two two-digit codes are handled as one through the following circumstance. One of the four-digit codes, 3411, metal cans, showed a higher Kpye than the remainder of Code 34. However, this remainder of Code 34 had a distribution which was indistinguishable from the distribution of Code 35. Since Code 34 and Code 35 have a quite similar type of processing as well as material, they were combined as a single code group, with Code 3411 as a separate code group due to the higher Kpye. The sub-codes and interviews were as follows:

Code	Description	Employees	Interviews
3411	Metal cans	53,745	3
342	Cutlery, hand tools	139,336	3
343	Plumbing and non-electric heating	72,467	1
344	Fabricated structural metal products	316,559	3
351	Engines and turbines	89,217	1
352	Farm machinery	120,797	4
353	Construction machinery	220,950	3
354	Metal working machinery	272,053	1
356	General industry machinery	240,998	1

Included in the projected codes were the remaining non-interviewed sub-codes in Code 35 as follows:

355	Special industry machinery	173,844
357	Office machinery, n.e.c.	156,281
358	Service industry machinery	112,163
359	Not elsewhere classified	140,072

There remain the following sub-codes in Code 34 which were placed in the non-projected codes because they had no interviews and it was not clear that they would have the same Kpye's as the interviewed codes:

Code	Description	Employees	Interviews
345	Screw machine products and bolts	93,502	
346	Metal stampings	135,239	
347	Coding and gravings	64,981	
348	Fabricated wire products, n.e.c.	55,795	
349	Not elsewhere classified	148,203	

2. WASTE TYPES

Typical waste types in all interviews were plant trash, shipping waste, and metal scrap. Typically, the metal scrap was a large fraction of the scrap and waste, averaging about three-quarters of the total.

3. WASTE QUANTITIES

For Code 3411 the three Kpye's had a median of 18.1 and a σ ratio of 1.11. If this is taken as characteristic of the 259 establishments in the nation, the average Kpye would be 18.1 and the confidence interval thereon from 16.6 to 19.7. Applied against the 53,745 employees, the scrap and waste is 973 million pounds per year.

The remaining eighteen interviews in the rest of Codes 34 and 35 were log-normally distributed with a median of 3.16 and a σ ratio of 3.09. If this is characteristic of the population of more than 25,000 establishments, the average Kpye would be 6.00 and the 68% confidence interval thereon from 4.6 to 7.9. Applied against the 2,056,286 employees in the projected sub-codes, this gives 12,337 million pounds per year of scrap and waste.

The disposition - disposal analysis indicates that 81.2% of scrap and waste from 3411 is utilized and 51.2% from the remainder of the projected sub-codes is utilized. On this basis, the waste for disposal for 3411 is 183 million pounds per year for 1965 and with a growth factor of 1.41, 258 million pounds per year in 1975. For the remainder of the projected codes, the 1965 waste for disposal is 6,020 million pounds per year and with a growth factor of 1.47, becomes 8,758 million pounds per year in 1975.

4. TRENDS

None of the interviews produced any evidence for changes in production practices which would alter the waste/product ratio in the next ten years.

SECTION VI

SURVEY RESULTS

X. SPECIAL WASTE TYPES

Two studies were made of special waste types common to a number of codes. One of these studies investigated plant trash and shipping waste, which to some degree, at least occur in all establishments. For this study there were available ten points giving shipping waste alone, twenty-nine giving plant trash alone, and thirty-three giving plant trash plus shipping waste. These three categories of Kpye's had log-normal distributions with characteristics shown in the following table.

	Number of Points	Kpye Median	σ Ratio	λ Mean	CI
Shipping	10	.47	4.46	1.45	(0.9-2.4)
Plant trash	29	.66	3.18	1.29	(1.0-1.6)
Plant trash & shipping	33	2.67	3.75	6.54	
Plant trash & shipping	39			5.96	(4.7-7.6)

These Kpye's showed no trend with number of employees or with two-digit codes among the seventeen codes from which they were drawn. Codes excluded from this study were:

Printing and Publishing	Demolition	Asphalt Roofing
Cotton Ginning	Saw Mills	Stockyards
		Super Markets

These were codes which either do not have shipping wastes or plant trash or in which these were not identifiable as such, especially not identifiable among a relatively huge quantity of process wastes. Most of the super market wastes are indeed shipping wastes since they consist of the cardboard boxes in which the incoming stock is received.

The distribution curve for the ten shipping waste points did not fit in with the other two categories in that the σ ratio was much higher, and the sum of the medians for shipping waste and plant trash was substantially less than the median for plant trash plus shipping waste, the same being true of the λ means. It was concluded that one of the three sets of data points was anomalous, and this was first taken to be the shipping waste points since these had the lowest number of points and the highest σ ratio. This would leave it preferable to project shipping waste as the difference between plant trash plus shipping waste and plant trash alone.

The λ mean figure of 6.54 for plant trash plus shipping waste is that for the thirty-three points having both plant trash and shipping waste data. However, the ten shipping waste points included six points for which plant trash was not available and thus, which do not appear in the thirty-three plant trash plus shipping waste distribution. The distribution of the six points was practically the same as the distribution for the ten points. Thus, their λ mean is about 1.45 and since all establishments have plant trash, they must be assumed to have a λ mean of plant trash of 1.29. Thus, the λ mean for the sum of shipping waste and plant trash waste for these six plants is 2.74; in other words, substantially less than the λ mean of the thirty-three plants having plant trash plus shipping waste. However, these six establishments are still part of the total sample of thirty-nine establishments, and when the λ mean for the thirty-nine is computed by properly weighing the six, the λ mean becomes 5.96.

Thus, the average plant trash is 1.3 Kpye and the approach just described would leave the average plant trash plus shipping waste as 6.0 Kpye, and the difference or 4.7 Kpye would represent shipping waste alone. But the national average Kpye is only 5.56 and therefore, it is concluded that the figure of 6.0 generated above must be non-representative and the discrepancy is not resolvable. The figure of 1.3 Kpye for plant trash is reasonable and acceptable, however.

It may be noted that the average manufacturing employee generates as plant trash, i.e. as office papers, lunch scraps and containers, coffee cups, paper towels and other sanitary items, newspapers, etc. just about as much solid waste during his working year as his assigned per capita generation while at home.

The second study on special waste types was concerned with metal wastes which are prevalent in Codes 34, 35 and 36. These were studied separately, separating out Code 3411, metal cans, which has its own special characteristics. The study was undertaken primarily in order to be able to fill in missing metal waste figures for certain establishments in these codes in order to generate a usable Kpye figure for every interviewed establishment.

The statistical characteristics of the Kpye's for metal waste alone, for those establishments having metal wastes, are shown in Table VIII.

The points for Code 36 could not be considered log-normally distributed. Also shown for comparison are the λ mean figures for Kpye total waste for the corresponding codes, drawn, it may be noted, from a greater number of establishments than contained in the metal waste analysis.

Because of the latter circumstance, it is not proper to assume that the average fraction of metal waste in total scrap and waste is given by the ratio of the last two columns. However, the ratio is of the proper general magnitude as shown by Table IX.

TABLE VIII

KPYE METAL WASTE

Code	Points	Median	$\frac{\sigma}{\text{Ratio}}$	$\frac{\lambda}{\text{Mean, CI}}$	$\frac{\lambda \text{ Mean Total}}{\text{Scrap \& Waste}}$
3411	3	14.60	1.22	15.9(13.6-18.6)	18.1
34 (ex. 3411)	8	.97	6.65	5.97(2.8-12.6)	6.0
35	7	1.15	1.81	1.39(1.1-1.8)	
36	5	.751	7.10	1.59*	2.75

* Distribution cannot be considered as log-normal; arithmetic mean of sample used instead.

TABLE IX

Code	λ Mean Metal Waste Kpye / λ Mean Scrap & Waste Kpye	Av. Fraction Metal Waste = $\frac{\Sigma \frac{\text{Metal}}{\text{Total}}}{n}$	Fraction Utilized
3411	0.88	0.81	0.81
34 (ex. 3411)	} 0.61	0.49	} 0.51
35		0.60	
36	0.58	0.43	0.24

The last column in this table shows the fraction of the scrap and waste which is utilized. The explanation for the similarities and differences between the last and next to the last columns is that, although in all three code groups practically all of the metal waste is sold, yet in Code 36 a substantial fraction of the establishments do not have metal waste, the 0.43 being the fraction metal waste in total waste for those establishments having metal waste.

SECTION VII

GENERAL DISPOSITION - DISPOSAL PATTERNS

The individual code sections have given information on disposition and disposal mode frequencies indicating merely the frequency of occurrence of indicated disposition and disposal modes. The categories covered were disposition agent, ultimate disposal or reduction facility type and ultimate disposal or reduction facility ownership. In a few code sections this disposition - disposal analysis was carried further by the "intermediate" method of average percentages in order to be able to eliminate from the Kpye data certain disposition or disposal modes which did not result in waste for disposal. In certain other individual code sections, adjustments to Kpye data and λ mean projections have been made using disposition - disposal percentages computed in this section.

This section reports a general study of disposition - disposal patterns made for each code separately. The results have also been combined for various presentation purposes and uses.

A. DEFINITIONS

In order to discuss the subject, it is necessary to introduce some new definitions concerning waste paths and waste disposal in industrial establishments. Figure 5 shows the possible flows of industrial scrap and waste and serves to illustrate the definitions.

1. SCRAP-AND-WASTE

Solid materials generated by an establishment other than the material which leaves as the primary product. While not used in the unhyphenated form the term "scrap" is intended to apply to process residues and the term "waste" is added to convey also the concept on non-process materials. Scrap-and-waste is the material which is a potential waste for disposal.

2. UTILIZED SCRAP-AND-WASTE

Scrap-and-waste which is utilized in some way and is not subject to ultimate disposal.

3. UNUTILIZED SCRAP-AND-WASTE

Scrap-and-waste requiring ultimate disposal or waste reduction and disposal.

4. BY-PRODUCT

A means of utilizing scrap-and-waste restricted to process scrap, fabricated or unfabricated, which is sold or given directly to a customer for a specific use.

FLOW PATTERN FOR INDUSTRIAL SCRAP-AND-WASTE

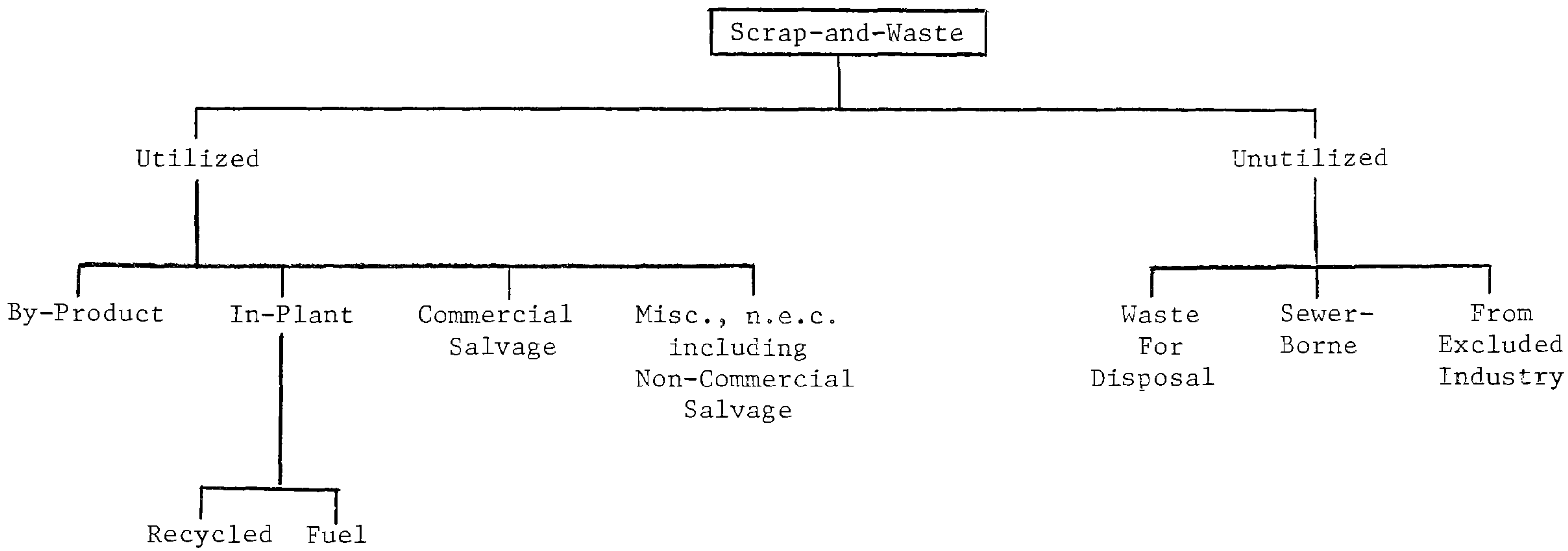


Figure 5

5. COMMERCIAL SALVAGE

A mode of utilizing scrap-and-waste by which it enters the commercial scrap market.

6. IN-PLANT UTILIZATION

Modes of utilizing scrap-and-waste which are accomplished within the generating establishment.

7. FUEL

In-plant utilization of scrap-and-waste for fuel.

8. RECYCLED

In-plant utilization of scrap-and-waste by recycling it to the process.

9. MISCELLANEOUS UTILIZATION

Utilization of scrap-and-waste in other ways, including that sold or given away to individuals for non-commercial purposes.

10. WASTE-FOR-DISPOSAL

For the purposes of this project, only that portion of the unutilized waste which falls in the category defined in the scope, namely unutilized waste excluding that from certain industries and excluding that which has a sewer-borne disposition and disposal.

11. UTILIZATION ACHIEVEMENT

The degree of success in utilization of scrap-and-waste, numerically the fraction:

$$\left(1 - \frac{\text{waste-for-disposal, mpy}}{\text{scrap-and-waste, mpy}}\right)$$

B. OBJECTIVES

The objectives of this section are:

1. To provide quantitative information on disposition and disposal modes for the total of the twenty code groups covered.

2. To provide for each code quantitative data showing the fraction of scrap-and-waste which the industry has succeeded in utilizing, i.e. the utilization achievement.

C. LIMITATIONS OF THE BASIC DATA

As may already have been learned from the individual code chapters, the second objective above was not at all provided for in the data collection plan. Where scrap-and-waste had a nearly universal utilization, information on its quantity was not actively sought since it was not to be used in the projection of waste-for-disposal. For example, many food sub-codes have scrap-and-waste which is utilized as by-product, e.g. animal feed. The meat packing industry has found it possible through the years to utilize more and more of the animal as by-product such that such materials have not for several generations been considered among scrap-and-waste. In the saw mill industry, it is common to sell chips as by-products in the East and to burn scrap-and-waste for fuel in the West. In the printing and publishing industry, a very large percentage of the total scrap-and-waste is scrap paper utilized as by-product or via commercial salvage. While the collection of information on these conventionally utilized materials was not part of the project plan, it happened that in a surprising number of the interviews such information was actually collected.

A second and much more serious deficiency of the data is the small size of sample bearing on disposition - disposal incidence and percentages. This is the case despite the fact that the interviews have been supplemented with the postcard disposition data previously collected -- which incidentally usually gave only the disposition pattern for the non-sold scrap-and-waste since this is the way in which the question was phrased. As has been shown with waste/employee ratios, it is possible to achieve secure projections from a small sample if the population happens to have some uniform and known characteristic distribution, and a distribution brought about by completely random influences. However, the nature of disposition - disposal patterns and basic causes is such that a very large sample is required for an adequate projection. The reason for this may be illustrated as follows. Attention may be focused on two codes as to the question whether one code tends to municipal pick-up while the other tends to self disposition. If a municipality offers free municipal pick-up to industrial establishments, most establishments, of course, will avail themselves of this and in that city there will be very little industrial contractor disposition. At the same time in another city, the municipal regulations may prohibit municipal pick-up of industrial waste and accordingly some industries will use self disposition and some contractor disposition. If contractor rates are very high in this city, most industrial disposition will be self disposition.

Now if one surveys a large number of cities, and therefore, a large number of establishments, for these two codes and all cities that fall into one or the other of the two categories, then he will find that the fraction disposing by one or the other of the modes (municipal or self) is approximately equal to the fraction in which the industry is present in the two types of cities. However, if one has in the sample only a few establishments, say six to twenty, then there is a good chance that most of the establishments in one code may come from one type of city and most in the other from the other type. The disposition pattern for the two industries would not be characteristics of the industries themselves at all, but rather the characteristics of the cities in which the sample happened to be concentrated.

A similar situation can be visualized, again for illustration, if one considers for example, the fate of wastes from restaurants. These may be picked up by the municipality or may have contractor disposition but in either case, let it be assumed that the ultimate disposal is in the city facility. Then the fraction of restaurant wastes going to incinerators as against sanitary land fills will depend upon whether the sample came from cities largely with incinerators or from cities largely with sanitary land fills.

Stating the situation, in general the disposition - disposal modes for establishments in samples of the size available to the study, depend upon the geographical, economic and political situation in the cities interviewed and have a high degree of dispersity. The only projection which can be secure, therefore, is one in which the sample size is very large so as to assure coverage of all the varying degrees and types of dispersity.

Implicit in the foregoing discussion is the concept that the S.I.C. Code really does not have a great influence on disposition mode. If sanitary land fills are common in a city, most wastes from all codes with some obvious exceptions will be disposed of by sanitary land fill. If, on the other hand, sanitary land fills are uneconomic and incinerators are the practice, most wastes from all codes will be disposed of by incineration. Indeed, it might be guessed that one would get a more accurate picture of the fate of industrial wastes, not self disposed, by considering the nation's capability in non-private dumps as compared with non-private incinerators than by making a survey of individual disposition and disposal in industrial establishments themselves.

A further corollary to these concepts is that a more accurate disposition - disposal pattern for each individual code would be achieved by summing the patterns for all 320 interviews in all 24 codes than by taking those restricted to the individual code itself. The reason is that the larger 24 code sample would contain the dispersity which the individual code sample did not.

The enabling assumption upon which the above remarks are based is that there are no differences in disposition pattern as a function of code. This assumption could no doubt be tested statistically and would be more likely to be capable of such testing if the sample size were larger in each code, but we do not presume to undertake this statistical test which is difficult enough even with an adequate sample size.

Rather, we make a virtue out of a necessity and since the second objective requires a disposition analysis and projection by individual codes, the entire disposition analysis has been based on individual codes, although they are summed for the final presentation. In general, the disposition - disposal results must be considered of considerably lower accuracy as an estimator of the national population they are the waste-for-disposal quantities.

D. PROCEDURE

Each one of the 320 interviews for the twenty-four codes and each of the eighty-five postcards for these codes was reviewed to determine the fraction having various disposition and disposal modes and also to determine the fraction of the total scrap-and-waste which had not entered into the waste/employee or waste/product ratios developed in the individual chapters. However, not all of these 405 interviews and postcards supplied disposition - disposal data so that only 305 individual cases were utilizable. These do not count the 4,865 cotton gins on which the pattern for that code is based. The postcard survey developed only the disposition of the non-sold scrap-and-waste so the fraction sold was developed only from interviews while the fractions and frequencies having other dispositions were developed from both interviews and postcard data.

For each code the fractions were averaged among all the establishments as divided among some 37 disposition - disposal modes. The average percentage to each disposition mode was obtained using the method described as the "intermediate method" in the procedure (see Appendix C).

The disposition - disposal modes actually encountered in the sample and for which percentages were computed are listed in Table X. There are a number of other possible combinations of the three modes, but those not listed were not actually encountered. It is seen that summations can be made in any desired category; for instance, all waste that is incinerated, all waste that is contract hauled, all waste that goes to a municipal owned ultimate disposal facility.

One of two methods was used to generate scrap-and-waste from the original Kpye or other figure used in the individual code chapters. One of these was applied when some single waste stream had been eliminated from the Kpye's because of some universal disposition such as sold, recycled, etc. The other method, used only for wooden boxes and for printing and publishing, was applied when it was not possible to separate out a single previously not accounted for stream in this way. In those cases, a new set of Kpye's was computed based on scrap-and-waste and the projections made with these just as described in the individual chapters, yielding a new figure for scrap-and-waste in contrast to the previous figure developed in the chapter.

D. RESULTS - PROJECTED CODES

The scrap-and-waste quantities thus projected and the utilization achieved are shown in Table XI. It is seen that the total scrap-and-waste for the 24 code groups projected is 350,500 million pounds per year, or excluding saw mills, about 157,900 million pounds per year.

TABLE X

DISPOSITION - DISPOSAL MODES ENCOUNTERED*

Self-owned ultimate disposal facility
- Incinerator or burner
- Dump - self haul
- Dump - contract haul
- Open burn
- Sanitary land fill
- Fill

Municipal-owned ultimate disposal facility
- Dump - municipal haul
- Dump - self haul
- Dump - contract haul
- Incinerator - municipal haul
- Incinerator - self haul
- Incinerator - contract haul
- Sanitary land fill - self haul
- Sanitary land fill - contract haul
- Ultimate disposal type unknown - municipal haul
- Ultimate disposal type unknown - self haul
- Ultimate disposal type unknown - contract haul

Contractor-owned ultimate disposal facility
- Sanitary land fill - self haul
- Dump - self haul
- Dump - contract haul
- Open burn - contractor haul
- Sanitary land fill - contractor haul
- Type of ultimate disposal unknown - contract haul
- Type of ultimate disposal unknown - municipal haul

Merchant ultimate disposal facility
- Dump - self haul
- Dump - contract haul

Ownership of ultimate disposal facility unknown
- Dump - self haul
- Dump - contractor haul
- Type of ultimate disposal unknown - self haul
- Type of ultimate disposal unknown - contract haul
- Type of ultimate disposal unknown - hauler unknown

Not waste-for-disposal
- Give-away - at plant site
- Give-away - self haul
- Give-away - contract haul
- Fuel - in plant
- Sold - self haul or at plant site
- Sold - contract haul
- Sewer

* Modes not encountered in the sample are not listed.

The last column in Table XI shows the total waste-for-disposal. The total is 181,500 million pounds per year or with saw mills omitted, 115,900 million pounds per year.

It is seen that some industries achieve a very high utilization of scrap-and-waste, these being cotton at 59 percent, mostly by return to the land as soil amendment; wooden boxes at 50 percent, mostly through sale of chips; saw mills at 66 percent by sale of chips and use of bark, slabs and sawdust for fuels; auto and aircraft at 50 percent, mostly by direct give-away at the plant site; stockyards at 60 percent by utilization for fertilizer; super markets at 40 percent, mostly by entering the commercial salvage stream; mill work at 47 percent, mostly by F.O.B. sale; and printing and publishing (greater than 250 employees) 68 percent, mostly as by-products or commercial salvage. As can be expected, fabricated metal products and machinery, except electrical, show a high fraction utilized, 81 percent for metal cans and 51 percent for the remainder of these two codes because most of their scrap-and-waste is metal scrap which readily finds utilization in the commercial salvage market. Meat packing is found listed at 44 percent, but this actually is 44 percent which did not enter the waste-for-disposal as defined. It was flushed to sewers.

Overall, 24 code groups, 48 percent of the scrap-and-waste does not enter the waste-for-disposal stream and 52 percent becomes waste-for-disposal. Over 23 code groups (except saw mills) about 73 percent is waste-for-disposal and 27 percent is utilized. The twenty manufacturing code groups alone have an even higher utilization of 56 percent but again this largely reflects the high utilization and high contribution of saw mills, being at 31 percent without this code.

Of the 48 percent not entering the waste-for-disposal stream, the greatest is sold with 29 percent out of the 48 percent. Next is fuel, 17 percent and finally give-away with 2 percent out of 48 percent. For the 19 code groups excluding saw mills sold is about 21 percent out of 26 percent, give-away 4 percent and fuel only 1 percent out of the 26. These figures indicate the great importance of fuel utilization in the saw mill industry. In dealing with the overall picture as for the twenty code groups, it should be recalled that the twenty code groups include four codes not in the manufacturing industries, namely cotton ginning, demolition, stockyards, and super markets. Also, it should be recalled that the remaining 16 code groups in manufacturing do not include all of manufacturing.

The remainder of this discussion concerns the waste-for-disposal, namely the 181,543 million pounds per year for the twenty-four code group or the 115,943 for the twenty-three code group excluding saw mills. Table XII shows the distribution in million pounds per year of waste for disposal among various disposition - disposal modes, both for the twenty-four codes and for the twenty-three codes, excluding saw mills, which make such a large contribution to the total and have a special characteristic disposition - disposal mode.

TABLE XI

SCRAP-AND-WASTE QUANTITIES AND UTILIZATION ACHIEVED

S.I.C. Code Group	Number of Interviews And Postcards Supplying Disposition, Disposal Information	Known Scrap and Waste 1965 Million/lbs/yr	Fraction Utilized or Otherwise Not Waste-For-Disposal	Waste-For-Disposal 1965 Million/lbs/yr
MANUFACTURING				
Food	14	11,500	0.08	
Meats	10	2,963	0.44	
Textile Mill Products, ex. 226, 8	10	2,629	.351	
Apparel & Related Products, ex. 235, 7	9	981	.291	
Wooden Containers	40	4,996	0.51	
Saw Mills	65	192,600	0.66	
Mill Work	9	1,072	0.47	
Wooden Furniture	14	4,197	0.26	
Paper	42	11,100	0.10	
Printing & Publishing	9	7,243	0.68	
Chemicals	11	2,625	0	
Paints	8	324	0	
Asphalt Roofing	7	1,180	0.03	
Rubber	11	2,900	0	
Tanning	7	608	0.02	
Glass	7	3,200	0.16	
Metal Cans, 3411	3	973	.812	
Fabricated Metal Products & Machinery ex. Electrical, 34 ex. 3411 ex. 345, 6, 7, 8, 9, & 35, ex. 364	18	12,337	.512	
Electrical Machinery	20	3,651	.244	
Auto & Aircraft	9	5,786	0.50	
Sub Total, 20 Manufacturing Code Groups		272,865	.56	120,782
Sub Total, 19 Manufacturing Code Groups (except saw mills)		80,265	.31	55,182
NON-MANUFACTURING				
Cotton Ginning	(4865)	3,836	0.59	
Demolition	8	38,100	0	
Stockyards (including auction)	11	1,919	0.61	
Super Markets	11	33,800	0.40	
Total, 24 Code Groups	293	350,520	.48	181,543
Sub Total, 23 Code Groups (except saw mills)		157,920	.27	115,943

The totals in Table XII and following tables do not correspond exactly with those in Table I. The differences arise from a recomputation of the data from which Table I was obtained, but the magnitude of the difference is negligible (about .6%) in view of the overall confidence interval of these figures.

Under disposition agent it is seen that about half of the waste is handled at the establishment site by the generator and an additional quarter of the waste is handled by the generator by hauling off the plant site. Contract disposition accounts for 21 percent. When saw mills are excluded, only about 22 percent is handled at the site and 30 percent is self hauled off the plant site. The contract share is about 33 percent.

As to type of ultimate disposal facility, incinerators and burners are about equal with dumps, each around 40 percent, with other modes much smaller in importance. With saw mills excluded, dump is the major mode with 57 percent followed by incinerator or burner and sanitary land fill with considerably smaller percentages.

As to ownership of the ultimate disposal or reduction facilities, private ownership is predominant with 50 percent followed by municipal with about 36 percent. When saw mills are excluded, the private ownership falls to 22 percent of that total and municipal becomes the major mode with 56 percent. Contractor or merchant disposal is quite minor.

It is of interest to specify how much of the material going to self-owned facilities is handled by the various types of facilities. This is shown in Table XIII. It is seen that incinerator or burner is the major type being 76 percent, dump being 18 percent and other modes of very minor importance. Excluding saw mills, the incinerator or burner still maintains predominance with 62 percent and dumps become 25 percent, open burning gaining some in importance. The difference between the 69,759 million pounds per year for the twenty-four codes and the 15,831 million pounds per year for the twenty-three codes shows the predominance of incinerator or burner as a disposal mode in the saw mill industry.

Another breakdown of interest describes the fate of industrial waste having contract disposition. This is shown in Table XIV for the 38,379 million pounds per year having contract disposition. Fifty-three percent of the contract disposed waste is known to go to municipal ultimate disposal or reduction facilities, but there is a large unknown component. If the unknown component is distributed in the same way as the three known components, the percentages would be self 1.1 percent, municipal 77.1 percent, contractor or merchant 21.8 percent. This indicates that 77 percent of the industrial waste collected by contractors goes to a municipal ultimate disposal or reduction facility, and only 22 percent to contractor or merchant facilities. The 1.1 percent self-owned facilities represent that portion of the industrial waste which is hauled by contractors to the generator's own disposal facility, a quite negligible amount.

TABLE XII

DISTRIBUTION OF WASTE-FOR-DISPOSAL AMONG

VARIOUS DISPOSITION - DISPOSAL MODES

Projected Codes
Manufacturing Plus Non-Manufacturing

DISPOSITION AGENT	Twenty-Four Codes		Twenty-Three Codes (Except Saw Mills)	
	Million/lbs/yr	Percent	Million/lbs/yr	Percent
Self (at site)	90,895	49.7	25,411	21.8
Self (remote)	45,806	25.1	45,806	39.3
Contract	38,379	21.0	38,379	32.9
Municipal	6,386	3.5	6,386	5.5
Unknown	1,247	.7	669	.5
Total	182,713	100.0	116,651	100.0

TYPE OF ULTIMATE DISPOSAL OR REDUCTION				
Incinerator and Burner	74,058	40.5	20,130	17.3
Dump	76,316	41.8	66,686	57.2
Sanitary Land Fill	14,380	7.9	14,380	12.3
Open Burn	4,555	2.5	2,629	2.3
Fill	424	.2	424	.4
Unknown	12,978	7.1	12,400	10.5
Total	182,711	100.0	116,652	100.0

OWNERSHIP OF ULTIMATE DISPOSAL AND REDUCTION FACILITIES				
Self	91,186	49.9	25,703	22.0
Municipal	65,308	35.7	65,308	56.0
Contract or Merchant	11,654	6.4	11,654	10.0
Unknown	14,563	8.0	13,985	12.0
Total	182,711	100.0	116,650	100.0

TABLE XIII

DISTRIBUTION BY ULTIMATE DISPOSAL OR REDUCTION TYPE FOR SELF-OWNED FACILITIES

Projected Codes
Manufacturing Plus Non-Manufacturing

	Twenty-Four Codes		Twenty-Three Codes	
	Million/lbs/yr	Percent	Million/lbs/yr	Percent
Incinerator or Burner	69,759	76.5	15,831	61.6
Dump	16,039	17.6	6,409	24.9
Sanitary Land Fill	771	.8	771	3.0
Open Burn	4,193	4.6	2,267	8.8
Fill	424	.5	424	1.7
Unknown	0	0	0	0
Total	91,186	100.0	25,702	100.0

TABLE XIV

DISTRIBUTION BY OWNERSHIP OF ULTIMATE DISPOSAL OR REDUCTION FACILITIES OF INDUSTRIAL WASTE HAVING CONTRACT DISPOSITION

Projected Codes
Manufacturing Plus Non-Manufacturing

	Twenty-Four Codes		Twenty-Three Codes	
	Million/lbs/yr	Percent	Million/lbs/yr	Percent
Self	291	.8	291	.8
Municipal	20,471	53.3	20,471	53.3
Contractor or Merchant	5,801	15.1	5,801	15.1
Unknown	11,816	30.8	11,816	30.8
Total	38,379	100.0	38,379	100.0

The data on the frequency of occurrence of the various disposition - disposal modes also suffers from the smallness of the sample compared with the dispersity of the population. As with the disposition - disposal percentages, the results on frequencies are presented as the best information as yet available. The frequencies simply indicate the total number of times in which each disposition - disposal mode was encountered in the interviews. This gives no information on the quantities of waste so handled since the use of an incinerator to incinerate 3 percent of an establishment's total waste would receive a tally of one, and the use of a dump to dispose of the remaining 97 percent would also receive a tally of one. This information may be useful for those wishing to form a general (and very preliminary) idea of just how many sales possibilities there might be for tepee burners, for example. Looked at in another way, the frequencies give the probability that any particular establishment chosen at random would have the particular disposition - disposal mode described. The results for the approximately three hundred occurrences are shown in Table XV.

It is noted that the frequencies of occurrence of the various modes parallel the percentage of the waste-for-disposal to the corresponding modes from Table XII. This suggests that frequency, which is much easier to determine, might be used as an estimator of percentage in future studies, and this is worth some exploration.

TABLE XV

FREQUENCIES OF DISPOSITION - DISPOSAL MODES

Projected Codes
Manufacturing Plus Non-Manufacturing

BY DISPOSITION AGENT	Percent of Occurrences
Self	60.7
Municipal	7.1
Contract	31.0
Unspecified Not-Self	1.2
BY TYPE OF ULTIMATE DISPOSAL OR REDUCTION	
Tepee Burner	17.8
Incinerator	19.0
Open Dump	47.4
Open Burn	5.0
Sanitary Land Fill	10.8
Unknown	not counted
BY OWNERSHIP OF ULTIMATE DISPOSAL AND REDUCTION FACILITIES	
Self	48.8
Municipal	37.5
Contractor	2.6
Merchant	4.1
Unspecified Not-Self	7.0

Tables and discussion similar to the preceding covering disposition - disposal for projected and non-projected codes combined will be found in the "Non-Projected Codes" chapter.

SECTION VIII

NON-PROJECTED MANUFACTURING CODES

This study has been largely confined to the manufacturing industries, S.I.C. Codes 19 - 39, with four additional industry codes included because it was thought they might have a high quantity of waste and a waste problem physically similar to those of the manufacturing industries.

If the authors were asked: "What solid wastes has your study missed?" they would first have to refer to the scope of the contract. This contract excludes certain activities which probably generate a very large quantity of solid waste. For example, the scope of the project excludes mining wastes, and farm and forest wastes such as agricultural and logging residues. The area studied can be approximately defined as those solid wastes generated in establishments physically resembling manufacturing establishments and which have a reasonable possibility of some interaction with municipal wastes. Such a definition provides for the inclusion of the four non-manufacturing codes studied; cotton ginning, demolition, stockyards and super markets, but it also permits the inclusion of a number of other industries not studied in the project such as contract construction and automobile scrapping. For some of these industries which are outside the scope of the project, the quantities are known. For example, the solid waste in automobile scrapping is of the order of 18,000 million pounds per year, or about 0.25 pounds per capita per calendar day. Nevertheless, the authors cannot hazard a guess as to how much has been missed because of insufficient knowledge of the codes which were not covered.

This reservation does not apply to the "non-projected" codes and sub-codes in the manufacturing division, for there it is perfectly definite as to which sub-codes have not been covered. They consist of all sub-codes not listed as projected codes in Table I. While not called for in the scope of work for this project, it was thought to be desirable to make an estimate of the waste for disposal in these "non-projected" codes. The 1964 "County Business Patterns" reports 16,050,119 employees in the manufacturing division excluding administrative and excluding S.I.C. Codes 29, Petroleum, but including 2952, Asphalt Roofing. Of these, only 10,146,132 have been covered in the projected codes. This chapter attempts to estimate the waste for disposal generated by the remaining approximately 5,900,000 employees in manufacturing.

A. METHOD

The method of projection will be to assign a Kpye to the non-projected codes and to compute the amount of waste from the known number of employees therein. Some of the Kpye assignments are drawn from actual interviews conducted from prior proprietary Combustion Engineering projects, but for certain technical reasons, non-projected in the study. For example, Kpye figures are known for the seven non-projected sub-codes in the food industry, and indeed they were excluded from the interviews in the present project because the prior information indicated that the waste quantities would be very low. Most of the Kpye assignments, however, are estimates based on similarities in materials and processing between unknown, non-projected codes and known interviewed codes. It is pointed out that some of the projected codes themselves are non-interviewed codes which have been assigned the Kpye of the interviewed codes on the basis of strong and close similarities between them and the interviewed codes. For the non-projected codes in this chapter, the similarity is less strong and therefore the Kpye assignment less secure.

That it is a knowledgeable estimate rather than a random guess can be demonstrated by actual project work which provides some measure of the validity of the estimates to be made. After the twenty codes had been studied, in the first stage of this project, the very question: "How much have you missed?" was investigated for the purpose of making an intelligent selection of additional codes to be interviewed in the second stage of the project. On the basis of similarities to the interviewed codes, Kpye's were assigned to the then non-projected codes, which when applied to the non-projected employees, produced an estimate that 41,700 million pounds per year had been missed in the non-projected manufacturing codes.

These estimated individual code mpy's were used as one of the bases for selecting the additional codes to be interviewed in the second stage. These additional codes were S.I.C. Codes 22, 23, 34, 35 and 36. In Code 36, five, 4-digit sub-codes had already been interviewed and projected. The estimated quantity missed in these five codes to be added, using the above procedure, was 9,403 million pounds per year. When forty-nine interviews were actually performed in these five codes, the total quantity picked up, now based on the secure Kpye figures, was 11,551 million pounds per year. This indicated that, for the group of five codes, the estimated figure was within 19% of the secure figure and that the twenty-four code total would have been off by only about 1% if the forty-nine interviews had not been performed. This experimental demonstration provides some justification of the validity of the estimates used for previously non-projected codes. Incidentally, specifically excluded from the project scope is the petroleum industry solid waste and this industry will not be included in the non-projected codes.

Except in Code 20 the scrap and waste Kpye was the one assigned, together with a disposition - disposal pattern for scrap and waste. In general, these assignments were taken to be the same as for some other projected code based on similarities. For example, it was judged that Code 19, Ordinance and Accessories, would be similar to codes 35 plus 34 (ex. 3411) and to Auto and Aircraft, Code 37, which had respectively scrap and waste of 6.0 and 4.25 Kpye, and disposition - disposal patterns quite similar such that the utilization fraction was about 50%, leaving respectively 2.93 and 2.14 Kpye as waste for disposal. Accordingly, for Ordinance, Code 19, there was used 6.0 for scrap and waste and 2.93 for waste for disposal. The Kpye values for several codes were assigned on the basis of the λ mean figure for plant trash and shipping wastes from Section VI. These were stone and clay (ex. glass) based on the λ

mean figure for plant trash and shipping waste, and primary metals based on the λ mean figure for plant trash plus one half the λ mean figure for shipping waste.

For foods (ex. meats) Code 20, the only non-projected codes were those for which previous proprietary information was already available, so the assigned Kpye's were derived from this information.

The growth factors used to project to 1975 were those available for the 2-digit codes previously used or available from the same source where not previously used.

B. RESULTS - NON-PROJECTED AND PROJECTED PLUS NON-PROJECTED CODES

The results for the non-projected codes have already been shown in the summary chapter Table I- and will not be represented here. The non-projected codes added 47,686 million pounds per year to the 1965 projection and approximately 5,900,000 to the employees covered. The total employees covered in projected and non-projected codes thus becomes approximately 16,048,000 in manufacturing codes.

The Kpye corresponding to these totals for the non-projected codes is 8.1. Since there is very little lumber industry (Code 24) waste in this total, the Kpye should be compared with that for the manufacturing codes (ex. saw mills) among the projected codes, where the Kpye is 5.56. This comparison highlights a basic reservation on the non-projected codes which the reader should keep well in mind in using these results. The Kpye assignments to the non-projected codes are for the most part not based on actual information but on an assignment of similarities between non-projected codes and corresponding or related projected codes.

The selected codes were selected because there existed prior information that they had relatively high Kpye's. Some of the non-selected codes were known to have low Kpye's but about the remainder there was simply a lack of information. Secondly, the true Kpye for the non-projected codes may indeed be less than the assigned values, for in the assignment a conservative viewpoint was taken of associating each non-projected code with a similar projected code, rather than making an outright guess on the Kpye of the non-projected code. The conclusion is that if the million pound per year total for the non-projected codes is in error, it is more likely to be higher than the true value rather than lower than the true value.

In addition to the foregoing uncertainties, there is one non-projected code which has a particular uncertainty which should be mentioned. Prior information on veneer and plywood plants indicated that the waste for disposal was zero because all waste was used as fuel. Considering the quantity of wood handled by the veneer and plywood industry, and the basis in only four interviews, this assignment of zero Kpye must be considered tentative, and one of the priority items in firming up the non-projected codes in future work should be to explore the veneer and plywood industry.

Accepting the reservation with respect to the non-projected codes, the total mpy in manufacturing codes projected plus non-projected is 168,468, or excluding saw mills, 102,868. For all codes covered, manufacturing and non-manufacturing and projected and non-projected, the total mpy is 229,229 or excluding saw mills, 163,629.

The non-projected codes in manufacturing contribute about 28% of the total manufacturing waste for disposal and about 21% of the manufacturing and non-manufacturing codes covered in the study.

The 1975 mpy for the non-projected codes is expected to increase in accordance with the growth factors for the 2-digit codes previously used. It will be remembered that in the 1975 predictions for the projected codes it was taken that the waste for disposal from the Western saw mills would become zero by 1975. If this does indeed occur, the waste for disposal for all manufacturing codes, projected plus non-projected, will remain about the same over the period, approximately 168,000 million pounds per year. The waste from manufacturing (except saw mills) will increase by about 40% reflecting the overall physical growth factor. That from all codes, manufacturing and non-manufacturing and projected and non-projected, is predicted to increase by about 5% reflecting the increase in the manufacturing (except saw mills) codes and the decrease in the Western mills.

C. DISPOSITION - DISPOSAL PATTERNS, PROJECTED PLUS NON-PROJECTED CODES

This chapter has explained that the waste quantities from the non-projected codes are estimates with a lower order of confidence than the projected codes quantities, and the disposition - disposal, Chapter VII has explained that the disposition - disposal pattern is less secure than the waste quantities, for reasons explained therein. This section is about to compound these insecurities by assigning disposition - disposal patterns to non-projected codes and applying these against the non-projected code quantities. With absolutely no information available, the only assignment pattern that could be made was the assignment of the same pattern as some corresponding industry among the projected codes, usually the very one from which the Kpye assignment was made. As has been previously maintained, the disposition - disposal pattern of an industry is probably not dependent upon the S.I.C. Code, but more likely to be dependent upon the particular physical environment of the industry. Since most of the establishments in the non-projected codes exit in urban centers, the pattern is that characteristic of the national pattern for urban centers.

When these assignments are made and the computations are made as described in Section VII, a set of disposition - disposal distributions corresponding to those presented in Tables XII, XIII and XIV of Chapter VII results.

The presentation of such distributions for the non-projected codes alone is not made here. The distribution quantities for the projected plus the non-projected codes are shown in Tables XVI, XVII and XVIII.

TABLE XVI

DISTRIBUTION OF WASTE FOR DISPOSAL AMONG

VARIOUS DISPOSITION - DISPOSAL MODES

Projected Plus Non-Projected Codes
Manufacturing Plus Non-Manufacturing

DISPOSITION AGENT	All Codes		All Codes Except Saw Mills	
	million/lb/yr	percent	million/lb/yr	percent
Self (at site)	110,121	47.8	44,637	27.2
Self Remote	54,108	23.5	54,108	32.9
Contract	56,678	24.6	56,678	34.5
Municipal	8,243	3.6	8,243	5.0
Unknown	1,247	.5	669	.4
Total	230,397	100.0	164,335	100.0

TYPE OF ULTIMATE DISPOSAL OR REDUCTION				
Incinerator or Burner	89,888	39.0	35,960	21.9
Dump	94,307	40.9	84,677	51.5
Sanitary Land Fill	23,471	10.2	23,471	14.3
Open Burning	5,921	2.6	3,995	2.4
Fill	428	.2	428	.3
Unknown	16,382	7.1	15,804	9.6
Total	230,397	100.0	164,335	100.0

OWNERSHIP OF ULTIMATE DISPOSAL OR REDUCTION FACILITIES				
Self	110,836	48.1	45,352	27.6
Municipal	79,923	34.7	79,923	48.6
Contractor or Merchant	20,546	8.9	20,546	12.5
Unknown	19,092	8.3	18,514	11.3
Total	230,397	100.0	164,335	100.0

TABLE XVII

DISTRIBUTION BY TYPE

FOR SELF OWNED FACILITIES

Projected Plus Non-Projected Codes
Manufacturing Plus Non-Manufacturing

	All Codes		All Codes Except Saw Mills	
	million/lb/yr	percent	million/lb/yr	percent
Incinerator or burner	84,853	76.6	30,925	68.2
Dump	19,133	17.3	9,503	20.9
Sanitary Land Fill	932	.8	932	2.1
Open Burn	5,490	4.9	3,564	7.9
Fill	428	.4	428	.9
Unknown	0	0	0	0
Total	110,836	100.0	45,352	100.0

TABLE XVIII

DISTRIBUTION BY OWNERSHIP OF DISPOSAL FACILITIES

OF INDUSTRIAL WASTE HAVING CONTRACT DISPOSITION

	All Codes		All Codes Except Saw Mills	
	million/lb/yr	percent	million/lb/yr	percent
Self	715	1.2	715	1.2
Municipal	26,338	46.5	26,338	46.5
Contractor or Merchant	13,303	23.5	13,303	23.5
Unknown	16,322	28.8	16,322	28.8
Total	56,678	100.0	56,678	100.0

While the waste quantities are different due to the addition of the non-projected codes, the percentage in these Tables does not differ greatly from those in the corresponding Tables XII, XIII and XIV, Section VII, and the discussion of the results in Section VII is applicable to the total of the projected and non-projected codes in the Tables just shown. The only slight change that would be made is that of the industrial waste collected by contractors (distributing the unknown in the same manner as the known) about two-thirds goes to a municipal owned facility and one-third to a contractor merchant owned facility.

When it is recalled that the disposition - disposal patterns for the non-projected codes were taken individually as the same as that for some projected code, it might be questioned why the percentages (except saw mills which do not occur in the non-projected codes) should change at all. The reason is that the proportions of the individual non-projected codes waste are of course not the same among the non-projected codes as the companion projected codes are among the projected codes.

SECTION IX

WASTE FOR DISPOSAL BY STATE

The same general methods used to project waste for disposal for the United States can be used, with some modifications, to project waste for disposal for each of the fifty states and the District of Columbia. In this projection it was assumed that the disposition and disposal pattern for each state was the same as that for the nation. This, of course, is not correct, but must remain as one of the approximations in the 51 state projections because to develop disposition - disposal patterns for each state would require 51 times as much information as for the national. Growth factors for the individual states also were not available and, therefore, projections were not made for 1975.

In general, with the exceptions noted immediately below, the Kpye's for waste for disposal were taken from the last column in Table I of Chapter II. These were multiplied by the number of employees in each code, developed as described below, to obtain the million pounds per year of waste for disposal for each code and each state. The code totals for each state were then summed to produce the totals for each state. The general Kpye method was also used for meat packing, Code 201, even though the U. S. total was developed by a non-Kpye route. Doing so requires the assumption that the ratio of meat packing establishments with slaughter to meat packing establishments without slaughter is the same in each state as it is in the nation. The exceptions to this procedure are detailed in the following.

For cotton gins, the original data has been developed via the state-by-state method using data on bales ginned.

The method of projecting demolition utilized a state per capita figure. This per capita amount was multiplied by the SMSA population in each state.

The saw mill projection was made on a pounds per board foot basis, distinguishing between Eastern mills and Western mills. These factors were applied to the board feet of lumber production for each state using the data from the 1963 "Census of Manufacturers". For example, in that listing, North Dakota, Nebraska and Kansas are grouped in board feet production. The group total was assigned to each of the three states in proportion to the number of establishments in each state.

For stockyards, the terminal yards contained in the sample itself are assigned to their respective states. The terminal yards not in the sample were computed via the cattle equivalents and assigned to their states. No information is available on the number of auction yards in each state. Accordingly, the U. S. total for auction yards was apportioned among the states in proportion to the number of cattle (not cattle equivalents) slaughtered. In the available information, the New England states are grouped. The million pounds per year for the group was apportioned among the individual New England states in proportion to the cattle on farms, January 1, 1965.

For super markets, the "County Business Patterns" data gives the number of reporting units with more than 19 employees in each state, but not the number of employees. The U. S. 1963 "Census of Business" had employees in establishments greater than 19 employees in the nation, but not by state. For the United States, there was obtained the average number of employees per reporting unit in reporting units above 19 employees and this average was applied to the number of reporting units in each state above 19 employees. The overall method used (see beyond) brought about the result that the U. S. total super market waste is distributed among the states in proportion to their population of employees in reporting units with more than 19 employees rather than of employees in establishments with more than 19 employees.

A. OMISSIONS FOR DISCLOSURE

In the U. S. projections it has been possible to obtain a census figure for the number of employees in each 4-digit code used. This was not so in the individual states because there were a number of omissions for disclosure. These are cases where numbers are deleted from the tables in order to avoid disclosure of information on individual establishments. It is of course more likely to occur where the total number of establishments is small as in the states. The "County Business Patterns" gives information on the number of establishments in each of several employee size classes without any omissions. It is common practice to multiply the number of establishments in each employee class by some number lying within the class which represents the average employees per establishment in that class. The sum of these products will be an estimate of the total number of employees in all classes. This amounts to an integration of number of establishments against average employees per establishment over all size classes. A customary approximation is that the average number of employees per establishment in a class is given by the mid-point of the class boundaries. However, this in general is true only if the distribution of establishments by number of employees is uniform. The true distribution of establishments by number of employees approximates log-normal and, therefore, the average in each class is in general not at the mid-point of the class.

Consider the following definitions and relationships:

$$\text{Integration Point } i_c = \frac{n_c}{e_c}$$

where:

n_c = employees in class

e_c = establishments in class

i_c = integration point for that class, employees per establishment then:

$$N = \sum_{c=1}^{c=8} i_c e_c$$

where:

N = total employees in all (8 census) classes

Now define a term r_c, integration point factor, such that

$$n_c = \left[L_c + r_c \; (U_c - L_c)\right] e_c$$

or

$$i_c = L_c + r_c \; (U_c - L_c)$$

where:

L_c = lower class boundary, number of employees

U_c = upper class boundary, number of employees

This integration point factor is the fraction of the interboundary distance above the lower class boundary at which lies the integration point. In customary practice, the integration point factor is taken at 0.5, i.e. the integration point is the mid-point of class.

Now:

$$N = \sum_{1}^{8} \left[L_c + r_c \; (U_c - L_c)\right] \; e_c$$

and with the real distributions found, a value of r = 0.5 will not give the correct total number of employees. However, there is a particular value:

$$r_c = R, \text{ fraction}$$

which uniformly applied to all classes will produce the proper total number of employees, R being termed the overall integration point factor. This R applied to any individual class will in general not give correctly the total employees in that class, but when all the ficticious employees in class are summed, the total N will be correct.

The value of R depends upon a nature of the distribution and also upon the particular size classes in which the data appear. For the employee size classes of census data, and for the real distribution of establishments by employees characteristic of the U. S., the best value of R if the single one must be chosen, is found to be 0.37. However, there are some differences among codes and to take this into account the overall integration point factors for the 2-digit codes were computed (from the 1964 distributions and totals). It was assumed that the overall integration point factor for the U. S. 2-digit codes was applicable to the 4-digit state distributions and the number of employees for the omitted 4-digit codes in each state was computed by applying the national 2-digit overall integration factors.

However, a complication arose in this because of the scheduling of data availability. When this task was begun, the 1965 distributions were available but the 1965 U. S. summary employee totals had not yet become available. Accordingly, the 1964 integration point factors were applied against the 1965 distribution data with the idea of thus approximating the 1965 totals. There was nothing against which to check the 4-digit totals so computed since the 1965 summary data were not available. However, when the 1965 projections of the 4-digit codes for each state were summed over all 51 states, these totals were in many cases quite deviant from the corresponding (and available) 1964 employee totals. Rather than awaiting the publication of the 1965 summary data which would allow the whole process to be repeated on the complete 1965 data, an adjustment was made to bring the individual 4-digit state totals, as above computed, back to values which when summed over the 51 states would produce the correct 1964 total. This was done by applying to each state a single correction factor which was the correct 1964 employee total divided by the incorrect sum previously arrived at. The result is that the individual state figures in these omitted 4-digit codes represent the 1964 totals computed as if the 1965 distribution applied.

Another complication modifying the above general procedure involved the establishments with greater than 500 employees which constitute an upper open-end class. This was treated separately, which means that the summations previously described for eight classes, the general case, were actually computed over only seven classes, and to the seven-class total was added the special greater than 500 class now to be described. There is available for each 2-digit code the number of employees in establishments greater than 500 and the number of such establishments. These two produce an average employee per establishment in establishments greater than 500 in each code, for the U. S. applied also to the individual states and to the 4-digit codes and the number of employees in the greater than 500 establishments was computed in this way.

The figures for the non-projected codes for each state were produced as described in Section VIII and the employees for the codes having omissions for disclosure were produced as just perviously described, except that for a few 2-digit codes the computation was shortened by taking an overall integration point factor of 0.37 instead of computing an ingegration point factor for these few codes so treated.

B. RESULTS

The 51 state data are shown in Table XIX. The second through fifth columns show the state totals for the projected codes in the four categories previously used.

TABLE XIX

WASTE FOR DISPOSAL BY STATE

State	Projected				Non-Projected	Projected and Non-Projected					
	Manufacturing Codes	Manufacturing Codes Except Saw Mills	All Codes	All Codes Except Saw Mills	Non-Projected Manufacturing Codes	Manufacturing Codes	Manufacturing Codes Except Saw Mills	All Codes	All Codes Except Saw Mills	All Codes Per Capita of Total Population Kpyc	Kpye Manufacturing Except Saw Mills
Alabama	3,882	821	4,361	1,300	532	4,415	1,353	4,894	1,832	1.404	5.71
Alaska	124	12	142	30	27	151	40	169	58	.635	10.6
Arizona	572	145	847	421	136	708	282	984	558	.625	5.1
Arkansas	4,456	600	4,717	860	536	4,993	1,136	5,253	1,397	2.706	11.3
California	9,938	3,873	13,754	7,690	3,503	13,441	7,376	17,257	11,193	.938	5.8
Colorado	478	231	834	588	274	752	505	1,109	862	.569	6.0
Connecticut	981	918	2,970	2,907	986	1,967	1,904	3,956	3,893	1.398	4.7
Delaware	289	221	523	455	130	419	351	653	585	1.298	8.7
District of Columbia	95	95	922	922	188	283	283	1,110	1,110	1.385	13.2
Florida	1,906	1,128	3,264	2,486	901	2,808	2,030	4,166	3,388	.719	9.0
Georgia	4,718	1,472	5,269	2,023	656	5,375	2,129	5,926	2,680	1.350	6.1
Hawaii	111	111	190	190	80	191	191	270	270	.380	8.3
Idaho	2,025	128	2,111	214	76	2,102	205	2,188	290	3.157	6.9
Illinois	4,250	3,898	8,333	7,981	3,794	8,044	7,692	12,127	11,775	1.140	6.8
Indiana	2,198	1,800	3,327	2,930	1,443	3,641	3,244	4,771	4,373	.975	5.5
Iowa	869	727	1,356	1,214	493	1,362	1,220	1,849	1,707	.670	7.0
Kansas	437	389	861	813	243	680	632	1,104	1,056	.490	5.6
Kentucky	1,802	668	2,411	1,278	589	2,391	1,258	3,000	1,867	.945	7.3
Louisiana	3,234	772	3,750	1,288	325	3,559	1,097	4,075	1,613	1.145	9.0
Maine	1,223	454	1,435	665	1,001	2,225	1,455	2,436	1,667	2.471	15.4
Maryland	1,421	967	2,775	2,321	674	2,096	1,641	3,450	2,995	.976	6.6
Massachusetts	2,454	2,244	6,331	6,121	2,401	4,856	4,645	8,733	8,522	1.629	7.4
Michigan	3,684	2,633	6,591	5,541	2,136	5,821	4,770	8,728	7,674	1.049	5.1
Minnesota	1,426	977	1,974	1,525	649	2,075	1,626	2,623	2,174	.736	7.4
Mississippi	2,923	540	3,171	788	710	3,633	1,251	3,882	1,499	1.681	10.2
Missouri	1,974	1,207	2,799	2,002	1,572	3,543	2,779	4,371	3,574	.973	7.4
Montana	1,462	40	1,533	112	58	1,520	98	1,591	170	2.263	7.1
Nebraska	301	287	525	511	225	526	512	750	736	.514	8.5
Nevada	54	14	126	86	40	95	55	166	126	.382	8.1
New Hampshire	624	280	766	423	234	859	515	1,001	657	1.487	6.4
New Jersey	2,278	2,198	5,687	5,607	2,205	4,483	4,404	7,892	7,813	1.164	5.9
New Mexico	309	39	432	162	59	368	98	491	221	.485	7.3
New York	5,350	4,493	16,230	15,372	6,347	11,697	10,840	22,577	21,719	1.247	6.5
North Carolina	5,728	1,880	6,545	2,697	1,026	6,754	2,906	7,571	3,723	1.534	5.7
North Dakota	34	25	86	77	31	65	57	118	109	.181	9.6
Ohio	5,162	4,358	8,736	7,932	2,736	7,899	7,095	11,472	10,669	1.120	6.1
Oklahoma	699	378	1,105	784	232	931	610	1,337	1,016	.546	7.4
Oregon	9,858	398	10,082	622	370	10,228	769	10,452	992	5.393	7.0
Pennsylvania	5,587	4,053	10,910	9,377	3,698	9,285	7,751	14,609	13,075	1.261	5.9
Rhode Island	305	305	986	986	335	640	640	1,321	1,321	1.482	5.9
South Carolina	2,687	819	3,047	1,178	367	3,055	1,186	3,414	1,545	1.339	4.6
South Dakota	200	58	279	137	40	240	98	320	178	.467	8.2
Tennessee	3,306	1,613	4,215	2,523	1,192	4,499	2,806	5,408	3,716	1.404	8.7
Texas	3,908	1,792	6,494	4,378	1,394	5,302	3,186	7,889	5,773	.745	6.7
Utah	198	190	354	265	117	315	307	471	382	.474	6.4
Vermont	515	174	554	293	114	630	289	668	328	1.656	9.5
Virginia	4,592	1,230	5,546	2,183	803	5,396	2,033	6,349	2,987	1.436	7.1
Washington	5,041	683	5,516	1,157	491	5,532	1,174	6,007	1,648	2.021	6.3
West Virginia	1,814	556	2,040	782	267	2,081	823	2,308	1,050	1.272	7.5
Wisconsin	2,738	2,011	3,738	3,011	1,264	4,002	3,275	5,003	4,276	1.208	7.4
Wyoming	146	11	182	47	29	176	40	212	76	.643	10.1
U. S. Total	120,366	54,916	180,732	115,255	47,729	168,109	102,661	228,481	162,918	1.182	6.5

Among the projected codes the states with the highest waste for disposal for all manufacturing are those which are heavy in saw mills, California with 9,990 million pounds per year and Oregon with 9,860. When the saw mill waste is eliminated, the high states are, of course, those which are high in manufacturing other than saw mills, New York with 4,500, Ohio and Pennsylvania with 4,050, California with 3,930, and Illinois with 3,880. Among the four non-manufacturing codes, the largest contributors are demolition and super markets which to some extent follow the population, but the per capita demolition in California is quite low. Accordingly, for all projected codes (except saw mills) New York is the highest with 15,380 million pounds per year followed by Pennsylvania with 9,370, California with 7,740, Illinois with 7,970 and Ohio with 7,620.

The sixth column shows the waste for disposal from the non-projected codes and the next four columns show the corresponding totals in the four categories for projected plus non-projected codes. For manufacturing (except saw mills), when projected plus non-projected codes are included, the top five states are still the same as for the projected codes, but in slightly different ranking; New York with 10,840 million pounds per year, Pennsylvania with 7,750, Illinois with 7,690, California with 7,380 and Ohio with 7,100.

When the four non-manufacturing codes are included, the ranking is the same.

New York	21,720 million pounds per year
Pennsylvania	13,080 million pounds per year
Illinois	11,780 million pounds per year
California	11,200 million pounds per year
Ohio	10,670 million pounds per year

Overall, codes covered in the study, manufacturing and non-manufacturing, projected and non-projected, the two states heavy in saw mills enter into the top six.

New York	22,580 million pounds per year
California	17,260 million pounds per year
Pennsylvania	14,610 million pounds per year
Illinois	12,130 million pounds per year
Ohio	11,470 million pounds per year
Oregon	10,450 million pounds per year

The last column shows the manufacturing plus non-manufacturing code wastes in ratio to the total resident population (P) both urban and rural, in units of Kpyc, kilo pounds per year per capita. This is more easily discussed by reference to Figure 6 which illustrates the intensity of waste for disposal generation in units from which the effect of high total populations has been eliminated. The states with the highest per capita intensity of waste for disposal are those in which the saw mill industry is prominent and the overall population is relatively low, these being Oregon, Idaho, Arkansas, Maine, Montana and

1965 PER CAPITA WASTE FOR DISPOSAL, BY STATE

Figures are KPYC thousand pounds per year per capita

U. S. Average: 1.18

Figure 6

Washington, in that rank order. The per capita intensity of waste generation in Oregon is 4.6 times the national average of 1.18 Kpye. This national average figure of 1.18 Kpyc signifies that the per capita waste generation in the codes covered for the nation is 1,180 pounds per year, or 3.23 pounds per calendar day.

States in the next mapped category of 1.5 to less than 2 Kpyc are those in which lumbering or woodworking are prominent, or manufacturing is intense, or both. This category includes Mississippi, North Carolina in the first class, Massachusetts in the second, and Vermont probably in the third.

The next mapped class from 1 to 1.5 Kpyc includes most of the remaining states east of the Mississippi except Indiana, Kentucky and Florida. These last find themselves in the next lower mapped class which is typical in the middle tier of states.

Finally in the lowest class of 0 to 0.5 Kpyc are the few remaining Western states which are heavy neither in lumbering nor in manufacturing

The reader is reminded that the codes covered in Figure 6 are all manufacturing codes, except 29, Petroleum Refining, for which there is included only a small 4-digit code, 2952, Asphalt Roofing, plus the four non-manufacturing codes studied, Cotton Gins, Demolition, Stockyards, and Super Markets with twenty or more employees. From the data presented in the tables, the reader may construct for himself other per capita maps showing manufacturing alone, manufacturing except saw mills, etc.

C. EFFECT OF S.I.C. CODE PROFILES

The state-by-state data provide an opportunity to test a question which has been lurking beneath the surface of the present study. The concept of the study is that the λ mean Kpye's for different codes will not be the same and, therefore, the total Kpy is obtained by summing the products of the Kpye for each code times the number of employees in that code.

Consider a quantitative description of an economic region, nation, state, county, or otherwise which may be termed the "S.I.C. code profile". Consider that the fraction code employees divided by total employees is plotted for each code in the form of a bar graph arranged according to increasing S.I.C. code number, taken here as 2-digit codes. Then the outline of this bar graph will be the S.I.C. code profile and will be a characteristic of the region considered. Taking only the manufacturing codes it may be visualized that the S.I.C. code profile for Washington and Oregon will be high at code 24 representing the lumber industry, whereas in other states not heavy in lumbering, for example Kansas and Nevada, the level of the profile at code 24 will be low compared to the remainder of the codes.

Now for each bar on these profiles there is associated a Kpye value corresponding to the code, and in this study taken as the same in all states for a given code.

Consider the following relations:

P = total employees in state

p_i = fraction of total employees in code i

K_i = Kpye for code i

Then:

$$\sum_i p_i P K_i = \text{Kpy waste in state}$$

$$\sum_i p_i P = \text{employees in state}$$

$$\frac{\sum_i p_i P K_i}{\sum_i p_i P} = \text{overall Kpye for state} = \frac{\sum_i p_i K_i}{\sum_i p_i}$$

But:

$$\sum_i p_i = 1.0$$

$$\therefore \; = \text{overall Kpye for state} = \sum_i p_i K_i$$

If the S.I.C. code profiles for each state were identical then the overall Kpye for each state would be the same, and therefore, one could estimate the Kpy of waste for disposal by using this overall Kpye multiplied by the number of employees in each state, without going through the code-by-code breakdown.

It is clear from the actual numbers that if saw mills are included, one cannot hope for a common Kpye over all 50 states since several of the states are heavy in saw mills and saw mills, having a very high Kpye, these states certainly would have a high overall Kpye. Thus, the meaningful question about to be proposed, and answered, applies to the entity/manufacturing codes, except saw mills, 242. The question is: "Are there enough differences among S.I.C. code profiles for manufacturing, except saw mills, from state to state to make it necessary to proceed with estimates via the code-by-code process, or do the S.I.C. code profiles differ from each other by an amount small enough to allow the successful application of such an approximation?"

This question can be answered. The overall Kpye's for the 51 states for manufacturing, except saw mills, are shown in the last column of Table XIX. The answer is "Yes", there is a considerable range in the

Kpye's presented from 4.6 to 15.4. These numbers are log-normally distributed with a median of 7.4 Kpye and a σ ratio of 1.30. About 35 percent of the states have Kpye's less than the national average of 6.50, but these states are not clustered in any particular geographical region.

Therefore, the conclusion is that there are enough differences in S.I.C. code profiles from state to state to make necessary the use of the S.I.C. code route in projecting state waste for disposal

SECTION X

WASTE FOR DISPOSAL BY COUNTY IN CONNECTICUT

The methods used to project waste for disposal for the individual states can be used, with still further modifications and approximations, to project the waste in individual counties. The state of Connecticut, comprising eight counties was selected for study because there was available a study[14] which attempted to project economic production to future years. The objective of the present chapter is a projection of the waste for disposal by Connecticut counties and the projection of these to 1975. The method used assumes that the disposition - disposal pattern for each county is the same as that for the nation. This assumption, of course, becomes less tenable as the size of the region being projected is decreased. The projected and non-projected codes were not handled separately, but were combined by generating a combined Kpye from Table I in the summary, Section II. The 4-digit sub-codes, having Kpye's differing from the residual sub-codes in any 2-digit code were treated separately, however. The resulting Kpye assignments are shown in Table XX.

The reader is reminded that these assigned Kpye values represent λ mean Kpye's developed from individual establishment Kpye's which have a scatter. By the general method used, the λ mean Kpye is that which will give the correct total when applied against each establishment in a large number of establishments such as a national population of establishments in a code. The mathematical mechanism, which makes this possible, requires not only that the population of establishments will rather closely approximate log normal, but also that the distribution will extend to percentile levels encompassing the entire population. i.e. to the 99th percentile if there are 100 in the population, to the 99.9 percentile if there are 1,000 in the population, etc. It has also been shown for the establishments actually interviewed, even though their number may be quite small (6 to 30 establishments), that the distribution for this interviewed sample is not too far from log normal. It only extends, of course, to a percentile corresponding to the sample size, e.g. to the 86th percentile for a sample of 6. The λ mean Kpye for a population of about the same size as such a sample would be lower than the λ mean Kpye assigned for populations of 1,000 or so which are common population sizes in the states and the nation. Thus, if one had 100 samples of 6 establishments each, for most of these 100 samples, the total Kpy would be less than that computed by application of the assigned Kpye. For a few of these 100 samples, the actual total would be much greater than that obtained from the assigned Kpye, and to such an extent that the total Kpy (for the 600 establishments taken together) would be found to be correct.

Now recognize that in the Connecticut counties one is dealing with code groups which may contain quite small numbers of establishments. The conclusion is, with the reservation stated in the next paragraph, that most of these will tend to be over-estimated in Kpy.

TABLE XX

KPYE ASSIGNMENTS

PROJECTED PLUS NON-PROJECTED CODES

FOR CONNECTICUT STUDY

Code	Description	Kpye
19	Ordinance	2.93
20	Residual Foods	10.8
2011, 2013	Meats	7.3
2015	Poultry	0
2043, 2044	(None in Connecticut)	
2051	Bakeries	5.96
2095, 2061	(None in Connecticut)	
21	Tobacco	10.8
22	Textiles	2.52
23	Apparel	0.562
242	Saw Mills, General	277
2431	Mill Work	8.65
2433, 249	Fre-fab and n.e.c.	87
244	Containers	85
25	Wooden Furniture	11.5
2514, 15, 22, 59	Metal Furniture	7.13
26	Paper	17.5
27	Printing and Publishing	16.5
28	Residual Chemicals	12.6
281	Basic Chemicals	0.47
285	Paints	5.3
295 less 2951	Asphalt Roofing	80.5
30	Rubber and Plastic	11.9
31	Leather	19.5
32	Stone, Clay, (Residual Glass-32)	5.01
322, 323	Glass	5.28
33	Primary Metals	3.04
34	Fabricated Metals	2.93
3411	(None in Connecticut)	
35	Machinery	2.93
36	Machinery, Electrical	2.08
37	Transportation Equipment	2.14
38	Instruments	5.36
39	Miscellaneous Manufacturing	4.59
0712	(No Cotton Gins in Connecticut)	
0719	Auction Stock Yards	None
1795	Demolition	By Total Population
541	Super Markets >19	35.7

However, completely over-riding this general tendency, which would be true if one were dealing with 100 counties, since we are dealing with only eight counties, it is quite possible that the relatively small numbers of actual establishments existing in one of these counties may find themselves to be from the high part of the Kpye distribution curve, or from the low part. This will be true with a certain number of samples, even out of 100 samples, but we do not have the information to determine whether it may have occurred in one or more of the eight counties being studied. To place this reservation in terms of a more faimilar concept, applying the Kpye statistical method, to entities as small as counties, is like utilizing the actuarial method of estimating how many people will die in a given year out of the total population, to predict whether certain particular persons will die. This study does not attempt to quantify the probability that this has happened. It simply points out this defect as a reservation.

For most codes, the mpy's were generated via the Kpye figure, but because of the small size of the regions considered, there were many more omissions for disclosure to be filled in by the method previously described. In the application of this method the single overall integration point factor of 1.37 was used rather than using those characteristic of the 2-digit codes. The employee data used was from the 1965 "County Business Patterns".[15]

Certain codes received special handling as follows. For demolition the figure of 1,579 million pounds per year found for Connecticut in the 51 state study was apportioned among the eight counties according to total population per county. Urban population per county might have been a better base, although probably differing not by much from total population, but the best available basis for projection to 1975 was by total population and therefore, total population was used.

In the U. S. and 51 state studies, saw mills was projected using production in board feet, but since there are only 161 employees in Connecticut in Code 242, the projection was based on the Kpye from Table I.

Super markets were handled in the same way as described for the 51 state study, with the reservations applicable as noted. However, the method was to apportion the 409.5 million pounds per year waste for disposal for Connecticut super markets from the state-by-state study among the eight counties by the employee proportions.

There are no terminal stockyards in Connecticut and this study did not determine whether there are any auction markets. Auction markets occur in Code 0719 and the state has only four reporting units in the 3-digit Code 071. Two of these are in the 20 to 49 and the 250 to 499 employment size classes and, therefore, not likely to be auction markets. The 51 state study assigned 0.6 million pounds per year to stockyard wastes for Connecticut and since this is so small, it will be considered zero in the Connecticut county-by-county study.

A. PROJECTION TO 1975

In view of the paucity of basic data available, the projection of waste quantity by county to 1975 requires considerable manipulation. Physical production growth factors were not available for Connecticut counties and, therefore, the only recourse was to use employee projections which were available. Elsewhere in this study it was assumed that waste/product ratios will change with time much less than waste/employee ratios because of the expected changes in productivity. The procedure used here involves a ficticious constancy of productivity over the prediction period. This is known to be incorrect, but on the other hand, the changes in productivity between different counties in the same codes will probably not be great and by that device the relative changes in county waste for disposal will be the result of the prediction. This also contains an approximation, however, in that productivity changes will probably be different for different codes and therefore, the overall productivity change in a county will be a function of its S.I.C. Code profile, which presumably is different from county to county among the eight counties. This can not be dealt with using available data.

To outline, there are data available which can produce for the entire state and for each manufacturing code the difference in employment between 1965 and 1975. Also, there are available data which can produce the difference between 1965 and 1975 employment for all manufacturing codes in each county. The sum of these differences is 89,151 employees. The method provides figures such that the total of all manufacturing codes for each county will equal the increase for each county, and the total of all counties in each manufacturing code will equal the difference in that manufacturing code. Stated in other words, the participation of each manufacturing code in a county is proportional to the participation of that code in the entire state; and the participation of each county within a manufacturing code is proportional to the participation of that county (for all codes) within the state. In contrast to this assumption of uniformity, a large percentage of the state's growth in a particular code, might be in some single county and that county might indeed be one of those whose total growth in all codes has been relatively small compared to the others. However, there is absolutely no way to obtain these individual characteristics from the available data and the present method has the virtue of giving the correct totals by county and by code.

The generation of the 1965 to 1975 employment differences by 2-digit code (some of them grouped) comes relatively simply from the difference between the 1975 figures and the 1965 figures.[14]

The method used computed the participation of Fairfield County, for example, in the state's total 1965 to 1975 increase in industrial waste. Thus, by the assumptions of the method, it will have 7.827 percent of the state's increase in each 2-digit code.

In this way, the employee change, 1965 to 1975, is computed for each county and each code or code group; some of the changes being negative. The employee change multiplied by the corresponding Kpye produces the waste quantity change over 1965, which when added to that figure from the 1965 computation produces the 1975 prediction.

For the increase 1965 to 1975, it was necessary to regroup some of the Kpye's because of the grouping of the basic data. This was done by developing a group Kpye which is the overall Kpye for the codes grouped for the entire state. Code groups so handled were 19 + 39, 21 + 29, 24 + 25. In addition, it was necessary to group some 4-digit codes to correspond with the 2-digit codes of the 1975 prediction, these being 28 + 32.

It should be recognized that each time there is a regrouping of codes and a computation of an overall Kpye for the group, there is involved the fiction that the make-up of the grouped code in the sub-codes grouped is the same in the entity to which it is to be applied as in the entity from which the grouped Kpye figure was computed. In this case, it means for example that the computations for the individual counties for the grouped codes 19 + 39 are done on the premise that the relative proportions of 19 + 39 employees in each county are the same as in the state. If it should happen that the codes grouped have identical Kpye's, then while the premise remains, the final result will be correct. However, in most cases the grouped codes do not have identical Kpye's.

For the 1965 to 1975 increase, the non-manufacturing codes received special handling as follows. There are no cotton gins in Connecticut in 1965 and the waste from whatever stockyard auction markets there may be was taken as zero. It was assumed that there would be no change to 1975.

For super markets, the increase was taken as proportional to the estimated increase of total population in each county at a rate of 0.1455 Kpyc (thousand pounds per year per capita) which corresponds to the 1965 waste total of 409.5 million pounds per year.

For demolition, the 51 state study had computed a 1975 quantity of 1,894 million pounds per year for the state which with an estimated 1975 total population of 3,222,452 is 0.5878/1,000 million pounds per year per capita of total population.

B. RESULTS

The results are presented in Table XXI.

In 1965 Hartford County makes the largest contribution with 1,047 million pounds per year followed closely by New Haven and Fairfield. This ranking is maintained in 1975. The highest percentage growth in the period, however, is for Tolland with 44 percent followed by Middlesex with 40 percent. Fairfield and Windham Counties have the smallest percentage growth.

The next to the last column indicates the overall Kpye for the manufacturing codes, 1965. Note that this is different from the Kpyc intensity figure discussed in the state-by-state portion of this report, Section IX. The ratio presented in Table XXI is a Kpye, and since Connecticut has very few saw mills, is most comparable with the corresponding Kpye figure for manufacturing codes (except saw mills) in Table I which has a national average of 6.50. The overall Connecticut average for this figure is 4.65. Middlesex County has the highest Kpye with 6.76 and Hartford County the lowest with 3.87.

TABLE XXI

WASTE FOR DISPOSAL

CONNECTICUT (BY COUNTY)

1965 and 1976

Counties	Mfg. Codes 1965	Mfg. and Non-Mfg. Codes 1965	Mfg. Codes 1976	Mfg. and Non-Mfg. Codes 1976	Kpye Mfg. Codes 1965	Percentage Growth 1965-1967 All Codes
Fairfield	485	1,010	516	1,098	4.61	8.6
Hartford	502	1,047	690	1,342	3.87	28.1
Litchfield	76	169	77	189	4.62	12.0
Middlesex	80	156	104	218	6.76	39.8
New Haven	538	1,035	656	1,271	5.62	22.8
New London	142	285	162	354	3.92	24.0
Tolland	16	72	34	103	5.06	43.8
Windham	81	138	84	153	5.40	10.8
STATE TOTAL	1,920	3,912	2,321	4,728	4.65	20.8

SECTION XI

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SECTION XII

APPENDIX A

INDUSTRIAL CHECK LIST

Establishment Data

Type of Establishment ________________

Products ________________

S.I.C. Code Classification ________________

Other S.I.C. Codes Produced ________________

Plant Capacity (product quantity, specify units) ________________

Number of Employees ________ total ________ production

Seasonality (of production plant)

Operating Season ________________

Hours/Day ________________

Days Per Week ________________

Weeks Per Year ________________

Changes in production pattern which would influence employee number per unit output, waste production or disposal during next ten years? (automation, process changes, product requirements, waste utilization etc.)

Industrial solid wastes will be generated by the following sources and must be researched individually (unless lumped together for disposal):

1. Office waste and general plant rubbish (lunch containers, paper, etc.)

2. Shipping waste, in and out (pallets, boxes, containers)

3. Process wastes

4. Solid waste collected by air cleaning devices

5. Solid waste collected by liquid cleaning devices

For each of the above waste streams, obtain:

Character

Description ______________________

% Moisture ______________________

Type of organic ______________________

Bulk density ______________________

Other ______________________

Present Disposition

A. Sold

How much of it ______________________

For what use ______________________

Price ______________________

F.O.B. ______________________

Quantity per day ______________________

Future ______________________

B. Municipal Disposal

Quantity per day ______________________

Collected by city ______________________

Hauled by self ______________________

How far ______________________

How many loads/day ______________________

Future ______________________

C. Contract Disposal

Quantity per day ______________________

How transported ______________________

C. Contract Disposal (cont.)

Ultimate disposal ______________________
(city or private dump or incinerator)

Future ______________________

D. Self Disposal

Method ______________________

If incinerator:

Make ______________________

Age ______________________

Size ______________________

Crew ______________________

Operating hours ______________________

Vehicle load ______________________

Cost (installed) ______________________

Satisfaction ______________________

Future ______________________

If open dumping, land fill or open burning:

Quantity ______________________

How far ______________________

Vehicle loads ______________________

Crew ______________________

Cost ______________________

Air Pollution
Requirements ______________________

E. Future plans

Hypothetical incinerator practice

Hours/Day ______________

Days/Week ______________

F. Identify and obtain quantity, disposition and future disposition of liquid wastes which are disposed of by means other than sewers (i.e. incinerated, land fill, etc.)

SECTION XII

APPENDIX B

MATHEMATICAL HANDLING OF WASTE QUANTITY DATA

In the earlier proprietary projects of Combustion Engineering, it had been taken as a hypothesis that the waste/employee ratio in a particular homogeneous group of industries would show little dispersion. This hypothesis is based on the premise that, with a similar type of operation, a single employee handles a certain amount of the physical material of the industry corresponding to the productivity in that industry, expressed as a product/employee or raw material/employee ratio. Furthermore, the fraction of waste generated in handling this material would be relatively constant within establishments in the industry and relatively independent of establishment size. For example, the fraction of the raw material, wood waste in manufacturing a chair would be the same from establishment to establishment allowing some fluctuations for different degrees of ingenuity in design and technique. The primary reasons for selecting waste/employee ratio as a means of projection rather than waste/product ratio were two-fold. First, it is easier to obtain employee size data for an establishment and for groups of establishments than it is to obtain product size data. Secondly, a desired result in the earlier projects was a prediction of the distribution of waste generating establishments by the amount of waste generated. Data are available on the distribution of establishments by employee size, which when applied against a waste/employee ratio, could generate this distribution. This distribution by size is not of interest in the present study, but the availability of number of employees data is much greater than the availability of units of production data and the original form therefore is preferable also for this study.

Probably a greater constancy can be expected for the ratio of waste/production employees than for waste/total employees since it is largely the activities of the production workers that generate the waste. However, data are not available in the desired form on number of production employees whereas the number of total employees is quite generally available.

As the number of data points in each industry code was built up through successive studies, including the present study, it became evident that the waste/employee ratio even for a technologically homogeneous group was not constant from establishment to establishment but had a dispersion. A technologically homogeneous group is one in which the establishments carried out almost precisely the same operations on the raw material, so as presumably to generate the same waste/product ratio. An example might be saw mills, in which precisely the same operations are carried on from mill to mill.

A technologically heterogeneous group is one in which the operations in the establishments within the group are quite different and thus may be expected to have different waste/product ratios. The food code, 20, is an example of a heterogeneous group including such things as rice milling, ice cream manufacture and pickle manufacture. The observed dispersion in waste/employee ratios may arise from a number of component dispersions including dispersions in productivity, dispersions in hours per year per employee, dispersions in waste/product ratio attributable to differences in manufacturing techniques and efficiencies, to errors in estimates of waste stream quantities, and to omission of certain components of the total waste stream from establishment to establishment.

While dispersion in productivity may contribute to the observed dispersion in waste/employee ratio, it probably is not the sole dispersion entering, because the dispersion in waste/employee ratio is considerably greater than would be expected for a dispersion in productivity. An opportunity was given to compare these dispersions in the wooden box industry and it was shown that the dispersion in waste/employee ratio is substantially greater than the dispersion in productivity.

Whatever the cause for the dispersion may be, it is an observed fact that among the 24 codes studied, the sample distribution of waste/employee ratios is log-normal in every code but one and one sub-code code of another. This is not at all surprising. Indeed, based on extensive experience with economic data of all types it would be quite surprising if these dispersions were not log-normal. The log-normal distribution has been found to describe a wide variety of social and economic statistics including costs of pipelines, water treatment plants, dams, costs of water treatment, sanitary land fill, pipelining of water, distribution of manufacturing establishments by employee size, of cities by population size, of water systems by water production, and many, many others.

Other workers have also found wide applicability for log-normal distribution, citing income, bank deposits, distributions of wealth, distributions of population, commodity prices and price changes, size or organisms, industrial statistics, production throughputs, human measurement, and the distribution of word frequencies.[16]

The log-normal distribution is one in which not the numbers themselves but the logs of the number are normally distributed. Such a distribution will plot as a straight line on log-probability paper, on which there is plotted the cumulative percentage of incidences having parameter values greater than (or less than) indicated on the log scale. With a small sample it is not to be expected that the points will lie precisely on the log-normal straight line since the sample is but a random selection of the universe or population of data points. However, it has invariably been found that as the number of points in the sample is increased, the broken curve passing through each plotted point more closely approximates a straight line and extends as such to higher and lower percentile values as extrapolated from the original sample. Figure 7 gives examples of one of the best sample distributions and one of the worst that were considered to be log-normal in this study. Also shown **is** another set of 95 points expressing the dispersion of a different set of economic data but included to show what happens when a sample size is

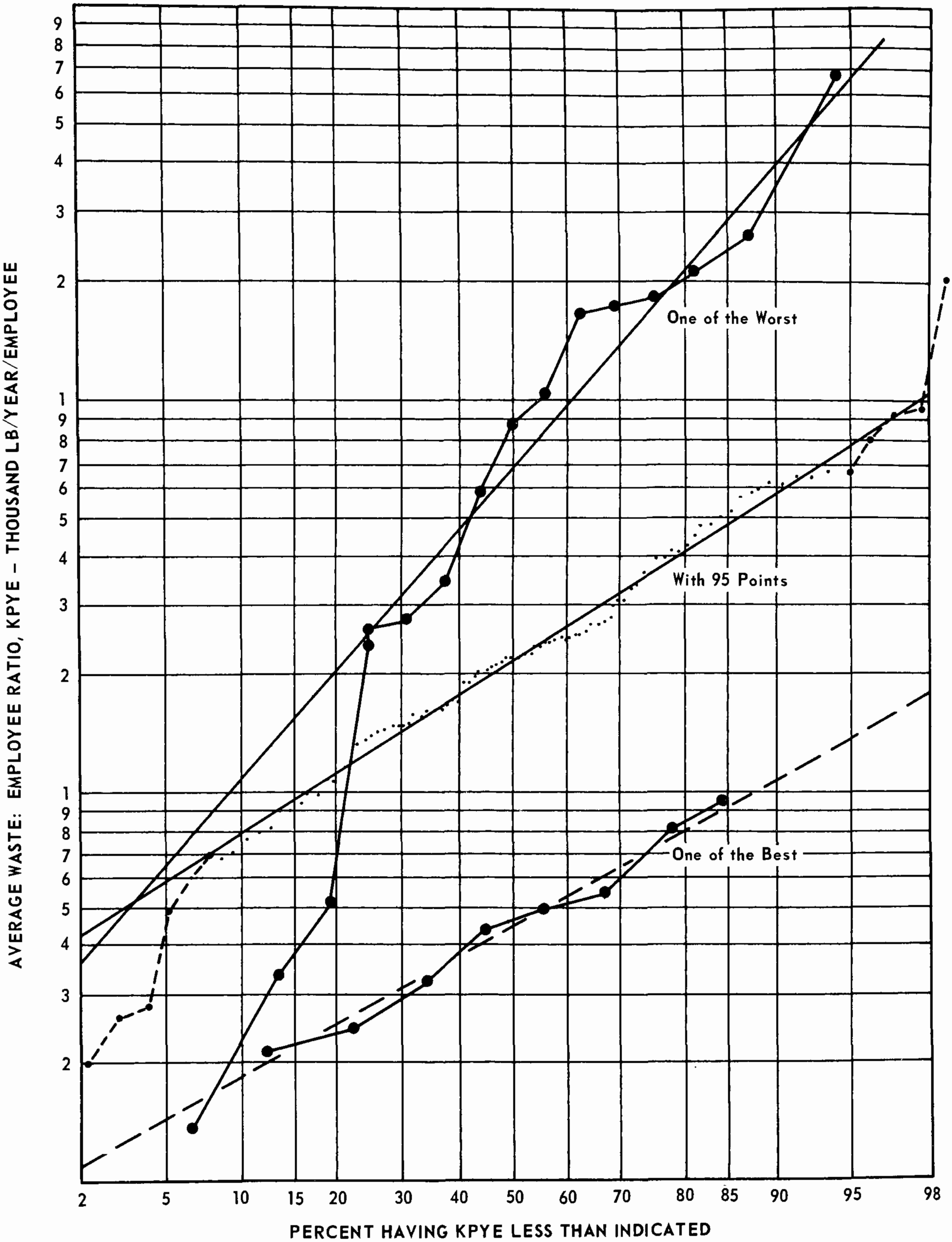
AVERAGE WASTE: EMPLOYEE RATIO, KPYE - THOUSAND LB/YEAR/EMPLOYEE
PERCENT HAVING KPYE LESS THAN INDICATED
One of the Worst
With 95 Points
One of the Best
2 5 10 15 20 30 40 50 60 70 80 85 90 95 98

Figure 7

increased to as much as 95. (The points happen to represent the distribution of deviations from a regression line expressing the relation between unit cost of sanitary land fill and annual tons.)

What this means is that the samples, with which we are dealing, appear to come from populations of random variables, here random waste/employee ratios, such that the total population of these random rations has a predictable statistical distribution. Why this should be so, and particularly why the distribution should be log-normal rather than some other type of uniform distribution, is a very intriguing question but is not within the scope of this project. The demonstratable empirical fact is that the distribution is indeed log-normal in practically all cases. Therefore, it is possible to achieve some useful predictions, together with confidence limits thereon, from the relative small samples available. The procedure is described below.

The discrete sample distribution plotted on log probability paper is taken as approximating the distribution of the entire population of waste/employee ratios for establishments in the S.I.C. codes. A straight line, the log-normal line, is drawn that best fits the points. The sample points approximate this line and the axiom is that the real population points will even more closely approximate this line. Accordingly, the median of the line is taken as the median of the population and the standard deviation of the line as the standard deviation of the population, of course in log units. The median is the middle logarithm in a large number of logarithms normally distributed, and the absolute value of the median, that is the anti-log of the median is also the median among all the absolute values of the corresponding points, i.e. among all the anti-logs of the logarithms. If the logarithms are indeed normally distributed the average of the logarithms will be equal to the median log, since this is characteristic of any normal distribution.

However, the average of the absolute values, that is of the anti-logs, will not be equal to the anti-log of the median or to the anti-log of the mean log. It is easily proved qualitatively that whereas the summation of all the logs in the population is obtained by taking the mean or median log and multiplying it by the number in the population, the summation of all the anti-logs is not obtained by multiplying the number in the population by the anti-log of the mean log or the anti-log of the median log. The average of the anti-log, that is of the absolute values, will be greater than the anti-log of, that is the absolute value of, the mean log. Stated in the terms in which it is actually used, this is the number (for example, the average waste/employee ratio), such that when multiplied by the number in the total population (the total number of establishments in the S.I.C. codes) is the summation of the total population (total waste per employee).

The average of the anti-logs, i.e. the average waste/employee ratio has a ratio to the median of the distribution which is a function of the standard deviation in log units, and of the number in the total population. This ratio between the arithmetic average and the median of a log-normal distribution is termed the lambda factor, symbol λ. The lambda factor allows one to compute the arithmetic average from the median if the population is log-normally distributed.

An example of how the λ factor is obtained from the data is presented below. Table XXII shows the data obtained from S.I.C. code 23; nine (9) interviews resulted in value of Kpye ranging from .12 to 2.39. First a regression line was fitted to the following function:

$$\log(10\ \mathrm{Kpye}) = A + B(\mathrm{employees})$$

to determine if log(10 Kpye) was a function of size of establishment. The correlation coefficient, R, equals .08438, and indicates that log(10 Kpye) was not a significant function of establishment size.

Next the data was plotted on probability paper as shown in Figure 8 to indicate that the distribution is log-normal.

TABLE XXII

ARRAY OF KPYE DATA

CODE 23 - APPAREL

Int. No.	Number of Employees	Waste/Employee Ratio Kpye
23-1	15	.705
23-2	14	2.390
23-3	530	1.510
23-4	8	.251
23-5	500	.264
23-6	175	.120
23-7	35	.350
23-8	50	.388
23-9	170	.910

LOG NORMAL DISTRIBUTION
OF SOLID WASTE PER EMPLOYEE RATIOS
FOR APPAREL (S.I.C. CODE 23)

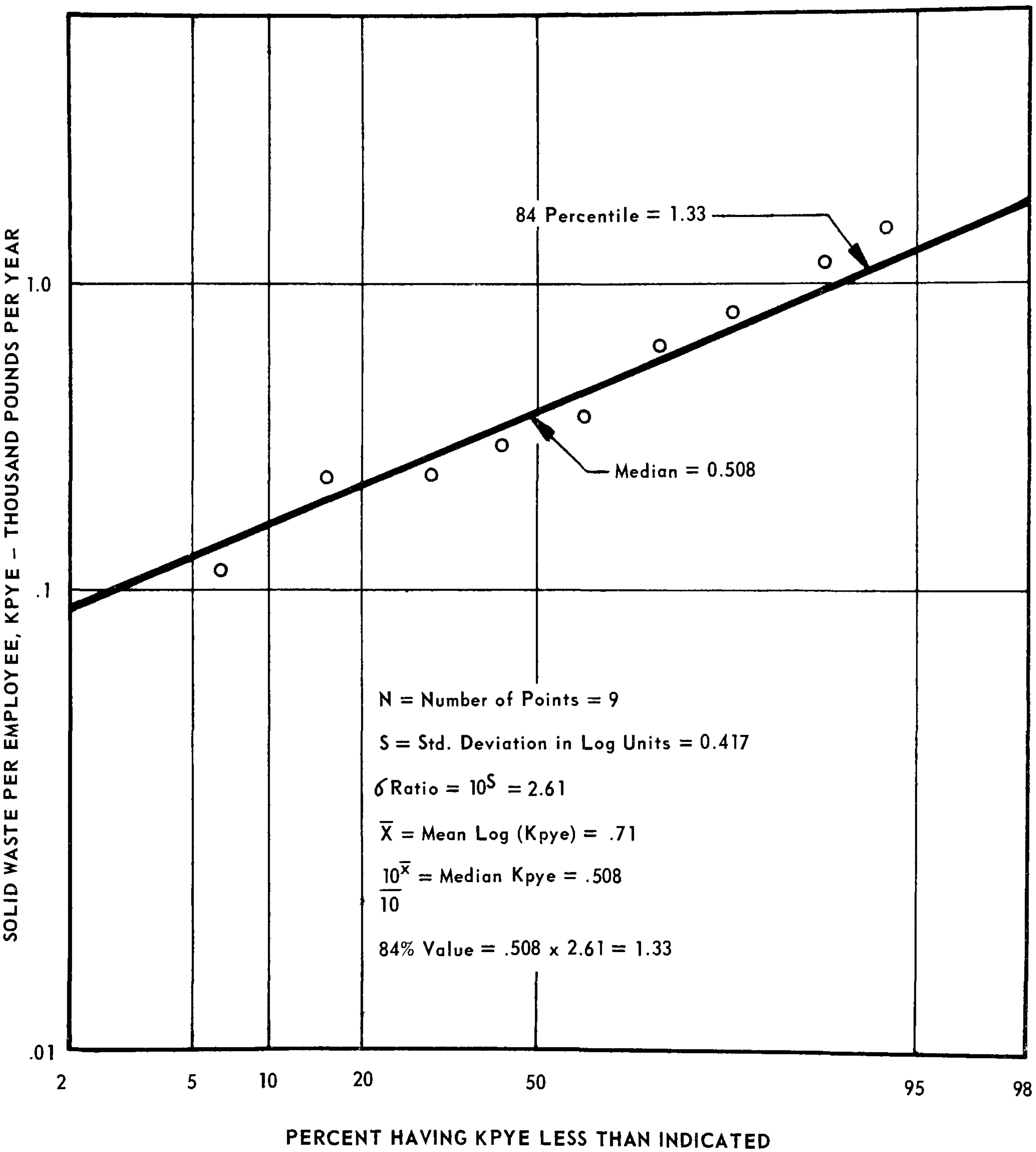

Figure 8

The lambda factor is then calculated as follows:

λ = ratio of average of anti-logs to median of the log-normal distribution with σ ratio and number in universe given, i.e. total number of establishments in S.I.C. Code 23.

ln = logarithm to base e

k = ln σ, standard deviation in ln units

Let σ = σ ratio

n = number in universe, i.e. the number of establishments in total population

P(z) = area under standard normal curve from zero to z. This table can be identified by:

z = 0	P(z) = 0
z = 1.0	P(z) = .3413
z = 2.0	P(z) = .4772
z = 3.9	P(z) = .5000

where:

$$z = \frac{\ln x - \overline{\ln x}}{k}$$

2 P(z) is the probability that z will be between $\overline{\ln x} \pm k$

$P^{-1}(\mu)$ signifies the z value such that P(z) = μ, e.g. P^{-1} (0.4772) = 2.0

$$z_2 = P^{-1}\left(\frac{n}{n+1} - 0.5\right) \quad = \text{the z where P is } \left(\frac{n}{n+1} - 0.5\right)$$

$$z_1 = -z_2$$

N(z) = P(z) + 0.5, for z > 0

or

0.5 - P(z), for z < 0

Then:

$$\lambda_{\sigma,n} = e^{\frac{k^2}{2}} \left[\frac{\int_{z_1-k}^{z_2-k} N(z)}{\frac{n-1}{n+1}} \right]$$

As $n \to \infty$

$$\lambda_{\sigma,n} \to \left[e^{\frac{k^2}{2}} \right]$$

The second term on the right hand side is a significant correction factor if n is less than a very large number; in our case, the number of establishments. For example, values of λ are presented below for two σ ratios.

n	λ for σ ratio = 2	λ for σ ratio = 3.5
10	1.119	1.42
100	1.228	1.92
1,000	1.262	2.122
10,000	1.270	2.190

If you go through the above you will find:

$$\lambda 2.61,\ 26{,}000 \text{ establishments} = 1.56$$

Computation of Kpye mean for Code 23:

$$\text{median} = 0.508$$

$$\sigma 2.61,\ 26{,}000 = 1.56$$

$$\text{Kpye mean} = 0.508 \times 1.56 - .792$$

The preceding statement requires that the λ factor itself be precisely known, that is, without dispersion. However, since the λ factor is a function of the standard deviation and the standard deviation of the population itself has a confidence interval, this means that the λ factor also has a unique confidence iterval. When this dispersion of the λ factor is taken into account, it produces a confidence interval upon the arithmetical mean which is greater than the one used in this study. Quantification of this effect awaits completion of the theoretical studies mentioned.

This development rests on the observed empirical fact that samples from populations of economic data, and specifically from waste/product and waste/employee populations, tend to approximate a log-normal distribution and that the entire population of such data closely approximate a log-normal distribution and that the greater the number in the sample the more closely the sample distribution approximates a log-normal distribution.

In the very few cases studied in this project where the distribution was not log-normal (and also not normal incidentally), the standard conventional statistical procedures were applied on the arithmetic values. It is known how to proceed from the median to the estimated total of the population when the distribution is normal, and the method outlined herein provides the means for proceeding from the median to the estimated arithmetic total of the population when the distribution is log-normal. However, the means for accomplishing this when the distribution is neither normal nor log-normal are not yet available to this study and the number of incidences of such requirements are so small as to not warrant their further exploration. Therefore, in these two the data were handled in the conventional manner as if they were arithmetically normally distributed in which case the arithmetic mean is the best estimate of the population mean.

SECTION XII

APPENDIX C

THE LOG-NORMALITY OF THE MULTI-CODE SAMPLE

It has been stated, as an empirical observation, that small samples from populations of waste/employee ratios tend to approximate a log-normal distribution, that the greater the number in the sample the more closely the sample distribution approximates log-normal, and that by extension the entire population of such data closely approximates a log-normal distribution. Figure 7 shows two of the sets of samples of waste/employee ratios from two different S.I.C. codes, one showing a high degree of approximation to log-normal and the other one of those most deviant from log-normal which still was used as log-normal in the projections. Also shown on Figure 7 is a set of different economic data comprising 95 points to show how large samples even more closely approximate log normality.

It would be highly desirable to demonstrate with actual waste/employee data that as the size of the sample in a given code is increased the distribution of the sample more closely approximates a log-normal distribution. Unfortunately, it is not warranted to collect additional waste/employee ratios by interview in a single code solely for this demonstration. However, there are available some scores of waste/employee ratios for different codes and it is possible, by statistical reasoning to be described, to generate from these a set of data points which do have a common distribution.

The distributions for the two codes on Figure 7 have different means and different standard deviations. In each case, the logs of the numbers are normally distributed but the means and standard deviations, that is the two parameters which determine the position and slope of the line, are different.

It is possible to so "reduce" the value of each data point so as to bring these means and standard deviations into coincidence. The procedure is that used in developing the standard deviate table, the z table, familiar to statisticians.

Let:

$$j_1, j_2, j_3 \text{ ---- } j_{n_j}$$

be the logs of the individual values, n_j in number, for one set and:

$$k_1, k_2, k_3 \text{ ---- } k_{n_k}$$

n_k in number, those for the second set. These sets have means $\bar{j}$ and $\bar{k}$ and standard deviations s' (j) and s' (k) and approximate straight lines on normal probability paper with mean $\bar{j}$ and standard deviation s' (j) and $\bar{k}$ and s' (k), respectively.

Now form new sets of values as:

$$(j_1-\bar{j}),\ (j_2-\bar{j}),\ ---,\ (j_{n_j}-\bar{j}),\ \text{and}\ (k_1-\bar{k}),\ ---\ \text{etc.}$$

These new sets will have the same means, namely zero, and will be distributed in the same way as the original values were, namely approximating normal with standard deviation of s' (j) and s' (k). The points will be scattered around the straight line in the same manner as the original points, and the curves will look like the original curves displaced downward to have means of zero (1.0 on the log scale of Figure 9). However, they will have different slopes.

To reduce the slopes to a common value form new sets:

$$\frac{(j_1-\bar{j})}{(k'_{(j)}},\ \frac{(j_2-\bar{j})}{(s'_{(j)}},\ ---\ \frac{(k_1-\bar{k})}{(s'_{(k)}}\ \frac{(k_2-\bar{k})}{(s'_{(k)}},\ ----$$

Each of these new values represents the number of standard deviations by which the value differs from the mean. When the distribution of these is plotted they will also look like the original sets but will now have not only the same means but also the same standard deviations, actually 1.0. Two such "reduced" distributions with means of zero and standard deviations of 1.0 are shown in Figure 9 drawn from the Kpye's for two actual codes studied.

These two sets of points, instead of being samples from two separate populations, i.e. two separate S.I.C. codes, are now samples from populations each of which has a mean of zero and a standard deviation of 1.0. In other words, they are samples from a single population having a mean of zero and a standard deviation of 1.0. They are thus two separate samples each having their own individual dispersions from the same population. If in conventional sampling work we have two samples of six each from the same population, we may equally well take them as one sample of twelve from that population. The sample of twelve will give a better estimate of the characteristics of the population than will either sample of six. By this reduction process, therefore, we have utilized the individual code data which in its original form could not be combined to produce a single sample which has the characteristics of the dispersion typically found in S.I.C. codes. In other words, the numbers we now have are such as would be obtained by taking a sample of 12 from a single code. Therefore, they should themselves have a distribution which, if our axiom is correct, should more closely approximate the ascribed distribution of the population than do the samples from the individual codes themselves. Such a manipulation has actually been performed on the two sets of data in Figure 9 and the result, the distribution of all points in the two codes, is shown as the curve labelled "combined Z value". It is seen that the line representing these

Z VALUE DISTRIBUTION PLOT

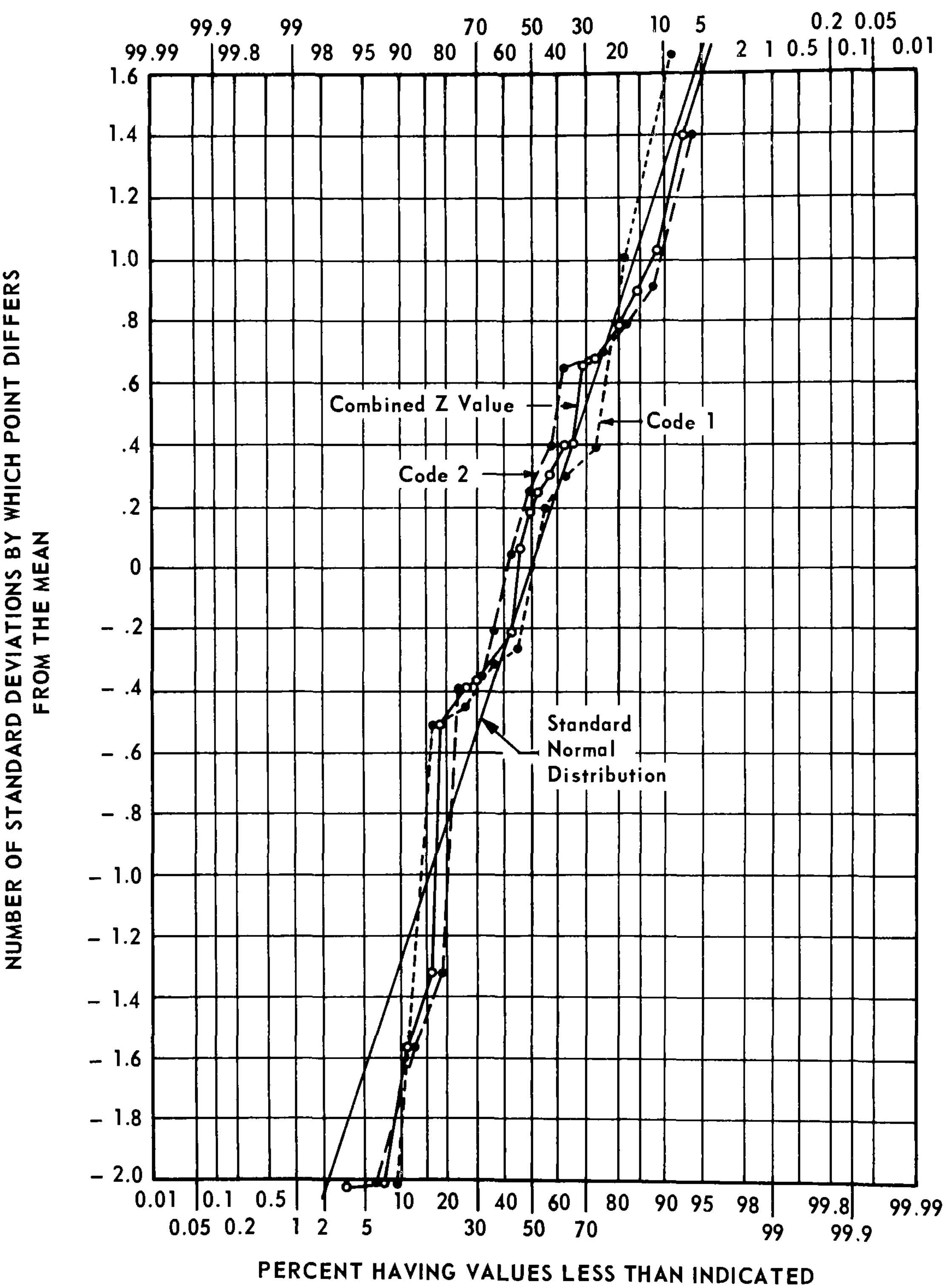

Figure 9

pooled samples more closely approximates the straight line over most of the field. Attention is directed particularly to the upper end at which it is considerably better than either of the individual samples. The reason for this is that one of the samples is low in this region and one is high. Thus, when they are plotted as a pooled distribution, the highest one becomes the highest value and the lower one becomes the second highest. It is this random nature of the individual samples which causes the pooled line to more closely approximate the straight line. At the lower end, this improvement has not occurred with the two samples shown because it happens that both samples have low points in the low percentiles. However, other random samples, i.e. other codes, will have points which are high in the low percentiles and the line pooled with these will more closely approximate the straight line. In terms of a sample of increasing size from a single code, this means that the samples taken happen to have points which are high in the low percentiles and the line pooled with these will more closely approximate the straight line. In terms of a sample of increasing size from a single code, this means that the samples taken happen to have points which do not fall on the line at the low end; however, as additional data points are added to the sample, these points will find themselves displaced to lower percentiles where they will fit on the line. Figure 10 shows a pooled distribution in the reduced form for all 122 Kpye values taken from ten codes having these in the present study. Thus "super code" is a projection of what would happen if the number of points in the sample for any particular code could be multiplied several fold. Also it shows the direction toward which the distribution would trend as the sample size approached the population size. If the distribution of the reduced values was not normal, that is, if the distribution of the original value was not log-normal, then if the populations from which the samples are drawn had some uniform type of distribution, the pooled curve would approach a curve representing that distribution on the normal paper. But it would not approach the straight line representing an original log-normal distribution. Likewise, if say half the sample had log-normal distributions and half had normal distributions, in that case also the pooled line would not approach the straight line on Figure 10. This demonstration may be taken as showing that the distribution of population in any code approximate log-normal. Of course, when reconverted to the "unreduced" form, the distributions for each of the codes will have different means and different standard deviations but they will be log-normal.

DISTRIBUTION OF 122 "REDUCED" OBSERVED KPYE VALVES FROM 10 CODES

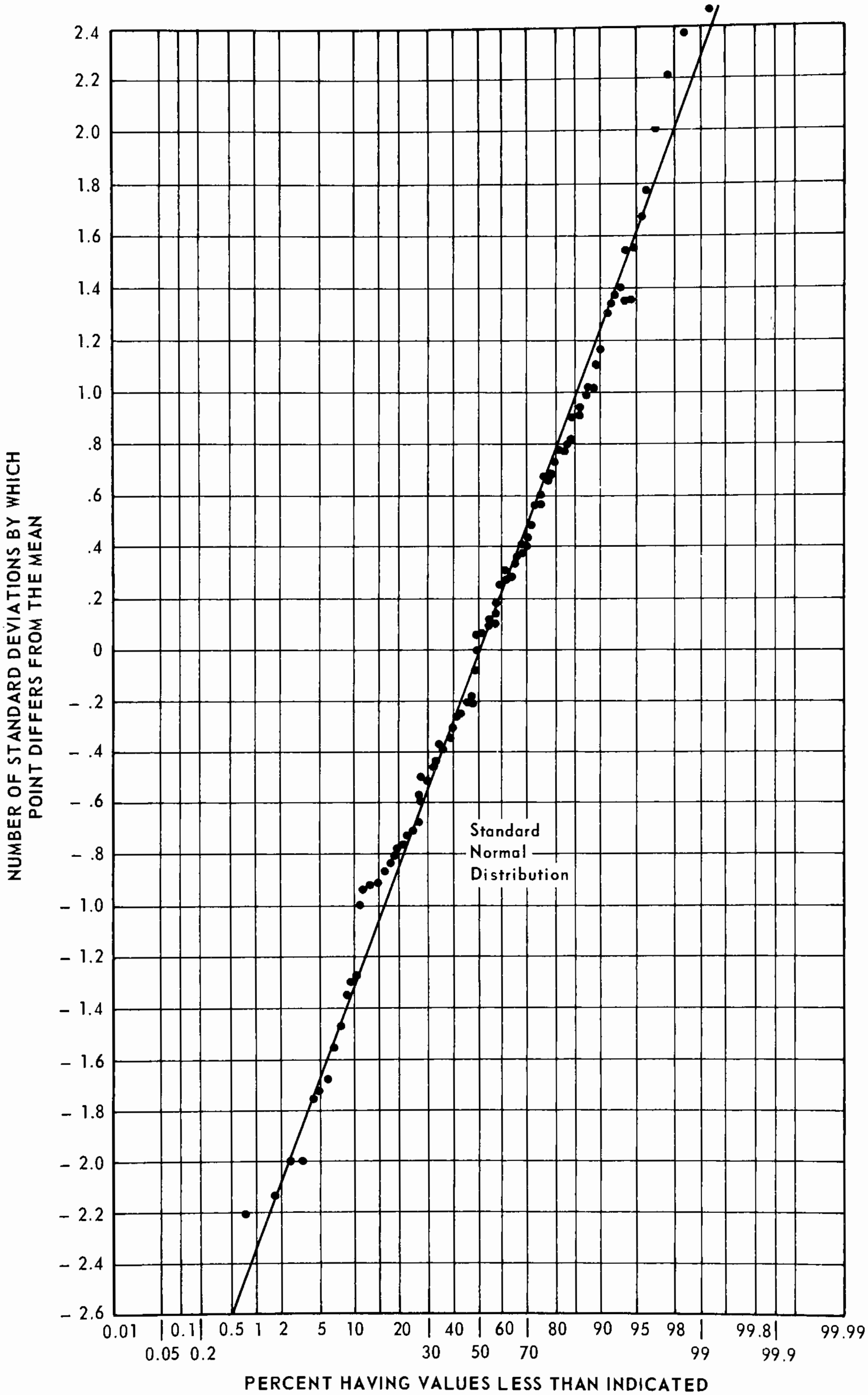

Figure 10

SECTION XII

APPENDIX D

MATHEMATICAL HANDLING OF DISPOSITION AND DISPOSAL DATA

Disposition is defined as the operation carried out on the waste between the point of production and the point of ultimate disposal. This usually comprises a conveyance operation frequently spoken of as "hauling". Ultimate disposal is defined as the waste handling operation which finally places the waste beyond further human contact. A reduction is defined as a process carried out on the waste to reduce its weight or volume prior to ultimate disposal. Incineration and other forms of burning are actually reduction operations since they reduce the weight and volume of waste but produce a residue for ultimate disposal. While it violates the strict definitions of these operations, incineration has been classed with ultimate disposal in the studies in this phase on disposition and disposal. It is implicit, however, that when incineration is mentioned among the ultimate disposal operations, it is the reduction operation that is actually meant.

The waste streams in the interview establishment were described as to type but then were grouped together for further analysis such that all waste streams having the same disposition and disposal were included in one group. Thus, if for example, plant trash and shipping waste were handled by the producer in his own incinerator, while process waste and sludge from liquid cleaners was contract-hauled to the city sanitary land fill, these two classes of disposition and disposal would be handled separately and counted separately in the tallies. In the case described there would be one tally for self-disposition and one tally for contract disposition. There would be one tally for self-ownership of the ultimate disposal facilities and one tally for city ownership. In this instance, the number of "disposition and disposal situations" would be two.

As implied in this illustration, the characteristics of the disposition disposal operation which were categorized were disposition by self, by city, or by contract, i.e. disposition agent; ultimate disposal by type, i.e. open dump, open burning, sanitary land fill, incineration, tepee burner, etc.; and ultimate disposal by facility ownership, self, city contractor owned, merchant.

For every interview in each S.I.C. code and for each waste stream group as described above, this disposition agency, ultimate disposal type, and ultimate disposal facility ownership was tallied and compared with the sum of all waste stream group tallies in that category. For example, in the illustration above, it would be stated that the disposition was 1 self, and 1 contract, the ultimate disposal was 1 incinerator, and 1 sanitary land fill, the disposal facility ownership was 1 self and 1 city. In some instances, it was possible to be more explicit, as for example to describe the ultimate disposal type and ownership together with one statement as comprising one self incinerator and one city sanitary land fill.

The method of analyzing disposition and disposal data just described provides frequencies of occurrences among all disposition or disposal occurrences. From such a frequency analysis one might develop results such as that a certain percentage of disposition occurrences were by contract. The occurrences are not limited to one per establishment but there may be as many disposition occurrences and disposal occurrences as there are separately handled waste stream groups in the establishment.

There are two other possible methods of handling disposition and disposal data. One of these would involve summing up the quantities of waste found in the sample to have a particular disposition or disposal mode and expressing this as a fraction of the total waste in the sample. In contrast to the frequency method which gives the fraction of occurrences this method would purport to give the fraction of the total waste having a particular disposition of disposal mode. However, such results would be definitely erroneous for the following reason. There is no evidence in the data that large establishments tend to one form of disposal or disposition while small establishments tend to another form. However, handling the data in the manner just described and then ascribing the percentage results to the universe required the assumption that the large establishments which happen to be in the sample are representative of all large establishments in the population and likewise with the small establishments. But with such a small sample, it is just as likely that in the next such sample the large establishment would have a quite different mode of disposition. It is not possible to strictly test this concept (that there is no trend of disposition mode with size) with such a small sample as is available to the project, but there does not seem to be any physical reason which would demand it. To test the concept would require a considerable number of interviews in each of several size classes in order that the frequencies of the various modes might be compared as a function of size class. This, of course, is out of the question with the number of interviews assigned to this study.

A better estimate of the percentage of total waste going to each disposition mode may be obtained by a procedure intermediate between the preceding two.

If, for each establishment, there is expressed the percentage of its total waste going to each disposition mode then the sum of the percents for a group of establishments in each disposition mode divided by the number of establishments gives the average percent to that disposition mode. Compared to the first method, this method provides some information on quantities as well as frequencies. Compared to the second method, this method avoids the weighting of the percentages by the amount of waste which was undesirable if disposition mode is not dependent upon size. If each establishment had only one mode of disposition, that is had either 100% or 0% in each disposition category, then the frequency method and this intermediate method would give the same results. However, since establishments sometimes have more than one mode of disposition, the results of the two methods will differ somewhat. This intermediate method also suffers from the smallness of the sample but the possibility has been eliminated that the chance inclusion of a large establishment in the sample might overweight the results.

Up to this point the discussion of disposition and disposal has been in terms of a waste stream which requires ultimate disposal and thus is of interest to this project. There are such entities, however, as waste streams within an establishment which find some satisfactory and socially acceptable mode of disposition such that although they represent a waste in respect to the main product, they do not represent a waste in the sense that means must be provided for the disposition and disposal. Thus, they are more akin to established by-products than to wastes. Such by-products or wastes may be either sold or given away for some other use, used for fuel in the producer's establishment, or utilized for some other purpose in the producer's establishment. In any of these modes, the producer does not actually have a waste problem, nor is it of concern to this project, since while usually not producing a great profit these operations are ordinarily conducted without cost to the producer or at a very nominal cost. Unless there is some change in the established utilization pattern the wastes are not likely to appear back in the general waste stream. Examples of these modes are wood chips sold for pulp-making, stockyard pen waste given away for fertilizer or to be processed into fertilizer, paper scraps and broke, repulped in the producing establishment or sold as waste paper for other establishments to utilize.

Mathematically, this project has two methods of handling such by-products. These two methods involve either including such by-products in the waste upon which the waste/employee or waste/product ratio is computed or not so including them.

If it is the common practice, i.e. practically universal and consistent, to have a by-product disposition for some waste stream, then this waste stream is not considered at all in the study. An example is the utilization of wood chips in the saw mill industry in the South and East. It is practically universal to sell these chips to the pulp mills, and therefore, it is only rare in the interviews and in the real population that these chips enter into the waste stream of interest. Accordingly, they are not considered at all as a waste in developing the waste/product ratio. At the other extreme, if in a few interviews it is found that mill work establishments occasionally give away a pickup load of wood scraps to some individual for home heating, this is not even excluded from the waste stream since both quantity and frequency are so small.

It is when the frequency of occurrence becomes high and the fraction so disposed is simultaneously high that some judgement must be used in deciding whether to include the waste in the waste/employee ratio or not. In general, the decision has been to include this waste in the waste/employee ratio analysis, and to drop it out later from the projection of the total waste of interest by a means to be described. The reason for including it is that to exclude such random occurrences would considerably increase the dispersion of the waste/employee ratio depending upon whether the establishment having excludable waste happened to have a high waste/employee ratio or not. For example, if 50% of the saw mills burned 80% of their waste sawdust and shavings for fuel, then the waste/employee ratio for that half of them so doing would be only 20% of the waste/employee ratio for those not so doing even if the basic generation of waste per employee were identical in all the establishments. Thus, it seems preferable from the standpoint of obtaining lowest possible dispersion in waste/employee ratios to include all waste stream dispositions except when such by-product utilization is almost universal. The exclusion of the by-product from the final waste stream is done by the intermediate method just previously described.

information system
(volume iii)

TECHNICAL - ECONOMIC STUDY OF SOLID WASTE DISPOSAL NEEDS AND PRACTICES

VOLUME III - INFORMATION SYSTEM

Conducted for the Public Health Service
under Contract #Ph 86-66-163

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WINDSOR, CONNECTICUT

November 1, 1967

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SECTION I

SUMMARY

A feasibility study has been conducted which assesses the need for a solid waste information system. The opinions of those responsible for solid waste management, as determined through questionnaire responses and personal interviews, indicate that significant inadequacies exist in the information available and that this is having a marked effect on the capability of these administrators to effectively plan and execute solid waste activities.

In the opinion of those approached, an information system would provide a meaningful and effective aid to administrators, so long as it were designed to serve their specific needs at a minimal cost. The most significant information gaps are in the areas of land requirements and facilities performance. In addition, to be most effective, a solid waste information system should provide some means to assist planners, administrators and other decision makers in the performance of their tasks. A system which provides a data clearinghouse service, a predictive information service and a planning information service would best meet the needs of solid waste planners and decision makers of all levels.

The data clearinghouse service would make available data which is pertinent to solid waste activities. The predictive information service would provide standardized trend predictions of significant solid waste parameters such as growth in pounds per capita of municipal, commercial and industrial solid waste. The planning information service would apply computer based mathematical models to solid waste planning and decision making questions. The complete system is discussed as System #7 in this report. The cost of such a system appears to be reasonable in relation to the potential benefits to the users. The potential cost for installing, operating and maintaining such an information system to serve the entire country would be approximately $13 million over a ten year period. Its potential savings have been conservatively estimated at about 5 percent of the total cost for new incinerator installations over the next ten year period. This alone offsets the ten year estimated cost of such a system.

It is recommended that an information system to serve the field of solid waste management be developed. Since the scope of the current study was necessarily limited, the initial steps in implementing this recommendation should include a more detailed study to refine the system concepts and cost estimates and to establish the preferred management organization.

A pilot system is recommended as a means to investigate proposed systems and techniques in sufficient detail to determine their feasibility and to establish the degree of sub-division required in an ultimate system to serve the entire nation. Preliminary design requirements for a pilot system to serve a limited area are included. An appropriate pilot system could be established and operated for four years for a total cost of approximately $1.3 million.

SECTION II

INTRODUCTION

Solid waste management has become a significant problem throughout the country and the cost associated with it has moved it into the category of big business. However, this field has been consistently plagued by lagging technology, high cost, pollution hazards and public criticism. Much individual effort has gone into attempts to upgrade the management of solid waste and to obtain gains in the performance of equipment and facilities, but such efforts have suffered from a lack of available information and a means for the interchange of experiences, successes or failures. This situation makes clear the need for an effective information system to assist planners and decision makers concerned with solid waste management.

An information system study program has been conducted as a part of the overall efforts by Combustion Engineering under contract Ph 86-66-163 in order to more precisely define the problem on the various Government levels, and in the private sector of solid waste management.

The results of the total program are reported in four volumes.

Volume 1	-	Municipal Inventory
Volume 2	-	Industrial Inventory
Volume 3	-	Information System
Volume 4	-	Technical - Economic Over-view

The study presented in this report (Volume 3) was initiated with a questionnaire and interview program, and a study of the available literature. These steps defined the information needs and determined whether an information system could satisfy the needs. The results have led to a statement of the information problem at various decision making levels, the compilation of system objectives, and the development of several alternative information systems to serve the field of solid waste management. These systems have been evaluated by a comparison of the extent to which each achieves the system objectives, and by a comparison of the costs with the benefits to the information users. The system which seems to best serve the overall objectives has been selected.

Further discussion is included on statistical sampling techniques which could be used to obtain adequate data inputs, and on the nature of other potential inputs and outputs from an information system. A specification for a pilot model of the recommended information system concept has also been developed and recommendations are offered for its implementation.

More extensive discussion of several phases of the work is incorporated in several appendices. These include a report on the questionnaire and interview program, detailed cost estimates of alternative systems, and a discussion of statistical sampling and refuse composition sampling.

This report was prepared by Peter W. Kalika and James E. Seibel of the Product Diversification Department, David R. Pearl, Manager. Mr. Marshall Spieth of Combustion Engineering's Corporate Systems Group participated in a consulting capacity. Mr. Ralph Black was Project Director for the Public Health Service; Mr. Elliot D. Ranard was Program Manager for Combustion Engineering, Inc.

SECTION III

CONCLUSIONS

A. The field of solid waste management is plagued with a significant lack of reliable information in a standard form to assist planners and decision makers in effectively performing their functions. Although some elements of information are available normally, these are not usually either complete or extensive enough for planning and decision making needs.

B. The greatest lack of information is in the areas of land requirements and facilities performance. These, and other information elements, are necessary for effective long range planning, which has been identified as the primary decision area in the solid waste field.

C. Solid waste management at all levels seem to welcome an information system if it served their specific needs for information and for planning assistance at minimal cost. An appropriately designed and managed solid waste information system could overcome many of the present information inadequacies and could provide significant assistance to solid waste planners and decision makers.

D. To be most effective, a solid waste information system should both provide the information necessary for more effective planning and decision making and should provide some means to assist planners, administrators and other decision makers in applying the information supplied to them.

E. Several alternative solid waste information system concepts have been evolved to assist planners and decision makers to varying degrees in performing their functions. The systems can either provide the means to improve information availability, provide the means to make available various decision making criteria, or both.

F. An information system which provides both information availability and decision criteria would best meet the needs of solid waste planners and decision makers at all levels. The cost of such a system appears to be reasonable and compares favorably with the potential benefits available to the users.

G. An information system which would provide decision criteria could either develop statistical trends on a regional basis, a "predictive information service", or it could provide information on an individual request basis, a "planning information service", or both. The "predictive information service" could satisfy the most important user needs, and the "planning information service" the remaining needs. There would be a 15 percent cost increase for providing both features over just providing the "predictive information service". The additional benefits to the users far outweigh this slight additional cost.

H. The potential cost for providing and maintaining a complete information system which would most effectively serve the needs of the users would be approximately $13 million over a ten year period, including initial and annual operating costs. This cost would support a system serving the entire nation.

I. Potential benefits available to the users from an established information system include:

1. Knowledge of the availability of standardized, ready-to-use, geographically representative data which could be quickly obtained.

2. The benefit of sophisticated and proven computer usage and techniques, regardless of community size and means.

3. Assistance in assuring that future plans are sufficient and timely.

4. Savings in providing effective solid waste collection and disposal facilities.

The value of these benefits significantly exceeds the estimated cost of the complete information system.

J. A pilot system to serve a limited area is the best means for initiating an effective total solid waste information system. The results of pilot system operations would define more precisely system parameters and management requirements of a total system to serve the entire nation. An appropriate pilot system could be established and operated for four years for a total cost of approximately $1.3 million.

K. The sampling of municipal refuse to determine chemical composition and heating value on a standardized and widespread basis would be expensive with little guarantee of success. The basic information which can be developed from accurate measurements of refuse quantities and related parameters is initially more important and less expensive. Detailed chemical sampling could be considered as a later phase of an information system. However, the sampling of certain selected physical and chemical characteristics will be necessary in the evaluation of systems for salvage and reclamation and should be undertaken as needed.

SECTION IV

RECOMMENDATIONS FOR FUTURE ACTIVITIES

A. The development of an information system to serve the field of solid waste management should be taken under consideration by the Solid Waste Program. The system should include a "predictive information service" function, a "planning information service" function and a "data clearinghouse service" function. This system could serve the entire nation through a number of local information centers.

B. Since the scope of the current study was necessarily limited, the initial steps in implementing the above recommendation should include a more detailed study to refine the system concepts and the estimates of their costs and to establish the preferred management organization.

C. Consideration should be given to the initiation of a pilot information system to serve a limited geographical area as a means to define more precisely system parameters and management requirements of a total system to serve the entire nation. The pilot system should encompass all of the features of the full scale national system, and upon completion should be capable of virtually complete integration into the overall system. The pilot system developed should encompass a sufficiently large and representative region of the country and should contain certain minimal historical and planned solid waste activity. It should investigate proposed systems and techniques in sufficient detail to determine their feasibility and should establish the degree of sub-division required in an ultimate system.

SECTION V

DISCUSSION

A. THE SOLID WASTE INFORMATION PROBLEM

The solid waste management field has been plagued consistently by lagging technology, high costs, pollution hazards, inefficient performance and public criticism. Much effort by individuals and individual municipalities has gone into attempts to upgrade the management of solid waste and to gain in performance efficiency. Such efforts have been expensive and sometimes less than completely effective because they must be accomplished on an individual basis with only limited means for an interchange of experiences, successes or failures. Because of such efforts and because the overall problem is not improving significantly, improved planning and decision making in the solid waste management field has become of increasingly greater concern to Government officials.

A primary reason for the existence of such problems as well as a primary deterent to finding more effective solutions to them is the present lack of reliable information and communication of information throughout the solid waste field. This situation defines the basic need for an effective information system to assist the planners and decision makers concerned with solid waste management.

In order to more precisely define the problem on various governmental levels and in the private sector of solid waste management, a questionnaire and interview program was conducted, along with a study of the available literature in the field. The development of the questionnaire and interview program and the specific results obtained are described in detail in Appendix A, and the flow of information in municipal refuse activities is shown in Figure 1. The application of the results obtained to the development of a solid waste information system will be discussed in the following paragraphs.

1. PRIMARY DECISION AREAS

The primary decision areas for each category of participant in the solid waste field are discussed in Appendix A and indicate that the majority of the categories consider long range planning as their primary decision area. State planners consider the evaluation of performance of refuse facilities as their primary decision area. This also represents the second most important decision area for all the categories as a total. Evaluating effectiveness of plans rates as the third most important decision area for the total list of categories.

2. INFORMATION REQUIRED FOR PLANNING AND DECISION MAKING

The specific types of information considered most important by solid waste management officials are related to the first and second decision areas of primary concern. These categories include information on land requirements, facilities performance, refuse quantity and costs of refuse activities, and would obviously be of primary concern for making long range plans and for evaluating the performance of refuse facilities.

3. INFORMATION NORMALLY OBTAINED BY REFUSE MANAGEMENT OFFICIALS

The categories of information which are regularly obtained by refuse management officials are also shown in Appendix A. Significant variation exists in both the type and amount of data normally obtained because of the great differences which exist in record keeping. Data is normally obtained on facilities performance, refuse quantity, population and costs of refuse activities. State and regional planners also appear to obtain data on land requirements, although only about one-third of the municipal planners normally appear to obtain such data. It is also significant to note that only equipment manufacturers and consultants normally appear to obtain information on air pollution control -- a subject which is currently receiving a great deal of public and Government attention.

4. INFORMATION GAPS

The information gaps can be defined as the differences between the information stated as necessary for proper planning and decision making and the information normally obtained by refuse officials. The categories of information which had to be specially obtained provide a good indication of the nature of these gaps. Appendix A illustrates the type of data that has had to be specially obtained by each of the decision maker categories. Data on land requirements frequently had to be specially obtained. But, in addition, data which was normally obtained, such as facilities performance, refuse quantity, and costs of refuse activities, was also quite frequently specially obtained. This indicates that normally obtained data may often be insufficient or incomplete for the decision required. Examples of data not considered important but which was specially obtained are data on air pollution, refuse composition and population. These will probably become more important with time. The primary usefulness of special data was in "providing a more accurate basis for decisions". Only manufacturers and consultants did not give this their first vote. These rated "more accurate design of facilities" as first choice. Since the primary usefulness of data is a "more accurate basis for decisions", and many of the categories have sought additional data in areas where data is normally received, then the data currently received on a normal basis is apparently not entirely adequate for decision making.

5. WHAT NEEDS TO BE DONE TO MAKE THE INFORMATION USEFUL

The raw data is often not very useful to the planner or decision maker until it has been standardized, processed or rearranged in some way. Solid waste management planning and decision making involves the application of judgment to a large number of variables and related factors. To apply judgment or to arrive at conclusions with too little data is perhaps no more difficult than being given too much data in an unassembled, uninterpreted form. Therefore, the raw data must first be processed or prepared in some way before it becomes a useful tool.

To be useful as a long range planning tool, parts of the data need to be developed into trend projections. Such trend projections should be developed for factors such as population, solid waste production, land availability or depletion rate, and refuse composition or heating value. Cost and performance information need to be defined in terms of what they include and preferably should be put into a standardized form. The data collected should be validated to assure its accuracy.

Planners and decision makers are most interested in what might occur and what steps should be taken, rather than in the individual details of bits and pieces of information. To arrive at an analysis of what might occur, the data collected needs to be interpreted for its significant meaning and implications for the future. It needs to be compared with historical data and with predicted trends. Quantities, timing and effect must be extracted from the data.

To arrive at the recommended steps to be taken, the future trends must be analyzed for possible effects and the probable means for managing the expected occurrences. Alternate facilities and management means need to be developed and the optimum approach must be found. Timetables for activities must also be developed on the basis of the timing needs indicated by the data. Optimization techniques may require the application of computerized data processing techniques. Such techniques can be applied to the data for both planning and operational optimization purposes.

6. GOVERNMENT INFORMATION REQUIREMENTS

Government agencies at various levels are responsible for performing certain regulatory, enforcing or legislative functions concerning the management of solid waste. In order to carry out these activities, they have needs for certain data and information on solid waste operations and their effects on the general public. Agencies on the federal level are primarily concerned with nation-wide trends in solid waste management, with research activities to upgrade the management and handling of solid waste, with assisting state and local governments in improving solid waste management functions and with the promotion of adequate state and local solid waste legislation and regulations to safeguard the health of the public. To carry out the planning and administrative activities necessary to accomplish these functions, the federal agencies need information on trends which affect solid waste management, and information on the effectiveness of local solid waste programs. They would also require information on research and development activities which could lead to improved solid waste planning and operating functions, and they require means for disseminating available information to those who could use it.

Agencies on the state level, most often the state departments of health, have indicated that their primary concern is with the evaluation of refuse facilities performance. They are also concerned with establishing standards and regulations and with insuring that local solid waste programs comply with them. State agencies must also be concerned with assisting the local officials in obtaining public support for solid waste programs. The information needs of these agencies in performing their required functions include significant trends which affect solid waste activities, land requirements and availability, facilities performance characteristics, refuse quantity trends, population characteristic trends, and costs of refuse activities. To establish standards and regulations, they also require information on the effects on public health of solid waste practices and information on research and development activities which could lead to improved solid waste planning and operating functions. In order to monitor the performance of refuse facilities and the extent of adherence to standards and regulations, the state agencies would need information on the operation of local solid waste programs and would periodically conduct on-site investigations and reviews.

Regional planning agencies are primarily concerned with long range planning of solid waste management programs for an entire region, with the obtaining of public support for regional and local programs, and with evaluating the effectiveness of plans which have been initiated. In order to accomplish these objectives, such agencies require information on land requirements and land availability, facilities performance, air pollution causes and regulatory trends, refuse quantity trends, refuse composition or source breakdown, population characteristic trends and the costs associated with refuse activities. Regional agencies could utilize the information and means which would allow them to optimize solid waste activities within the region.

Municipal planning agencies would be primarily concerned with long range planning for solid waste control, with facilities planning and installation, with establishing local standards of performance and regulations and with the evaluation of the effectiveness of plans which have been initiated. In implementing long range plans, municipal planners are typically responsible for determining what the solid waste handling and disposal needs of the city are, for developing plans to satisfy these needs, and for arranging financing and installation of the physical facilities required. They must be concerned with optimization of the total cost for solid waste management and are usually responsible for coordination of overall solid waste management functions for their city. They frequently utilize consultants to study and prepare plans, and contractors to implement facilities installations. The typical relationship between municipal planners, municipal operators, other city, regional or state agencies, and consultants and contractors is depicted in Figure 1. To accomplish their required functions, municipal planning agencies require local level information on land requirements and land availability, time oriented requirements for land and facilities, facilities performance, refuse quantity and costs of refuse activities. They could utilize the information and means which would allow them to optimize the planning and installation of new or expanded facilities

Municipal operators, on the other hand, are primarily concerned with the operation of refuse facilities and equipment, with the evaluation of performance of refuse facilities and only thirdly with long range planning functions. As such, to carry out their functions, they require information on facilities performance, equipment inventory, refuse quantity and costs of refuse activities. They could utilize information on the development of new equipment or facilities for solid waste collection, handling and disposal, and the information and means which would allow them to optimize the operations of the solid waste management functions.

7. PRIVATE SECTOR INFORMATION REQUIREMENTS

Solid waste administration also affects various private concerns who are directly involved in solid waste activities. Such private concerns include consultants, contractors, equipment manufacturers and various research oriented organizations. Consultants, in performing their functions of analyzing local solid waste problems and planning facilities for solving such problems, are faced with the problem of developing data inputs on which to base their analysis or they must depend on readily available data which is often sketchy, incomplete or inaccurate. The task is made more difficult by the fact that solid waste disposal technology is largely old and outdated. This appears to be the case because the information necessary to upgrade the state-of-the-art is apparently lacking. The results of consultants' efforts could therefore be improved by the availability of more and better information on solid waste activities and practices, particularly in the areas of refuse quantity, facilities performance, standardized costs and land availability trends. They could also utilize more complete information on new developments and on the results of current research.

Contractors responsible for the actual construction of facilities and for refuse collection could utilize better information on facilities performance and new developments and techniques in the field.

Equipment manufacturers, responsible for developing and providing the equipment for handling and disposing of solid waste could utilize better information on solid waste trends, facilities performance, cost factors, refuse composition and air pollution requirements. Latest research results and information on developments in the field could help this group in its efforts to upgrade the state-of-the-art of waste handling and disposal technology.

Researchers could be aided in their tasks by the ready availability of better information on trends in solid waste and on the areas which need significant attention to solve problem situations.

8. SUMMARY OF PROBLEM

The solid waste information problem consists basically of an information gap between the type and nature of information required for planning and decision making purposes and the extent of information normally obtained by those who require it for this purpose. The study of this problem leads to the following summary of results:

a. PRIMARY DECISION AREAS OF GOVERNMENT OFFICIALS

- Long range planning
- Evaluations of Refuse Facilities Performance
- Evaluation of the Effectiveness of Plans

b. PRIMARY INFORMATION REQUIRED FOR PLANNING AND DECISION MAKING

- Land Requirements Information
- Facilities Performance Information
- Refuse Quantity Information
- Costs of Refuse Activities Information

c. INFORMATION NORMALLY OBTAINED BY PLANNERS AND DECISION MAKERS

- Facilities Performance Information
- Land Availability Information
- Refuse Quantity Information
- Population Information
- Cost Information

d. INFORMATION GAP - AVAILABLE INFORMATION INSUFFICIENT

- Land Requirements Information
- Facilities Performance Information
- Refuse Quantity Information
- Costs Information
- Air Pollution Information
- Refuse Composition Information

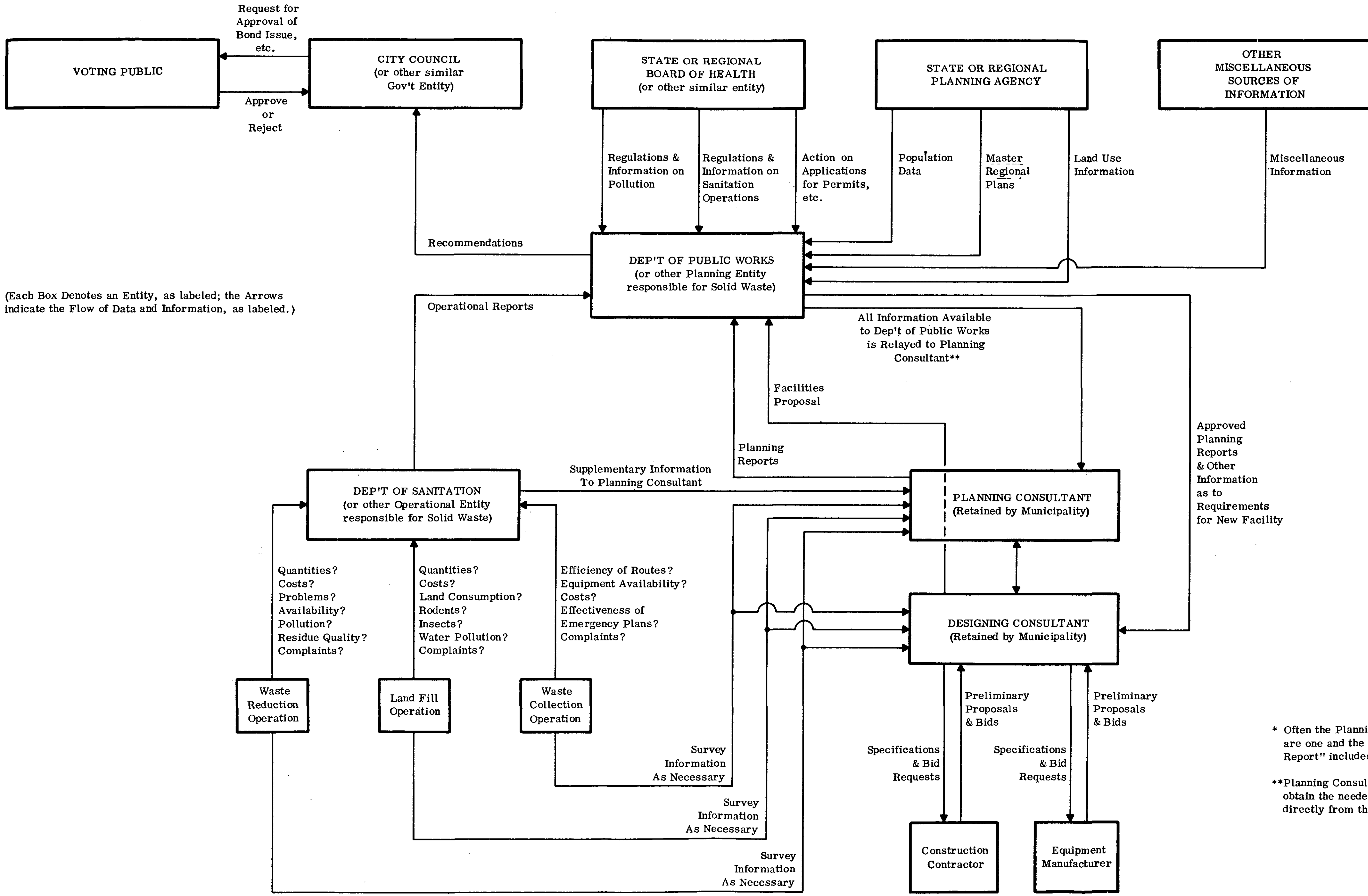
e. REQUIRED TREATMENT OF INFORMATION FOR BEST USE

- Validation
- Standardization
- Interpretation
- Processing - Development of Trend Projections

f. PRIMARY USEFULNESS OF BETTER INFORMATION

- More Accurate Basis for Decisions
- More Accurate Design of Facilities

THE FLOW OF INFORMATION IN MUNICIPAL REFUSE ACTIVITIES



* Often the Planning & Designing Consultants are one and the same, and the "Planning Report" includes the Facilities Proposal.

**Planning Consultant May often obtain the needed Information directly from the Sources.

Figure 1

B. INFORMATION SYSTEM OBJECTIVES

The previous section has discussed the solid waste information problem and the related requirements of the Government and private sectors of the solid waste field. The problem reduces basically to a lack of readily available information for effective planning and decision making in solid waste activities, and therefore, defines the need for an information system to assist planners, administrators and other decision makers in the field.

Before the system can be designed, the desired objectives to be achieved through the use of an information system must be defined. The objectives should state the end result desired from the system, on the basis of the problems to be solved.

Two sets of objectives for a solid waste information system have been defined. The first set is directed toward the problem of information availability (provide the information necessary for more effective planning and decision making in the area of solid waste collection and disposal). The second set is directed toward the problem of information utility and effectiveness (provide a means to assist planners, administrators and other decision makers in applying the information supplied to them). These two basic sets of objectives have been sub-divided as follows:

1. Provide the information necessary for more effective planning and decision making in the area of solid waste collection and disposal.

    a. Provide the means to insure that adequate data for any selected system will be collected.

    b. Provide the means to improve the quality of the information.

    c. Provide the means to make information more readily availalbe.

    d. Provide the means to standardize the information collected.

    e. Provide information in a convenient and readable format.

    f. Serve as a data clearinghouse system.

2. Provide the means to assist planners, administrators and other decision makers in applying the information supplied to them.

    a. Provide the means to develop predictions of trends in significant solid waste parameters.

    b. Provide the means to predict the saturation of existing facilities.

    c. Provide the means to predict required capacity of new facilities.

    d. Provide the means to minimize the total cost of refuse collection and disposal.

e. Provide the means to develop timetables for planning the acquisition of solid waste facilities.

f. Provide the means for decision makers to request specific information and planning services.

g. Provide the means to optimize day-to-day operations.

DISCUSSION OF OBJECTIVES

1. a. PROVIDE THE MEANS TO INSURE THAT ADEQUATE DATA FOR ANY SELECTED SYSTEM WILL BE COLLECTED

The information system should include a means for assuring that sufficient data is collected in solid waste activities on the local level to match the information needs for planning and decision making. This includes accurate data on refuse collected, cost of refuse activities, information on population and land availability, and information on the operation of refuse facilities. It has been found that many communities do not now collect this data, or only collect a portion of it. The achievement of this objective will be one of the more difficult tasks of an information system. In order to accomplish this objective, local communities must be convinced of the need for collecting adequate data and of the potential benefits to them of such data.

1. b. PROVIDE THE MEANS TO IMPROVE THE QUALITY OF THE INFORMATION

Comments from potential information system users have indicated that the quality of information available is often insufficient for the needs of planners and decision makers. Information quality refers to the accuracy, the reliability and the completeness of the information. The common use of relatively unscientific measurement methods, and the exclusion in many cases of factors relevant to the definition of the data, results in a lowering of the quality of the information usually available. Since the results of planning and decision making depend to a large extent on the quality of the information available for this use, this objective is basic to the effective utilization of an information system.

An information system could achieve this objective by providing a means to validate the data collected by establishing criteria for evaluation of the data, and by assuring that all relevant factors are defined for the specific data reported.

1. c. PROVIDE THE MEANS TO MAKE INFORMATION MORE READILY AVAILABLE

Much of the information generated concerning solid waste is not now available to all those who could effectively utilize it. Much of it is publicly financed information and, therefore, should be available for wider use. Some information, such as refuse and incinerator residue chemical characteristics, is unavailable in all but very isolated instances. There presently is no convenient means for the gathering of this information and for making it available to those who could utilize it. An information system, in achieving this objective, could serve as a central agency for the gathering of this and other similar information, and could serve the function of applying the information to the specific cases which could make use of it.

1. d. PROVIDE THE MEANS TO STANDARDIZE THE INFORMATION COLLECTED

In order to make information most useful for planning and decision making, it should be presented in a standard form. Cost and performance information can only be of value for comparative purposes if they are based on the same standards and incorporate the same elements. The correlation of many facets of solid waste data from many different sources depends to a large extent on the inclusion of comparable factors and the use of a uniform standardized format for its presentation.

This objective could be achieved by supplying an information system with all of the elements and factors relevant to the data to be standardized, and then to allow the system to organize this data into a standardized format.

1. e. PROVIDE INFORMATION IN A CONVENIENT AND READABLE FORMAT

To be of maximum use to planners and decision makers, an information system should have the capability of organizing information into a form most convenient for their use. In the achievement of this objective, particular attention should be given to avoiding the situation where a user must browse through hundreds of superfluous pages to reach the needed information.

1. f. SERVE AS A DATA CLEARINGHOUSE SYSTEM

The information system should serve as a collection and dissemination point for all information concerned with solid waste. At present, there does not exist a single system which performs this information distribution function for all areas of solid waste activities, including collection, disposal and administration. Since the information system would be the prime recipient of information concerning solid waste, it should also logically perform this function.

2. a. PROVIDE THE MEANS TO DEVELOP PREDICTIONS OF TRENDS IN SIGNIFICANT SOLID WASTE PARAMETERS

The information provided as a result of the primary Objective 1 is not a sufficient tool by itself. The decision maker must develop plans for future programs and contingencies and must therefore develop means with which to predict the future trends in certain parameters. Given only basic information, the prediction means evolved are likely to be quite inconsistent among the users who will apply widely differing techniques and utilize only portions of the available information. Since under an information system, data collection, and the development of basic information from that data, will be handled by computer programs, it is logical that the programming be extended to develop a unified and consistent set of trend predictions.

2. b. PROVIDE THE MEANS TO PREDICT THE SATURATION OF EXISTING FACILITIES

The question which is consistently asked first by decision makers is, "How long will my current facility be capable of disposing of the refuse?" Armed with the appropriate parameter trend predictions, the decision maker is well on his way to the answer, but certain calculations must still be made. These combine various trends, and they require knowledge of the current status of facilities. Although it is not a difficult or overly tedious calculation, it is again subject to inconsistencies and differing levels of understanding and technique. A computerized information system can easily perform a myriad of such calculations when supplied with the necessary data. The additional programming is minimal and therefore the stated objective is considered a reasonable achievement to expect from the system.

2. c. PROVIDE THE MEANS TO PREDICT REQUIRED CAPACITY OF NEW FACILITIES

This objective is a logical extension of Objective b. Supplied with the trend information and with data on current facilities, the system's calculation of the required capacity for new facilities is straight-forward. Again, it would be possible to perform these calculations individually, but the characteristic of consistency inherent in a computerized information system makes it more beneficial to perform such predictions in large quantities. In addition, the calculations require the cumulative and simultaneous application of several trends and can potentially be subject to considerable error if manually accomplished.

2. d. PROVIDE THE MEANS TO MINIMIZE THE TOTAL COST OF REFUSE COLLECTION AND DISPOSAL

This objective provides the transition from a purely information collection system to a management information system. Whereas the replacement of hand calculation in Objectives b and c has been more for convenience and consistency than for necessity, the achievement of this objective requires the application of a computer. The number of alternatives as to size, location and performance of facilities and equipment, for which the cost could be calculated, is usually well beyond manual techniques. If the costs were to be studied over the life of the facilities, the various influential trends could be superimposed on all the alternatives. The modern high speed computer could dispose of hundreds of alternatives in minutes, contrasted to years of hand calculation. Additional information must be provided to the system for this technique to be applied. Unit cost factors, weighed against facility capacity and predicted trends, must be available as basic information. This objective makes the information system a true management tool, and makes sophisticated optimization techniques available to all users.

2. e. PROVIDE THE MEANS TO DEVELOP TIMETABLES FOR PLANNING THE ACQUISITION OF SOLID WASTE FACILITIES

This objective applies the results which would accrue from the achievement of Objectives a, b and c to the development of a timing schedule for additional facilities to replace or reinforce existing facilities.

2. f. PROVIDE THE MEANS FOR DECISION MAKERS TO REQUEST SPECIFIC INFORMATION AND PLANNING SERVICES

Since it will not be possible to anticipate all of the planning and information problems which may be encountered by the potential users of an information system, an objective of flexibility is necessary. The users should be able to request replies to their own specific problems, without excessive delays.

2. g. PROVIDE THE MEANS TO OPTIMIZE DAY-TO-DAY OPERATIONS

The availability of a high speed digital computer offers the possibility of the optimization of solid waste operations on a day-to-day basis. A classic example is the optimum routing of refuse collection truck fleets. It should be an objective of a solid waste information system to provide the computer program to achieve this type of optimization. The achievement of this objective will not provide benefits as widely applicable as those provided by the planning objectives already discussed, and it will require a substantial data input from the user.

The objectives listed in the foregoing discussion may be categorized as either "must" or "want" objectives. That is, some of the objectives are so basic to the entire concept of an information system for solid waste, that they must be achieved, while others are not as basic and although one would want to achieve them, failure to do so would not involve immediate rejection of a proposed system, as would be the case with the "must" objectives. "Want" objectives, therefore, could be used to provide a graduated yardstick for system evaluation, whereas the "must" objectives provide a "go - no go" choice.

The following are the recommended "must" objectives for a solid waste information system:

MUST OBJECTIVES

1. a. Provide the means to insure that adequate data for any selected system will be collected.

1. b. Provide the means to improve the quality of the information.

1. c. Provide the means to standardize the information collected.

2. a. Provide the means to develop predictions of trends in significant solid waste parameters.

The following are recommended as the "want" objectives for a solid waste information system:

WANT OBJECTIVES

1. c. Provide the means to make information more readily available.

1. e. Provide information in a convenient and readable format.

1. f. Serve as a data clearinghouse system.

2. b. Provide the means to predict the saturation of existing facilities.

2. c. Provide the means to predict required capacity of new facilities.

2. d. Provide the means to minimize the total cost of refuse collection and disposal.

2. e. Provide the means to develop timetables for planning the acquisition of solid waste activities.

2. f. Provide the means for decision makers to request specific information and planning services.

2. g. Provide the means to optimize day-to-day operations.

C. ALTERNATE SYSTEMS

Certain of the objectives stated in the previous section have been recommended as "must" objectives while others have been recommended in a "want" or "less necessary" category. Various information system concepts may be evolved to meet some or all of these objectives. A number of potential systems are defined, and a list of potential inputs and outputs is provided for each. This is followed by schematic block diagrams for several of the systems. The extent to which the stated objectives would be achieved by each system is discussed.

1. DESCRIPTION OF SYSTEMS

a. SYSTEM #1 - DATA CLEARINGHOUSE (Figure 2)

The data clearinghouse service would make data more readily available to decision makers. This would be accomplished by means of literature and data survey activities reported through a periodic newsletter, and by the publication of annual statistical data solicited from solid waste administrators and operators.

There is much information of a non-statistical nature generated in the solid waste field which is of interest to decision makers in the field. Reports on research findings, data on standards and regulations, information on Government grants, published reports and articles of various types, academic theses, consultant reports, data on pilot tests, etc., could all find many valuable uses. Often little of this material reaches the audience who could most benefit from it. Municipalities often cannot afford to maintain a full time librarian to track down this type of data, and even when they can, there is still much which escapes notice, or is just not available or even publicized. Consultant studies and surveys are a prime example of this.

There is also statistical data available from other Government programs which is significant in the planning of solid waste activities. Examples of this data are population trends, economic trends, data from highway programs, data on industrial production trends, etc. as available from the Bureau of the Census, the U. S. Department of Agriculture, the U. S. Department of Transportation, the Department of Commerce and the Public Health Service. Although available on request, the existence of this data is not always known, or if known, its significance may not be realized.

If the information and data mentioned above were to be available to a decision maker in its entirety, his task in extracting what is useful to him would be monumental. In effect, supplying too much data and in the wrong form is often as bad as supplying too little. In either case, the user falls back on his intuition or experience.

System #1 could provide a valuable service as a data clearinghouse, where much of the avaialble data is distilled and arranged for ready use. In addition, the availability of certain reports, theses, and articles could be made known through a periodic "newsletter". This publication would not necessarily include any data itself, but would summarize that which is available and provide instructions as to how it might be obtained. A service similar to this is provided by the U. S. Department of Agriculture in their monthly "Statistical Summary" and their monthly "Checklist of Reports". This service would require full time staff members to monitor the literature and to prepare summaries.

There are, in addition, a number of cities and smaller municipalities who do maintain records with regard to quantities of refuse processed, rate at which land is utilized, performance of facilities, costs, etc. This data could be of service to other communities if it were made available. System #1 proposes that municipalities be queried, by mail questionnaire, on any such data they may collect.

SYSTEM #1
DATA CLEARING HOUSE
SERVICE

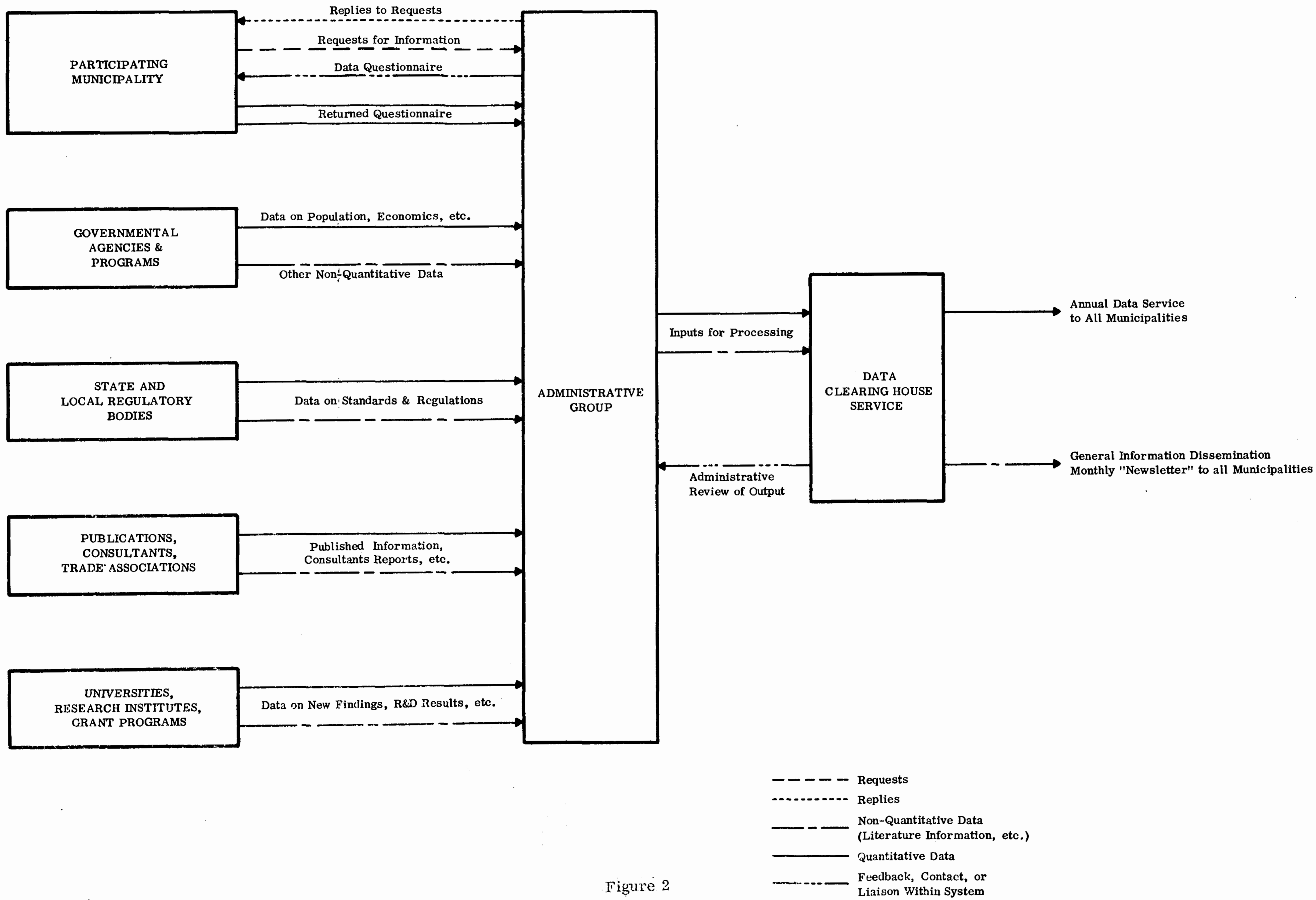


Figure 2

Those that participate will be asked to report on a specific format, and will be asked certain questions to ascertain the extent of measurements actually taken, what is included in the costs reported, etc. The participation would be voluntary and no field verification is contemplated. The data collected would be subjected to a minimum of processing including some minor calculations and rearrangement to provide information on a unit (per capita, per ton, etc.) basis. The output would be reported only for the contributing municipalities, but would be sent to all municipalities above a certain population size.

In addition to the data collected in this manner, certain statistical data might become available which could be of more use to solid waste decision makers if it were rearranged, expanded or condensed. Often this data is available on cards or tape, and the administrative group could program the system's computer to recompile it.

System #1 would also be set up to reply to specific requests regarding the availability of certain types of data. It is not intended that copies of all available data be stockpiled, but that the user is referred to the data's issuing agency from whom he could request it directly. If he has difficulty in this, the service could assist him.

b. SYSTEM # 2 - PREDICTIVE INFORMATION SERVICE (Figure 3)

The predictive information service would provide standardized trend predictions of significant solid waste parameters to all solid waste decision makers. These predictions would be based on verified data gathered from a number of cities which would be established as data gathering centers. These cities would be selected in size, location and other characteristics to be statistically representative of large regions of the country and in this report are called "sample cities".

The output would be in the form of predictions as to the change with time of such parameters as population, per capita generation of refuse, refuse density and compactibility, refuse composition; i.e., whether residential, commercial or industrial, bulky versus mixed or combustible versus non-combustible, costs of refuse operations per ton of material collected, disposed, etc. This information would be reported in a standardized fashion on the basis of data gathered at "sample cities" data sources.

The "sample cities" would be statistically selected in several significant regions of the country. Statistical techniques would be used to establish the number and location of such cities to assure that a representative sampling is achieved. In these cities, data gathering and reporting would be closely controlled to assure that all refuse is weighed, all dispositions, both public and private are accounted for, all costs are reported and standardized, etc. The performance of collection and disposal equipment would be carefully recorded and reported. Measurements of land fill consumption, refuse density and compactibility, incinerator residue density, etc. would be accomplished on a regular controlled basis. The effects of seasonal variations would be clearly determined.

Each "sample city" would be provided with funds to assist them in upgrading their measurement and record keeping capability. Inspectors would periodically review the data gathering operation to assure its continued effectiveness. Basic data would be communicated to the administrative center on a frequent basis at the outset, but after "qualification" of the source, the frequency could be reduced to semi-annual or annual.

Certain cities would be in the position of having kept some data for a number of prior years. Such data would be utilized to the maximum possible extent. The administrative center would review such data for its potential in providing a measure of early functional output of the system.

The administrative group would manually process all incoming data to weed out inconsistencies which may be readily apparent, and would prepare the data for the computer program. The computer program itself must be continually maintained and refined to assure the continued high quality of the output information. The administrative group would monitor the feedback of actual data for comparison to predicted trends, significant deviations would receive close study. The administrative group would also have the responsibility for the inspection of the "sample cities"

The computer program would basically be designed to gather annual incoming data and to perform high speed regression analysis to fit curves to a minimum number of historical data points. These curves would then be extrapolated into the future to provide predictions of changes in the various parameters. If the system were to become at least partially operational in less than five years, previously collected data would have to be used where it is available. The annual output of trends in various significant solid waste parameters may be issued in chartbook form, similar to the "Handbook of Agricultural Charts" issued by the U. S. Department of Agriculture.

The computer program would be designed to incorporate a data validation feature which would accomplish a check on incoming data. If current data deviated excessively from either past data or projected trends, the program would inform the administrative group, which through the inspection system would take necessary steps for verification. Then corrective action could be taken to eliminate any errors or to modify previously projected trends in light of later data.

SYSTEM #2
PREDICTIVE INFORMATION
SERVICE

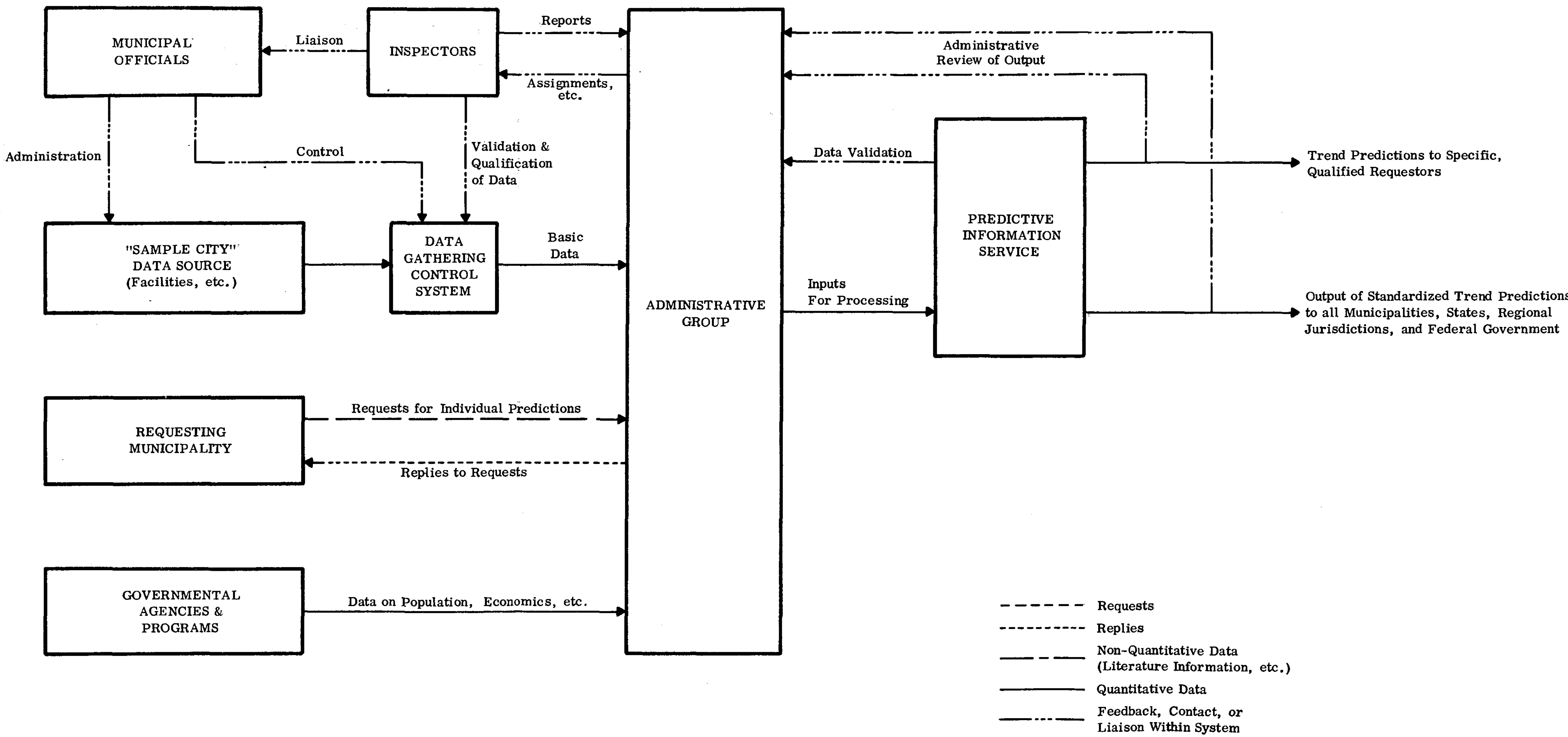


Figure 3

Cities other than the "sample cities" could submit their historical data for the purpose of having their own predictions developed. This will encourage the improvement of data gathering and recording activities on the part of all municipalities. However, many cities do not usually exert the necessary control over their refuse activities and record keeping, as compared to the "sample cities". This individual prediction service would, therefore, be offered only to those municipalities where satisfactory data gathering and record keeping has been instituted.

c. SYSTEM #3 - PLANNING INFORMATION SERVICE (Figure 4)

The planning information service would provide computer based mathematical models which could be applied to solid waste planning and decision making activities. The service would be available on a request basis. The models would be of a standardized format, and requests would be adjusted to fit the models.

Computer programs would be created and maintained for the specific purposes of providing communities with planning tools for solid waste decisions which would not normally be available to them. The requesting communities would supply certain basic data such as number, capacity and location of current facilities, equipment, land fill sites, etc., number, location and size of potential land fill sites, and their likelihood of being put to this use, etc. These data would be applied to standard computer programs to assist the requesting community in locating and sizing new facilities, equipment and land, for minimum overall collection and disposal costs. The standard programs would be designed for a minimum adaptation of input data for application to any community's problem.

Many solid waste decisions require the consideration of large numbers of alternatives. A good example is the situation where several sites for a disposal facility are available. The decision maker wishes to know what type facility he should consider, what capacity, where to place it (or them), etc. so that he may achieve minimum cost. He may wish to minimize the overall collection and disposal costs not only for the immediate future, but perhaps for a ten year period.

He requires knowledge of the trends of significant parameters, including costs, population trends, population density trends, distances for hauling, etc. Some of this he provides himself, and some of it is made available by the system. The trend predictions provided by this system would be based on a relatively non-controlled collection of available data rather than on controlled data from sample cities such as in System #2. As such, the trend prediction results would be less accurate than those resulting from System #2.

Even with all the information in hand, the decision maker would still be faced with the possibility of dozens of separate alternatives whose cost must be calculated. Often the calculations are of a trial and error nature, and the total number of calculation cases reach unreasonable proportions. Without high speed calculational assistance, the decision maker's intuition and prejudice would take over to reduce the problem to more manageable proportions. This is likely to result in costs higher than they need be, and with location and type of facility inconsistent with future needs. It is not intended to belittle the excellent intuitive ability of certain decision makers who can often correctly select among many alternatives. This individual, unfortunately, is the exception, and the majority could use assistance. A standardized program to accomplish planning optimizations of the type described is considered feasible. This has been demonstrated to some extent.[1, 2]

If a community provides only the basic data as to the current capacity of incineration facilities and the life of land disposal sites, System #3 would be capable, with the trend predictions, of developing timetables which indicate when current facilities will be saturated and recommending the size and timing of new facilities.

In addition to planning optimizations as described above, optimization of certain day-to-day operations would sometimes be possible by means of high speed computations. The optimization of a collection system routing has been attempted[3] and further demonstration of the technique is planned.[4] A standardized program could probably be made available in this area also.

The response to specific user requests, not applicable to the previously described standard programs, but involving the manipulation of basic information available within the system would be within the capabilities of the system. A program would be available which can readily call on the information within the system, and arrange it in virtually any format requested. Thus, a specific request, coded for processing, would be matched against this general program. If the basic factors of the question are within the scope of the program, it would be answered. If not, the question would be returned with suggestions for revisions which will make it match.

The standard programs described for System #3 would not be available for use on individual computers. Instead, users would query the system, and the programs would be applied at the appropriate regional center. Duplicates of replies to queries would be made available to regional planning agencies, state agencies and the Federal Solid Waste Program. Thus, the using municipalities' activities with regard to solid waste planning would be monitored, at least to the extent that they request

SYSTEM #3
PLANNING INFORMATION
SERVICE

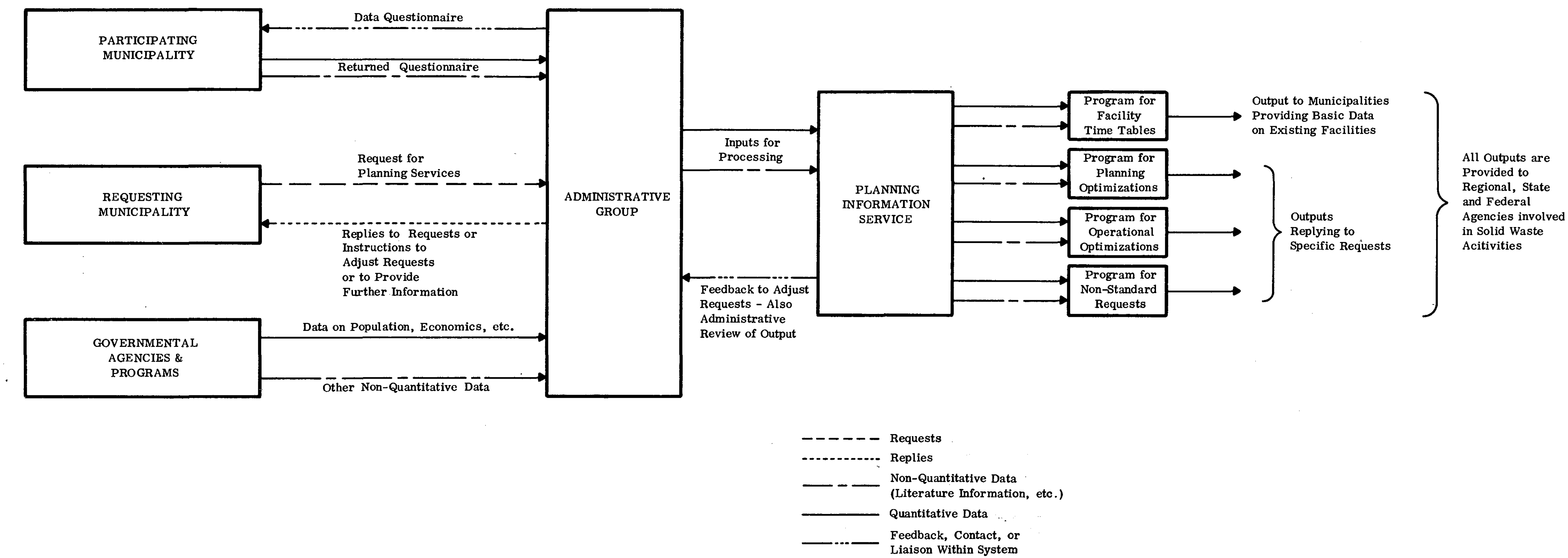


Figure 4

services. Should a grant program for solid waste facilities be instituted, the use of these planning aids could be made mandatory for qualification.

Administration of this system would primarily involve the monitoring of incoming requests and their preparation for processing. Incoming requests may require adjustment before processing and the computer output would be reviewed prior to return to the requestor. Other functions of the administrative group would involve the solicitation and processing of data from municipalities who now collect such data, and the maintenance and improvement of the computer programs.

d. SYSTEM #4 - PREDICTIVE AND PLANNING INFORMATION SERVICE

This system would combine the features of Systems #2 and #3. Since System #2 would provide predictions of trends on a controlled statistical basis, there would be no need for the unverified questionnaire approach to gathering data for trend predictions associated with System #3. In combining the features of Systems #2 and #3, System #4 would achieve more of the objectives than either of the other two individually.

e. SYSTEM #5 - DATA CLEARINGHOUSE AND PREDICTIVE INFORMATION SERVICE

This system would combine the features of Systems #1 and #2. Since System #2 would provide predictions of trends on a controlled statistical basis, there would be no need for the unverified questionnaire approach to gathering data incorporated in System #1.

f. SYSTEM #6 - DATA CLEARINGHOUSE AND PLANNING INFORMATION SERVICE

The data clearinghouse and planning information service would combine the features of Systems #1 and #3. All data pertinent to solid waste activities would be provided, along with computer based mathematical models for solid waste decision making activities on a request basis.

g. SYSTEM #7 - PREDICTIVE AND PLANNING INFORMATION SERVICE WITH DATA CLEARINGHOUSE (Figure 5)

The predictive and planning information service with data clearinghouse would combine the features of Systems #1, #2 and #3. All data pertinent to solid waste activities would be provided. Standardized predictions of solid waste parameters would be made available to all solid waste decision makers, and computer based mathematical models would be applied to planning and decision making activities on a request basis.

SYSTEM #7
PREDICTIVE & PLANNING INFORMATION SERVICE WITH DATA CLEARING HOUSE

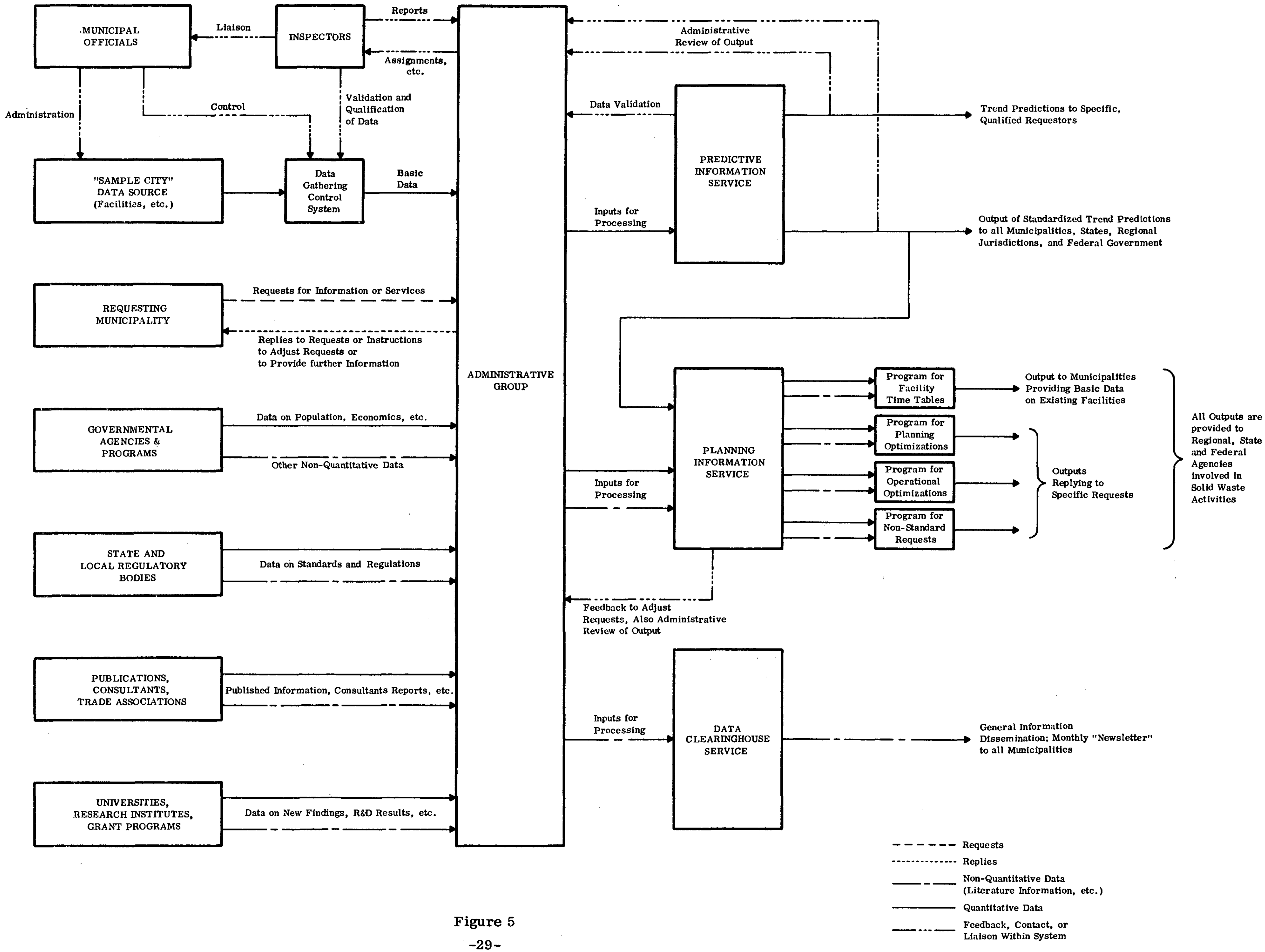


Figure 5

2. SYSTEM INPUTS AND OUTPUTS

The effective operation of an information system is largely dependent upon the inputs fed into the system and on the outputs which the system will generate. The basic objectives of a solid waste information system involve improvements in information (data) inputs and the development of outputs useful for planning and decision making purposes.

The inputs would be obtained from participating cities in a region and from other available sources concerned with solid waste. In addition, certain factors, necessary for the development of desired outputs, which may not be directly involved with operation of solid waste facilities, would also be obtained. In the development of trend projections for entire regions, the required data may be obtained from statistically selected sample cities.

System outputs should be designed to be generally useful to many cities and to be specific for cities facing a potential or actual solid waste problem. The outputs should include not only general solid waste related trends, but also should include specific planning or decision making criteria required by the requesting cities.

a. INPUTS

The inputs to a solid waste information system could be categorized under two broad areas.

(1) OPERATIONAL DATA - related to the collection, handling and disposal of solid waste.

(2) PLANNING DATA - related to the planning and decision making in solid waste management.

Operational data is that data concerning the amounts of refuse collected and the conduct of the collection, storage and disposal functions. Table I provides examples of operational input data, and serves to further define the systems described previously.

Planning data is that data which will have an effect on the solid waste management function, but which is not directly involved in the operation of facilities and equipment. Table II provides examples of inputs and outputs for the systems described previously.

b. OUTPUTS

The outputs of a solid waste information system must serve a number of specific decision making needs to be useful for solid waste management planning and decision making. Table III provides examples of output information and indicates which of the systems described previously would provide the outputs listed.

TABLE I

OPERATIONAL DATA INPUTS FOR

SOLID WASTE INFORMATION SYSTEMS

Data Category	Data Item	Applicable Systems
Quantity and Composition of Refuse	Refuse collected, by weight	#2, 4, 5, 7
	Refuse incinerated, by weight	"
	Refuse land filled, by volume	"
	Percent combustible	"
	Percent non-combustible	"
	Density of combustible refuse	"
	Density of non-combustible refuse	"
	Composition of combustible refuse	"
	Composition of non-combustible refuse	"
	Quantity of incinerator ash, by volume	"
	Quantity of incinerator ash, by weight	"
	Disposition of incinerator ash	"
	Composition of incinerator ash	"
	Rate of decomposition in land fills	"
Source of Refuse	Municipal, percent by weight	"
	Commercial, percent by weight	"
	Industrial, percent by weight	"

TABLE I, Cont.

Collection of Refuse	Municipal tons collected by city	#2, 4, 5, 7
	Municipal tons collected by private collectors	"
	Commercial tons collected by city	"
	Commercial tons collected by private collector	"
	Industrial tons collected by city	"
	Industrial tons collected by private collectors	"
	City collection facilities, number and size of trucks	"
Cost of Collection, City	Average distance hauled	"
	Equipment operating cost	"
	Manpower cost	"
	Average frequency of collection	"
Disposal of Refuse	Land fill volume	"
	Number and size of land fill sites	"
	Incineration capacity	"
	Number of incinerators and capacity	"
	Number of furnaces and capacity	"
	Breakdown of land fill disposal, by volume, by source and by collection	"
	Breakdown of incinerator disposal by weight, by source and by collection	"
	Other disposal methods used	"
	Weight and/or volume disposed by other methods	"

TABLE I, Cont.

Cost of Disposal	Cost per ton incinerated	#2, 4, 5, 7
	Cost per ton land filled	"
	Cost per cubic yard land filled	"
	Equipment operating cost	"
	Manpower cost	"
	Factors included in cost figures	"
Operating Schedules	Number of days of collections per week	"
	Number of hours per day of collections	"
	Number of days of incinerator operation per week	"
	Number of hours per day of incinerator operation	"
	Operating time of incinerator at various percentages of full load	"

TABLE II

PLANNING DATA INPUTS FOR

SOLID WASTE INFORMATION SYSTEMS

Data Category	Data Item	Applicable Systems
Population	Residential population	#2, 4, 5, 7
	Population density	"
	Population area	"
	Commercial population	"
	Industrial population	"
	Population growth trends	"
	Income levels by groups	"
Land Availability	Present acreage owned by city suitable for land fill use	#3, 6, 7
	Potential acreage for land fill use	"
	Water table information	"
	Stream locations	"
	Zoning regulations	"
	Location of potential land fill acreage	"
	Distance of potential land fill acreage from city center	"
	Distance of potential land fill acreage from population, industrial and commercial centers	"
	Land prices and price trends	#2, 3, 4, 5, 6, 7
Local and State Regulations	Solid waste disposal laws	#1, 7
	Air pollution control regulations	"

TABLE III

TYPICAL OUTPUTS OF

SOLID WASTE INFORMATION SYSTEMS

Trend Projections	Population versus year	#2, 4, 5, 7
	Per capita generation of combustible refuse versus year	"
	Per capita generation of non-combustible refuse versus year	"
	Percent of combustible refuse collected by city versus year	"
	Percent of non-combustible refuse collected by city versus year	"
	Percent of combustible refuse collected privately versus year	"
	Percent of non-combustible refuse collected privately versus year	"
	Density factors versus year	"
	Refuse composition versus year	"
	Land fill availability (life) versus year	"
	Incinerator use availability (capacity tons) versus year	"
	Actual incinerator use versus year	"
Land Requirements and Availability	Regional land availability for disposal use	#3, 6, 7
	Regional net land deficiencies for disposal use	"
	Capacity of each land fill site in terms of population served and for how long	"

TABLE III, Cont.

Land Requirements and Availability	Remaining life of land fill sites	#3, 6, 7
	Inventory of land available for disposal	"
	Standards and regulations affecting use of site for land fill disposal	#1, 7
	Effects on land availability and life of the use of incineration or other disposal methods	#3, 6, 7
	Geography and water shed characteristics of available land fill sites	"
Population Characteristics	Population growth trends	All
	Population density factors	All
	Percent population served by facilities	#3, 6, 7
	Population income levels and effect on waste generation (trends)	#2, 3, 4, 5, 6, 7
	Commercial population location, density and growth trends	"
	Industrial population location, density and growth trends	"
	Areas of municipalities served by facilities	#3, 6, 7
Facilities Operation	Number and capacity of incinerators in region	#2, 4, 5, 7
	Standard per capita operating cost of each incinerator in region	"
	Percent of population served by incineration	"
	Percent of population served by land fill	"
	Collection systems used	"

TABLE III, Cont.

Facilities Operation	Standard per capita operating cost of municipal collection systems	#2, 4, 5, 7
	Percent use factor of incinerators in region	"
	Performance characteristics of facilities	"
	Land fill operation reports, monthly	"
	Incinerator operation reports, monthly	"
	Age and condition of equipment at each location	"
Research Results	Studies on waste composition	#1, 7
	Studies on new disposal methods	"
	Studies on the effects of various factors on waste generation and waste disposal	"
	Studies on optimization methods	"
	Studies of computer technology application to solid waste management	"
	Health and welfare effects of solid waste management	"
Literature Availability	Literature available on all aspects of solid waste generation and disposal	"
Planning Aids	Trend projections	#2, 4, 5, 7
	Needs projections	#2, 3, 4, 5, 6, 7
	Collection optimization studies	#3, 6, 7
	Disposal optimization studies	"
	Facilities location studies	"

TABLE III, Cont.

Planning Aids	Facilities needs recommendations	#3, 6, 7
	Timetables for facilities capacity saturation	"
	Timetables for new facilities planning	"
Standards and Regulations	Agency responsibilities for solid waste generation and disposal	#1, 7
	Technical, procedural and financial assistance availability from agencies	"
	Acceptable standards for facilities performance	"
	Regulations regarding solid waste collection, handling and disposal	"
	Regulations regarding air, water and land pollution	"
	Sampling and testing regulations and requirements	"
	Federal controls (across state lines)	"
	Design requirements for incinerators, land fill and other disposal facilities	"
	Disposal sites sanitary code	"
	Land fill ordinances, pollution, burning, zoning, vermin, penalties	"
Financing	Means of charging for refuse services	"
	Magnitude of refuse charges	"
	Means of financing new facilities	"
	Investment required per population area	"
	Opportunities for sale of waste products	"
	Cost of capital	"

3. ACHIEVEMENT OF OBJECTIVES

Table IV indicates how well each of the systems meet the objectives.

System #1 achieves very few of the objectives.

System #2 is seen to provide all of the "must" objectives. With respect to "want" objectives, 2-b, 2-c and 2-e would be considered "somewhat" achieved in that the trend predictions for key parameters would permit the calculation of facilities saturation and needs timetables on the part of individual decision makers. Although the results of such individual calculations are likely to vary in consistency and accuracy, the objective would be achieved to a slight extent because the calculations would have been made on the basis of better information than was previously available.

System #3 does not achieve any of the "must" objectives and, as such, is inadequate by itself. Since System #3 would collect available data in the manner of System #1, that is, without statistical control or field verification, its achievement of Objectives 1-a, 1-b, 1-c and 1-d would be similar to that of System #1. However, since some trend predictions would be developed to apply to the standard programs of System #3, Objective 2-a would be partially achieved. Objectives 2-b, 2-c and 2-e would be partially achieved in that trend predictions will be available, but since they are not based on the "sample cities" approach, their accuracy is limited.

System #4 would achieve all of the "must" objectives. Only the objectives of providing the data clearinghouse and information which is not now readily available would not be entirely achieved by System #4. The latter would be partially achieved, but not all information of interest would be provided.

System #5 would achieve all of the "must" objectives, and would achieve Objectives 2-b, 2-c and 2-e somewhat in that the trend predictions for key parameters would permit the calculation of facilities saturation and needs timetables on the part of individual decision makers. This would also be provided by System #2.

System #6 would not completely achieve any of the "must" objectives and, as such, is inadequate by itself. The partial achievement of Objectives 2-b, 2-c and 2-e would be based on predictions of parameter trends not grounded in data obtained by statistically controlled sample cities, but is based on unverified data only from those cities who claim to collect it.

System #7 combines all features of Systems #1, #2 and #3, and would satisfy all the system objectives. In combining the best features of Systems #1 and #3 with the trend prediction features of System #2, the need for the gathering of unverified data from solid waste administrators and decision makers would be done away with. The data would be entirely based on the "sample cities". The addition

TABLE IV

ACHIEVEMENT OF OBJECTIVES

Objective	Recommended Objective Category	System 1	System 2	System 3	System 4	System 5	System 6	System 7
1-a Adequate Data	"Must"	No	Yes	No	Yes	Yes	No	Yes
1-b Quality of Information	"Must"	Somewhat	Yes	Somewhat	Yes	Yes	Somewhat	Yes
1-c Information More Readily Available	"Want"	Partially	Partially	Somewhat	Partially	Partially	Partially	Yes
1-d Standardize Information	"Must"	Somewhat	Yes	Somewhat	Yes	Yes	Somewhat	Yes
1-e Information in Convenient Format	"Want"	Somewhat	Partially	Yes	Yes	Partially	Yes	Yes
1-f Data Clearinghouse	"Want"	Yes	No	Somewhat	No	Yes	Yes	Yes
2-a Trend Predictions	"Must"	No	Yes	Partially	Yes	Yes	Partially	Yes
2-b Predict Facility Saturation	"Want"	No	Somewhat	Partially	Yes	Somewhat	Partially	Yes
2-c Predict Capacity Requirements	"Want"	No	Somewhat	Partially	Yes	Somewhat	Partially	Yes
2-d Minimize Cost	"Want"	No	No	Yes	Yes	No	Yes	Yes
2-e Predict Planning Timetables	"Want"	No	Somewhat	Partially	Yes	Somewhat	Partially	Yes
2-f Request Service	"Want"	Somewhat	No	Yes	Yes	Somewhat	Yes	Yes
2-g Optimize Operations	"Want"	No	No	Yes	Yes	No	Yes	Yes

of System #1, the data clearinghouse, provides general "state-of-the-art" information in addition to the special planning and decision making tools provided by Systems #2 and #3.

On the basis of meeting the most important or the "must" objectives, the list of system alternatives can be reduced from seven to four. The preferred systems are:

a. System #2 Predictive Information Service

b. System #4 Predictive and Planning Information Service

c. System #5 Data Clearinghouse and Predictive Information Service

d. System #7 Predictive and Planning Information Service with Data Clearinghouse

D. EVALUATION OF SYSTEMS

Seven systems have been developed to meet all or part of the information system objectives. These systems must be evaluated on the basis of meeting the stated objectives, the estimated cost for operation of the system and the benefits to be derived through use of the systems. The results of these evaluations will provide the means for recommending the best system for further consideration and possible implementation.

The cost of solid waste collection and disposal in the United States has been estimated to range from $1.5 to $3.0 billion annually.[5] Much of this expenditure is not handled effectively, as has been indicated by the lack of certain types of information and by the apparent ineffectiveness of facilities, equipment and services for which the money is spent. Better information and the better decision making tools which can be derived from the information can be expected to help expend the resources more effectively. From an economic point of view, the question is straight-forward: "What will the better information cost, and how much will it save?" The answer to the question is not straight-forward. The benefits are difficult to quantify, and although the costs are perhaps less difficult to estimate, they have, at this conceptual state, a wide variability.

1. COST ESTIMATES FOR EACH ALTERNATIVE SYSTEM

Although four of the seven systems are preferred, the cost of each of the seven systems is presented for completeness. The cost of each system has been estimated on the basis of a ten year operational period, based on separate estimates for first cost and annual operating cost. Since estimates are based on preliminary concepts, they exhibit a range of variation to account for the uncertainties inherent at this stage. The results of the cost estimates are shown on Table V. Details of the development of cost estimates for each proposed system are given in Appendix B. The cost estimates are based on certain assumptions concerning unit costs for such items as keypunching, programming, data gathering, computer time, printing time, reproduction per page costs, etc. These assumptions are also listed in Appendix B. Further assumptions are developed within the estimates to indicate the limitations of the activities described. It should be understood that the estimates would change significantly if the assumptions and limitations were changed.

Cost factors used include the following.

a. DATA GATHERING

Cost estimates for each of the systems are based on the accurate and complete gathering of data at several selected localities which can be used to statistically represent a large region comprising many times the area and population actually accounted for by the "sample cities". The data gathering operation requires the acquisition and operation of certain equipment in each of these cities. This equipment includes:

Weighing scales and other measuring instrumentation, sampling apparatus, etc. Equipment to determine refuse composition is not included (see Appendix C).

Personnel are required to gather data, operate equipment, record and tabulate data, inspect data gathering systems, etc.

Miscellaneous supplies, including paperwork and hardware are also required.

The type of data to be gathered in the "sample cities" includes all basic refuse tonnage and volume data as well as other refuse and residue measurements, land fill consumption measurements, etc. The number, location and other pertinent characteristics of the "sample cities" are selected on the basis of the presumed sources of variation of the quantities to be measured. If the number of sources of variation leads to a large number of possible combinations, the "sample cities" are established by random selections. The accumulation of data with time would allow the application of multiple regression analysis on a time basis which would lead to extrapolated predictions of trends in significant parameters. A more detailed analysis is presented in Appendix D.

b. DATA PROCESSING

The data processing function includes the following cost factors:

Manual processing to prepare data for machine operation and to screen out errors.

Keypunching and verification.

Conversion of cards to tape, screening of data and creation of master file(s).

TABLE V

SUMMARY OF SYSTEM COST ESTIMATES

(all cost values shown are ±20%)

	System	"Must" Objectives Totally Achieved	"Want" Objectives Totally Achieved	First Cost (First Year) Cost	Annual Cost	Ten Year Cost
#1	Data Clearinghouse Service	None	1	$ 225,000	$ 170,000	$ 1,755,000
#2	Predictive Information Service	All (4)	None	1,600,000	1,000,000	10,600,000
#3	Planning Information Service	None	4	360,000	212,000	2,270,000
#4	Predictive and Planning Information Service (#2 & #3 combined)	All (4)	7	1,860,000	1,134,000	12,066,000
#5	Data Clearinghouse and Predictive Information Service (#1 & #2 combined)	All (4)	1	1,713,000	1,095,000	11,568,000
#6	Data Clearinghouse and Planning Information Service (#1 & #3 combined)	None	5	465,000	308,000	3,237,000
#7	Predictive and Planning Information Service with Data Clearinghouse (#1, #2 & #3 combined)	All (4)	All (9)	1,940,000	1,220,000	12,920,000

c. PROGRAMMING

Conversion programs to convert existing data.

Screening to assure data consistency.

File maintenance to enter new data.

Calculations to recompile data and to generate desired output.

Report generation to print output in desired format.

Systems analysis to conduct preliminary studies and to assure information systems effectiveness.

Annual program modifications and eventual redesign.

Miscellaneous programs.

d. COMPUTATION

Program testing to "debug" programs.

Initial processing, calculation and report generation.

Annual processing, calculation and report generation to handle annual as opposed to initial data load.

Printing of output for reproduction.

e. REPRODUCTION AND DISTRIBUTION

Reproduction for distribution to municipalities.

Mailing and handling.

f. ADMINISTRATIVE COSTS

Administrative personnel to supervise the operation.

Clerical assistance, i.e. secretaries, clerks, etc.

General supplies and equipment.

Although personnel costs are distributed throughout the various cost factors as indicated above, the various personnel categories which may be required for the information system are as follows:

a. Administrative personnel

b. Systems specialists

c. Systems assistants

d. Programmers

e. Librarians

f. Keypunch operators

g. Secretaries

h. Clerks

2. EVALUATION OF BENEFITS

The benefits of each of the preferred systems must be defined and an assessment made of whether there is basic economic justification for the establishment of the information system. Many significant benefits will result, but all of them are difficult to quantity. There will be a gradual evolution of more and better information for the planning and operation of solid waste activities, which will result in a general up-grading of the "state-of-the-art" and in more effective decisions over the long term. Expected benefits will be listed and a broadly based analysis conducted to determine whether the level of expenditure is justifiable in terms of benefits to the users. Specific quantifying of benefits will then be attempted to determine whether the added cost increment required to achieve all objectives is justified.

a. BENEFITS

The benefits for Systems #2, 4, 5, and 7 are presented in terms of their realization by the decision makers who would use the system. The following is a list of benefits expected from the information system. Following each benefit is the number of the system which provides the benefit.

(1) The user would know what data is available and that he is not missing anything significant - #5, #7.

(2) The user would obtain his needed data quickly, without repeated inquiries - #4, #7.

(3) The user would have his needed data in ready-to-use form - #2, #4, #5, #7.

(4) The user would know that the data is based on consistent standards - #2, #4, #5, #7.

(5) The user would know that the data is representative of his geographic region - #2, #4, #5, #7.

(6) The user would know that the data was developed on the basis of proven and accepted techniques - #2, #4, #5, #7.

(7) The user would be given the benefit of sophisticated computer usage and techniques, regardless of his community's size and means - #2, #4, #5, #7.

(8) The user would know with reasonable certainty whether his future plans are sufficient and timely - #2, #4, #5, #7.

(9) The user would know that his plans and operations are as optimum as modern management technology can make them - #4, #7.

(10) The user would have available an information service from which he could request assistance - #4, #7.

(11) The user would be likely to improve his own data gathering, planning and operations as a result of the positive influence of a well organized information system - #4, #7.

(12) The user would save money he would otherwise spend on surveys which are often of questionable value - #4, #7.

(13) The user would save money because he can plan more quickly and effectively - #4, #7.

(14) The user would save money because significant changes in facilities and operations would be planned for well in advance - #4, #7.

(15) The user would save money because he would have better knowledge as to how well his money is being spent - #2, #4, #5, #7.

b. BROAD ANALYSIS OF SYSTEM BENEFITS

(1) VALUE OF INFORMATION

According to the 1960 census, there are over 6,000 communities above 2,500 population and of basically urban character. Of these, approximately 270 operate incineration facilities and can be assumed to also operate weighing scales to obtain basic refuse tonnage data. If the presence of a weighing scale is assumed to indicate that a limited capability for accumulating data exists, then it is assumed that these communities would not place any value on such data developed elsewhere. Similar remarks apply to those of the remaining 5,730 communities which operate weighing scales at land fill sites. Data developed by means of a statistically based information system can be expected to be of some quantifiable value to the remaining communities. Estimates of this value in terms of dollars per year, multiplied by the number of cities, gives an indication of an annual "value" of the information developed. Table VI summarizes this calculation.

TABLE VI

CALCULATION OF THE "VALUE" OF BETTER INFORMATION

Community Populations	Number In U.S. 1960[1]	Number Incinerating[2]	Estimated Number With Scales at Land Fills[3]	Number Requiring Data[3]	What Are They Willing to Pay ?/Year (each)[3]	What Are They Willing to Pay? (Total)[3]
1,000,000 and over	5	4	1	0		
500,000 to 999,999	16	11	5	0		
250,000 to 499,999	30	10	10	10	$3,000 to $5,000	$30,000 to $50,000
100,000 to 249,999	81	18	30	33	$1,500 to $2,500	$49,500 to $82,500
50,000 to 99,999	201	50	40	111	$500 to $1,000	$55,000 to $111,000
25,000 to 49,999	432	41	20	371	$300 to $500	$111,000 to $186,000
10,000 to 24,999	1,134	79*	10	1,045	$200 to $400	$209,000 to $418,000
5,000 to 9,999	1,394	56*	0	1,338	$50 to $150	$67,000 to $201,000
2,500 to 4,999	2,152		0	2,152		
Under 2,500 Urbanized	596		0	596		
Urban Total	6,041	269		5,656		$521,500 to $1,048,500

* Reference 5

1 1960 Census Data.
2 From results of Contract Ph 86-66-163 except as noted by asterisk.
3 Combustion Engineering, Inc. estimates.

Thus, the estimated value of the information ranges from approximately $500,000 to $1,000,000 per year, compared to an average annual cost for System #7, of $1,300,000. This rather simple and conservative calculation clearly shows that the cost of the information provided is likely to be largely offset by what the users might be willing to pay for it if they had to buy it. Any benefits accruing from the availability of the information are in addition to this basic balance of "value" versus cost.

(2) EFFECT OF INFORMATION ON FUTURE FACILITIES

The estimated 1966 incineration capacity in the United States is approximately 75,000 tons (per day). The results of the mathematical analysis conducted under this program indicate that in 1975, the capacity will increase to somewhere in the range of 108,000 to 125,000 tons, or there will be an increase of 33,000 to 50,000 tons. If a typical incineration plant is assumed to consist of two 250 ton furnaces, then 66 to 100 new plants may be built by 1975. If the unit cost of these plants is assumed to be $6,000 per ton, then the total cost per new plant would be $3,000,000 and the total estimated investment in incineration facilities between 1966 and 1975 would be $198,000,000 to $300,000,000.

If an information system is operative during this period, and the objectives are achieved as stated, some portion of the above investment may be saved, due to the availability of better planning information and a general upgrading of the "state-of-the-art". In addition, many surveys will be made unnecessary and the moneys saved can be assigned to more effective designs. The optimization of the number and location of regional incinerators in given situations can be expected to provide substantial long term savings. It will be assumed that the aggregate of all potential savings attributable to an information system will amount to 5 percent of the above investment total. Thus, the anticipated savings will range from $9,800,000 to $15,000,000. These figures bracket the anticipated ten year cost of System #7. This estimate of savings does not account for any savings attributable to better facilities decisions with regard to land fill operations, nor does it consider any savings achieved in the operation of facilities.

c. SELECTION OF BEST SYSTEM FOR MAXIMUM COST EFFECTIVENESS

System #2, the predictive information service, does not achieve any of the "want" objectives, and as such it does not achieve benefits 1, 2, 9, 10, 11, 12, 13 and 14 (Reference section 2-a).

When Systems #2 and #3 are combined to make System #4, the added cost increment (ten year total) is $1,400,000. This system does not achieve benefit 1, but benefits 2, 9, 10, 11, 12, 13 and 14 are achieved at an additional cost of approximately $140,000 per year.

When Systems #1 and #2 are combined to make System #5, the added cost increment (ten year total) is $900,000, and it does not achieve benefits 2, 9, 10, 11, 12, 13 and 14. Thus, the additional cost of approximately $90,000 per year has achieved only the additional benefit 1.

When all systems are combined, System #7 results, and it achieves all the stated objectives and provides all the benefits. This system requires an additional $2,225,000 over System #2 (ten year total), or approximately $225,000 per year to achieve Objectives 1, 2, 9, 10, 11, 12, 13 and 14.

Benefit 1 is provided by the data clearinghouse system (System #1) which, when coupled with System #2 to make System #5, adds a literature search and literature surveillance service; at a cost of $90,000 per year. This amounts to about $16 per year for each community assumed to need data. The potential benefits of having all these communities receive the means to remain well informed certainly is well worth this nominal cost.

Benefits 11, 12, 13 and 14 are those which deal with more timely and effective planning and they are primarily achieved by System #3 acting in conjunction with #2 to make System #4. The potential benefits of improved planning have already been quantified in a broad sense in Section b-2. The addition of System #3 to #5, to give #7, requires an additional $136,000 per year. This is again a nominal cost for providing additional assurance that the data to be gathered by System #2 is properly applied.

Thus, System #7 is recommended and provides the potential of benefits whose estimated value substantially exceeds its cost.

E. SPECIFICATION FOR A PILOT SYSTEM

In order to demonstrate that the recommended system can be successfully implemented, a pilot program is indicated. This pilot system should encompass, on a smaller scale, all of the features of the full scale System #7, which has been recommended for implementation, and upon completion should be capable of virtually complete integration into the overall system. The pilot system should encompass a sufficiently large and representative region of the country and should contain certain minimum historical and planned municipal solid waste activity. The historical activity should be reasonably well documented, so that the changing pattern of decision effectiveness may be assessed.

1. OBJECTIVES OF PILOT SYSTEM

a. PROOF OF PROPOSED SYSTEMS AND TECHNIQUES

The pilot system should investigate proposed systems and techniques in sufficient detail to prove out their feasibility and practicability to a reasonable level of confidence. It should also be capable of altering and developing proposed systems and techniques until they are workable. In this sense, the pilot system should also provide an R & D capability.

b. ESTABLISH OPERATIONAL FORMAT FOR FINAL SYSTEM

The pilot system should establish the degree of sub-division required in an ultimate system. That is, the pilot system should help decide whether the administration of the ultimate system be centralized or distributed. The administrative center for the pilot system should, therefore, either be considered the prototype of several others, or possibly the nucleus of a single center for the ultimate system.

c. ABSORPTION IN FINAL SYSTEM

The pilot system should be capable of absorption into a broader nation-wide system with a minimum of alteration. Some "sample cities" may have to be dropped. However, the cost of maintaining these cities active should be carefully weighed against the already expended cost of establishing them, and their continued value in the system.

d. COMPATIBILITY WITH INFORMATION SYSTEM TECHNOLOGY

Information systems for municipal activities are receiving more widespread attention. The pilot system for a solid waste information system should attempt to function to the maximum possible extent in cooperation with such efforts.

2. CHARACTERISTICS OF PILOT REGION

a. SIZE

A reasonably significant portion of the United States would be a plausible size for the pilot system's area. One of the Public Health Service's nine regions, preferably one with some climatic variation within its boundaries, would be a logical choice; however, the potential political difficulties of operating in a multi-state area should be recognized and dealt with at the outset.

b. POPULATION

Since the solid waste problem is most serious in areas of current and expected high population density, the pilot region should be one of the more populous regions of the country.

c. ECONOMIC MAKE-UP

The pilot region should include areas of all economic ranges, from relatively wealthy communities, to poor, or depressed communities. Cities within the region should have similar economic ranges within their own individual boundaries.

d. ZONING CHARACTERISTICS

The region should encompass communities of all types, including residential, suburban communities and industrial urban communities. The region should include at least one relatively large metropolitan area, and several moderately large cities.

e. SOLID WASTE ACTIVITIES

The region should contain solid waste activities of all types, from incineration and composting to land fills and modified land fills, to open dumps. Collection activities by both private and municipal agencies should be present. There should have been relatively recent solid waste decisions of a significant nature, with several additional decisions pending within a year or two. Most of the cognizant state agencies should be active in solid waste programs, and should be willing to participate in the pilot program.

3. CHARACTERISTICS OF THE PILOT SYSTEM

a. SAMPLE CITIES

The region should include a sufficient number of sample cities to assure a statistically valid sample. Wherever possible, existing data-taking operations should be qualified to increase the number of samples. The total for the pilot region should significantly exceed the number of sample cities which would be allocated to it if the nation-wide system were to be established all at once.

b. INPUTS AND OUTPUTS

Input data should be gathered on refuse quantities in weight and volume units, on refuse disposition, on refuse generation by economic areas and on rate of land consumption by land fill and incinerator operations. Cost data should be accumulated, with all cost elements included. Significant operational data on collection should be gathered, such as haul distances, haul times, number of stops, costs, etc.

Output information should be developed to provide trend predictions in the significant solid waste parameters and to provide planning recommendations applicable to specific planning situations as may be encountered during pilot system operation.

c. HISTORICAL DATA

Cities within the region should be asked to provide whatever historical data is available. The administrative center would scrutinize this for its utility and would base early system output on it, while new data is accumulated.

d. COMPUTER PROGRAMS AND COMPUTER OPERATION

Since the pilot program may prove of a temporary nature, computer programming and operation should be obtained through service bureaus, of if possible, through the cooperation of one of the participating states' EDP system, or at a university computer center if it can accommodate the required load. All of the complete and detailed programs called for by the recommended system need not necessarily be developed. It may be possible to develop brief programs tailored to specific decision situations as they arise, and these programs would eventually be combined to absorb all desirable features into a broader general program. The request service program may not need to be developed, since in the pilot program it is more likely that the administering body must seek out situations to which they will apply the techniques of the system.

e. ADMINISTRATIVE STAFF

A full administrative staff must be established at the outset, including all inspection and other feedback features. This staff would solicit initial cooperation with state and local officials and would monitor the data gathering process. They would administer whatever grant funds would be necessary to help upgrade the data gathering capability of a given community. The administrative staff would be responsible for periodic status reports to assure that the continuation of the pilot program was warranted.

f. DURATION OF PILOT PROGRAM

The pilot program would probably require one full year to become operative, and an additional two to four years to develop sufficient data to provide trend predictions. However, evaluation of whether the system would be feasible for nation-wide application could be accomplished earlier than this, if the system were apparently operating successfully.

g. COST OF PILOT PROGRAM

The estimated cost of establishing the pilot program (also the first year cost) is $419,000. The estimated annual operating cost is $303,000. The total cost until integration into a nation-wide system after an assumed four duration is $1,328,000. The details of these cost estimates are given in Appendix B. They have an anticipated range of variability of ±20 percent.

The estimated pilot system cost represents approximately 10 percent of the total system ten year cost.

SECTION VI

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SECTION VII

APPENDIX A

QUESTIONNAIRE AND INTERVIEW PROGRAM

A. PURPOSE

1. A basic element of the solid waste information system study is the determination of the type of information required by planners and decision makers concerned with solid waste collection and disposal. A further element is the determination of how much of this information is readily available and what information is not now available to these people. A mail questionnaire program was devised as a means to survey the information needs and the information availability. Those surveyed for this purpose were the planners and decision makers who would actually have use for the information.

2. Another element of the solid waste information system study is the determination of problems and practices involved in the use of information systems by Governmental agencies. A questionnaire survey was taken of the designers of Governmental information systems in order to accomplish this.

3. Another purpose of the questionnaire surveys was to determine the current information practices in the area of solid waste collection and disposal. The practices considered to be important include the sources of information and their reliability, methods of obtaining the needed information, the cost of obtaining the information and the usefulness of the information gathered.

4. In addition to the questionnaire surveys taken, twenty-one personal interviews were conducted. These interviews were intended to obtain a more detailed understanding of current information practices and the problems in obtaining the needed information, to further assess the need for and the possible nature of an information system, and to confirm the questionnaire findings.

B. APPROACH

1. Two types of questionnaires were used for the information system study. One was directed to those who would use the information for planning and decision making purposes in their capacities as refuse officials. This questionnaire (Questionnaire A at the end of this appendix) contained questions concerning the type of information required, the type of information normally obtained, the type of information which has to be specially obtained, and the methods and practices used in obtaining the special information. It also attempted to define the specific nature of the information needed and the reasons why some of this information cannot at present be readily obtained.

The recipients of this questionnaire were categorized by their specific function and area of interest. This was done for several reasons. First, it was necessary to insure that the responses would be representative of a number of different viewpoints. Categorization of the questionnaire addressees made possible the development of a mailing list covering these different viewpoints. Second, it was considered desirable to categorize the responses received in order to define the various areas of decision concern and to define the specific information required by each decision area. The categories used for this questionnaire were concerned with planning and other decision making activities in the refuse field. They included the following:

a. State Planners (e.g., State Health Department)

b. Regional Planners (Where Regional Authorities exist)

c. Municipal Planners (e.g., Directors of Public Works)

d. Operators (Municipal, Regional, Private - e.g., Superintendent of Sanitation)

e. Equipment Manufacturers (e.g., Incinerators, Packers)

f. Consultants (e.g., Planning and Design Consulting Engineers)

g. Researchers, Civic Groups and Others

No geographic preference was used in choosing the specific recipients within each category. The discussion of results to follow will cover the responses both by categories and as an aggregate.

2. The second questionnaire used was directed to those involved in the design and application of information systems for Governmental use, and where possible, with regard to refuse activities. This questionnaire (Questionnaire B at the end of this Appendix) included questions concerning the areas of primary responsibility, methods used for collection of data, handling and analyzing of data and information, costs of information handling systems and usefulness of the results obtained. It also attempted to define some of the problems in utilizing Governmental information systems and some of the specific information needs for these systems. The recipients of this questionnaire were also categorized by their functional areas of activity. Again, this was done to insure representative responses from the various functional areas of interest, and to determine any differences in needs from these areas. The mailing list was made up on the basis of the following categories:

a. Federal Planners

b. State Planners

c. Consultant Planners

d. Authors

e. Research Institute Planners

f. Trade Association Planners

g. Miscellaneous

Again, no geographic preference was used in choosing the specific recipients within each of these categories. In the analysis of responses to this questionnaire, it was found that too few responses came from each individual category to allow valid conclusions to be drawn on a category basis, nor did any significant differences appear to exist between categories. The results to follow are therefore presented on the basis of the aggregate response to this questionnaire.

3. The interviews were also categorized in order to insure that the results were representative of those areas considered of primary importance with regard to refuse activities. Time and cost limited the personal interviews to only a sampling in each category. These categories included:

a. State Planners

b. Municipal Planners

c. Regional Planners

d. Operators (Municipal and Private)

e. Consultants

f. Researchers

g. Equipment Manufacturers

C. RESULTS

1. RESPONSE

Response to the questionnaire mailing, both to "Refuse Officials" and "Data System Specialists", was quite good, with better than one-third of the mailing returned as usable responses.

The following are the response statistics:

a. "Refuse Official" Questionnaire (Ouestionnaire samples at end of this appendix)

198 sent	73 usable responses	37 percent

Category - State Planners

13 sent	9 usable responses	70 percent

Category - Regional Planners

12 sent	5 usable responses	42 percent

Category - Municipal Planners

53 sent	21 usable responses	40 percent

Category - Operators

49 sent	13 usable responses	27 percent

Category - Manufacturers

24 sent	4 usable responses	17 percent

Category - Consultants

24 sent	14 usable responses	58 percent

Category - Researchers, Authors and Miscellaneous

23 sent	7 usable responses	30 percent

b. "Data Systems Specialists" Questionnaire (Questionnaire samples at end of this appendix)

68 sent	27 usable responses	40 percent

Although various categories were used in developing a mailing list for the "Data System Specialists" questionnaire, it was not considered significant to report the response in accordance with these categories, especially since the number of respondents in most of them is too small to draw any meaningful categorized conclusions.

A copy of the "compilation questionnaire" for each type of questionnaire is included at the end of this appendix. This will permit the reader to examine in detail the aggregate response to each question. The discussion to follow will delve into the significance of these responses, particularly for the "Refuse Official" questionnaire, where response by category is most pertinent to the feasibility and design of an information system for municipal refuse.

2. DISCUSSION OF THE "REFUSE OFFICIALS" QUESTIONNAIRE

QUESTION 1(b)

This question asked the respondents to rate their primary decision areas. The results of this rating are presented on Figure 6. This chart clearly shows that the majority of the categories consider long range planning as their primary decision area. Only operators of refuse facilities and state planners did not choose long range planning as either a first or second choice. The second choice, in the aggregate, was "the evaluation of performance of refuse facilities". The third choice was "the evaluation of effectiveness of plans".

QUESTION 2(a)

Figure 7 illustrates the type of data that is normally obtained by each of the "Refuse Official" categories. The results are presented on the basis of percent of each category responding. The chart emphasizes those cases where more than 50 percent of the respondents in a category nromally obtain the type of data indicated. The chart shows that data on facilities performance, refuse quantity, population and costs of refuse activities can be considered normally obtained by most of the categories.

QUESTION 2(b)

Figure 8 illustrates the type of data that is considered important in decision making by each of the "Refuse Official" categories. The chart shows that data on land requirements, facilities performance, refuse quantity, and costs of refuse activities can be considered as most important. Comparison with Figure 7 shows that data on land requirements is important, but generally lacking.

QUESTION 3(a)

Figure 9 illustrates the type of data that has had to be specially obtained by each of the "Refuse Official" categories. The chart is arranged to emphasize those cases where more than 33 percent of the respondents in a category had to take special steps to obtain the type of data indicated. As expected, data on land requirements frequently had to be specially obtained. But, in addition, data which was normally obtained, such as facilities performance, refuse quantity, and costs of refuse activities, was also quite frequently specially obtained. This indicates that normally obtained data is probably often insufficient or incomplete for the decision required. Comparison of Figures 8 and 9 also indicates a few areas where data was not considered important, but has been obtained specially. Examples are data on air pollution, refuse composition, and population. These will probably become more important with time.

PRIMARY DECISION AREAS OF "REFUSE OFFICIALS"

1 - First Importance
2 - Second Importance
3 - Third Importance

Categories	Long Range Planning	Obtaining Public Support	Evaluating Effectiveness of Plans	Establishing Standards & Regulations	Operation of Refuse Facilities & Equipment	Evaluation of Performance of Refuse Facilities
State Planners		2		3		1
Regional Planners	1	2	3			
Municipal Planners	1		3	2		
Operators	3				1	2
Manufacturers	1				3	2
Consultants	1		2			3
Researchers, Authors & Misc.	2		3		1	

Figure 6

INFORMATION NORMALLY OBTAINED BY "REFUSE OFFICIALS"

	Land Requirements	Facilities Performance	Equipment Inventory	Air Pollution	Refuse Quantity	Refuse Composition	Population	Costs of Refuse Activities
State Planners (9 Replies)	56%	56%	22%	45%	45%	22%	78%	45%
Regional Planners (5 Replies)	60%	60%	20%	40%	60%	40%	60%	40%
Municipal Planners (21 Replies)	38%	61%	52%	38%	90%	14%	47%	71%
Operators (13 Replies)	38%	53%	69%	46%	100%	30%	38%	92%
Manufacturers (4 Replies)	0%	25%	25%	50%	75%	50%	50%	50%
Consultants (14 Replies)	28%	64%	21%	57%	71%	64%	85%	78%
Researchers & Misc. (7 Replies)	29%	29%	14%	43%	57%	43%	29%	29%
Aggregate (73 Replies)	37%	55%	38%	45%	77%	34%	56%	66%

Percents shown are percent of each category which normally obtains the particular class of information. For example, 90 percent of the twenty-one municipal planners normally obtain refuse quantity information.

Figure 7

INFORMATION CONSIDERED IMPORTANT IN DECISION MAKING BY "REFUSE OFFICIALS"

	Land Requirements	Facilities Performance	Equipment Inventory	Air Pollution	Refuse Quantity	Refuse Composition	Population	Costs of Refuse Activities
State Planners (9 Replies)	56%	67%	45%	22%	56%	45%	45%	67%
Regional Planners (5 Replies)	80%	60%	20%	60%	80%	60%	80%	60%
Municipal Planners (21 Replies)	52%	71%	14%	38%	90%	19%	28%	71%
Operators (13 Replies)	30%	53%	53%	46%	100%	38%	30%	84%
Manufacturers (4 Replies)	0%	25%	0%	50%	75%	50%	50%	50%
Consultants (14 Replies)	50%	57%	14%	57%	92%	78%	64%	78%
Researchers & Misc. (7 Replies)	86%	71%	43%	43%	100%	71%	57%	71%
Aggregate (73 Replies)	51%	62%	27%	44%	88%	47%	48%	73%

Percents shown are percent of each category which considers the particular class of information as important.

Figure 8

INFORMATION SPECIALLY OBTAINED BY "REFUSE OFFICIALS"

	Land Requirements	Facilities Performance	Equipment Inventory	Air Pollution	Refuse Quantity	Refuse Composition	Population	Costs of Refuse Activities
State Planners (9 Replies)	45%	56%	33%	45%	45%	45%	56%	45%
Regional Planners (5 Replies)	60%	0%	20%	80%	40%	40%	40%	20%
Municipal Planners (21 Replies)	47%	28%	14%	28%	33%	19%	14%	38%
Operators (13 Replies)	38%	38%	7%	30%	61%	7%	15%	61%
Manufacturers (4 Replies)	0%	25%	50%	25%	50%	50%	25%	50%
Consultants (14 Replies)	7%	42%	7%	42%	57%	28%	21%	35%
Researchers & Misc. (7 Replies)	43%	43%	14%	29%	71%	43%	0%	43%
Aggregate (73 Replies)	36%	36%	16%	37%	49%	27%	22%	42%

Percents shown are percent of each category which had to obtain the particular information by special means.

Figure 9

Figure 10 shows the percentage of respondents in each category who had to obtain special data in areas where they already received data normally. This clearly shows where the normally obtained data required extension or refinement. Refuse quantity data and cost of refuse activities data exhibited this characteristic in almost all categories of decision makers.

Figure 11 provides a semi-quantitative illustration of the apparent data deficiency. Where a category of decision maker considers a particular data item important, and has also had to obtain special data in that area, that box in the matrix is darkly shaded to indicate a strong data need. Where the decision maker considers the data important but appears to have adequate data available, the box is lightly shaded, indicating a potential data need. Where the decision maker did not consider the data area as important to his decision making responsibility, but then indicated that he had to obtain special data in that area, the matrix is marked with an "X". In general, the areas of information need are in land requirements, facilities performance, refuse quantity and costs of refuse activities. Refuse composition and population information are considered important, but adequate data for present needs is apparently available. Air pollution was not considered overly important except by regional planners, manufacturers and consultants.

QUESTIONS 3(b) AND 3(c)

Figure 12 graphically illustrates the aggregate response of the "Refuse Officials" to questions dealing with the specially obtained data. Only the aggregate response is presented because it was not considered that the response by category would be significant. Figure 12 gives the percent response as to the staff used, the method of collection, and the cost for obtaining the special data.

Eighty percent of the "Refuse Officials" had to obtain additional special data during the past year. They primarily used their own staffs, and they used interviews, direct measurements and their own records as the means for collecting the required data. Their estimates of the cost varied from under $200 to over $5,000 with no range strongly emphasized. Some may have included the costs of using their own staff and some not. Approximately 50 percent of those who obtained special data in the last year estimated that the cost was in excess of $1,000.

QUESTION 3(d)

Figure 13 summarizes the respondents' opinions about the usefulness of the special data. The primary usefulness was in "providing a more accurate basis for decisions". Only manufacturers and consultants did not give this their first vote. These rated "more accurate design of facilities" as first choice. In the aggregate, this latter was second, and "improved services" was third choice. The speed with which a decision is made seems to be of little concern

INFORMATION BOTH NORMALLY AND SPECIALLY OBTAINED BY "REFUSE OFFICIALS"

	Land Requirements	Facilities Performance	Equipment Inventory	Air Pollution	Refuse Quantity	Refuse Composition	Population	Costs of Refuse Activities
State Planners (9 Replies)	45%	45%	11%	33%	33%	11%	56%	33%
Regional Planners (5 Replies)	40%	0%	0%	40%	20%	20%	40%	0%
Municipal Planners (21 Replies)	19%	28%	9%	23%	33%	0%	9%	38%
Operators (13 Replies)	15%	30%	7%	23%	61%	0%	7%	61%
Manufacturers (4 Replies)	0%	0%	25%	25%	50%	50%	25%	50%
Consultants (14 Replies)	0%	28%	0%	35%	35%	21%	14%	35%
Researchers & Misc. (7 Replies)	14%	14%	14%	14%	43%	14%	0%	14%
Aggregate (73 Replies)	18%	26%	7%	27%	40%	11%	18%	37%

Percents shown are percent of each category which both normally obtained the particular class of information and also had to supplement this with information obtained by special means.

Figure 10

APPARENT DATA DEFICIENCIES FOR "REFUSE OFFICIALS"

	Land Requirements	Facilities Performance	Equipment Inventory	Air Pollution	Refuse Quantity	Refuse Composition	Population	Costs of Refuse Activities
State Planners (9 Replies)	A	A	C	C	A	C	C	A
Regional Planners (5 Replies)	A	B		A	A	A	A	B
Municipal Planners (21 Replies)	A	B			A			A
Operators (13 Replies)	C	A	B		A			A
Manufacturers (4 Replies)			C	B	A	A	B	A
Consultants (14 Replies)	B	A		A	A	B	B	A
Researchers & Misc. (7 Replies)	A	A			A	A	B	A
Aggregate (73 Replies)	A	A		C	A	B	B	A

A — Important plus obtained special additional data.

B — Important-adequate data apparently available.

C — Not considered important but did obtain special additional data.

Figure 11

STAFF USED, METHOD OF COLLECTION AND ESTIMATED COSTS
OF SPECIALLY OBTAINED DATA - "REFUSE OFFICIALS"

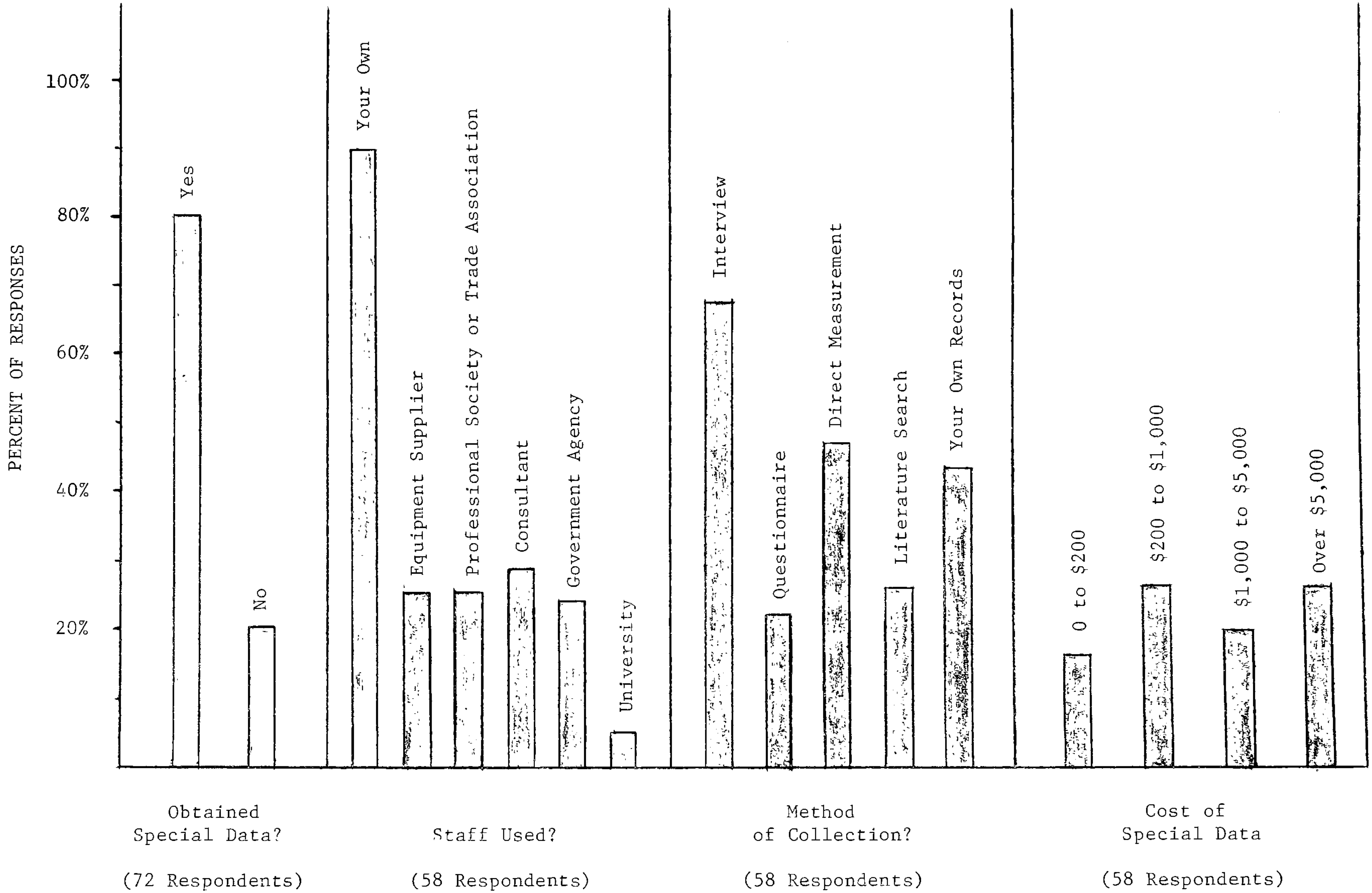

Figure 12

USEFULNESS OF SPECIALLY COLLECTED INFORMATION BY "REFUSE OFFICIALS"

1 - First Choice
2 - Second Choice
3 - Third Choice

Categories	Faster Decisions	More Accurate Basis for Decisions	Saved on Expenses or Capital Outlays	Increased Public Support	Improved Services	More Accurate Design of Facilities
State Planners		1	2		3	
Regional Planners		1	3	2		
Municipal Planners		1		2		3
Operators	2	1			3	
Manufacturers		3			2	1
Consultants		2	3			1
Researchers, Authors & Misc.	2	1				

Figure 13

to these decision makers. Since the primary usefulness of data is a "more accurate basis for decisions", and many of the categories have sought additional data in areas where data is normally received, then the data currently received on a normal basis is apparently not entirely accurate for decision making.

QUESTIONS 3(e), 3(f) AND 3(g)

Additional data "Refuse Officials" might have wanted included more information on refuse composition, quantities, land fill effects on ground water, more information on land, air pollution and costs. They were prevented from obtaining the additional data by time, cost, unreliable available data, and no source for such data. None of these factors was predominant.

QUESTION 4

In Question 4, the "Refuse Officials" were asked whether they would like to receive certain additional types of facts from a central data center, and if yes, what specific facts would they like to receive.

QUESTION 4(a)

They were asked if they would like more facts on land requirements and availability.

*They voted: 32 Yes 18 No

Specifically, they asked for more facts on:

a. Costs of land for sanitary land fill.

b. Population (served) per acre for sanitary land fill.

c. Methods of acquiring land with public support.

d. Anti-pollution requirements and restrictions.

e. Projected land needs.

---

* The totals of Yes and No votes to each question will not consistently add to the same number of responses. Not all respondents voted on each part of Question 4.

QUESTION 4(b)

They were asked if they would like more facts on efficiency and performance of refuse facilities and equipment.

They voted:	57 Yes	7 No

Specifically, they asked for more facts on:

a. Costs of operation and maintenance.

b. Efficiency of operation.

c. Air pollution control efficiency.

d. Disposal of bulky trash.

e. Design and legal restrictions.

QUESTION 4(c)

They were asked if they would like more facts on costs and financing of refuse operation.

They voted:	49 Yes	11 No

Specifically, they asked for more facts on:

a. True total costs with accurate division of cost between collection and disposal.

b. Standardized installation and operating costs of various disposal methods.

c. Comparisons of costs for private, city or county operations.

d. Financing in areas without tax help (e.g., county-wise).

QUESTION 4(d)

They were asked if they would like more facts summarizing existing equipment and facilities.

They voted:	40 Yes	15 No

Specifically, they asked for more facts on:

a. Efficiency of operation.

b. Actual owning and operating costs.

c. Various types of equipment and where it is being used.

QUESTION 4(e)

They were asked if they would like more facts on the quantity and composition of refuse.

They voted: 42 Yes 14 No

Specifically, they asked for more facts on:

a. Different kinds of waste collected which must be disposed of in land fills.

b. Sources of waste.

c. Seasonal or daily fluctuations.

d. Refuse chemical composition.

QUESTION 4(f)

They were asked if they would like more facts on population and other factors affecting refuse produced.

They voted: 38 Yes 16 No

Specifically, they asked for more facts on:

a. Per capita generation rates for residential, commercial and industrial refuse with seasonal and geographical influences accounted for.

QUESTION 4(g)

They were asked if they would like more facts on recommended standards and on regulations applicable to refuse operations.

They voted: 41 Yes 14 No

Specifically, they asked for more facts on:

a. Air pollution control requirements.

b. Ground water contamination from land fills.

c. Responsibility of private versus municipal operations.

QUESTION 4(h)

They were asked if they would like any other information not included in Questions 4(a) through 4(g). They asked for more facts on:

a. Legal decisions relative to solid waste disposal.

b. Practical applications for heat recovery.

c. New disposal methods for garbage.

d. Trends in characteristics of refuse.

e. Composition of stack gases.

No significant differences were detected when the above responses were examined by "Refuse Official" category; therefore, categorization of the reported responses to Question 4 was not attempted. It would not be facetious to say that the decision makers would like as much additional data as they "can lay their hands on". Certain of their specific requests include items of information which one would expect them to obtain on a regular basis. That they often do not have what they need has already been well confirmed by the responses to Question 2 and 3. The replies to Question 4 provide specific direction to some of the general conclusions available from Questions 2 and 3.

QUESTION 5

The "Refuse Officials" were asked which item of Question 4 was most important to them now, and in future planning efforts.

Question 4(a), 4(b), 4(c) and 4(e) received the greatest response in both cases. That is, information on land, on efficiency and performance, on costs and financing, and on quantity and composition, is most important now and for future planning. This confirms the findings of Questions 2 and 3.

QUESTION 6

The "Refuse Officials" were asked whether they primarily use consultants in formulating plans.

19 said Yes 31 said No

If the consultant category is excluded, this vote is 17 Yes and 23 No. It is interesting that most say that they do not use consultants in planning for new refuse equipment and facilities. It has been generally accepted that consultants are more widely used than this response would indicate.

QUESTION 7

This question asked the "Refuse Officials" to indicate their preference for outside source(s) of data. The results indicate that their primary sources for outside data are professional societies and consulting firms.

QUESTION 8

This question was intended to explore their experience with what was referred to as a "central information center". They were asked if they had ever been prevented from obtaining data from one.

They voted: 31 Yes 32 No

Of the 31 who voted Yes, 25 said it was because there was "no information center".

Apparently, the potential users of an information center are divided in their concepts of what constitutes such a center. Half say that no such center exists. The other half apparently considers certain outside sources as information centers and, therefore, indicate that they have had no trouble using them. In either case, it seems that once a center is established and publicized, it would be used.

3. DISCUSSION OF "DATA SYSTEM SPECIALISTS" QUESTIONNAIRE

The "Data Systems Specialists" questionnaire was designed to determine the nature and extent of problems which are encountered in achieving effective use of information systems for governmental agencies. Categorization was used to facilitate the development of a mailing list, but it is not considered significant to report the responses by categories, partly because the total response (27 out of 68) is not large enough to allow it to be sub-divided to any great extent, but also because the main purpose of the questionnaire phase of the information system feasibility study was to establish the information and decision making needs and practices of the potential users. The surveying of the designers of information systems as to the problems they encounter in their work with governmental agencies was a secondary objective and the results will be reported in that context.

QUESTION 1

The "Data Systems Specialists" consider that their work deals primarily with the area of "data analysis". "Data handling" (processing, etc.) and "data" collection are less important.

QUESTION 2

Figure 14 graphically illustrates the responses to Question 2. The majority of the respondents developed and anlayzed special data for municipal officials within the past year. They primarily used their own staffs and, to a lesser extent, government agencies, to obtain the data. They used interviews, questionnaires and literature searches, and recorded the data by keypunch and written means. Data transmission was primarily by report and punched cards.

RESPONSES TO DATA SYSTEM SPECIALISTS QUESTIONNAIRE

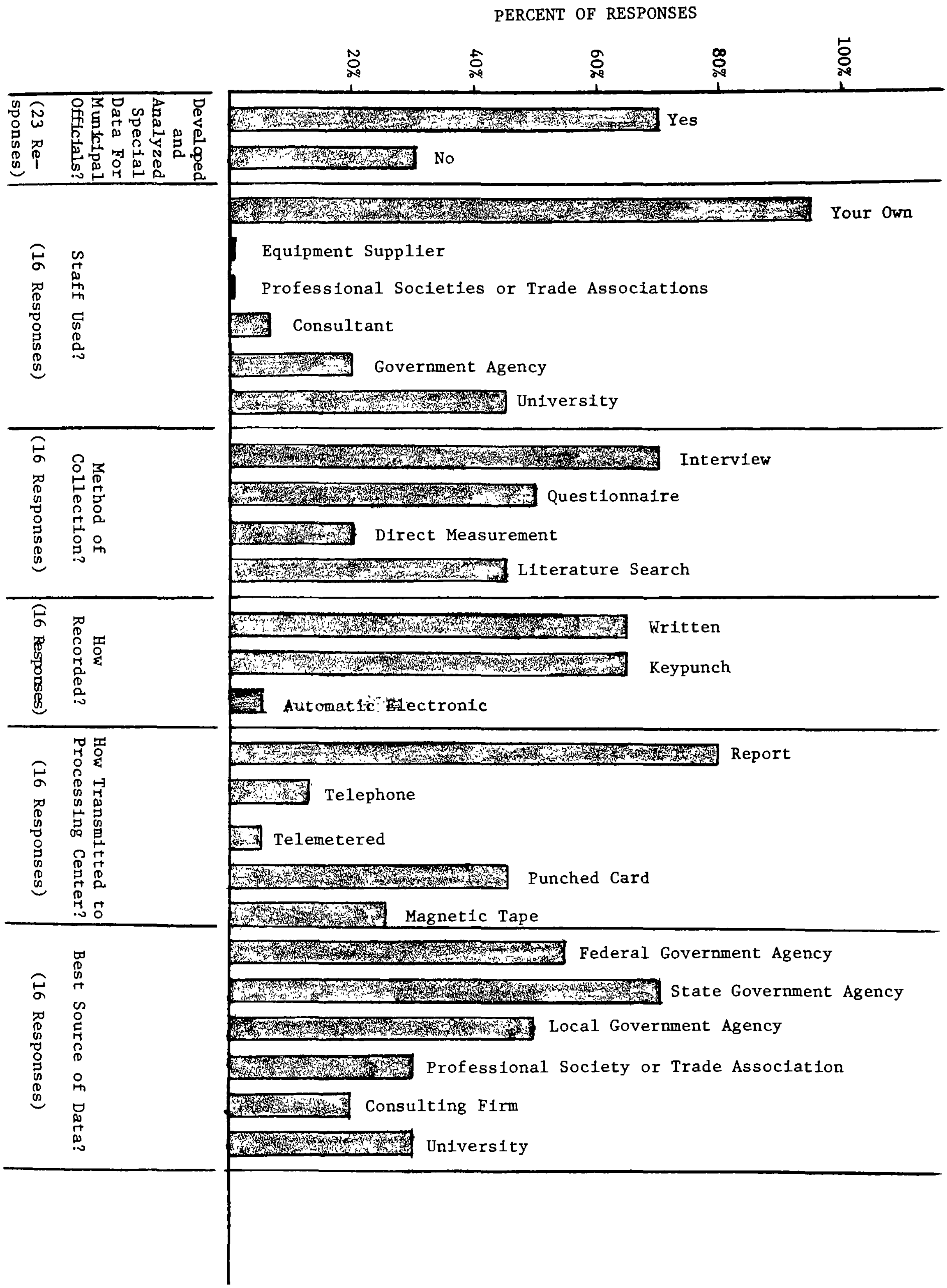

Figure 14

The majority used special machines to process the data, and only reports were used to transmit the results to data users (as opposed to more rapid or electronic means).

Estimates of cost for collection, handling and analysis of data ranged from a few thousand to over 100,000 dollars.

The usefulness of the data was primarily in providing a more accurate basis for decisions. There was little order of preference shown in the five other choices given (faster decision, savings, increased public support, improved services, more accurate design), and they were rated significantly below the first choice.

Almost all respondents wanted to develop additional data, but were prevented from obtaining it primarily by time and cost.

QUESTION 3

They were asked to indicate their preference for outside sources of data. The results are shown on Figure 14. They depend primarily on government agencies. In contrast, the "Refuse Officials" prefer professional societies, trade associations and consultants.

QUESTION 4

When questioned as to any difficulties they may have had in suggesting or using a central information center, the majority responded that they had no such difficulties. Of those that did, only four indicated that it was because there was "no available information center". Four said it was because costs were too high and four because of lack of standardization.

As expected, then, these respondents have a better concept than did the "Refuse Officials" of what central information centers are and the majority have had some experience with them.

QUESTION 5

When asked why they thought some central data systems have been unacceptable to municipal officials, cost was given as the primary reason. Some responses also indicated that a basic mistrust of unknown and mysterious technology often makes information and data systems unacceptable.

QUESTION 6

This question explored the respondents' need for data relative to municipal refuse. About 43 percent of the respondents said that they needed such data. As to their choice of data categories (Figure 7), they expressed an equal need for all the data. With respect to the reporting of this information, most wanted regular reports on a monthly or yearly basis.

In general, the response to the "Data Systems Specialists" questionnaire provided no surprising results. There is perhaps less tendency toward "exotic" techniques than might have been supposed (micro-wave data links, fascimile transmission of reports, digital data recording in-the-field, etc.). More or less conventional techniques are used in conjunction with the computer hardware.

Comparison of what "Refuse Officials" estimated for the costs of their special data, and what the "Data System Specialists" estimate for the costs of their projects, points out clearly why the major difficulty in obtaining central data system acceptance has been the cost factor (Question 5). Where the "typical special data" project for the "Refuse Official" might be estimated to cost $5,000, the "typical" project by the "Data System Specialist" might be $30,000. It is not unreasonable to suppose that there are some costs missing from the former, but not enough to make up the entire difference. One possible explanation for the discrepancy is that the "Data Systems Specialist" is perhaps more thorough in analyzing his true data needs, whereas the "Refuse Official" would be more likely to "get as much as he can for the money available".

4. DISCUSSION OF INTERVIEWS

A limited number of personal interviews were conducted in order to obtain a more detailed analysis of present information practices, information needs, and possible applications of an information system if one were available. A total of twenty-one interviews were conducted as follows:

State Planners	3 Interviews
Regional Planners	3 Interviews
Municipal Planners	5 Interviews
Operators	2 Interviews
Consultants	4 Interviews
Researchers	3 Interviews
Equipment Manufacturers	1 Interview

The interview results were reviewed by specific categories to determine correlations, or to define any significant differences which might exist. In general, the interview results tend to confirm the questionnaire results in all categories. It is significant to note that there do exist some differing viewpoints on refuse information among the various categories. For example, state planners and consultants hold the view that the information presently available on refuse activities is shallow in nature and not extensive or standardized enough to aid in planning and decision making. The consultants seemed to agree that the "state-of-the-art" of refuse activities is at a low level and has remained essentially unchanged for many years. Both state level officials and consultants felt that improved information generation and availability is necessary before the "state-of-the-art" can be significantly upgraded and before refuse activities can be significantly improved upon.

On the other hand, regional officials, municipal officials and operators involved in refuse activities saw a problem in information availability but did not imply that the progress of refuse activities is seriously hampered by this problem. Regional agencies indicated that they are just beginning to initiate serious activities in this area and have not yet become deeply enough involved to recognize all the longer range problems. Municipal officials seem to be deeply involved in and concerned about refuse activities, but deal more in the nearer term. Longer range planning activities must often take a back seat because of the pressure of the more immediate problems of the next few years. They also rely on consultants to provide the suggested solutions to the longer range problems and, therefore, they expect the consultant to be the one primarily concerned with information availability.

In all cases, the need for and the concept of an information system for refuse activities was recognized as a desirable step toward improving the overall situation. Opinions differed as to the use of such a system. State agencies, regional agencies and consultants were primarily concerned with the longer range planning applications of such a system. Municipal planners and operators indicated more interest in the more immediate term, operational applications of the system. Researchers appear to be primarily interested in the detailed aspects of refuse composition and analysis, which could be categorized as a long range planning problem.

The comments made by those interviewed fell into several categories as follows: (Much of the text to follow is extracted from the interview reports.)

a. PRESENTLY AVAILABLE DATA

In general, the comments agree that certain problems exist in obtaining accurate information. The principal problems seem to be (1) the unavailability of information, (2) inaccuracies in the information which is available, and (3) standardization of information. For some factors such as refuse composition and air pollution, very little information is available anywhere. For other factors such as quantities of refuse and land availability, the availability of information depends on the record keeping practices of the municipality involved.

The information which is available is often considered inaccurate. As one interviewee put it, "information exists in great profusion, but its accuracy is questionable". Part of this is apparently due to the methods of obtaining the data, which include rough, non-scientific means of measurement. Part is also due to a lack of completeness of the data. In many localities, facilities such as scales are not available and any records kept are sketchy and spotty. The relevant variables are often not identified. Rough estimates are often used to define refuse quantities and composition.

Standards are not used in defining the information which is available. Consultant studies are non-standard in nature and the reports vary as to what information is actually included. Comments made by consultants indicate that heat values, for one example, are usually undefined as to whether they are high or low, or based on wet or dry analysis. Air pollution data is usually far too general to be of any real use. Further comments indicate that there are gaps in the data as to what reported quantities really represent and what they include or do not include. This is particularly true with regard to information on operating costs and refuse quantities. In summary, the available information appears to lose its value because of poor definition, thus creating foggy communications.

b. INFORMATION NEEDED

Municipalities, regulatory bodies, consultants and equipment suppliers all indicated a need for more, better and more standardized information. The exact nature of the information needed would depend on its intended use. Some factors mentioned included:

(1) Land use requirements.

(2) Air pollution regulations.

(3) Tonnages and compositions by cities, areas, regions, etc.

(4) Historical trends.

(5) Data on refuse density and compactibility.

(6) Data on equipment performance.

(7) Statistics on "typical" smaller and larger cities.

c. INFORMATION SYSTEM OUTPUT

The output of an information system should be an answer to a specific question. The system must work out the answer from available memory information and other inputs. The accuracy of the output is, of course, dependent on the accuracy and value of the inputs. The information system input should include consultants' reports, annual municipal reports and annual independent surveys of municipalities.

The information system would have to interpret the meaning of the information fed into it. One interviewee pointed out that data can be standardized, but the questions asked cannot be. Standard factors for data seldom match the factors present in a specific question. In answering any particular question or request for information, the question's factors must be matched to the data factors and then appropriate modifications in the data made in order to provide a useful and accurate answer. The factors present in a specific question depend to a large extent on the agency asking the question and on what will be done with the answer. The system should be designed with sufficient flexibility to respond to virtually any request for output information.

A central information center could handle only certain general information concerning land requirements and land availability. Specific information for a particular city on population and land availability at a specific time would have to come directly from that city. These factors would be subject to frequent change and to many outside influences such as zoning changes, politics and public attitude.

As to availability, the basic question to answer is, "What is the optimum way to make the information available in a usable form?" Should it be stored on tapes at a remote location and should it be periodically printed and published in report form? In some cases, the individual is not really sure what information he needs to make a decision, nor does he know what information may be available to him. A basic requirement of the information system would be to process the data. A decision maker or planner needs to know what is going to happen and what he can do about it; not what the population is, or what the refuse quantity is. These factors are merely components of the answer he desires.

d. VALUE OF AN INFORMATION SYSTEM

The interviewees generally agreed that there is value to the concept of an information system for refuse activities. There are, however, a number of interpretations given to this "value". One comment indicated that the primary value of an information system would be for broad planning purposes as a first approach to a specific problem. Another felt that a very important function of an information system would be for gathering of actual experience data from municipalities to be used as a guide where this information is not now available.

The opinion was expressed that for smaller communities, information of a local nature on other, similar communities refuse operations, would be useful. For the major cities, however, their individual problems are too unique in most cases to bear any significant resemblance to other large cities or to the smaller cities.

In a broad sense, there is a need for a central data system to serve as the basic stimulus for upgrading the "state-of-the-art". In a narrower, or shorter term, it would be useful as an operational aid to communities, particularly with regard to collection systems.

It would be very difficult to determine the actual pay-out of an information system. This basically depends on the quality of the information available and how much help it is to the person using it. In certain cases, it might be possible to attach dollar figures to the benefits resulting from the use of an information system. In most cases, however, these benefits would be of an intangible nature and it would be very difficult, if not impossible, to attach direct dollar figures to their value.

Some comments implied that consultants and professional planners such as regional planning agencies would probably benefit the most from an information system because they are the ones primarily concerned with actual development of long range plans for refuse handling. Other comments indicate that all parties concerned with refuse activities would benefit from such a system, but some to a lesser extent than others.

e. GENERAL COMMENTS

The greatest problem to be faced in utilizing an information system would be in convincing the mayor and city engineers on the usefulness of the information. In one instance, it was pointed out that immediate operational application of the system, resulting in quickly realizable cost benefits, would be necessary to gain acceptance by municipal officials.

The most basic need with regard to an information system is a standardization of (1) units of measurement and (2) ways of reporting. To be of any value, an information system must contain accurate standardized information and must be able to make this information readily available to those who might need it. Screening of incoming information would be necessary to make sure it is in a usable form. The information which municipal people have is usually out of date and inadequate for accurate planning purposes. Minimum requirements should be set for doing studies and for reporting the information. For example, a minimum time period for physical measurement should be required. These minimums should be set up as legally required standards in order to insure that they will be met.

One area where valuable information is being generated, but the information is not available to those who could utilize it, is the area of consultant studies for specific municipalities. In most cases the reports submitted by the consultants are not available from the cities and less often from the consultants themselves. This represents an untapped source of planning information which certainly should be included in any information system.

D. CONCLUSIONS

1. The data normally obtained by the various categories of "Refuse Officials" is usually insufficient for their decision making needs and additional special data must be obtained. This includes routine data such as refuse quantity and costs of refuse activities.

2. The primary decision area of the "Refuse Officials" is that of long range planning, and most data obtained is used in formulating these plans and to provide a more accurate basis for the decisions involved. A refuse information system should therefore, be oriented toward serving planning decisions.

3. Regional planners and consultants consider the broadest range of information important in making decisions. They will probably be the most likely user category to benefit from a refuse information system.

4. The greatest data "gap" at present is in the area of "land requirements" and "facilities performance". The planners of facilities apparently have difficulty in finding appropriate locations for the facilities and in knowing what performance they can expect.

5. Data on air pollution, refuse composition and population were not considered important by more than half the respondents, yet about 30 percent of them obtained special data in these areas. Apparently, the importance of this data is gradually being recognized

6. Refuse officials probably would welcome a central information center if it served their specific information and decision area needs, and if the costs to them were minimal.

MUNICIPAL REFUSE DATA SYSTEMS SURVEY
(COLLECTION, STORAGE AND DISPOSAL)

TO:

COMPILATION
QUESTIONNAIRE "A"

Total Responses	77
Usable Responses	70
Total Sent	198
Percent Usable Responses	35%

1. (a) Are you regularly required to make decisions regarding municipal refuse activities?

YES [50] NO [7]

(b) Are these decisions primarily involved with:

Long range planning (5 yr. or more) of new facilities? [2.3]

Obtaining public support for plans? [3.9]

Evaluating the effectiveness of plans? [3.3]

Establishing standards and regulations? [3.6]

Operation of refuse facilities and equipment? [3.6]

Evaluation of the performance of refuse facilities? [3.1]

Please number in order of importance

Responses were averaged to obtain these ratings.

Other, please specify Intermediate planning less than five years.
Design & construction; primarily of new incinerator facilities

2. (a) Do you regularly get statistical data in any of the following areas? If YES, please check off the area or areas the data covers:

Land requirements	24	Quantity of refuse	51
Facilities performance	36	Composition of refuse	22
Inventory of equipment	27	Population	38
Air pollution	29	Costs of refuse activities	43

Other, please specify Local regulations.
Water pollution aspects.

(b) Which of this statistical data is especially important to you in making decisions?

Land requirements	36	Quantity of refuse	59
Facilities performance	43	Composition of refuse	32
Inventory of equipment	20	Population	32
Air pollution	30	Costs of refuse activities	49

Other, please specify
Costs are too non-uniform to be of value.
Local regulations and practices.
Water pollution aspects.
Source of refuse, i.e. industrial, commercial, residential, traffic.

3. Within the past year, has an important decision required you to obtain special additional data?

YES [58] NO [14]

(a) If YES, which areas did the "special" data cover?

Land requirements	22	Quantity of refuse	35
Facilities performance	24	Composition of refuse	19
Inventory of equipment	11	Population	16
Air pollution	24	Costs of refuse activities	31

Other, please specify *Water pollution Potential Social aspects Method of disposal - Management practices Floor area*

(b) How did you obtain the "special" data?

Staff used:

Your own	53	Consultant	16
Equipment supplier	15	Government agency	14
Professional Societies or Trade Associations	15	University	3

Other, please specify *Use data publications.*

Method of Collection:

Interview	39	Direct measurement	27
Questionnaire	13	Literature search	15
		Your own records	25

Other, please specify *Route study; visiting other operations. Earlier interview confirmed by questionnaire.*

(c) How much do you estimate the "special" data cost?

0 - $200	9	$201 - $1000	15
$1001 - $5000	11	If over $5000, please check	15

(or indicate approximate cost, if it is not confidential *$10,000, $15,000, $40,000*)

(d) In what way was the data most useful?

Faster decisions	3.1
More accurate basis for decisions	2.1
Saved on expenses or capital outlays	2.9
Increased public support	4.1
Improved services	2.7
More accurate design of facilities	2.5

Please number in order of importance

Responses were averaged to obtain these ratings.

Other, please specify *Avoid fruitless expenditures, development of systems through research, basic data no degree of usefulness, remove charge of "politics" for greater bi-partisan efforts.*

(e) If you were in a similar situation again, would you spend that money again?

YES [52] NO [1]

(f) What additional data would you also have wanted?

See attached sheet

(g) What factors prevented you from getting the additional data?

Time	12	Available data unreliable	10
Cost	12	No source for such data	12

Other, please specify *No comments*

4. If a central data center (from which you could receive rapid response to your requests for data) were set up, which of the following data would you like to receive from the center?

a. More facts on land requirements and land availability? YES [32] NO [18]
If YES, what kind of facts? *See attached sheet*

b. More facts on efficiency and performance of refuse facilities and equipment? YES [57] NO [7]
If YES, what kind of facts? *See attached sheet*

c. More facts on costs and financing of refuse operations? YES [49] NO [11]
If YES, what kind of facts? *See attached sheet*

d. More facts summarizing existing equipment and facilities? YES [40] NO [15]
If YES, what kind of facts? *See attached sheet*

e. More facts on the quantity and composition of refuse (solid wastes)? YES [42] NO [14]
If YES, what kind of facts? *See attached sheet*

f. More facts on population and other factors affecting refuse produced? YES [38] NO [16]
If YES, what kind of facts? *See attached sheet*

g. More information on recommended standards and on regulations applicable to refuse operations? YES [41] NO [14]
If YES, what kinds of information? *See attached sheet*

h. Other information not included in (a) through (g)? YES [11] NO [5]
If YES, what kinds of information? *See attached sheet*

5. Which of the facts in question 4 is most important to you?

(a) Now? a (14), b (17). c (13), d (7) e (18), f (5) g (5), h (2) all (4)

(b) In future planning efforts? a (15), b (15), c (6), d (9), e (14), f (10), g (5), h (2), all (4).

6. Do you primarily use consultants in formulating plans for new refuse equipment and facilities?

YES [19] NO [31]

7. In getting data from outside sources, which of these sources do you believe is most reliable?

	Fed'l	State	Local
Government agency	9	9	14
Professional Societies or Trade Associations		25	
Consulting firm		22	

University [8]

Other, please specify Trade publications, Own staff, Personal study, APWA, Equipment manufacturers own data to max. extent possible, interested facets of the industry.

8. Has there ever been something which prevented you from obtaining data from a central information center?

YES [31] NO [32]

If YES, was it because:
(please check factor or factors which apply)

Cost too high	1	Only national data	2
Too slow	1	Only local data	1
Unreliable	2	Data not clear	0
Outdated data	6	No information center	25
Not standardized	2	Other, please specify	______

Thank you for your cooperation.

- - - - - - - - - -

PLEASE RETURN THIS QUESTIONNAIRE USING THE ENCLOSED SELF ADDRESSED STAMPED ENVELOPE, AS SOON AS POSSIBLE.

If you would like to expand further on the subject at a later date, please check here ____.

Did we address the letter correctly? ______________________

If not, please give corrections ______________________

____

COMPOSITE REPLIES TO QUESTION 3(f)

1. More information on composition of waste.
2. More information on quantities of waste (variation, per capita generated)
3. Potential effect of sanitary land fill on ground water.
4. Available land.
5. Air pollution.
6. Costs of operating and maintaining all types of equipment.

COMPOSITE REPLIES TO QUESTION 4

4(a)
1. Costs of land for sanitary land fill
2. Population/acre for sanitary land fill.
3. Methods of acquiring land with public support.
4. Restrictions - anti-pollution requirements.
5. Projected land needs.

4(b)
1. Cost of maintenance (operation).
2. Nature of residue after processing.
3. Efficiency of operation (burning and operation).
4. Air pollution control efficiency.
5. Disposal of bulky trash.
6. Collection equipment.
7. Design and legal restrictions.

4(c)
1. True total costs with accurate division of cost between collection and disposal.
2. Costs of various disposal methods compared in uniform units (tons) (installation and operation costs).
3. Financing in areas without tax help (county-wide).
4. Comparison of cost for private, city or county operations.

4(d)
1. Efficiency of operation.
2. Actual owning and operating costs.
3. Various types of equipment and where it is being used.

4(e)
1. Accurate records of different kinds of waste collected which must be disposed of in land fills.
2. Accurate records on source of waste.
3. Records on seasonal or daily fluctuations.

4(f)
1. Generation rates, residential, commercial, industrial, seasonal and geographical.
2. Per capita generation.

4(g)
1. Air pollution control requirements.
2. Ground water contamination from land fills.
3. Responsibility of private versus municipal operations.

4(h)
1. Legal decisions relative to solid waste disposal.
2. Practical applications for heat recovery.
3. New disposal methods for garbage (other than land fill)
4. Trends in characteristics of refuse.
5. Combustion of stack gases.

MUNICIPAL REFUSE DATA SYSTEM SURVEY
DATA SYSTEMS DEVELOPMENT

TO:

COMPILATION
QUESTIONNAIRE "B"

Total Responses	*27*
Usable Responses	*23*
Total Sent	*68*
Percent Usable Responses	*34%*

The objective of this questionnaire is to help evaluate the feasibility of an information system for municipal solid waste activities. As a developer of data systems which assist municipal decision-makers, your responses will be an important factor in the evaluation. It will help assess current municipal data system practices and to determine the problems of getting such systems into effective use.

This questionnaire is being sent to you as one of a group of selected data system developers. A second questionnaire covering specific data needs is being sent to municipal refuse officials.

Responses were averaged to obtain these ratings.

1. Are your responsibilities most concerned with:

   Data collection (field testing, interviews, etc.) [2.7]

   Data handling (transmission, processing, etc.) [1.9]

   Data analysis (systems, operations research, etc.) [1.4]

   (Please number in order of importance)

   Other, please specify ____________________

2. Within the past year, has a study requirement made it necessary for you to develop and analyze special data for municipal officials?

   YES [16] NO [7]

   (a) If YES, how did you obtain the special data?

   Staff used:

Your own	15	Consultant	1
Equipment Supplier	0	Government Agency	9
Professional Societies or Trade Associations	0	University	4

   If other, please specify ____________________

   (b) Method of Collection:

Interview	11	Direct Measurement	3
Questionnaire	8	Literature Search	7

   Other, please specify ____________________

   (c) How was the data recorded?

Written	10	Automatic Electronic Recording	1
Keypunch	10	If other, please specify ______	

(d) How was the data transmitted from point of collection to the processing center?

Report	13	Punched Card	7
Telephone	2	Magnetic Tape	4
Telemetered	1	If other, please specify ________	

(e) Did you use special machines to automatically or electronically process the data?

YES [8] No [6]

(f) If YES, could you list these machines? ________________________________

____

(g) How did you have the results transmitted to the data users?

Report	16	Electronic Data Links	0
Telephone	0	If other, please specify ________	

(h) What is your estimate of the costs in time and/or dollars?

	Hours	Dollars
For data collection (field test, etc.)	4 MW	80,000, 50,000, 150,000
For data handling (processing, etc.)	20-40 MW	150, 2,500, 30,000 100,000
For data analysis (systems, operations research, etc.)	16-20 MW	150, 1,000, 50,000 100,000
Other, please specify ________	____	____

(i) In what way was the data most useful to your client?

Faster decision	3.4
More accurate basis for decision	1
Savings on expenses or capital outlays	3.1
Increased public support	3.1
Improved services	2.8
More accurate design of facilities	2.8

Please number in order of importance those factors which apply.

Responses were averaged to obtain these ratings.

If other, please specify ________________________________

(j) Was there additional data you would also have wanted to develop?

YES [14] No [2]

(k) What factors prevented you from developing the additional data?

Time	12	Unreliable available data	1
Cost	11	No source for such data	2

If other, please specify

3. In getting data from outside sources, which of these sources most satisfy your need for reliable and complete data?

	Fed'l	State	Local		
Government Agency	9	11	8	University	5
Professional Societies or Trade Associations	5			Other, please specify	
Consulting Firm	3				

4. Has there ever been something which prevented you from suggesting or using a central information center?

YES 8 NO 13

If YES, was it because:
(Please check factor or factors which apply)

Cost too high	4	Only national data	0
Too slow	0	Only local data	0
Unreliable	0	Data not clear	0
Outdated data	1	No available information center	4
Not standardized	4	Other, please specify	

5. From your experience, why have some central data systems been unacceptable to municipal officials?

Cost	12
Mistrust of data	3
Mistrust of outside information system personnel	4
Reluctant to use standard costing and performance factors	3
Reluctant to use labor-saving or time-saving equipment	3

Other, please specify

6. Do you need further data relative to municipal refuse for your work?

YES [10] NO [13]

If YES, what kind of facts would this data include?

Land requirements	[8]	Quality of refuse	[5]
Facilities performance	[6]	Composition of refuse	[7]
Inventory of equipment	[5]	Other, please specify	____________
Air pollution	[7]		____________

If this information were made available, in what form would you like to receive it?

a. Regular report [9] Special report at your request [5]

b. If regular report, how often?

Weekly [0] Monthly [4] Yearly [2]

PLEASE RETURN THIS QUESTIONNAIRE USING THE ATTACHED SELF ADDRESSED STAMPED ENVELOPE, AS SOON AS POSSIBLE.

If you would like to expand further on the subject at a later date, please check here ___.

Did we address the letter correctly? ____________________

If not, please give corrections ____________________

____

SECTION VII

APPENDIX B

COST CALCULATIONS FOR SYSTEMS EVALUATIONS

A. ASSUMPTIONS

Cost estimates are based on certain assumptions concerning unit costs for each of the factors and functions involved. The assumptions used are as follows. Other assumptions are given in the detailed cost summaries as required.

B. LABOR RATES

The following were the labor rates, including overhead, which were used in the cost calculations. Where a range is given, the upper end (underlined) was used; these represent typical rates from service bureaus and consultants.

Category	Rate (including overhead)
Administrative Director	$20/hour
Systems Analyst	$12 to <u>$17.50</u>/hour
Computer Programmer	$10 to <u>$15</u>/hour
Research Librarian	$10/hour
Field Inspector	$ 9/hour
High Level Systems Assistant	$ 9/hour
Keypunch Operator	$ 8/hour
Medium Level Systems Assistant	$ 7/hour
Secretarial	$ 6/hour
Weighing Scale Operator	$4.50/hour
Clerical Assistant	$4.50/hour

C. COMPUTER RATES

The following are the machine rates used in the cost estimates:

Computation	$300 to $450/hour/ use $375/hour
Printing	$100 to $150/hour; use $125/hour

D. MISCELLANEOUS

Reproduction, including printing, collating, binding, etc. $.04/page
Mailing, average $.25/item

E. COST ESTIMATES BY SYSTEM

The estimated cost for each type of information system discussed in Section V-C has been calculated using the foregoing assumptions. The cost details are as follows.

COST ESTIMATES

System #1
DATA CLEARINGHOUSE SERVICE

Cost Factor	First Cost (Also First Year)		Annual Cost	
	Hours	Dollars	Hours	Dollars
A. Data Gathering				
1. Questionnaire				
Questionnaire design @ $15/hr	700	10,500	160	2,400
Reproduction: 36,000 copies @ $.04		1,400		1,400
Mailing & handling 6,000 @ $.25		1,500		1,500
2. Data from other sources				
First review @ $10/hr	1,200	12,000		
Annual full time scrutiny			2,000	20,000
B. Data Processing				
1. Questionnaire				
Manual preparation @ $7/hr	700	4,900	700	4,900
Keypunch & verify @ $8/hr	700	5,600	350	2,800
Conversion to tape @ $375/hr	7	2,625	2	750
2. Data from other sources				
Manual preparation (incl. in A-2)				
Keypunch & verify @ $8/hr	2,500	20,000	600	4,800
Conversion to tape @ $375/hr	20	7,500	5	1,825
C. Programming				
Conversion, screening, file Maintenance, calculations, report Generation & miscellaneous @ $15/hr	2,000	30,000		
Systems analysis @ $17.50/hr	350	6,125		
Annual programming @ $15/hr			650	9,750
D. Computation				
Test & calculation @ $375/hr	20	7,500	10	3,750
Printing @ $125/hr	10	1,250	10	1,250
E. Reproduction & Distribution				
40 pg. annual report, 6,500 copies 6 pg. monthly report, 6,500 copies 730,000 pages @ $.04		29,000		29,000
Mailing & handling 83,500 @ $.25		21,000		21,000
F. Administration				
Administrative director @ $20/hr	2,000	40,000		40,000
Clerical help @ $6/hr	4,000	24,000		24,000
Supplies and equipment (misc.)		2,000		2,000
Total		225,415		171,125
Ten Year Total			1,765,540	

NOTE: All costs are estimated at ±20% of the values shown.

COST ESTIMATES

System #2
PREDICTIVE INFORMATION SERVICE

Cost Factor	First Year (Also First Year)		Annual Cost	
	Hours	Dollars	Hours	Dollars
A. Data Gathering				
1. Sample Cities (50 cities)				
Installation of weighing scales @ $10,000 per city		500,000		
Maintenance costs @ $200 each/yr				10,000
Operator @ $4.50/hr	130,000	586,000	130,000	586,000
Clerical help @ $4.50/hr	52,000	234,000	52,000	234,000
Inspection: 1st yr @ $9/hr	3,000	27,000		
2nd-5th yr @ $9/hr			1,500	13,500
5th-10th yr @ $9/hr			1,000	9,000
Subtotal		1,347,000		852,500
Design of data gathering system (forms, procedures, controls, reports, etc.) @ $17.50/hr	900	15,750		
Reproduction, mailing, handling, etc.		1,000		1,000
2. Data from other sources				
First review @ $10/hr	500	5,000		
Continuing scrutiny @ $10/hr			300	3,000
B. Data Processing				
1. Sample cities (50 cities)				
Manual processing, 4 reports/yr 2 hrs/report @ $7/hr	400	2,800	400	2,800
Keypunch & verify Assume 100,000 char annually per city, or 12.5 hrs KP & 12.5 hrs verify @ $8/hr	1,250	10,000	1,250	10,000
Conversion to tape @ $375/hr	5	1,875	5	1,875
2. Data from other sources				
Estimate 5 x 10^6 characters initially				
Estimate 1 x 10^6 characters annually				
Keypunch & verify @ $8/hr	1,250	10,000	250	2,000
Conversion to tape @ $375/hr	10	3,750	2	750
C. Programming				
Conversion, screening, file maintenance, calculations, report generation & miscellaneous @ $15/hr	3,300	49,500		
Systems analysis @ $17.50/hr	1,500	26,250		
Redesign at 5th yr @ $15/hr	1,250	18,750		
Annual programming @ $15/hr			650	9,750

System #2
PREDICTIVE INFORMATION SERVICE, Cont.

D. <u>Computation</u>				
Test @ $375/hr	30	11,250		
Calculation: 5,000 regressions @ 11 sec. @ $375/hr	25	9,375	25	9,375
Printing @ $125/hr	15	1,875	15	1,875
E. <u>Reproduction & Distribution</u>				
80 pg. annual report to 6,500, 520,000 pages @ $.04		20,800		20,800
Mailing & handling 6,500 @ $.25		1,600		1,600
F. <u>Administration</u>				
Administrative director @ $20/hr	2,000	40,000	2,000	40,000
Clerical help @ $6/hr	8,000	48,000	8,000	48,000
Supplies & equipment (misc.)		2,000		2,000
Total		1,607,825		1,007,325
Ten Year Total			10,692,500	

<u>NOTE</u>: All costs are estimated at ± 20% of the values shown.

COST ESTIMATES

System #3
PLANNING INFORMATION SERVICE

Cost Factor	First Cost (Also First Year) Hours	First Cost (Also First Year) Dollars	Annual Cost Hours	Annual Cost Dollars
A. Data Gathering				
1. Questionnaire				
Questionnaire design @ $15/hr	700	10,500	160	2,400
Reproduction 36,000 copies @ $.04		1,400		1,400
Mailing & handling, 6,000 @ $.25		1,500		1,500
2. Data from other sources				
First review @ $10/hr	500	5,000		
Continuing scrutiny @ $10/hr			300	3,000
3. Request handling				
200 requests/yr, 1/3 adjusted @ $9/hr	2,400	21,600	2,400	21,600
B. Data Processing				
1. Questionnaire				
Manual preparation @ $7/hr	700	4,900	700	4,900
Keypunch & verify @ $8/hr	700	5,600	350	2,800
Conversion to tape @ $375/hr	7	2,625	2	750
2. Data from other sources				
Estimate 5 x 10^6 characters initially				
Estimate 1 x 10^6 characters annually				
Keypunch & verify @ $8/hr	1,250	10,000	250	2,000
Conversion to tape @ $375/hr	10	3,750	2	750
3. Request handling				
Assume 10,000 char/request				
Keypunch & verify @ $8/hr	700	5,600	700	5,600
Conversion to tape @ $375/hr	7	2,625	7	2,625
C. Computer Programming				
1. Questionnaire results & other data				
Conversion, screening, file Maintenance, calculations, report Generation and miscellaneous @ $15/hr	1,200	18,000		
Systems analysis @ $17.50/hr	200	3,500		
Subtotal		21,500		
Annual maintenance @ $15/hr			200	3,000
2. Facilities timetables program				
Preliminary study @ $17.50/hr	150	2,625		
Program preparation, debugging & trial application @ $15/hr	350	5,250		
Subtotal		7,875		
Annual maintenance @ $15/hr			100	1,500

C. Computer Programming, (Cont.)				
3. Planning optimization program				
Preliminary study @ $17.50/hr	500	8,750		
Program preparation, debugging and Trial application @ $15/hr	1,050	15,750		
Subtotal		24,500		
Annual maintenance @ $15/hr			200	3,000
4. Operational optimizations program				
Preliminary study @ $17.50/hr	500	8,750		
Program preparation, debugging and Trial application @ $15/hr	1,050	15,750		
Subtotal		24,500		
Annual maintenance @ $15/hr			200	3,000
5. Non-standard requests program				
Preliminary study @ $17.50/hr	400	7,000		
Program preparation, debugging and Trial application @ $15/hr	700	10,500		
Subtotal		17,500		
Annual maintenance @ $15/hr			150	2,250
Redesign at 5th year 25%		24,000		
Programming Total (not including redesign)		95,875		12,750
D. Computation				
Test @ $375/hr	100	37,500		
Calculation @ $375/hr	200	75,000	200	75,000
Printing @ $125/hr	50	6,250	50	6,250
E. Reproduction & Distribution				
200 requests @ 10 pg. @ 20 copies @ $.04/copy		1,600		1,600
Mailing & handling, 4,000 @ $.25		1,000		1,000
F. Administration				
Director @ $20/hr	2,000	40,000	2,000	40,000
Clerical help @ $6/hr	4,000	24,000	4,000	24,000
Supplies & equipment (misc.)		2,000		2,000
Total		358,325		211,925
Ten Year Total			2,289,650	

NOTE: All costs are estimated at ±20% of the values shown.

COST ESTIMATES

System #4
PREDICTIVE AND PLANNING
INFORMATION SERVICE

Cost Factor	First Cost (Also First Year)		Annual Cost	
	Hours	Dollars	Hours	Dollars
A. <u>Data Gathering</u>				
1. Sample cities (See System #2)		1,363,750		853,500
2. Data from other sources (See System #2)		5,000		3,000
3. Request handling (See System #3)		21,600		21,600
B. <u>Data Processing</u>				
1. Sample cities (See System #2)		14,675		14,675
2. Data from other sources (See System #2)		13,750		2,750
3. Request handling (See System #3)		8,225		8,225
C. <u>Computer Programming</u>				
1. Sample cities (See System #2)		75,750		9,750
2. On request programs (See System #3)		85,000		10,000
3. Five year redesign		40,000		
D. <u>Computation</u> (See Systems #2 and #3)				
1. Tests		48,750		84,375
2. Calculation		84,335		8,125
3. Printing		8,125		
E. <u>Reproduction & Distribution</u> (See Systems #2 and #3)				
1. Reproduction		22,400		22,400
2. Mailing & handling		2,600		2,600
F. <u>Administration</u>				
1. Administrative director		40,000		40,000
2. Clerical help		60,000		60,000
3. Supplies & equipment (misc.)		3,000		3,000
Total		1,857,000		1,134,000
Ten Year Total			12,103,000	

<u>NOTE</u>: All costs are estimated at ±20% of the values shown.

COST ESTIMATES

System #5
DATA CLEARINGHOUSE AND
PREDICTIVE INFORMATION SERVICE

Cost Factor	First Cost (Also First Year)		Annual Cost	
	Hours	Dollars	Hours	Dollars
A. Data Gathering				
1. Sample cities (See System #2)		1,363,750		853,500
2. Data from other sources (See System #1)		12,000		20,000
B. Data Processing				
1. Sample cities (See System #2)		14,675		14,675
2. Data from other sources (See System #1)		27,500		6,625
C. Programming				
1. Clearinghouse (See System #1)		18,000		6,000
2. Sample cities (See System #2)		77,000		9,750
3. Redesign at fifth year		18,750		
D. Computation				
1. Test (See Systems #1 and #2)		15,000		
2. Calculation (See Systems #1 and #2)		16,875		16,875
3. Printing (See Systems #1 and #2)		3,125		3,125
E. Reproduction & Distribution				
1. Reproduction (See Systems #1 and #2)		40,000		40,000
2. Mailing & handling		22,000		22,000
F. Administration				
1. Administrative director		40,000		40,000
2. Clerical help		60,000		60,000
3. Supplies & equipment (misc.)		3,000		3,000
Total		1,712,925		1,095,550
Ten Year Total			11,591,625	

NOTE: All costs are estimated at ±20% of the values shown.

COST ESTIMATES

System #6
DATA CLEARINGHOUSE AND
PLANNING INFORMATION SERVICE

Cost Factor	First Cost (Also First Year)		Annual Cost	
	Hours	Dollars	Hours	Dollars
A. Data Gathering (See Systems #1 and #3)				
1. Questionnaire		13,400		5,300
2. Data from other sources		12,000		20,000
3. Request handling		21,600		21,600
B. Data Processing (See Systems #1 and #3)				
1. Questionnaire		13,125		8,450
2. Data from other sources		27,500		6,625
3. Request handling		8,225		8,225
C. Computer Programming (See Systems #1 and #3)				
1. Questionnaire and other data		36,125		9,750
2. Request programs		74,375		9,750
3. Redesign at fifth year		24,000		
D. Computation (See Systems #1 and #3)				
1. Test		41,250		
2. Calculation		78,750		78,750
3. Printing		7,500		7,500
E. Reproduction & Distribution (See Systems #1 and #3)				
1. Reproduction		30,600		30,600
2. Mailing & handling		22,000		22,000
F. Administration (See Systems #1 and #3)				
1. Administrative director		40,000		40,000
2. Clerical help		36,000		36,000
3. Supplies & equipment (misc.)		3,000		3,000
Total		465,450		307,550
Ten Year Total			3,257,400	

NOTE: All costs are estimated at ±20% of the values shown.

COST ESTIMATES

System #7
PREDICTIVE AND PLANNING INFORMATION
SERVICE WITH DATA CLEARINGHOUSE

Cost Factor	First Cost (Also First Year) Hours	First Cost (Also First Year) Dollars	Annual Cost Hours	Annual Cost Dollars
A. <u>Data Gathering</u>				
1. Sample cities (See System #2)		1,363,750		853,500
2. Data from other sources (See System #3)		12,000		20,000
3. Request handling (See System #3)		21,600		21,600
B. <u>Data Processing</u>				
1. Sample cities (See System #2)		14,675		14,675
2. Data from other sources (See System #1)		27,500		6,625
3. Request handling (See System #3)		8,225		8,225
C. <u>Computer Programming</u>				
1. Clearinghouse (See System #1)		18,000		6,000
2. Sample cities (See System #2)		77,000		9,750
3. Request service (See System #3)		74,375		9,750
4. Five year redesign		24,000		
D. <u>Computation</u> (See Systems #1, #2 and #3)				
1. Test		52,500		
2. Calculation		88,125		88,125
3. Printing		9,375		9,375
E. <u>Reproduction & Distribution</u> (See Systems #1, #2 and #3)				
1. Reproduction		41,000		41,000
2. Mailing and handling		22,000		22,000
F. <u>Administration</u>				
1. Administrative director		40,000		40,000
2. Clerical help		66,000		66,000
3. Supplies & equipment (misc.)		4,000		4,000
Total		1,940,125		1,220,625
Ten Year Total			12,949,750	

<u>NOTE</u>: All costs are estimated at ±20% of the values shown.

COST ESTIMATES

PILOT SYSTEM

Cost Factor	First Cost (Also First Year)		Annual Cost	
	Hours	Dollars	Hours	Dollars
A. Data Gathering				
1. Sample cities (10 cities)		275,000		170,000
2. Data from other sources		12,000		20,000
B. Data Processing		15,000		6,000
C. Computer Programming				
1. Systems analysis & computer programming		30,000		30,000
D. Computation		20,000		10,000
E. Reproduction & Distribution		2,000		2,000
F. Administration				
1. Administrative director		40,000		40,000
2. Clerical help		24,000		24,000
3. Supplies & equipment (misc.)		1,000		1,000
Total		419,000		303,000
Four Year Total			1,328,000	

NOTE: All costs are estimated at ±20% of the values shown.

SECTION VII

APPENDIX C

SAMPLING OF REFUSE COMPOSITION

The sampling of refuse and of incinerator residue is an area of study where little work has been accomplished. Refuse chemical composition and heating value are significant parameters in incinerator design. Both influence the design and capacity of furnace enclosures, grates, air and exhaust gas fans, ducts, spray systems, controls, air pollution control equipment, stacks, storage pits, and cooling equipment. Significant underestimation of these characteristics can result in serious capacity limitations of incinerator systems, leading potentially to early saturation of facilities, over-temperature in furnace enclosures, insufficient furnace draft, and other similar difficulties. Overestimation can lead to excessive furnace volumes and difficulties in maintaining proper combustion, not to mention unnecessarily high costs of construction. Residue sampling is important to assure that putrescible content is below acceptable maximums and to provide a measure of incinerator performance in terms of extent of removal of combustible content. A current program has this under study.[6]

Refuse or residue sampling is a difficult procedure. Extreme errors are possible under even the best conditions. It is an expensive procedure, and usually an insufficient number of tests are accomplished to assure that experimental, day-to-day and seasonal variations are accounted for.

Refuse as delivered to a municipal disposal site is a heterogeneous mixture including garbage, cardboard, paper, metal, glass, wood, plastic, etc., whose make-up can vary markedly from day-to-day, depending upon point of origin, weather conditions, time of year, climate, etc. A sampling procedure usually involves the systematic reduction of about 1,000 pounds to a finely ground quart jar sample for laboratory analysis.

Between these extremes lies several steps of quartering and grinding until the refuse particle size is quite small. Extreme care is taken to account for original moisture content during the entire procedure, and it is a testimonial to the patience and technique of some researchers[6, 7, 8, 9] that any meaningful data has become available at all. Similar procedures are required in analyzing incinerator residue. It is a procedure whose cost precludes its application in the design stages of most cities' incinerator programs, and consultants usually apply the "broad average" suggested by the available research findings. Serious reductions in design capacity can result if the local refuse is markedly different from the "average".

Another consideration with respect to refuse sampling is the variation of the characteristics with time. The combustible content and the heating value of municipal refuse have increased steadily over the last ten to fifteen years, and this increase is continuing. When the "broad average" data is applied in design, it is usually today's average, and potential increases with time are generally ignored. In an incinerator plant designed for a twenty to thirty year life, it would be logical to plan for some variation in the fuel. The incinerator operator is primarily interested in the tonnage of material to be effectively burned. The fact that the furnace still handles the same number of Btu/hour it did ten years ago is small consolation if capacity has been reduced by 25 percent.

Thus, refuse sampling on a consistent cyclic basis could provide valuable historical data which is sorely needed for more precise incinerator design. Unfortunately, it is an expensive and tedious procedure which requires a high level of skill, and which will be difficult to standardize for widespread application. The representation of a great many tons of material by a very small prepared sample leaves the procedure open to potentially large errors.

There is a concept of sampling the characteristics of refuse and residue which overcomes some of the difficulties of this potentially large error. This technique would not require refuse sample preparations at all, but would handle refuse "as delivered". The proposed technique would utilize an entire incinerator as a test container. This incinerator would be specially instrumented to provide highly accurate heat and mass balances. With knowledge of the weights of incoming refuse, air and water, and of outgoing flue gas, residue and water, along with flue gas analysis, the refuse chemical composition could be calculated. By careful measurements of the temperatures of all incoming and outgoing materials and by minimizing and accounting for the heat losses, the refuse heating value can also be calculated. This approach has been suggested and is actually under development in Germany.[6] In addition to doing away with the need for sample preparation, the equipment need not be portable and can, therefore, be built more ruggedly and accurately. The data can be automatically logged and stored in a small computer for daily or weekly averaging of results as desired. An incinerator such as this, centrally located within a region, can either be statistically representative of the region, or can be used as a sampling station to which various communities could deliver a substantial sample of their refuse.

Selective sampling, using this concept, accomplished four times yearly to account for seasonal variations, could provide participating communities with precise data on which to base future incinerator designs. Although the test incinerator construction (or conversion) would require special attention to instrumentation and controls, and would require a larger and more highly skilled staff, the overall costs would be less than the "conventional" sampling techniques, and the data would be more reliable. When not being used for testing purposes, this incinerator could be used for normal refuse incineration by the community in which it is located.

Other refuse and residue characteristics are also of sufficient interest to warrant sampling. These are fortunately less difficult to measure, and the availability of data on them over a period of time is also important in the economical design of equipment and facilities. Examples of these characteristics include density and compactibility (both by compression equipment and in land fills). These factors assist in the design and selection of packer collection trucks and in the planning and acquisition of land for sanitary land fills.

Refuse and residue composition sampling is not recommended for initial inclusion in any of the information system concepts discussed in Section V-C The basic information which can be developed from accurate measurements of refuse quantities and land consumption is initially more important. A widespread program to incorporate standardized refuse and residue sampling could be prohibitively expensive with little guarantee of success. Such a program could be considered as a later phase of an information system.

SECTION VII

APPENDIX D

STATISTICAL SAMPLING OF MUNICIPAL REFUSE DATA

A. INTRODUCTION

Decision making requires a steady supply of up-to-date information, and information requires a continuous flow of accurate, reliable and representative data. In the municipal solid waste field this is almost totally lacking. There is no consistency to the gathering of data. Some communities are quite diligent regardless of their size, while some large communities are totally negligent. Data gathering techniques and equipment are not standardized, and even the data that is gathered is unavailable for any but the most minimal distribution. Even if this data were available, there is little likelihood that it would be representative of large populations and areas. It is apparent that any decision making information developed from this inadequate data pool can lead to poor decisions.

Statistics has repeatedly been proven to offer a means to represent the characteristics of large populations or areas by relatively small samples, if the samples are obtained under closely controlled conditions. The problems of data gathering in the municipal solid waste field are no less amenable to this approach, and it is proposed that trend predictions of significant solid waste parameters be developed for the entire United States and regions thereof on the basis of a relatively small number of "sample cities".

The cities would institute a rigorous data gathering, recording and reporting program, regardless of their current level of solid waste activity. Weighing scales would be installed, and all solid waste generated within the community would be weighed. Its source would be noted whether commercial, industrial or residential, and its disposition also recorded. Land fill consumption, refuse densities and compactibilities, etc. would also be measured periodically. The data gathering system in each city would be designed to issue reports to a central administrative agency on a sufficiently frequent basis to assure that seasonal and climatic variations are accounted for.

The techniques to be applied in the selection of the parameters to be measured and the number and location of the cities is discussed in the sections to follow.

B. FACTORS SIGNIFICANTLY INFLUENCING SOLID WASTE PARAMETERS

In attempting to develop a means for selecting the number and location of sample cities, the factors which significantly influence the solid waste parameter under consideration must be determined. Per capita generation will be used as an example, but the technique would apply to any of the parameters. The calculation of the generation of refuse in pounds per capita per day, requires the gathering of refuse weight data and the availability of current population data.

For municipal refuse generation in pounds per capita per day, the influencing factors in a given city might be:

1. Population of the city.

2. Per capita income, or other economic indicator.

3. Zoning complexion; i.e. residential versus industrial, etc.

4. Climate and seasonal effects; i.e. north, south, etc.

5. General community complexion; i.e. urban versus rural, etc.

6. Policy with regard to industrial waste; i.e. accept it at the disposal site or not.

Additional factors certainly exist; these six are some of the apparent ones influencing per capita generation. Other parameters may have larger numbers of influencing factors. The above six are probably expandable into ten or more possible factors which give a "Yes", "No" alternative. The next step would be to determine which, either singly or in combination, most significantly influence the per capita generation.

C. RELATIONSHIPS AMONG VARIABLES

If a test were to be attempted for each potential combination, then the number of cities in which testing would be established would be given by the formula:

$$S = 2^n$$

where:

S is the number of tests

n is the number of sources of variation

If a total of ten influences were to be studied,

$$S = 2^{10} = 1024$$

That is, 1024 separate cities would have to be tested, if that many could be found which have the required combinations of factors.

Sometimes the factors have a stronger influence acting in combination than when acting singly. This would lead to an upward revision of the list of the sources of variation, and further, more involved study.

Except in the most simple cases, complete study of all combinations is impractical and a sampling approach must be taken. Generally, the number of samples should, at a minimum equal the number of influencing factors, and two to one is a good design ratio. Thus, for example, if there are fifteen influencing factors, then a sample of thirty tests is indicated

The combinations of the influencing factors, or sources of variation, for each of the thirty tests is determined in a random fashion, but with a balance in the sources of variation. That is, if one of the sources is, for example, urban versus rural characteristics, the random selection should result in fifteen cities with an urban characteristic and fifteen with a rural characteristic. Randomized adjustment is continued until balance is achieved in each case. Table VII gives an example of this procedure.

The procedure involves the use of a table of random numbers. Using the North and South (N versus S) source of variation, the N is assigned odd numbers, the S even numbers. The first tabulation results in 10 N and 20 S. The table is then searched for random numbers between 1 and 30, finding those numbers which correspond to excess N's and changing those to S's, until the 5 excess N's have been changed to S's, as indicated, to balance the choices. This procedure is repeated for all sources of variation. The result gives a random combination of characteristics for any of the test cities.

Thus, referring to Table VII, test city number 5 will have a southern climate characteristic, will be economically rich with an urban character, etc., for the other influences.

The output of per capita refuse generation developed from the data taken in each sample city will then be subjected to linear or curvilinear multiple regression analysis according to the following equation:

$$Y = a_o + a_1X_1 + b_2X_2 + \; . \; . \; . \; . \; . \; . \pm tS_y$$

where:

Y is the variable of interest; in this case, the per capita municipal refuse generation.

a_o, a_1, b_2, etc. are the regression coefficients.

X_1, X_2, etc. are the sources of variation. There can be combinations of other variables; for example, $X_3 = X_4 \times X_5$; or powers of other variables; for example, $X_3 = (X_4)^2$

S_y is the standard error of the estimate.

t is the multiplier which provides various levels of confidence that the regression equation provides a true measure of the variability in Y.

TABLE VII

Test No.	North or South (N or S)	Rich or Poor (R or P)	Industrial or Residential (I or R)	Urban or Rural (U or R)	etc.	etc.
1	N	R	I	R		
2	~~S~~N	P	R	U		
3	N	P	~~I~~R	U		
4	S	R	R	~~R~~U		
5	S	R	I	R		
6	N	R	R	U		
7	S	R	I	R		
8	S	P	I	R		
9	~~S~~N	R	R	U		
10	N	R	R	R		
11	N	P	R	R		
12	S	P	I	R		
13	S	P	I	R		
14	S	R	I	~~R~~U		
15	S	R	R	R		
16	~~S~~N	P	I	U		
17	~~S~~N	R	I	R		
18	N	P	I	U		
19	S	R	R	R		
20	N	P	R	U		
21	S	P	R	U		
22	N	R	I	U		
23	S	P	R	R		
24	N	R	I	R		
25	N	R	R	U		
26	S	P	I	U		
27	S	P	R	U		
28	S	P	I	R		
29	~~S~~N	R	I	R		
30	S	P	R	U		
Total	10 N 20 S	15R 15P	16 I 14 R	18 R 12 U		
Adjusted Total	15 N 15 S		15 I 15 R	15 R 15 U		

Note that the equation may include various combinations of the influencing factors. The form of these combinations is largely a matter of intuitive feel and mathematical experimentation. If a sufficiently small number of factors are under consideration, all possible interactions may be included at the outset. This is not usually the case, however, and judgment must be applied.

The standard error of the estimate is a good measure of how well the selected sources of variation and their selected combinations have accounted for all variation. The usually applied criterion is the correlation coefficient, R, which is related to the standard error as follows:

$$S_y = \sqrt{(1-R^2)\sigma_y^2}$$

where:

σ_y is the standard deviation of y

A typical criterion for the correlation coefficient is that $R^2 = .80$ or $R = .89$.

Often the initial number of samples is made smaller than the total expected and additional samples are added sequentially to increase the correlation coefficient. The regression equation would be used to calculate, in the example, the expected per capita generation for all possible combinations. Then the high and the low values would be pinpointed, and sample cities found to actually account for these combinations. The choosing of the high and low values provides the most powerful means to increase the correlation coefficient. This is illustrated by Figure 15.

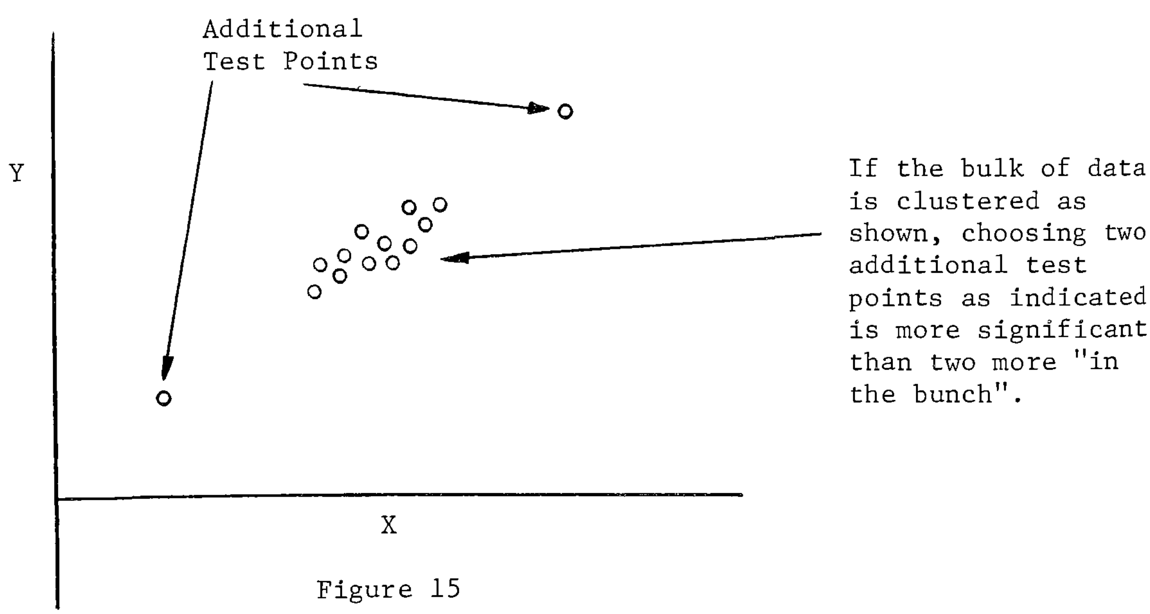

Figure 15

The procedure would continue until the desired level of correlation coefficient was obtained, or until the allotted number of samples were exhausted. Once the regression equation is established, the standard error of the estimate would then be evaluated as if it was acceptable. The size of the error incurred by using it to represent the true relationship between the per capita generation and the sources of variation is a function of the level of confidence desired in using the equation:

$$y = a_o + a_1X_1 + b_2X_2 + \;.\;.\;.\;.\;.\;.\;.\; \pm tS_y$$

If:

t = 1, then the confidence is 68.26 percent
t = 2, then the confidence is 95.45 percent
t = 3, then the confidence is 99.37 percent
t = 4, then the confidence is 99.99 percent

Thus, a 95 percent confidence gives an error which is double the standard error.

Upon examination of the final equation, the combinations of certain of the coefficients a_1, b_2, etc. and their corresponding variables, will be seen to be quite small, which means that their influence is negligible. They may be dropped and the remaining equation used, although the standard error will increase somewhat. In addition, variables may be dropped if the standard error of the coefficient exceeds twice the coefficient itself. In this case, coefficients will be selected for a confidence level of 95 percent. The elimination of certain influences will, in some cases, simplify the data gathering procedures and simplify the selection of further sample cities. It may even be possible to achieve desired results before all samples are obtained.

D. TIME-DEPENDENT RELATIONSHIPS AMONG VARIABLES

The primary output of a basic information system for municipal solid waste would be the predictions of time-based trends in various solid waste parameters, such as the per capita generation used in the example. Thus, data must be collected on a continuous basis. Several years' data must be gathered to permit the trends to be developed. The basic regression equation technique is still applicable, except that the time variable, Θ, is added to the equation. It may be that the influence of the other sources of variation is not time-based, and the annual regression equation will simplify to a single variable in time. That is:

$$y(t) = a_o + b_1(\Theta) \pm t\ S_y$$

Generally, data at two points in time is required to establish a linear trend and three points for a curvilinear trend; however, these are minimums when the time intervals are relatively large. For yearly data, additional points are required, and four to five years is a reasonable figure. The remarks regarding the level of confidence in the time-based line apply for the historical data only. The confidence in the extrapolation of the regression line into the future is not given by the regression analysis. The longer the time periods used to project into the future, the less accurate the prediction is. On the other hand, the more data used to develop the regression line, the better the accuracy.

E. GENERAL REMARKS

The size of the sample, or the number of sample cities to be established, if the results are to be typical of the entire nation, should probably be about thirty. If the nation is arbitrarily regionalized, such as into the nine Public Health Service regions, more than thirty would probably be required, if a reasonable sample is to be established in each region. The regression analysis will determine the extent of the influence of geographic and climatic considerations, and the need for regionalization could await these initial results. Since sequential addition of samples may be considered in any event, further cities could be added to round out the regions as desired.

technical-economic overview
(volume iv)

INTRODUCTION TO VOLUME IV - TECHNICAL - ECONOMIC OVERVIEW

This volume is part of a four volume report. The other volumes are:

Volume I	-	Municipal Inventory
Volume II	-	Industrial Inventory
Volume III	-	Information System

Volume IV has nine parts. Part 1, LANDFILL OPERATIONS, was obtained primarily from a review of the literature and selected interviews. The report was reviewed by qualified people in the field.

Part 2, COMPOSTING, was based on personal interviews and a review of the literature. This report was also reviewed by a consultant with many years of experience in composting practices.

Part 3, APARTMENT HOUSE INCINERATORS, was prepared by a consultant who for the past several years, until his recent retirement, was a member of the New York City Department of Air Pollution Control.

Part 4, A REVIEW OF THE STATE OF THE ART OF MODERN MUNICIPAL INCINERATION SYSTEM EQUIPMENT, was prepared by Combustion Engineering personnel and is based on personal interviews, plant visits, and Combustion Engineering's extensive experience in this field.

Part 5, INCINERATOR AIR POLLUTION CONTROL EQUIPMENT, is based on Combustion Engineering experience; equipment costs were based in part on quotes from vendors of air pollution control equipment.

Part 6, POTENTIAL ENERGY CONVERSION ASPECTS OF REFUSE, gives some technological trends in municipal burning systems.

Part 7, THE EFFECTS OF MUNICIPAL REFUSE VARIABILITY ON INCINERATOR EXHAUST GAS, WATER AND AIR FLOWS AND BURNING CAPACITY, is an original analytical computer study which indicates how changes in refuse composition affect the design and performance of municipal burning systems.

Part 8, THE COSTS OF CONVEYING SOLID WASTES BY RAIL, was prepared by Dr. Louis Koenig of Louis Koenig Research, San Antonio, Texas. Dr. Koenig conducted the study under a sub-contract to Combustion Engineering.

Part 9, MUNICIPAL BUYING PRACTICES, presents the industry - municipality relationships as they exist today when municipalities purchase burning systems.

The material in this volume was prepared by Combustion Engineering personnel and outside consultants. The individual authors are given at the beginning of each part. Mr. Elliot D. Ranard served as Program Manager for Combustion Engineering; Mr. Ralph J. Black served as Project Director for the Public Health Service.

PART 1

LANDFILL OPERATIONS

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November 1, 1967

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SECTION I

SANITARY LANDFILL

A. INTRODUCTION

As defined by the American Society of Civil Engineers, "sanitary landfill is a method of disposing of refuse on land without creating nuisances or hazards to public health or safety, by utilizing the principles of engineering to confine the refuse to the smallest practical area, to reduce it to the smallest practical volume, and to cover it with a layer of earth at the conclusion of each day's operation or at such more frequent intervals as may be necessary".[1]

Sanitary landfills were first used in England in 1916 where the process was called "controlled tipping". Around the 1930's, New York City and Fresno, California were the first communities to try it in this country. Early successes prompted many other communities to adopt this method of refuse disposal. By the end of 1945, 100 cities were using this process. By 1960, 1,400 cities had begun to use it.[2] Sanitary landfills absorbed less than 10 percent of the refuse collected in early postwar years. They now account for just under 50 percent of the refuse collected.[3]

B. BENEFITS

In the last thirty years, thousands of acres of worthless and low value land have been improved to the point where they are now being used for parks, playgrounds, parking areas and other useful facilities.[4] In fact, were it not for sanitary landfill, parts of the nation's two largest cities, New York and Chicago, would not even exist today. In New York's five boroughs, landfills created bathing beaches, waterfront parks, marinas and redeemed land for expressways. In Chicago, much of the famous lakefront was created by carefully planned landfill.[5] Completed sanitary landfill sites are currently being used for parking lots, parks, playgrounds, golf courses and all other types of recreational areas. Construction of buildings has, for the most part, been confined to light structures. In some areas, better growth of plant life is obtained than the original ground surface would support.[4] Depending on root depth, even trees can be planted.[2]

C. OPERATIONS

Landfill sites fall into one of two major classifications: (1) area landfills, which comprise sites on primarily flat land such as marsh land, tideland or marginal lowland; (2) depression landfills, which comprise sites that utilize natural or man-made depressions or irregularities in the terrain such as quarries, sand and gravel pits. The "area landfill" classification is further sub-divided into categories according to method of operation. Three of the most practical methods used are progressive excavation, cut and cover and imported cover method.[6]

1. AREA LANDFILL

a. PROGRESSIVE EXCAVATION

The simple continuity of the progressive excavation method is its most distinguishing feature. Cover material is excavated directly in front of the working face and is placed directly on the previously compacted fill. The cover is excavated only as needed to properly cover the fill material. This type of landfill is usually serviced by bulldozers or clam-shell machines and utilizes a ramp type working face. Draglines are sometimes used to operate a trench-type progressive excavation.

In a ramp type project, it is easier to see the work and control the spreading of the refuse if it is discharged at the base of the working face and spread from the bottom up. This method of operation also has the tendency to screen the operation from the public view and minimize the nuisance of blowing paper.[6]

b. CUT AND COVER

When the material excavated from a trench is stockpiled adjacent to the site and later used for cover over the compacted refuse, the operation is called a "cut and cover" type of area fill. In some cases, the excavated material may exceed the requirements for the cover needed and the extra material is sold. The rate of excavation bears no relation to the rate of refuse disposal and in many cases long parallel trenches are opened considerably in advance of the need for refuse disposal. This is sometimes a big advantage where there is excessive rainfall or the ground may become frozen in the winter.

The cut and cover method for operating an area fill is well suited to sites where excavation may be made below the water table. A dragline is essential in an operation of this type and the refuse is discharged at the top of the working face. The dragline may be used to spread and compact the refuse.[6]

c. IMPORTED COVER

The imported cover type of landfill is used when depressed areas of land are available but sufficient cover cannot be secured at the site. Fills in rock quarry pits are a good example. The refuse is placed and compacted by a bulldozer or dragline as in other types of landfill. Cover material is usually stockpiled or delivered as needed to the site. Waste sand from nearby gravel mining operations and earth from building site excavations or from highway excavations are a common source of cover material.[6]

2. DEPRESSION LANDFILLS

In depression fills the total depth of refuse generally exceeds the depth for a single layer of lift operation. Each stratum or lift is constructed by the placing and compacting of the refuse so that cells are constructed, with fill material on all sides to prevent travel of fire through the mass and for the control of rodents, flies and odors.

Pit and quarry sites are normally used for depression landfill operations. The distinguishing characteristic of all pit and quarry sites is that they are lower at all points than the surrounding terrain. The pits are usually of such a depth that several lifts or strata are necessary to bring them to grade. If there is available cover material and no drainage problems are created, there is no reason why the area may not be filled to a level much higher than the original ground, particularly if the area was originally characterized by rough terrain.

Refuse is transported to the working face by way of access roads. If compaction is done by bulldozing from the bottom up in sloping layers, a high density can be achieved. Maximum capacity can also be secured because the weight of several lifts will help create a greater density than would normally be achieved in a cut and cover area landfill. It may be advisable to operate the first lift by the progressive excavation method of landfill. The fill should be above the ground water level unless it can be shown that any pollution of the ground water will not adversely affect adjacent areas.

It is important that the pit and quarry sites include enough suitable excavatable cover material around their perimeters or that there is enough overburden and non-marketable materials available on the site to provide a volume of cover equaling at least 25 percent of the refuse.[6]

Sanitary landfills must be first class operations. Facts and plans will do most to insure acceptance -- a carefully thought-out master plan which will illustrate the potential benefit to the community is needed. These plans must be flexible to accommodate changes in real estate development. Cooperation of cities and counties as well as their respective departments is a must.[4] Municipalities or contractors should select and buy land in advance for future disposal needs. It is important that the land deed state that the area will be used as a refuse disposal site for a specified number of years. Thus forewarned, housing developers and citizens can plan accordingly.

The American Public Works Association Research Foundation has prepared a method for determining "landfill area required". The formula used is as follows:

$$V = \frac{FR}{D} \left(1 - \frac{P}{100}\right)$$

where:

V = Landfill volume in cubic yards required for refuse disposal per capita per year.

F = A factor which incorporates the cover material, averaging 17 percent for deep fills and 33 percent for shallow fills with corresponding F values of 1.17 and 1.33.

R = Amount of refuse contributed in pounds per capita per year.

D = Average density of refuse in pounds per cubic yard delivered at the landfill (about 325 for collection by compactor trucks).

P = Percent reduction of refuse volume in the landfill, varying from zero to 70 percent.

D. POTENTIAL PROBLEMS

There are several problems that can arise at sanitary landfill sites. The most significant include the following:

1. WATER POLLUTION

A principal hazard of sanitary landfill disposal is the possibility of fluids leaching from the fill and polluting the streams. Such problems can be minimized, or prevented, by constructing the fill in such a manner that it does not become saturated. This can be accomplished by filling all space below maximum ground water level with inert material, providing an impervious dike around the fill to exclude flood waters or surface drainage from adjacent higher ground, and covering and grading the top of the fill to drain off much of the precipitation which falls on its surface.[7] Studies have also been conducted to determine the risk to ground water from refuse tipped into dry and wet pits.[8]

Besides the problem of ground water pollution, the filling of swamps of flood plain lands can have an adverse effect upon flood conditions. Flood control is essentially a space allocation problem, and under natural conditions flood plains and swamps provide natural channel storage areas for surplus water. If these areas are filled, they are no longer available for flood water storage, and space needed to accommodate flood waters can be obtained only by raising flood stages. In addition, enroachment in the channel cross-section reduces hydraulic efficiency of the waterway and may cause it to back up behind the constriction. Although the use of sanitary landfills is sometimes extolled as a desirable way to "reclaim flood plain areas", care must be exercised to see that the operations are properly designed and located so that they will not cause adverse effects on flood stages.[9]

2. GASES

The amounts of gas produced seem to be directly proportional to moisture content of the fill. Temperatures and climatic conditions are also factors. No way has yet been found to prevent methane gas production in sanitary landfills.[2] Odorous gases, particularly hydrogen sulfide gas, have been noticed in sites where contractors have disposed of gypsum board and similar building materials having a sulfate content. This is a result of the formation of hydrogen sulfide by the action of sulfate-reducing bacteria on these materials.[7] An incident in a Chicago landfill which was completed twenty-five to thirty years ago illustrates the extent of gas production and danger. The sanitary landfill site was covered with two feet of snow, sealing the natural openings through which the gas normally escapes. The result was to force the gas into sewers serving homes in the area, causing an explosion.[4]

3. FLYS AND RODENTS

Fly and rodent control is a problem in any landfill operation. Fly control is best accomplished by using a cover material with a binder which is well compacted. A well compacted cover of 2 5/8 inch prevents fly emergence. With an uncompacted earth fill of 5 foot thickness, 90 percent fly emergence has been noted. Covering the refuse every night eliminates the attraction of rodents.[10]

4. FIRES

Landfill fires also present significant control problems. Fires can be controlled by proper supervision of personnel and dumping procedures. Minimum amounts of area should be open at one time to prevent wide spread of fires. Watering down of refuse tends to reduce possibility of fire while at the same time aiding compacting.[2]

5. DECOMPOSITION

Studies on factors which affect the rate of decomposition of organic matter in sanitary landfills have been made in several areas. These factors include moisture, soil mixture, depth of fill, type of soil, aeration and temperature. In Los Angeles County, such factors prevent decomposition of refuse in landfills. However, in Seattle, Washington where there is heavy rainfall, decomposition does take place.[2] More investigation is needed to determine the effects of moisture and seasonal changes on decomposition.

In a landfill site near Chicago, after seven years, a sanitary landfill site was excavated and almost complete deterioration of material was noted. This material made excellent cover and supported the growth of grass. It was an excellent soil additive. Even material buried only four years showed considerable decomposition and a low moisture content. The sites were on an old lake bed, but the fill itself was considerably above ground level.[2] Whether decomposition is desirable or not must to some extent depend on what future use is planned for the site.

E. COSTS

Costs of sanitary landfill method for refuse disposal cover a wide range. The total cost includes the land cost plus site development plus operating and equipment costs. Since the land should increase in value, even in a remote area, the cost of the land from a long range point of view is sometimes neglected.[6]

Data obtained in 1954 showed that the total cost of plant and equipment required for sanitary landfill for a community of 10,000 persons was approximately \$8,000, for a community of 50,000 persons \$20,000, and for 90,000 persons \$25,000.[7] More recently, there is almost unanimous agreement that costs will usually range from \$.80 to \$1.50 per ton. A cursory evaluation of landfill costs yields the following equation (not including transportation costs).[11]

$$\$/\text{ton} = .50 + \frac{6{,}000}{\text{tons per year}}$$

Transportation costs need to be added to operating and equipment costs[12] to obtain total cost per ton. There are two methods of figuring transportation costs. The better method is based on hauling time; the second method is based on mileage.

The first method of figuring costs is the "ton minute". The unit cost of "ton minute" is arrived at by dividing the dollar cost per minute by the net tons on the load. It does not matter whether the vehicle travels 15 miles per hour on surface streets or 60 miles per hour on the freeway. What does matter is the length of time the trip requires, since the vehicle is being paid for on a time basis rather than mileage base. The cost of any direct haul vehicle can be represented on a graph. A line drawn through the origin with a slope equal to the cost per ton per minute represents the cost for hauling a ton for any length of time.[12]

The hauling time method is also helpful in determining when a transfer station type of operation is economic. In any transfer operation, the cost of owning and operating the station itself is not productive of moving refuse to the place of final disposal. This cost must be "earned back" by the greater efficiency of the haul vehicle being used. There also might be other unproductive expense at the disposal site, since the transfer vehicle will quite likely be less maneuverable, require the removal of covering tarpaulins, and may require a longer time to unload than a collection vehicle.[13]

The second and older method is based on cost/ton/mile, i.e., 15¢/ton/mile, 30¢/ton/mile. These costs are based on average speeds of 15 miles per hour on city streets and 45 miles per hour on freeways, full operating, maintenance, and depreciation cost of equipment, labor costs including fringe benefits and overheads.[10] Adding to these figures a cost of $1 per ton for dumping, and assuming a ten mile haul distance from collection route to dump, the total cost per ton would come to: twenty miles at $.15 = $3 plus $1 or $4 per ton total cost.

F. ADVANTAGES AND DISADVANTAGES

The advantages of sanitary landfill over other solid waste disposal methods are:

1. Less capital investment.

2. Can accommodate peak refuse quantities readily.

3. Combined refuse collection, including garbage, ashes, combustible rubbish and non-combustible rubbish is possible thus reducing collection costs.

4. Operations can easily be terminated without a great loss in equipment or land. The equipment is of a type which can readily be used for other municipal functions and the land at any stage is no worse, and usually is better than it was before the operation began.

5. Sanitary landfill requires less land than open dumping because the refuse is compacted to between 40 percent and 50 percent of its original volume and can be deposited to a greater depth by digging ditches. Approximately one acre per year is required for 10,000 persons (seven acre feet).

6. Unusual materials and bulky articles do not usually cause difficulties of operations.

7. Sanitary landfill can be established immediately upon the purchase or rental of standard digging and compacting equipment and authorization to use the land. No plant has to be built before operations can begin as is true of other solid waste reduction methods.

The disadvantages of sanitary landfill are:

1. Large amounts of land are required.

2. Sites located outside of a city are usually under some other Governmental jurisdiction.

3. Winter operations present difficulties.

4. Prevention of ground water pollution may be costly.

5. If the distance to the sanitary landfill site is very great, the cost of transfer operations may be high.

Additional information sources on landfill operations are available.[14, 15, 16]

SECTION II

OPEN TRENCH BURNING

The burning of refuse at dumps is commonly considered to be an undesirable practice. Smoke and other air contaminants normally emitted cause nuisances in nearby developed areas and contribute to the community-wide air pollution problem. As a result, dump burning is being prohibited by air pollution control legislation in populated sections of many states. However, controlled burning methods are being used in some locations which avoid some of the undesirable features commonly associated with dump burning. Such methods are not a "cure all" that would make it possible to establish burning sites in or very near populated areas. These practices, however, can reduce the amount of smoke produced with little additional cost. Also, they may furnish an interim solution to the refuse disposal problem even in areas where burning may ultimately be prohibited for air pollution control reasons.[17]

The three types of controlled burning dumps used reflect the influence of the topography of the site selected. They are the single lift fill, the trench fill, and the canyon fill.

A. SINGLE LIFT FILL

The single lift fill is used where level low ground can be improved by filling. Roadways and a bank with a safety berm are constructed so that the completed fill will fit the contours of the surrounding land.

B. TRENCH FILL

The trench fill is constructed by excavating a trench in level ground. It is operated as if it were two single lift fills facing each other. The excavated material can be used to cover the completed fill or to provide fill material for other work. The cost of excavating the trench makes this type of operation slightly more expensive than the other two.

C. CANYON FILL

In a canyon site, conditions similar to the single lift fill can be created by cutting two shelves along the side of the canyon. The upper shelf is maintained for burning by occasionally bulldozing the ashes down to the lower shelf where they create a solid and permanent fill. The main purpose of the lower shelf is to limit the dumping area and facilitate salvage. Burning is confined to the upper shelf.

D. LAND REQUIREMENTS

Conveniently located marginal land can often be found that is suitable for the establishment of one of these types of controlled burning dumps. Regardless of the terrain, there are five requirements to consider.

1. Sufficient isolation so that surrounding residents will not be affected.

2. Caretaker (full time preferably) to supervise the dumping and police the operation.

3. Clean level roadways and a safety berm for trucks and cars to back up against. Together with good housekeeping, these encourage the cooperation of the public in dumping over the bank.

4. A bank approximately 15 feet high with a 45 degree slope to cause the load dumped for a collection truck to properly loosen and scatter down the bank. This procedure allows enough air to get to the refuse for efficient combustion.

5. Sufficient length of dump face for proper segregation of materials.

Trench fills or single lift fills on low ground should be so located that no portion of the fill intercepts ground water. Problems of water pollution, stuck equipment, and difficulties in removing salvage are common in marshy areas. Provisions must be made for handling drainage water from the fill and roads, as well as any surface water that normally flows through the site. A slope of one to two percent is sufficient to prevent difficulties on the roadways and in the trenches. Access roads should be constructed so that they are passable throughout the year. Fire breaks must be carefully constructed and maintained to prevent the spread of fire to surrounding property.

E. SEGREGATION OF REFUSE

Separation reduces objectionable smoke and odors, and permits maximum salvage. By providing separate areas for dumping, it is usually possible to accomplish a great deal of segregation as dumping proceeds. When the people using the site have become accustomed to the system, signs alone may be sufficient. The degree to which segregation is carried must be fitted to the area in which the dump is operated and the degree of perfection that is required. The following separation into five classes of materials has been successfully used in a number of operations.

1. Household rubbish, mixed refuse, paper, cardboard cartons, cans, bottles, toys, and similar materials. After the non-ferrous materials are salvaged, the remaining refuse can be burned daily with almost no smoke. The tin cans and other ferrous metals can be periodically salvaged by using a mobile crane and electromagnet. With salvage of cans, the useful life of the trenches can be extended significantly over their life without salvage.

2. Stoves, refrigerators, washers, tanks, drums, beds, and other large items. These items are almost totally salvable and should be kept separate to conserve space.

3. Tires, ground rubber, roofing paper, linoleum, other heavy smoke producing materials, such as concrete and bricks. Salvageable items can be removed and the remaining material buried without burning. If these heavy smoke producing materials must be burned, particular attention should be paid to selecting a time when atmospheric conditions are the most favorable to disperse the smoke.

4. Lawn clippings, brush and tree trimmings. These green materials need to be thoroughly dried before burning or they will only smolder. In order to avoid fly production in cases where large quantities of green lawn clippings are received, they should be buried immediately.

5. Dirt and ashes. By providing a separate storage area, dirt and ashes can be saved for cover material.

F. BURNING PROCEDURE

When refuse is dumped in a pile and set afire, excessive amounts of smoke are commonly produced. However, with little additional expense, proper conditions for controlled burning can be established. Gravity is utilized to do most of the work of loosening and scattering the refuse on a properly constructed bank.

Usually the caretaker uses a long handled hook fork to finish breaking open and spreading the dumped refuse. After the refuse is properly spread, the fire is started on the downwind side. This keeps the fire from smothering itself, and so results in a cleaner burn. At the tail end of the burn, any matted material such as newspapers or grass clippings, will have a tendency to smolder and produce smoke. These matted materials are broken open at this time with a long handled hook fork so that the air can get to them and complete the burning quickly. When the burn is conducted in this manner, the refuse spread out on the bank can get sufficient air for efficient combustion and yet it is still concentrated enough to generate the necessary temperature to sustain good combustion. The bed of cans and bottles acts as a grate, allowing air to get underneath as well as around the refuse. The time required for combustion of one truckload of refuse is reduced from an hour or more to approximately 15 minutes. Also, the amount of smoke produced is markedly reduced. Best results are obtained when a maximum of four or five truckloads of refuse are burned at one time.

G. ADVANTAGES

Controlled burning dumping offers the following advantages:

1. A minimum amount of land and equipment are required, thus minimizing the capital investment.

2. Dump sites last longer.

3. Proper bank slope and depth promote complete, clean, fast burning with a minimum of smoke.

4. Maximum salvage of metals helps maintain the operations, conserves dump space, reduces costs and conserves natural resources.

5. The final residue is held to an absolute minimum and the land can be returned to immediate use.

6. The safety berm prevents accidents and encourages dumping over the bank.

H. DISADVANTAGES

The disadvantages of controlled burning dumping are:

1. Some smoke and air contaminants are produced, so that an isolated site is required.

2. Burning is a fire hazard to surrounding property.

3. Fly control is not as effective as at properly operated sanitary landfills.

4. Public cooperation is necessary in separation.

5. Dead animals, swill, cannery wastes, wet manure, and other wet wastes must be specially handled.

SECTION III

COMPACTING

The compacting of refuse can occur at any or all three of the areas involved in refuse disposal. Compacting units have been built for on-site use. That is, at apartment buildings, schools, super markets, institutions, etc. where large amounts of refuse are generated. The collection of refuse today is largely made by collection vehicles with compactor units. The final area of compacting is at the disposal site where heavy equipment is run over the refuse or, as in the case of North Tonawanda, New York, a special vehicle is used to provide compacting.

Compacting of refuse is easily accomplished by the machinery available today. Hydraulic or pneumatic cylinders can exert forces as high as 90,000 pounds, reducing the original volume of the refuse by 60 to 80 percent. However, refuse is not like scrap metal which retains its compacted shape. Refuse must be restrained in its compacted shape by keeping it under pressure, either by bagging, baling, or some other means.

A. ON-SITE COMPACTORS

There are several basic systems of on-site compaction. One is a proprietary system which utilizes a pneumatic ram to compact the refuse into paper sacks or plastic containers. The principle of operation is relatively simple. The machine compressor and paper bag holder are mounted below a refuse chute. As the refuse enters the bag, it triggers a mechanism that shunts the bag under the pneumatic ram, places a clean bag under the chute, compresses the collected refuse and the partially filled bag stands ready to be shunted back under the chute until full.

A four-bag machine, operating under high compaction pressures (3,000 psig), would cost approximately $3,000, including the air compressor unit.[18] Each bag will hold approximately 3.5 cubic feet of refuse having a total weight of 75 pounds. The bags will cost approximately twelve cents each. Therefore, for a typical 100 unit apartment housing 250 people and assuming a waste generation rate of 2.25 pounds of refuse per capita per day, 560 pounds of refuse would be generated each day. This amount could be handled by eight bags at 8 x 12 or 96¢ per day for bags.

The paper bag compactor has a number of significant advantages in that it:

1. Provides a sanitary method of collection.

2. Reduces the volume to one-third of its original volume.

3. Produces refuse packages that are relatively easy to handle.

4. Reduces the amount of on-site storage required.

5. Reduces the need for expensive compaction equipment on the municipal collection vehicles.

The disadvantages are:

1. The requirement for a high-pressure (300 psig) storage vessel on the premises.

2. The critical dependence on electrical energy.

3. The possibility of poorly manufactured paper bags of low strength. As these systems are installed, it is possible that the relatively high bag costs (12¢) will stimulate the manufacture of cut-rate bags.

4. Unknown system reliability and maintenance costs.

5. No reduction in weight of refuse.

The other system of compaction in general used today consists of a horizontal ram and compression area connected to a wheeled detachable container reportedly reduces the volume to about one-quarter of its original volume.

The system is reported to cost approximately $4,500. When the detachable container is fully loaded, a signal is energized and it will not accept any additional refuse. The standard detachable container will hold approximately 1,000 pounds of compacted refuse which then can be wheeled to the area for municipal or private collection. It has all of the advantages and disadvantages of the bag compactor except for the size of the refuse container and several additional disadvantages:

1. The location of the collection chutes must be controlled to make sure that the loaded refuse container can be moved to outside collection.

2. It requires modification of, or special types of municipal collection vehicles.

3. Because of the size and weight of the detachable container, it probably will require the services of at least two custodial personnel if it must be removed to another location by the collection truck.

There are also on the market a number of systems in which a heavy duty crusher or disintegrator crushes or chews up the refuse. The crushed or disintegrated refuse is then delivered to a baling machine where it is wrapped and sealed for later pick-up. This type of system might lend itself to a central station concept wherein refuse from a number of chutes is conveyed to a central station for compaction and baling. In general, it has little application to a single multi-family unit.[18]

B. COLLECTION OF REFUSE

Compactor type collection vehicles are used extensively throughout the United States today. There are approximately thirty manufacturers of these vehicles. At present, about three-quarters of all refuse trucks in operation are of the compactor type, and virtually all vehicles sold by 1980 will compact waste. Needs exist for a higher ratio of payload to dead weight in such trucks -- today's models are so big and heavy and compact materials so effectively, that they often exceed legal weight limits when full. Another improvement needed is some device or system that retains the compaction achieved in the truck. At present the compressed material regains much of its bulk when dumped, and must be recompressed at the landfill site.[3] Trucks in operation today can exert up to 90,000 pounds of force on the refuse and compact 60 cubic yards or 10,000 pounds of refuse into a 20 cubic yard truck.

C. DISPOSAL SITE COMPACTORS

Almost all compacting done at landfill sites is accomplished by dragging a crane bucket (dragline method) over the refuse or running over the refuse with a bulldozer. The amount of compaction obtained would depend on the make-up of the refuse (moisture content), amount of previous compaction either on-site or in collection, the number of times the bulldozer runs over the refuse and the spring-back of the refuse before it is finally covered with earth.

Another method has been developed for compacting and is currently being used in North Tonawanda, New York. A large automated vehicle, which has a compactor built into it, moves along the landfill site digging a trench about 4 feet wide by 8 feet deep. It accepts truck-loads of refuse, compacts the refuse and extrudes it into the trench. While still under pressure, earth is filled in over the refuse as the vehicle moves along so that the refuse has no opportunity to spring-back. The manufacturers of this equipment claim that one machine of this nature could service a town of 80,000 to 100,000 people. This machine will be evaluated under a demonstration grant in Niagara County, New York. The project is expected to be completed May 31, 1969.

The economics of refuse disposal are reasons enough for compacting. However, with stricter air pollution laws which are in some cities calling for the shut-down of apartment building incinerators, on-site compacting is becoming a necessity. Compacting is a space and time saver. Space, whether on-site, in collection trucks or at landfill sites, is at a premium. In addition, the compacting in collection trucks enables collection crews to collect three to four times as much refuse as without compactors, allowing a substantial saving in labor costs.

SECTION IV

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PART 2

COMPOSTING

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SECTION I

SUMMARY

Composting has not been an effective means for municipal solid waste reduction and disposal in this country. Despite its very early use as a soil conditioner and fertilizer in Europe, composting has made little progress toward an industry of any significance in the United States. Several reasons for its limited progress are: (1) the low cost and wide use of chemical fertilizers, (2) the high operating and distribution costs of compost, (3) the limited number of successful composting operations in the United States and (4) the reluctance of municipalities to enter commercial ventures.

At the present time, there is an increasing interest in composting stimulated by proponents of a natural organic fertilizer method of crop production, soil biologists, and horticulturalists and equipment manufacturers or process designers-licensors. This current interest is supported by a forecast of increasing amounts of municipal waste, the decrease of economic landfill sites and the belief that composting operations can be operated profitably.

This report describes the different composting processes, and the business environment. Recommended future activities in the technical and marketing areas are also presented.

SECTION II

INTRODUCTION

Compost results from aerobic decomposition of municipal refuse. When organic material is decomposed in the presence of oxygen, the process is called "aerobic". Under proper conditions, municipal refuse will yield a compost in the form of a granulated material resembling coarse coffee grounds. Certain materials such as tin cans, glass, and plastic materials will not convert to compost and must be either salvaged or disposed in a landfill site.

Composting is a logical consideration for solid waste reduction because it converts municipal refuse into a useful soil conditioner and because it can be used to treat not only solid refuse but sewage sludge as well. The general principles of composting as related to treatment of town wastes are shown in Figure 1.

Although composting has had some success in Europe, its success in the United States has been extremely limited. This study was conducted to determine the reasons for its limited success and to make recommendations for future activities. Data for the study was obtained by a review of the literature, a survey of equipment suppliers, and selected interviews with knowledgeable persons in the composting field.

GENERAL PRINCIPLES OF COMPOSTING AS RELATED TO TREATMENT OF TOWN WASTES.

Reference 1

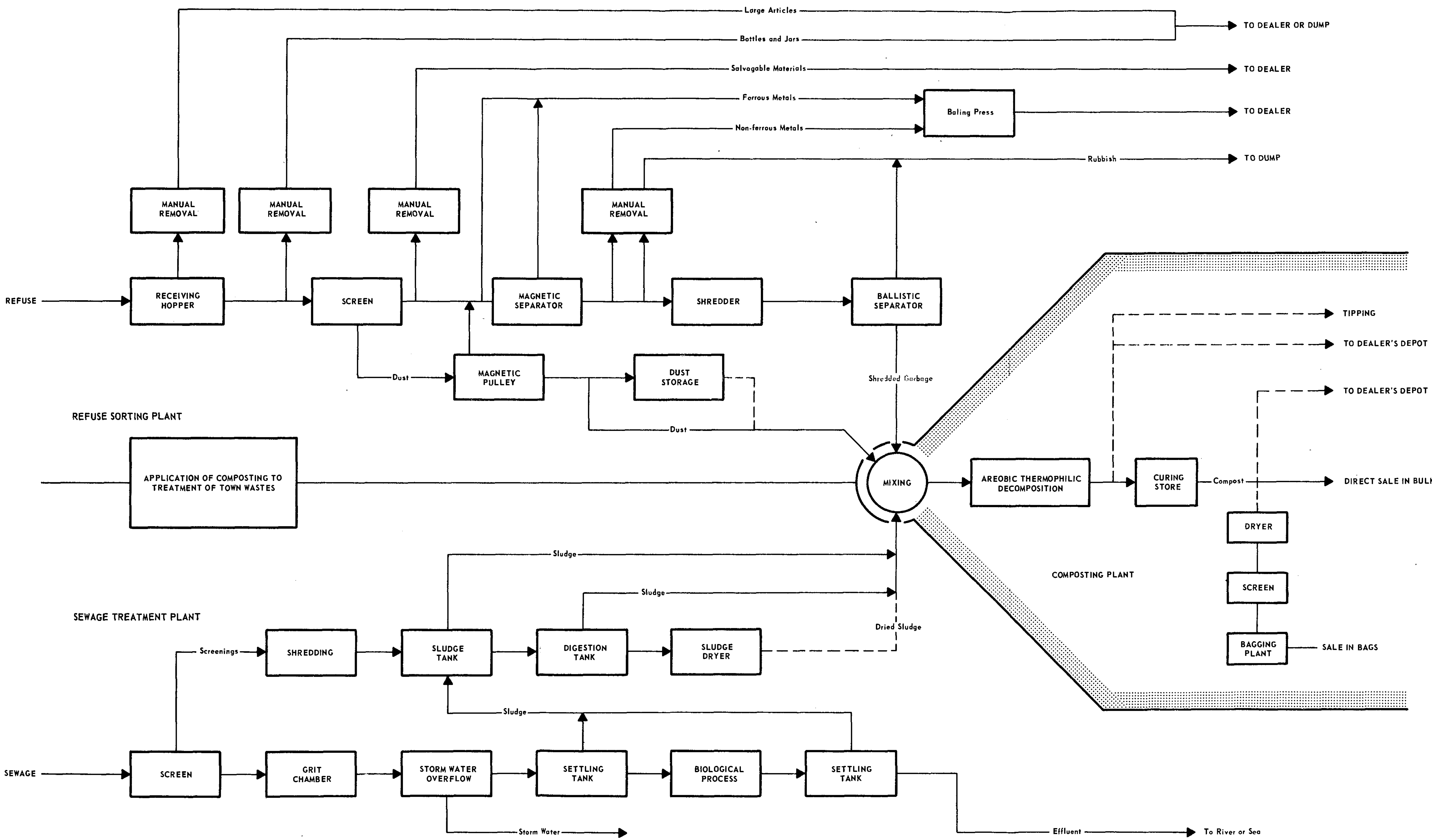

Figure 1

SECTION III

CONCLUSIONS

A. Current demonstration projects, sponsored by Government and private industry, will determine cost and performance levels of municipal composting plants and compost usage. The outcome of these programs can influence the future course of composting in the United States.

B. The success of composting plant ventures must depend on acceptance of compost as a necessary soil conditioner. It should be noted that the whole institutionalized effort of agricultural research has been based on the concept that commercial fertilizers are adequate; and the productivity of land so fertilized has demonstrated the correctness of their practice.

C. The economics of composting must be evaluated by each city and consideration should be given to:

1. The compost supply, the amount of the demand, and its location.

2. The availability of land for composting, i.e. open windrows versus enclosed digesters.

3. The alternatives available to composting will determine the "dumping fee" that the city will pay to the composting plant operator to handle its refuse.

4. Storage space availability for inventory accumulation because of the seasonal nature of the demand.

SECTION IV

RECOMMENDATIONS FOR FUTURE ACTIVITIES

A. MARKETING

1. NEW VIEW OF COMPOSTING

A new view of composting, divorced from the present view that it must be a commercial venture, should be developed. One possibility is to use compost in routine landfill operations.

2. PRODUCT SPECIFICATIONS

Determine those qualities and properties that relate compost benefits to agriculture, horticulture and silviculture.

3. STATE AGRICULTURAL SOIL TEST STATION ASSISTANCE

Agricultural laboratories are in a position to increase user demand by incorporating compost recommendations in their soil testing service. However, the whole institutionalized effort of agricultural research and extension has been based on the concept that commercial fertilizers are adequate, and the productivity of land so fertilized has convinced the agriculturist of the correctness of their practice.

4. EDUCATION PROGRAM

A planned educational program is necessary to inform the potential consumer of the benefits to be derived from the utilization of compost. The core material for such a program is the subject of other recommended marketing and technical studies listed in this section.

5. CREATION OF INDUSTRIAL WASTE UTILIZATION GROUPS

The establishment of such groups to foster industrial waste composting could reduce the burden on municipal refuse disposal systems and benefit the municipality directly. Such organizations could also assist in the educational task faced by the composters to develop a consumer acceptance of compost.

6. INVESTIGATE POSSIBILITY OF BALANCING COMPOST PRODUCTION CAPABILITY AND POTENTIAL CONSUMPTION

A study should be established to determine the relationship between compost production potential and soil accommodation or market saturation. Can such a situation exist, and if so, when? Can such a situation be prevented in the near term by selective municipal compost plant construction authorization or regulation? The leverage of Federal Subsidy should be included in this study for its impact and effectiveness.

7. REVIEW OF STATE REGULATIONS AND CLASSIFICATION OF COMPOST

Existing regulations of fertilizer packaging information imposed by all fifty states require a guaranteed minimum analysis of all ingredients in fertilizer. As long as compost is to be marketed at a price premium over non-nutritive soil conditioners like humus or peat, it must rely on its primary and trace nutrient content. Being a raw material derived product, its ingredient composition will vary. A study to determine the basis for the state regulations and their applicability to compost or a new legal description of compost would ease the marketing problem facing the composter in both intrastate and interstate distribution.

8. A STUDY OF MUNICIPALITY PARTICIPATION IN PROFITABLE ENTERPRISES

A question arises when considering the extent and nature of a municipality participating in a profit making venture. There are few guidelines for the city administration to follow in this regard and a study of precedents or reasonable positions would be of value to assist in their deliberations.

B. TECHNICAL

1. UTILIZATION - EVALUATION METHODS

Establish methods of analysis and evaluation of raw refuse material samples (and sludge blends) to assess final product compost qualities for an intended regional market that can be economically served.

2. COMPOST STANDARDS

Prepare national standards of grade and "potency potential" for categories of compost. Set quantitative ranges for structure, fertilizing value, trace elements, micro-organism determinations, etc. Such a standard could also be used as a blending objective by the municipal compost operator.

3. TECHNICAL COORDINATION

The appropriate Federal fertilizer agencies should seek to actively participate in, monitor, or seek to assist in planning the programs of the International Research Group on Refuse Disposal as they relate to European Municipal compost practices of production, product utilization and distribution.

4. EQUIPMENT DEVELOPMENT FOR COMPOST SOIL

In an effort to penetrate and realize the commercial compost market potential, specially designed equipment can be produced that will facilitate farm soil additions. The spring season soil imposes restrictions on conventionally available fertilizer spreaders designed for the summer growing season for fertilizers.

5. PROPER SOIL BALANCE TO COMPENSATE FOR STEADY CHEMICAL FERTILIZER AND PESTICIDE (BACTERICIDAL) CROP DOSAGE

To shed light and provide answers for the proponents of natural fertilizers who claim that the soil is rapidly being denuded of its basic structure, trace elements, and micro-organisms content by the present level of dosages of chemicals as fertilizers and insecticides, herbicides, defoliators, etc., studies should be conducted to assess the level and rate of this depletion, and the potential capability of compost to arrest and correct such a condition if, in fact, it does exist.

6. NON-COMPOSTABLE, NON-SALVAGE SOLIDS DISPOSAL

Effective disposal methods must be evaluated for the composter of municipal refuse for non-compostable, non-salvage solids. Such items as aluminum cans, non-magnetic metallic items, rubber tires, mattresses, plastic materials, glass bottles, and wood wastes, etc., must be disposed of in a pollution-free sanitary method that does not burden the plant operating costs disproportionately.

7. NON-COMPOSTABLE SOLIDS REMOVAL

Materials handling methods are required that will process the incoming raw refuse material and separate the non-compostable solids for either salvage sales (when possible) or disposal. The labor cost involved in sorting this material creates a major cost differential between natural organic composting and municipal refuse composting operations.

SECTION V

BACKGROUND

Compost is produced as a result of natural fermentation that occurs in moist cellulosic materials, and is available as a granulated dark brown material resembling coarse coffee grounds. The finished product, after drying, contains organically bound nitrogen, a large portion of carbonaceous matter (humus), micro-organisms, and important micro-nutrients. The compost is usually dried to 10 percent to 15 percent or less moisture.

The major raw materials today employed in domestic commercial natural organic fertilizers are cow manure, bedding straw and other animal excrement. Municipal dried activated sewage sludge is also marketed and can be blended with compost raw material to enhance the fertilizer value of the product.

Municipal refuse, containing much cellulosic material is successfully composted today. This new material, however, contains a high ratio of cellulosics to nitrogenous compounds, and more digestive bacterial cycles converting carbon to carbon dioxide (gas) are required to reduce carbon content to the accepted ratio range of 20 to 30: 1 parts, C/N. Blending with higher nitrogen sewage sludge hastens the process by improving the ratio and also upgrades the final product.

The relative importance of this category of natural organics (and its compost) can be judged by Department of Agricultural data[2, 3] shown in Table I.

There are numerous processes in operation both here and abroad that can produce compost. They vary in scope, complexity, and first cost from the most primitive form of windrow (long mounds) to those employing enclosed digestors, quantitatively designed, and on which processes and equipment patents are held.

Prior to describing the major processes in use, it will be well to review the agricultural, horticultural and sylvicultural value of compost.

There are six properties of compost that are of interest and concern: (1) organic nitrogen content, (2) humus content, (3) micro-organisms present, (4) micro-nutrients content, (5) presence of incorporated solid extraneous matter, and (6) the possible variation of the chemical and physical proportions of the various ingredients (attributable to its raw material).

The organic nitrogen is a water insoluble form of nitrogen. Thus rain, irrigation or watering will not leach away this portion of the total nitrogen not immediately taken up by the roots. It will be slowly converted to the active state by the action of the micro-organisms present. Thus, the 5 percent to 7 percent nitrogen in an enriched compost is longer lasting and is made available over a longer period of time.

The humus content improves the soil structure enhancing growth and increasing water absorption and retention, especially important in clay soils.

TABLE I

CONSUMPTION OF COMMERCIAL

FERTILIZERS IN THE UNITED STATES[2]

(tons)

	1960	1965	1966
Blood, dried	2,186	3,290	2,762
Compost	20,428	54,855	36,134
Castor pumice	7,791	3,252	3,498
Cotton seed meal	3,814	8,776	6,864
Manure, dried	312,224	360,402	357,009
Sewage sludge, activated	89,580	88,340	91,996
Sewage sludge, other	32,778	43,099	41,221
Tankage	12,730	12,098	10,497
Other	9,933	15,117	12,495
Natural Organic Material	491,464	589,229	562,476
Mixtures, N-P-K, N-P, N-K, P-K	15,649,622	18,558,949	19,658,957
Nitrogen Materials	4,544,646	7,695,040	8,779,205
Phosphate Materials	2,339,229	2,535,919	2,781,565
Potash Materials	474,325	935,980	1,288,624
Secondary & Micro-Nutrient Materials	1,378,129	1,521,286	1,461,388
Total	24,877.415	31,836,403	34,532,215

Note:	1960	1965	1966
Average percent primary nutrient content in all commercial fertilizers sold in the United States[3]	31.76%	36.78%	37.63%

The micro-organisms present act as soil revivifiers. They convert chemically prepared nitrogen found in synthetic fertilizers into an available form for the plant and in this fashion the nitrogen participates in the nitrogen cycle.

The micro-nutrients, also called trace elements, serve as the necessary catalysts (enzyme activators), insuring plant health and growth. The exact mechanism is not completely understood, but seven chemical elements have been identified in this category.

These four properties of compost comprise the advantages of compost to the soil scientists and users. These properties are common to manure and dried, activated sewage sludges. The detractors of compost, and natural organics, generally, however, point to two additional properties associated with compost that is prepared from refuse material.

Since the raw material for this discussion is municipal refuse, it will contain all manner of debris (i.e. rubber tires, tin cans, other ferrous and non-ferrous materials, glassware and a host of plastic containers and wrappers). These materials, either all or part, can and do find their way into the final product, despite varying amounts of care directed to their removal. The risks engendered by their presence are the jamming or breaking of spreaders and tillers, or the ingestion by grazing animals of the broken glass.

Since the refuse raw material is of varying composition, the percentage of the basic nutrient elements varies, which, in the case of two of the seven micro-nutrients, is critical -- boron and manganese. Variation in primary nutrient content, nitrogen, phosphorous or potassium, is not critical to the plants, but raises legal problems concerning minimum guarantees of chemical composition of the compost, which are required by state registration laws governing the sale of fertilizers.

Thus, we have compost that can be produced from municipal solid wastes (whose value can be enhanced with nutrient additions when blended with sewage solids during its processing), capable of making positive and lasting contributions to plant soil environment. Why is it not a more important contributor to the fertilizer statistics?

SECTION VI

COMPOSTING PROCESSES

A. GENERAL TECHNICAL DISCUSSION

Composting in the United States generally employs processes which involve aerobic decomposition. When organic material is decomposed in the presence of oxygen, the process is called "aerobic". In aerobic stabilization, living organisms, which utilize oxygen, feed upon the organic matter and develop cell protoplasm from the nitrogen, phosphorus, some of the carbon, and other required nutrients. Much of the carbon serves as a source of energy for the organisms and is burned up and respired as carbon dioxide (CO_2). Since carbon serves both as a source of energy and as an element in the cell protoplasm, much more carbon than nitrogen is needed. Generally, about two-thirds of the carbon is respired as CO_2, while the other third is combined with nitrogen in the living cells. If the excess of carbon over nitrogen in organic materials being decomposed is too great, biological activity diminishes and several cycles of organisms may be required to burn up most of the carbon. When some of the organisms die, their stored nitrogen and carbon become available to other organisms. The utilization of the nitrogen from the dead cells by other organisms to form new cell material once more requires the burning of excess carbon to CO_2. Thus, the amount of carbon is reduced and the limited amount of nitrogen is recycled. Finally, when the ratio of available carbon to available nitrogen is sufficiently low, nitrogen is released as ammonia. Under favorable conditions, some ammonia may be oxidized to nitrate. Phosphorus, potash, and various micro-nutrients are also essential for biological growth. These are normally present in more than adequate amounts in compostable materials and present no problem hence a discussion of their metabolism by the biological cells will not be included.

The natural cycle of nitrogen and carbon in aerobic decomposition is the one which takes place on ground surfaces such as the forest floor, where droppings from trees and animals are converted into a relatively stable humus or soil manure. There is no accompanying nuisance when there is adequate oxygen present for the bacteria. The energy released in the form of heat in the oxidation of the carbon to CO_2; a gram-molecule of glucose dissimilated under aerobic conditions, 484-674 kilogram calories (kcal) of heat may be released. When the organic material is in a pile or is otherwise arranged to provide some insulation, the temperature of the material during fermentation can rise to over 70°C. (158°F.). If the temperature exceeds 65° to 70°C, however, the bacterial activity is decreased and stabilization is slowed down. When the temperature exceeds about 45°C. (113°F.), thermophilic organisms, which grow and thrive in this range, develop and replace the mesophilic bacteria in fermenting the material. Only a few groups of thermophiles carry on any activity above 65°C. (150°F.). Oxidation at thermophilic temperatures takes place more rapidly than at mesophilic temperatures and, hence, a shorter time is required for stabilization. The high temperatures destroy pathogenic bacteria and protozoa, hookworm eggs, and weed seeds in the material that are detrimental to public health and agriculture.

Complete or perfect aerobic oxidation of organic matter produces no objectionable odor. When odors are produced, the process is not entirely aerobic, and the carbon is converted to methane and any sulfur present to malodorous chemicals. Aerobic decomposition can be accomplished in silo digesters, pits, bins, stacks, or piles, if adequate oxygen can be provided. Turning the material at intervals, or other techniques for adding oxygen are necessary to maintain aerobic conditions.[4]

To determine how this material can and is being promoted to be made commercially available, we shall review the current domestic available processes. Basically, they fall into two major categories -- open windrow fermentation, with various modifications and enclosed mechanical digestor fermentation. Both methods provide and claim, with varying degrees of success, processes that are aerobic, provide optimum bio-digestion conditions that maximize yields, with minimum time and plant area requirements, and to have eliminated burdensome sanitation problems (i.e. pathogen destruction, odor-free, vermin-free and insect-free processing).

B. OPEN WINDROW, PILES OR VENTILATED CELLS METHODS

1. WINDROW

The windrow process is conducted in open air and relies on natural ventilation with periodic turning to insure aerobic conditions.[4] Only one plant of this type is operating in the United States. It is located at Wilmington, Ohio, was built in 1963, and processes twenty tons of refuse per day. "A minimum of sorting is provided and two hammermill grinders are used in series. The ground refuse is composted in windrows where it is turned weekly by means of a front-end loader until the material is converted to compost. Difficulties have been experienced in selling the finished compost."[5]

2. VENTILATED CELL

Ventilated cell composting employs a multi-story building with a vertical arrangement of progressive cells. Mixing and aeration occur when the material drops from cell to cell.[4] Several different methods have been tried based on the ventilated cell process. In the United States the Naturizer Process, the Riker Process, the Frazer-Ericson Process, and the Fairfield-Hardy Process have all been tried with little success.

a. THE NATURIZER PROCESS

The first plant using the Naturizer Process was built in Norman, Oklahoma in 1959. It was closed in 1964 except for experimental purposes. "Two unique features of the plant were a specially designed swing hammermill and the Naturizer Composter. The digester system provided six day retention in two, three story buildings with a movable floor in each story. Considerable time and effort were expended to build up a market for the product, with sales activity extending as far away as Dallas, Texas." The second plant using this process was located in San Fernando, California and began continuous operation in July of 1963. It was shut down in October of 1964. "The plant had a capacity of 70 tons of refuse per day, but operated at only about 40 tons per day. It was an improved version of the process developed at the Norman, Oklahoma plant. Appreciable salvage operations were performed. It was necessary to provide an afterburner on top of the composting unit to comply with Los Angeles County Air Pollution Control District requirements to insure that no odors would be discharged. Compost was sold in bags and in bulk. A unique development for the use of compost was called 'Sta-Soil' which was a water suspension of compost, chemical fertilizer, grass seed and shrubs. It was sprayed over denuded slopes, or cuts and fills, to provide a blanket against soil erosion and a 'soil' in which grass and shrubs would quickly take root."[4] The latest plant using this process is located in St. Petersburg, Florida. The International Disposal Corporation operators of the plant have a twenty year contract with the city of St. Petersburg. This contract calls for the disposal of 100 tons of refuse per day, six days a week, at a cost of $3.24 per ton to the city.

The digester is a five story building with conveyors running the length of each floor. In operation the conveyors will travel their length (150 to 165 feet) in twelve hours and remain stationary for twelve hours. After passing through the digester and final screening, the material is dumped in the finishing yard where it is left for two weeks. The material is marketed under the name of "Cura" and finds favorable acceptance for use in citrus groves, golf courses, commercial nurseries, and with industrial landscape architects. The St. Petersburg plant cost $1.5 million.

b. THE RIKER PROCESS

A plant using this process was built in Williamston, Michigan in 1955. It was closed in 1962 when the only customer it had stopped purchasing the compost. "This four tons of refuse per day plant treated garbage, vacuum-filtered raw sewage sludge and corn cobs. Ground garbage and corn cobs, mixed with sludge cake were composted for twenty-one days in two, four compartment vertical composters."[4]

c. THE FRAZER-ERICSON PROCESS

A plant operating under this process was built in Springfield, Massachusetts in 1954. It was closed in 1962 when the city failed to renew the contract. The plant had a capacity of twenty tons of garbage a day. The garbage, being too wet to compost aerobically, was held for about two days to dewater. This frequently created fly, rat and odor problems.[4]

d. THE FAIRFIELD-HARDY PROCESS

A plant located in Altoona, Pennsylvania began operations in 1950 using the windrow method, but was converted to the Fairfield-Hardy Process type operation in 1963. "Refuse is ground in a wet pulper, followed by dewatering presses (Figure 2) before it is fed into the Fairfield-Hardy Digester for a five day cycle."[5] "Stirring is provided by augers suspended from a rotating bridge in a circular tank. Air is provided by means of a blower and air pipes embedded in the floor of the tank. Normal operating temperatures are about 140 to 160°F. The plant has a capacity of 45 tons per day but normally operates at about 18 to 23 tons per day. Successful experiments have been run in which digested sewage sludge was added to the ground refuse."[4] The city of Altoona pays the operators of the plant $4.63 per ton for processing their garbage. From the 7,000 tons of garbage processed a year, 3,150 tons of saleable compost are obtained. A total of 1,300 tons of coarse compost sells for $5 per ton and 1,850 tons of the dried and pelletized compost sells for $20 per ton if it has a 5 percent to 17 percent moisture content. A plant of this type which could process 100 tons per day would cost approximately $900,000, including land. A prototype plant built in Largo, Florida originally utilized the Fairfield-Hardy Process, but was rebuilt in 1963 by the National Composters Company who installed a digester of their own design. "This plant has a capacity of 50 tons per day. Operating five days a week, it treates 40 to 50 tons per day of mixed refuse to which is added 1,000 to 1,500 gallons per day of essentially raw sewage sludge."[4] The essential difference in the digester is that the material is turned, not by the augers, but by a rail-mounted bucket elevator moving in either direction.[5] The product sells for $16 per ton.[6] Another plant has been built in Houston, Texas, by the builders of the Largo, Florida plant. This $1.75 million plant has been designed to process 300 tons of garbage per day, six days per week. The city of Houston pays $4.51 a ton for this service. The end product of the operation is called "Metroganic 100". It is being sold to rice farmers, citrus growers and others engaged in agriculture, particularly those in the Rio Grande Valley. To date, the success of the operation has not been determined.

C. CONTINUOUS MECHANICAL COMPOSTING

This process involves continuous mixing with gradual particle size reduction and positive aeration.[5] There are several systems that use continuous mechanical composting -- the Dano Method, however, is the only one used in the United States.

SCHEMATIC OF COMPOSTING PLANT UTILIZING FAIRFIELD–HARDY DIGESTOR.

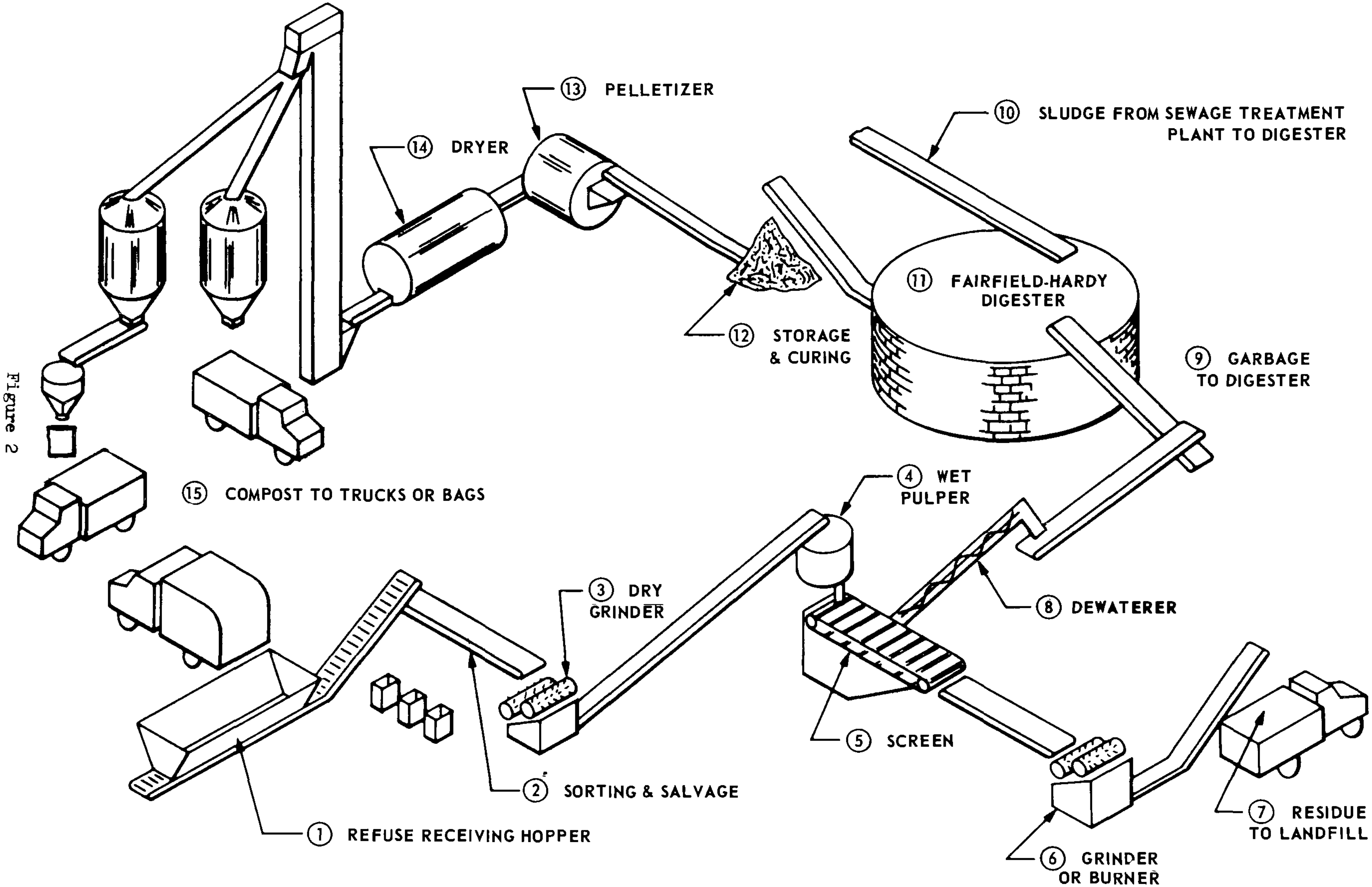

Figure 2

1. THE DANO BIOSTABILIZER SYSTEM

The Biostabilizer is a large drum, 9 to 12 feet in diameter and 60 to 100 feet long. It is designed to effect continual mixing, aeration, grinding and decomposition in one unit. Refuse material first passes through sorting and magnetic separation before being charged into one end of the slowly revolving unit (.25 to .8 rpm). Water and sludge are also added at the inlet. Slow grinding is accomplished by the tumbling shearing action of the Biostabilizer which, with decomposition, processes the refuse so it will pass out through coarse perforations (4 inch diameter) at the outlet end. This operation is followed by a second magnetic separation, vibrating screen and a ballistic or gravity separator before the partially decomposed refuse is arranged in windrows for curing. It is said that five to seven days' composting in the Biostabilizer unit is equivalent to three to four weeks of windrow composting with several turnings, although material coming out of the Biostabilizer is not sufficiently decomposed to be stable and will reheat again when moist. For this reason, windrow composting is used in the finishing stage.[5] The first plant to use the Dano System in the United States was built in Sacramento County in 1957. It had a capacity of about 40 tons per day. It was closed in 1963 for lack of a market for its product. The second plant using this system was built in Phoenix, Arizona in 1962, originally scheduled to process 300 tons per day with two Dano Biostabilizers using a three day cycle. However, two additional units were added and actual capacity was still only 175 tons per day. The plant was closed in 1965 because it could not compete with the cost of landfill operations.

SECTION VII

THE BUSINESS ENVIRONMENT

A. GENERAL

To properly understand the marketing and financial problems, let us consider the current business environment in which compost finds itself.

There has been a constant increase in the sales of chemical fertilizer with steadily increasing concentrations of prime nutrients (see Table I). This reflects the increasing pressure for greater yields per acre of commercial crops by the grower. Insecticides follow the same trend, and are produced by the same manufacturers. Approximately 2 percent of the tonnage of the total commercial fertilizer marketed is composed of natural organics. Compost, included in this category, approximates 0.1 percent of the total fertilizer consumption. To date, therefore, it does not represent a significant factor to be reckoned with by the fertilizer industry. Of more concern to the municipal composter are the other suppliers in the natural organic category of Table I who will be competing for the same portion of the market.

The recent interest in composting is stimulated not by new potential users clamoring for its availability, but rather by potential suppliers and equipment manufacturers of composting plants. A critical gap exists between those ready to supply compost and those who are ready to use the material. This gap constitutes the marketing problem facing the potential municipal refuse composters.

The attractiveness of a process capable of converting a waste that must be ultimately and completely destroyed into a saleable commodity (at a profit) has strong appeal to the entrepreneur. Its appeal has also not been lost to the municipalities by which they hope to ease their tight fiscal situations.

A municipality has a number of approaches to consider. The municipality can: (1) own and operate the plant and market the product, (2) own and operate the plant and contract out the product marketing, (3) contract for its refuse to be composted and marketed by a private operator, and (4) as in (3), except it can additionally contract for the collection.

It accepts the greatest financial risk when it assumes the total scope -- owns, operates and markets; it accepts the least risk when it contracts for the collection, operating and marketing. Irrespective of this consideration, the municipality cannot escape its prime responsibility for the safe and complete elimination of its solids waste. It should, therefore, view any arrangement with this long term major objective clearly in mind.

There are cases of a city owning the waste material processing plant and marketing the product. The products, however, are dried or processed sewage sludges. The raw materials are brought to the plants by underground pipe and the collection, sorting and preliminary operations of composting are not necessary. The drying (and packaging) operations are added to an otherwise normal sewage treating plant. The marketing of the material is handled by the community. Milwaukee (Milorganite), Houston (Hu-Actnite), Chicago (Chicagrow), Pasadena (Nitroganic), Schenectady (Orgro) are a few of the trade named products successfully marketed.

The operating costs, in order to produce a marketable commodity, are but incrementally increased over and above the cost of normal processing of sewage wastes. The material is marketed at a low enough price, on a dollar per unit of active ingredient basis, to be attractive to users, and the return on the incremental portion of the cost of production is attractive to the city.

Thus, there exists a precedent for a city to operate and own a product manufacturing and marketing capability. The major difference between sludge and compost lies in the incremental cost of producing a dried or activated sludge and the equipment cost to compost (or incinerating) that requires a major capital investment in a new facility.

A city can produce the material and at a yearly auction, or through sealed bid procedure, contract out the annual plant capacity. This approach also has been used with sludge.

In the third and fourth alternatives mentioned above, the city pays the operator a fee for each ton of its refuse delivered to the contractor's compost facility. The contract is usually of twenty or more years duration, to satisfy the private operator's need of a continuing source of supply for his plant. The fee agreed upon by the city (dumping fee) will be less than the cost of any practical alternative for its waste disposal, and must be enough to contribute substantially to the operating revenues. He theoretically can thus market the compost at prices that are competitive and profitable and that are an economically attractive source of soil conditioner-fertilizer to the grower-user.

The city "dumping fee" and the compost sales income are the only reasonable revenue sources. A salvage income is sometimes quoted in connection with the "sorting operation"; however it does not appear to be good business practice to rely on this very flexible, non-stable income when forecasting future profitability.

The physical compost plant can be designed and erected by an operator's organization, by a turn-key plant builder under contract to the operator, or by an architect-engineer who designs, purchases and manager construction of the plant.

B. COSTS

Estimates of plant costs obtained from the literature are given in Table II. A detailed cost estimate for three different plant capacities which was provided by Fairfield Engineering Company is presented in Table III. In addition to plant costs, this table gives an idea of the "dumping fee" which is the charge to the city for every ton of refuse handled. "Dumping fees" are presented for two different situations: (1) a private owner-operator and (2) a private operator.

Some additional comments on qualitative costs of composting plants are given in Appendix A.

C. PROBLEMS

Some problem areas which have constrained the growth of composting are listed below.

1. INSUFFICIENT OR LACK OF OPERATING PROFIT (DUMPING FEE)

There are instances of operating plants closing for lack of profit. The total income of any plant is the sum of compost, salvage and dumping fee revenues. The operating plant cash expenses include plant labor, utilities, the cost of initial investment capital, supplies and chemicals, administrative, insurance, taxes and advertising and sales promotion. The non-cash expenses include depreciation of equipment, and in some cases, the amortization of process development.

All the expense and cost items are standard, industrial type plant operating expenses, and if we assume a properly sized plant has been constructed, and a uniform delivery of municipal refuse is maintained, these costs remain essentially constant. Further, the sales price of salvage items must not be included in income projections as it is subject to wide fluctuations in price value with time and by location. The sales price of compost is variable, but a market value will be established that should be essentially constant for a given moisture content, primary nutrient content, package size, grind size and uniformity.

The last item of plant income, and subject to negotiation, is the city dumping fee. The upper limit is usually fixed by the cost of the next reasonable, practical method of solids disposal. This fee is set for a long term, and is critical to the eventual success of compost venture. If the city accepts an unrealistically low offer by an optimistic composter, it may ultimately end up with a non-operating plant and no place for its waste.

2. LACK OF PRODUCT COMPOST SALES (PRICING)

When the operator above seeks to remedy his profit picture, he can only raise his sales price. The scope of the plant is fixed as are the sanitary and other standards and regulations that control his

TABLE II

COSTS AND LISTING OF DOMESTIC MUNICIPAL SOLIDS REFUSE COMPOSTING PLANTS

IN OPERATION, UNDER CONSTRUCTION OR AUTHORIZED AS OF JUNE 1967

(Over 45 T/Day Capacity)

Location	Capacity	Operator	Type	Approximate Plant Cost (000's Omitted)	Status
Altoona, Pennsylvania	45 T/Day (1)	FAM	Enclosed Digestor	-	Operating
Boulder, Colorado	100 T/Day (Est.)	Rich-Land	Open Windrow	$ 250 (Est.)	Operating
Gainesville, Florida	150 T/Day	Metro	Enclosed Digestor	$1,100	In Construction
Houston, Texas	300 T/Day	Metro	Enclosed Digestor	$1,750	Operating
Houston, Texas	300 T/Day	United Compost	Enclosed Digestor	-	Not Operating
Johnson City, Tennessee	60 T/Day	TVA-PHS-City	Open Windrow	$ 750	In Construction
Largo, Florida	50 T/Day	Metro	Enclosed Digestor	-	Used for Development Work
Mobile, Alabama	300 T/Day	City of Mobile	Open Windrow	$1,100	Operating
St. Petersburg, Florida	105 T/Day	International Disposal Corp.	Enclosed Digestor	$1,500	Operating

(1) Tons per 24 hour day of refuse.

TABLE III

ESTIMATED COSTS FOR 100, 200 & 300 TON PER DAY ENCLOSED DIGESTOR PLANTS

FURNISHED BY FAIRFIELD ENGINEERING COMPANY, MARION, OHIO

Fairfield-Hardy Disposal Plant, March 28, 1967

Daily Capacity of Plant	Annual Tonnage 5 1/2 Day/Week	Construction Cost	Annual Amortization & Financing Cost	Annual Operating Cost (1)	Dumping Fee to Operator Who Owns and Operates Plant	Dumping Fee to Operate Plant Only
100 Tons of Refuse	28,600	$1,370,000	$129,000	$125,000	$6.50 per ton of Refuse	$4.37 per ton of Refuse
200 Tons of Refuse	57,200	$2,000,000	$189,000	$196,000	$5.50 per ton of Refuse	$3.43 per ton of Refuse
300 Tons of Refuse	85,800	$2,500,000	$234,000	$248,000	$4.50 per ton of Refuse	$2.90 per ton of Refuse

(1) These plant operating costs cover refuse conversion costs only. To market product compost, the annual operating cost would be increased, but these costs can be offset by sales revenues.

Assumptions:

1. One pound of compost for every three pounds of refuse.
2. 7.3 percent return on investment.
3. Land not included.
4. Real estate and personal property tax not included.
5. Amortization and Financing Costs: 20 years - buildings and stationary equipment; 5 years - mobile equipment; interest at 6 percent.

method of operation. His product must bear a price value relationship to other competitive natural organics or humus-nutrient blends. When this is arbitrarily altered, he is no longer competitive nor is he providing a product of economic benefit. Accordingly, he will lose whatever market he has succeeded in developing.

3. LACK OF PRODUCT COMPOST SALES (USER DEMAND)

Despite the potential benefits of compost additions to soil, the readily apparent improvement to crop yield is adequately met by chemical fertilizers. Compost-soil additions are long term in their effects. Such protracted benefits are not met with enthusiasm by the large commercial operators in but a few isolated exceptions. In many cases, organic matter additions are incorporated into the soil by plowing under, either stalks remaining after harvest, or by "green manure". Many farms prepare their own compost piles and thus derive all the benefits mentioned earlier without placing any demands on the commercial compost or natural organics markets. Abundant supplies of manures and other natural organics are readily available in all agricultural markets (see Table I).

4. LACK OF PRODUCT COMPOST SALES (TRANSPORTATION COSTS)

The municipality and its composter have no control over location of the market. The cost of shipping urban produced compost to either the rural consumer grower or the regional commercial fertilizer blending plant is a marketing distribution constraint.

The figures tabulated in Table IV from the Uniform Freight Calssification of September 20, 1966 are the costs per ton for two slightly different commodity freight classes, for various selected mileages.[7]

TABLE IV

FREIGHT COST - DOLLARS PER TON[7]

Miles	Class 20 (humus, sewage sludge, etc.)	Class 22-1/2 (peat moss)
100	$ 6.40	$ 7.20
200	8.40	9.40
300	10.00	11.20
400	11.60	13.00
500	13.00	14.60
600	14.20	16.00
800	17.00	19.20
1,000	19.20	21.60

It should be noted that between 400 to 500 miles, in category 20, the shipping cost equals the product cost. This distance has also been mentioned as a limit to the economic distance compost can be shipped.[8]

The natural organics or peat moss supplier, with a much lower cost of production, can ship at least once again as far as the municipal refuse composter for equivalent freight costs because their production cost is but a fraction of the refuse composter, (i.e. the former from $1 to $5 per ton, whereas the net cost of compost is $10 to $12 per ton). He requires no elegant physical plant in an urban surrounding; he requires no sorting labor, and his land costs are much less, enabling him to windrow compost.

5. LACK OF SALES (USER DEMAND - EDUCATION)

This market could be expanded but would require the indirect assistance of the state agricultural services. These organizations will analyze soil for any interested citizen or organization, but the standard analyses are presented in terms of chemicals required. This can be related directly to pounds of chemical fertilizer. No data is available from these routine analyses concerning the qualitative aspects of soil beneficiation to be expected from the incorporation of compost. This further suggests a consumer education enlightenment program to make the benefits possible from compost additions more widely recognized and appreciated.

6. OPERATING PROBLEMS (SANITARY)

Certain of the forced shut downs have been attributed to malfunctioning processes that have created problems of odor, vermin infestation, or insect growth. Such processing problems have contributed much to the lack of new plant construction despite constant technical improvements.

7. POLITICAL EXPEDIENCY

Since many composting plants have been forced to shut down for one reason or another, municipal authorities are cast as innovators if they recommend composting plants for their communities. Many plants must be in successful operation in order for composting to be a "safe" recommendation.

8. SOCIAL UNATTRACTIVENESS

As the cost of landfill operations and incinerator costs increase, the operating cost advantages of a municipal compost plant become apparent -- a fixed location for the delivery of the refuse. For any given community there is a cost benefit of size scale-up that can help to reduce the per pound production costs of the compost. These two cost benefits (delivery and scale-up) combine to suggest that the largest reasonable size plant be located as close to the population center as possible. For large (over 500,000) populated cities, this same reasoning applies to multiple centrally located plants. This places the compost plant(s) within the city proper and the locally affected neighborhood citizen reaction can be expected to argue against any such nearby location, despite any and all of the operator arguments and guarantees.

These considerations are the major constraints on the compost industry. Obviously, they do not all apply to every situation, and hence some headway has been made, attested to by the fact that an infant compost industry does exist. Each of the negative points can be answered when raised one by one. In the face of them altogether, however, the task appears formidable.

SECTION VIII

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SECTION IX

APPENDIX A

COMMENTS ON COSTS OF COMPOSTING PLANTS

The following comments by Gotaas[9] serve to describe the general problems involved in developing cost estimates of composting plants.

"It is impossible to develop cost estimates that would be significant for different installations, locations, or currencies. Perhaps the best economic analysis can be made by comparing cost estimates and data for composting with the costs of incineration in a given locality, or by comparing the cost of production of the compost with the selling value of fertilizers of similar quality to composted municipal wastes, for example, animal manure. The value of compost as a fertilizer and soil builder is not established in many parts of the world.

In the Netherlands, the composting of organic municipal wastes has been practiced in several places for many years and has proved cheaper than incineration of the wastes and, in areas where there is a good nearby market for the compost, as cheap as sanitary landfill. Disposal of refuse by composting and selling the product as a fertilizer has been found to be economic in Denmark, Germany, Italy, India, the Union of South Africa, and several other parts of the world. In California, the Compost Corporation of America, in analyses used as the basis for planning a plant, found that compost of a nutrient quality as good as that of stable manure and free from weed seed, could be profitably produced to sell for less than the normal price of stable manure. Seabrook, after experience of pilot plant composting at Tacoma, Washington, has estimated that the Tacoma refuse can be composted at a profit to the city, without including the savings affected by eliminating the present method of disposal by sanitary landfill and is proceeding on this basis with the development of a full scale composting plant.

At the five ton per day Bio-stabilizer composting plant at Rüschlikon, Switzerland, the returns from the sale of compost and salvage amount to 50 percent of the cost of composting, thereby reducing the cost of refuse disposal. It is believed that the costs per ton would be lowered considerably in a larger plant.

It is estimated that in the United States the cost for converting refuse delivered to the site into a compost, using the windrow method, will be as low as 30 to 60 percent of the cost of incineration for plants with a capacity of over 100 tons per day. Provided that delivery to the compost site did not require a much more expensive haul than delivery to the incinerator site, then, even if the compost were given to those who would haul it away, the operation would be cheaper than incineration. The major part of the difference in cost between composting by the windrow method and incineration lies in the fixed cost of the plant. Cost estimates for the windrow method plant as compared to the incineration plant, on a per ton per day basis and a one shift operation, indicate that the compost plant will cost from 20 percent to 25 percent less than an incinerator installation for capacities of over 100 tons per day.

Estimates for the costs of composting with the Dano Bio-stabilizer plant with a capacity of 25 or 50 tons per day are about the same as for incineration. The initial cost per ton of refuse is considerably higher for the small Bio-stabilizer plants than for the larger windrow method plants. However, the Bio-stabilizer, like the incinerator, can be located in the city to reduce hauling costs.

The major uncertainty regarding costs of disposal by composting appears to be whether or not the material will be accepted by farmers and gardeners and can be readily sold or disposed of."

PART 3

APARTMENT HOUSE INCINERATORS

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SECTION I

SUMMARY

As part of an overview of solid waste disposal in urban areas, a brief investigation was conducted on disposal methods of solid waste in apartment houses in New York City. This report is based primarily on the experience of the writer, who during the last few years was Assistant Director of Engineering of the New York City Department of Air Pollution Control.

New York City has approximately 12,610 incinerators installed in apartment houses having a total population of 2,700,000. The two principal types of incinerators are (1) flue-fed incinerators in which refuse is charged through hopper doors on each floor into a refractory flue, the bottom of which opens directly into the top of the furnace or combustion chamber, and (2) chut-fed designs where refuse is charged through hopper doors on each floor and collected in a basement hopper, from which it is transferred either manually or mechanically to the incinerator furnace.

Methods of upgrading present incinerators are described, together with suggested research and development programs.

SECTION II

RECOMMENDATIONS FOR FUTURE ACTIVITIES

A. Develop simplified test procedures for measuring pollutants in stack gas to replace the tedious and costly methods now required, and instruments to indicate and record emissions continuously, which is now possible for smoke, but not for fly ash.

B. Develop means for elimination of the water vapor plume frequently emitted when wet scrubbers are employed, which may be mistaken for smoke and which becomes the source of complaints.

C. Develop means for feeding the refuse continuously rather than intermittently to the incinerator, to avoid the peaks and valleys which seriously interfere with good combustion control.

D. Improve the design of charging hopper doors on each floor, to reduce air leakage, prevent plugging of the flues with oversize refuse, and overcome the smoke-outs now experienced.

E. Develop water cooled furnaces to reduce slagging of refractory, permit higher furnace temperatures, decrease excess air requirements, thus minimizing fly ash and other undesirable emissions, and which may incorporate heat exchangers for generation of hot water, etc.

F. Design low cost dust removal equipment such as electrostatic precipitators, bag filters, or dry type high efficiency cyclone collectors, all of which would reduce the water consumption and handling problems inherent in wet type designs.

SECTION III

NUMBER AND SIZE RANGE OF APARTMENT HOUSE INCINERATORS

New York City has prohibited incinerators in buildings which house less than 12 families for many years, largely because of improper maintenance and excessive pollution. Typical incinerators range from 85 pounds per day capacity to a maximum of 3,400 pounds per day, which would satisfy the needs for a 2,000 tenant building. The average incinerator design capacity is about 350 pounds per day. There are some 12,610 incinerators serving apartment houses, having a total population of 2,700,000. The average refuse per person per day is about 1.63 pounds. Total refuse incinerated in these buildings is approximately 800,000 tons per year.

The residue has one-tenth to one-fifteenth of the volume of the original refuse, with a weight reduction of at least 75 percent. Most of this residue is in the form of bottles, cans, and ash, with 5 to 15 percent combustible, largely food products. The following composition of residue has been reported.[1]

Metal and glass over 1/4 inch	64 percent
Ash from combustible matter	12 percent
Unburned combustible matter	16 percent
Moisture from latter	8 percent

Tests have shown unburned combustible matter can be decreased to under 5 percent, with no measurable moisture, with improved incinerator design.

SECTION IV

WASTE DISPOSAL METHODS

A. INCINERATION

This method will reduce the volume of the residue to 10 percent or less of the refuse charged, and the weight to 25 percent or less on the same basis. There is therefore a major reduction in the handling and storage requirements at the building, as well as in the pickup and disposal facilities to the dump area. The residue is sterile and odorless compared with the refuse, so that tenant complaints, and health hazards from vermin are minimized. Fire danger is also eliminated.

Incineration at the building will reduce the number of cans of refuse to be stored from ten or fifteen to one required for the residue. Tests observed in 1966 reduced sixteen cans of refuse to one can of residue, most of which comprised cans and bottles.[2]

B. COMPACTION

The compaction volume may be reduced to one-half or one-third the volume of the original refuse, so that storage room requirements are decreased with no change in weight. There are several systems for this purpose. In the first, refuse is forced into metal containers by mechanical pushers, stored until dumped into the pickup trucks, during which operation it may regain much of its original volume.

Another compaction system forces the refuse into heavy paper bags, which are then sealed and deposited in the truck, so that the initial reduction in bulk is retained. This is satisfactory for landfill disposal, but experience has shown that the bags must be broken apart if delivered to a municipal incinerator, to avoid delayed combustion in the furnace and high unburned combustible loss. In a third system, the refuse is compressed in portable metal containers, which are picked up and carried to the disposal facility for unloading, and returned to the building, at added hauling cost.

In the above compaction systems, there is no reduction in the weight of the refuse, and a temporary decrease in bulk. The refuse remains in a putrescible state and is inflammable, which may require fireproofing the storage room to avoid fire, and cooling to avoid odor and vermin problems.

C. SHREDDERS, GRINDERS, AND PULPING

By addition of water after maceration, these methods reduce the volume, but add materially to the preparation cost. The ultimate disposal problem may be complicated because the finely ground material has been found to pack, and burn too slowly in an incinerator, especially when water has been added.

D. GARBAGE GRINDERS

This method requires separation of the food products in the refuse from most of the other material. As the former comprises only ten to fifteen percent of the total refuse, and is the least bulky for storage, the saving in disposal costs is relatively small. Such equipment is prohibited in New York City, because of the added load on the sewage disposal system, into which the ground material is discharged.

E. BALING NEWSPAPERS

When there is a market for scrap paper, which may comprise up to 20 percent by weight of the total refuse, the cost of separation and handling can be justified. Loose collection in cans or bags requires the greatest storage room space, and handling labor, as well as being most subject to fires, odor and vermin problems.

F. BULK DENSITIES

Bulk densities of the several materials involved have been measured as follows, subject to variations in moisture and other factors. Weight of the refuse as deposited in the incinerator through the usual charging flue is 4.1 pounds per cubic foot or 111 pounds per cubic yard. Residue as removed from the incinerator, including some moisture used for quenching is 15.4 pounds per cubic foot or 416 pounds per cubic yard. This includes 65 percent to 70 percent metal, mostly cans, and glass such as bottles and jars.

SECTION V

INCINERATION REQUIREMENTS

There are two general types of incinerators available; the major difference being the method of feeding the refuse from the various floors into the furnace.

A. FLUE-FED INCINERATORS

Flue-fed incinerators are those in which the refuse is charged through hopper doors on each floor into a refractory flue, the bottom of which opens directly into the top of the furnace or combustion chamber. In the single flue design[3] shown in Figure 1, the combustion products flow upward through the charging flue and are discharged above the roof of the building, whereas in the double flue type the refuse is charged down one flue, and the combustion products normally flow upwards in the parallel flue, both flues being lined with refractory material.

At suitable intervals the hot gas from the auxiliary burner may be discharged upward through the charging flue to purge or sterilize it of any odors or vermin that may have accumulated on the walls. For this reason, both flues must be open at the top for free exit of whatever combustion products are produced. As an alternate to this hot gas purging the charging flue may be sterilized by use of suitable spray nozzles and detergents.

B. CHUTE-FED DESIGNS

Chute-fed designs are those in which the refuse is charged through hopper doors on each floor as above, into a metal chute, collecting in a basement hopper, from which it is transferred either manually or mechanically to the incinerator furnace (see Figure 2). The combustion products pass up and out through a refractory flue, above the roof.[3]

C. UPGRADING EXISTING INCINERATORS

Many of the existing incinerators can be brought up to satisfactory performance by incorporating the design factors that have been found beneficial in the new units, without major changes or costs. Because of the intermittent nature of refuse charging, the incinerator normally operates for only three to four hours per day. By spreading this burning period, the load for each burn is reduced, so that even an undersize furnace can be made to function satisfactorily.[4]

Many cities have permitted burning only during daylight hours, or when the day porter was on duty. In New York City for example, the burning time was 7 A.M. to 5 P.M. One result was that between 5 P.M. and 7 A.M. the refuse would pile up in the charging flue to the second or third floor, which causes a serious pollution problem when the porter ignites the refuse the next morning.

SINGLE FLUE WITH WASHER OR PRECIPITATOR ON ROOF

Reference 3

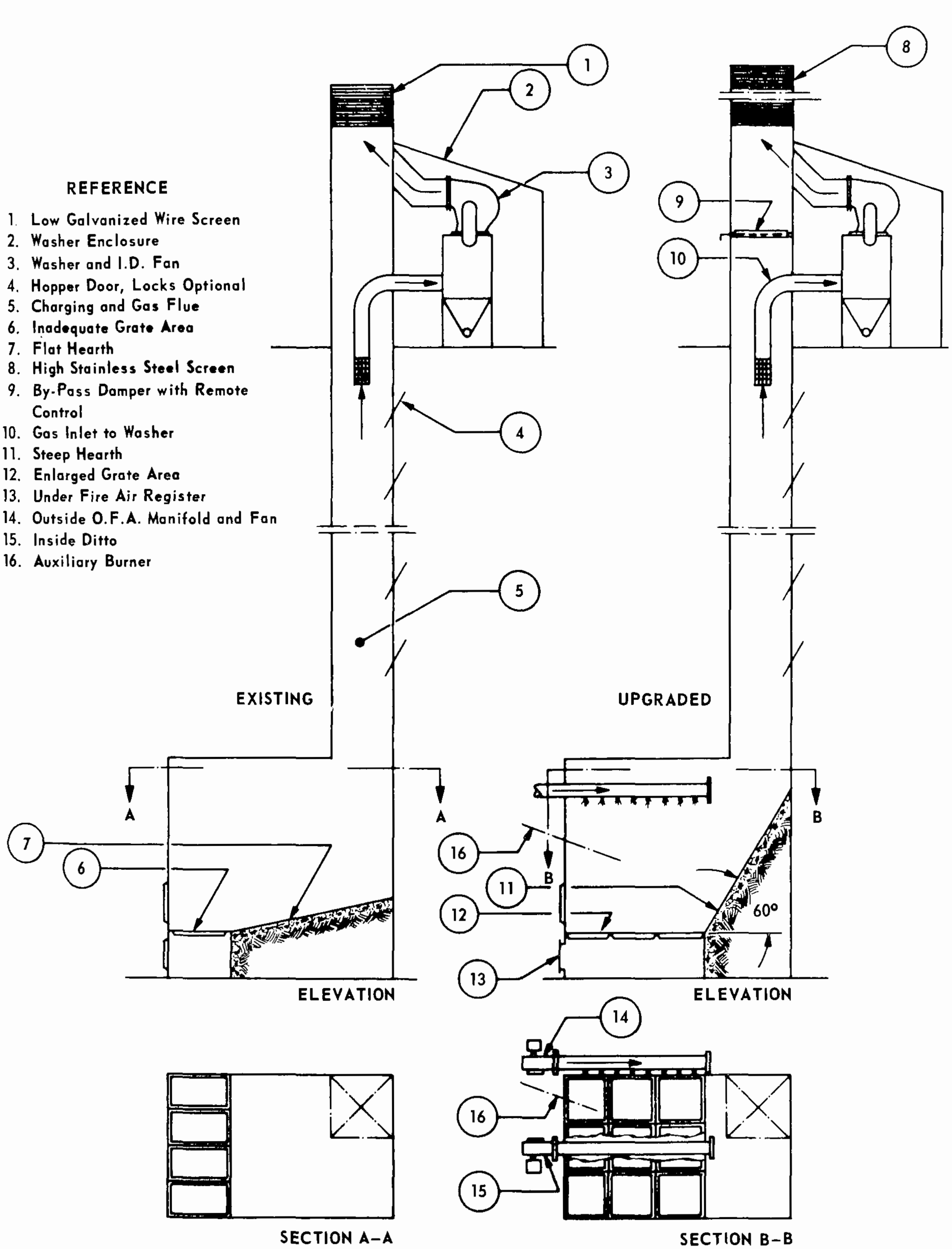

Figure 1

DIRECT FED INCINERATOR AND CHARGING CHUTE

Reference 3

REFERENCE

1. Safety Cap for Fire Protection
2. Detergent Spray for Purging
3. Sprinkler Head for Fire Protection
4. Hopper Door
5. Refuse Chute
6. Refuse Hopper
7. Cleanout Door
8. Grating for Drainage
9. Waste Water to Sewage
10. Stainless Steel Screen
11. Roof Slab
12. Gas Flue
13. Draft Control Damper
14. Barometric Damper
15. By-Pass Damper Auto. Controlled
16. Charging Apron
17. Hearth
18. Grate Area
19. Guillotine Charging Gate Power Operated
20. O.F.A. Manifold and Fan
21. Washer and I.D. Fan
22. Auxiliary Burner

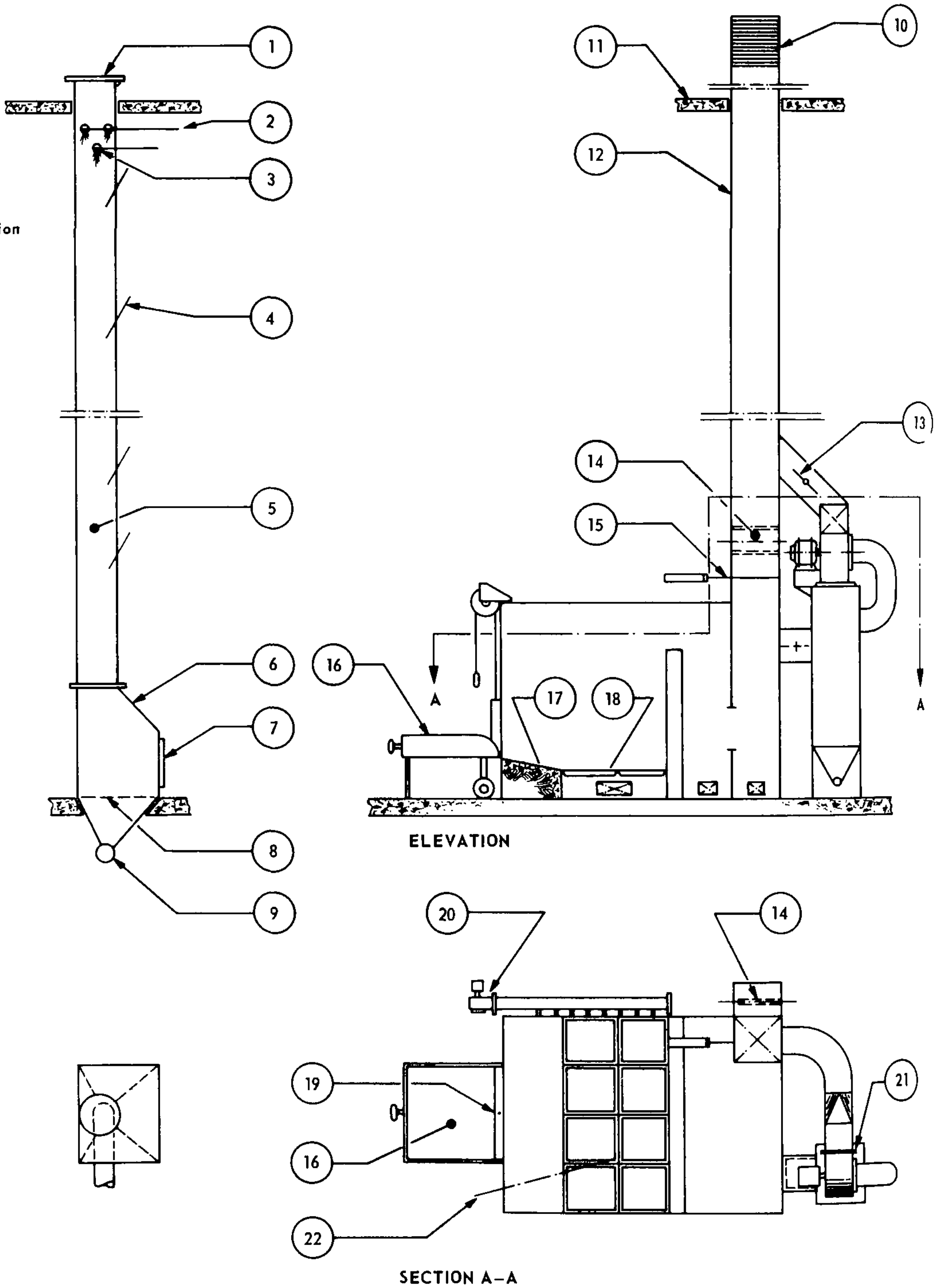

Figure 2

The introduction of automatic controls for igniting the refuse in the furnace and controlling the combustion air, has permitted extending the burning time, in some cases to 18 hours or more so that the overnight pile-up is eliminated and four or more burns are accomplished, with major improvement in the performance. The principal elements included are listed below.

1. Auxiliary burner in the furnace or primary chamber to ignite the refuse and maintain desired temperature in conjunction with the heat from the refuse.

2. Overfire air fan with manifold and nozzles to assure adequate turbulence and complete burnout of the volatile combustibles.

3. Programming electric clock with 24 hour dial and adjustable contact pins to permit starting and stopping of the above items at preset intervals. All controls to be enclosed in tight steel box.

4. Fly ash removal equipment adequate to meet the local ordinances.

The reduction in emissions by the methods described above is approximately as follows:

Equipment	Reduction of Emissions in Percent
1. Overfire air jet system	40
2. Overfire air system plus auxiliary burner	62
3. Items 1 and 2 plus wet or dry cyclone collector	85 - 90
4. Above items 1 and 2 plus wet scrubber, impact or plate type	94
5. Items 1 and 2 plus electrostatic precipitator, bag filter or venturi scrubber	99

The installed cost of adding items 1 and 2 ranges between $1,500 and $2,000. Items 3 and 4 would cost between $5,500 and $8,500. Item 5 ranges from $12,000 to $15,000 based on what little data is available.

Conversion of single flue incinerators to the double flue type should be done whenever possible, as the separation of refuse charging and gas emission flues has been found to be very beneficial.

Accomplishing the above items in a practical and economical manner is fully covered in Reference 4.

SECTION VI

PERFORMANCE STANDARDS

Satisfactory performance of new incinerator installations may be accomplished by the use of either of several types of filing requirements, such as performance standards[5] or construction specifications, or possibly a combination of the two. In the former, minimum requirements are prescribed, such as fly ash, smoke and other emissions, as well as unburned combustible in the residue, while in the latter, specifications covering furnace dimensions and construction, flue sizes, controls and air pollution removal equipment, are established. In either case, complete filing of plans and details is necessary.

Many localities permit installation in accordance with the filer's plans and specifications, subject to final approval upon completion of satisfactory performance tests, or based on previous tests of prototypes. In some cases the manufacturer's guarantee may be accepted, tests to be required only if violations are experienced. Usually the cost of such tests must be paid by the installer rather than by the control agency.

Incinerator emission tests are relatively expensive and require specialized equipment and personnel. The cost will range from $500 to several thousand dollars and take from one to several days for preparation, setting up equipment, and actual testing which should be done as closely as possible under normal operating conditions and at the design capacity.

Development of continuous monitoring devices which is now underway to a limited extent, will aid both the operator and the control agency. The former now has no way of telling whether or not the incinerator emissions are excessive, while the latter can vouch for performance only at the time of his visit. The value of indicating and recording instruments would be to show whether or not a new installation was ready for approval and to determine the validity of complaints which at present is often difficult or impossible to resolve. A project or grant for research to aid in the development would be desirable.

SECTION VII

CONSTRUCTION SPECIFICATIONS

These specifications are similar to the specifications issued by architects or consulting engineers and are in accord with building and equipment codes. Construction specifications have been developed through the years to set up minimum standards that will assure satisfactory performance, regardless of variations in the details of construction of the several bidders.

Rather than being restrictive, a well developed and flexible construction criteria benefits the manufacturer of adequate, well constructed and possibly more expensive designs by setting up the minimum requirements that will be accepted. Such criteria are also helpful in examining and approving applications, reducing the possibility of one examiner in the control agency turning down a design which another examiner might have recently approved, based on inadequate knowledge or experience.

It should be noted that approval of an application under the above system does not relieve the filer or user of the equipment of responsibility for satisfactory performance as the best of equipment must be properly operated to avoid violations.

An example of the implementation of the above is shown in the "Criteria for Apartment House Incinerators"[3] currently in use in New York City. Similar criteria are issued by a number of air pollution control agencies in cities such as Los Angeles, Chicago and Milwaukee.

SECTION VIII

REFERENCES

1. Kaiser, E. R. New York University College of Engineering. Performance of a Flue-Fed Incinerator. Technical Report 552.1, 1958.

2. New York City Housing Authority, Project Statistics, June 1966.

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4. New York City Department of Air Pollution Control. Criteria Used for Upgrading of Existing Apartment House Incinerators, May 1966.

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PART 4

A REVIEW OF THE STATE OF THE ART OF MODERN MUNICIPAL INCINERATION SYSTEM EQUIPMENT

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SECTION I

INTRODUCTION

The objective of this section of the report is to describe the construction and operational principles of the various kinds of equipment and systems currently in operation or on contract for the central incineration of mixed municipal solid refuse in the United States. Much of the material presented here has previously been published in technical references listed in the bibliography. However, this essay will attempt to organize the information and present it with an explanation of technical terms and trade jargon so as to make it most useful to non-technical decision makers. In addition, the apparent problem areas and future technological trends, as disclosed in interviews with leading incineration engineers, operators and manufacturers will be discussed.

The purpose of incineration is the thermal reduction of wastes to a small volume of inert solids and the conversion of the rest of the material to innocuous gases. The essence of the ideal incineration process is combustion (burning), in which the hydrocarbon compounds of the combustible refuse combine chemically with the oxygen of the air to form carbon dioxide and water, and leave the minerals and the metals as solid residue. This chemical reaction, called oxidation, releases heat energy which can sterilize the residue, destroy odorous compounds in the refuse, and convert the water into vapor, which, together with the carbon dioxide becomes an acceptable and invisible part of the atmosphere.

Like any other chemical process, if the constituents are not intimately mixed in the proper proportions, and if they are not sustained at the proper temperature for the proper length of time, the reaction will be incomplete, and undesirable products and effects may result. An uncontrolled rubbish fire which causes smoke, airborne particulate matter, odors and putrescible residue is an example of incomplete combustion.

For nearly one hundred years, engineers and technicians have been developing the art of incineration of solid wastes in equipment designed for this purpose. It has become evident that if the goals of efficient, sanitary and acceptable refuse volume reduction are to be achieved through combustion, the entire incineration process, from the receipt of the refuse to the discharge of clean gas and sanitary residue, must be considered as an integrated system.

SECTION II

CONCLUSIONS AND RECOMMENDATIONS FOR FUTURE ACTIVITIES

Municipal refuse incineration equipment and systems have been developed and demonstrated to perform the necessary thermal reduction function efficiently, reliably and economically. Further fundamental technological "breakthroughs" are not required to provide satisfactory incineration service to municipalities. Modern system engineering can do it if the following principles are observed.

A. Standards of performance, expressed in clear, quantitative engineering terms must be created and acknowledged. The fear that municipal mixed refuse is so variable that standards are impossible has been allayed by several studies which have shown that most refuse can be defined within reasonable ranges of chemical and physical terms. Incinerator performance can be based on refuse in these ranges with the occasional excursion outside these ranges handled by special control equipment.

B. Specifications for procurement of incinerators should be expressed in terms of engineering performance and not in terms of ambiguous perfection ("shall be odorless, smokeless and perform to the satisfaction of city officials") nor in terms of equipment dimensions and materials ("furnace shall be xxx inches wide and refractories shall be of xxx material").

C. Methods of testing performance to specification must be established, acknowledged and implemented. Statistically reliable tests of refuse, flue gas and residue composition, tests of system capacity and of power and water used are expensive and are therefore often curtailed to the point that true system performance is not known. There is need for development of simplified test instrumentation and techniques, and perhaps for Government financial support of incinerator acceptance test programs.

D. Economic consideration should be given to total cost evaluation, including the sum of capital investment, operating costs and maintenance costs to meet specified performance for the life of the investment, rather than to simple consideration of lowest first cost for each separate item of equipment.

E. Unification of responsibility for incineration system design, construction and performance is necessary with the assurance of standby financial resources to "debug" and develop new incinerator system installations until they are performing to specification. A Government supported insurance program, rather than present punitive performance bond arrangements might be a constructive approach.

SECTION III

ELEMENTS OF AN INCINERATION SYSTEM

Many systems of incineration have evolved over the years as technology improved, as living habits changed, and as solid waste collection practices developed. Although considerably different in construction and operation, it is clear that all successful systems of central municipal mixed refuse incineration include provisions for carrying out the following essential functions:

1. Receiving loads of mixed refuse at varying rates of supply.
2. Measuring the quantity of refuse received.
3. Storing a "buffer" amount of refuse in a sanitary, accessible, yet nuisance-free manner.
4. Sorting, mixing or otherwise preparing refuse for incineration.
5. Feeding the refuse to a furnace at a controlled rate.
6. Drying the refuse sufficiently to permit ignition of combustibles.
7. Burning the refuse to produce essentially inert solid residue and tolerable gases.
8. Dissipating the heat of combustion.
9. Collecting, cooling and removal of non-combustible residual solids.
10. Cleaning and discharging effluent gases and liquids in an acceptable form.
11. Controlling the process for safety, efficiency, economy and community acceptance.
12. Protecting the personnel and equipment from the elements, from dangerous refuse and from careless operation.

Before proceeding to the description of the principles of the equipment used to perform each of the above twelve functions, it is necessary to clarify the popular method of "rating" modern municipal incinerators, since often there are different kinds of equipment used for different size-rated incineration systems. It has become common practice to rate municipal incinerators in tons of burning capacity per 24 hour day. This is an unfortunate and often ambiguous scale of measurement, because a ton (2,000 pounds) of mixed refuse may easily have as much as 50 percent variation in its heating value (Btu/pound) due to different amounts of paper, plastics, wood, vegetable matter, moisture, cans and bottles, etc. (The effect of variation in heating value on the effective capacity of an incinerator is discussed in another section of this report.) Also, in the absence of uniform standards for

ELEMENTS OF A MUNICIPAL REFUSE INCINERATION SYSTEM.

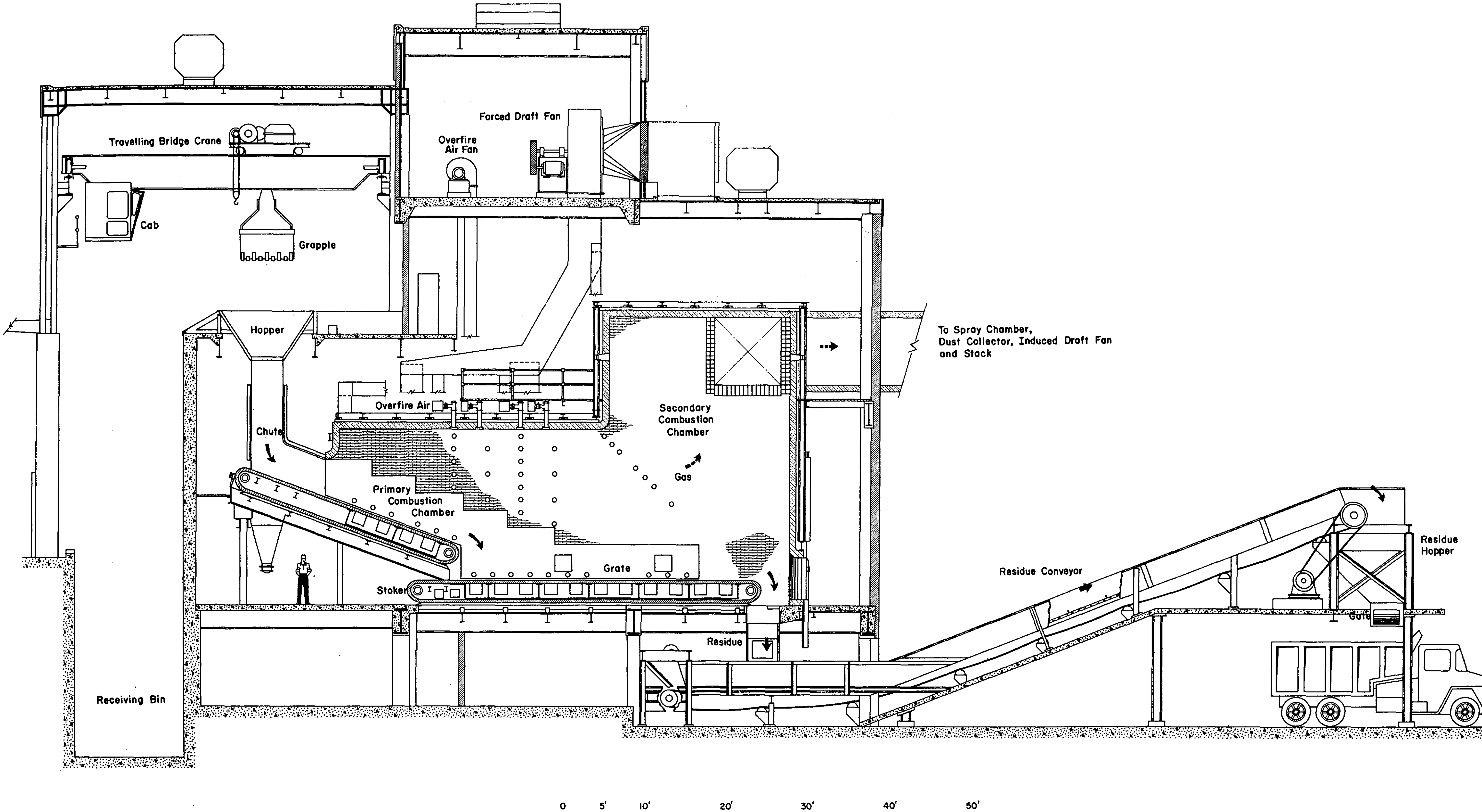

Figure 1

measuring the degree of completeness of combustion, the "capacity" in tons per day burned in a given incinerator may be considerably increased if less complete combustion is accepted. Furthermore, relatively few incinerators are operated for full 24 hour days, and the starting up and shutting down operations, at partial load, lead to confusing concepts of the amount burned "per day". Nevertheless, it does not appear likely that the tons per 24 hour day (TPD) method of rating will be easily changed, so it will be used as a classifying parameter in this report.

Municipal incinerators have been built or offered in size ranges of 30 to 1,200 tons per day (TPD). In all but the smallest installations, it is considered desirable to provide at least some measure of duplication of important pieces of equipment, so that a single "outage", whether due to equipment breakdown or normal maintenance, will not prevent the plant from operating at partial capacity. Generally, the larger incinerator plants consist of groups of two, three or more 150 TPD to 500 TPD furnaces fed by a common loading system, with either common or separate gas and solid residue discharge systems.

A. REFUSE RECEIVING FACILITIES

In the United States, practically all refuse is delivered to central incinerators by motor vehicles, usually in "packer" trucks of 16 to 26 cubic yard capacity which results in loads of three to six tons of moderately compacted refuse. The more modern packers have means for mechanically ejecting these loads onto a level floor or into a pit, but many of the older types dump their loads by tilting the truck body so the refuse slides out the back. These are suitable for dumping (tipping) their loads into a pit, but may not eject their entire load onto a level floor unless the truck is driven forward with the body tilted. Many smaller communities, and larger communities in emergency situations, still use standard three to five cubic yard open dump trucks for refuse delivery, and in the aggregate, there are many deliveries made by all sorts of private vehicles, ranging from the family sedan with a pail of refuse in the trunk, to light trucks with crates of refuse or old furniture, to large vans loaded with special industrial wastes.

The receiving facilities of modern incinerators are designed primarily to accommodate packer trucks, but they must also be able to handle the other types of vehicles. There are two principal types of receiving stations:

1. The floor dump, which is an open paved floor area on which the trucks deposit their loads. A tractor then pushes or lifts the refuse into conveyors or feed hoppers or piles the refuse in storage heaps for later disposition.

2. The bin dump which is a concrete lined pit with a curbing at one edge to which trucks can back their rear wheels and discharge the load to a level below grade, from which it is later lifted by a crane.

Although there is much to be said in favor of enclosed tipping areas -- protection from the elements, reduction of windblown refuse, containment of noise and odor and night storage of vehicles -- a significant number of incinerators, in the interests of low first cost, make do with only a canopy over the tipping bays, or nothing at all.

Traffic control and personnel safety are important considerations with heavy trucks backing into close quarters to dump their loads, and many receiving areas attempt to provide multiple dumping areas (three to six bays usually) to handle peak delivery loading, and separate exits so the "empties" don't have to thread their way back through incoming traffic. Sometimes a special bay is reserved for cars and light trucks to keep them out of the way of the big packers.

B. REFUSE MEASURING EQUIPMENT

Refuse received at a municipal incinerator is usually measured by weight, by volume, or by number of delivery vehicles, in order to:

1. Compare performance against system rating.

2. Establish patterns of refuse receipt for planning purposes.

3. Measure the quantities and rates of refuse collection from a controlled area.

4. Establish a basis for service charges to various sources of refuse.

5. Detect unusual or undesirable loads.

The most common method of measurement is by weighing on a truck scale which is usually located so that all incoming vehicles must cross it to reach the tipping floor or bins. The weighing equipment varies from direct reading mechanical scales to the more sophisticated scales including load cells, remote indicators and automatic print-out devices. Usually, the scale is attended by a weighmaster who checks the credentials of the reufse truck driver. Many incinerators restrict their service to specific towns, licensed private collectors, homeowners who have obtained a permit, etc. He checks the empty weight of the vehicle, and inspects the load for obviously undesirable refuse like demolition masonry, logs, large metal home appliances or explosives which may damage the incinerator.

The newest weighing systems can be made fully automatic so that the driver of the incoming vehicles inserts a coded license card or key in a box to open barrier gates, and the load is weighed, recorded and admitted to the dumping floor, and finally the empty truck is weighed and released through another barrier gate, all without need for a scale attendant.

In some cases, the scales are used to record weights of loads of brush, furniture, home appliances and other refuse which is taken directly to a land fill.

Another method of weighing is by use of a load cell on the bucket suspension of the travelling crane. This can accurately measure the weight of refuse actually fed into the incinerator furnaces. However, it affords no control over the amount of refuse received from each incoming truck.

Residue leaving the incinerator is usually measured by estimating volume, if it is measured at all. In most cases, the residue is wet from the quenching process, and the amount of water is quite variable, so weight measurements are not considered reliable indications of the residue weight. The residue is frequently carried off to a land fill in open body dump trucks of three to five cubic yard capacity, and it is therefore measured by the number of truckloads. If a sample is dried and weighed, the volume estimate can be converted to weight in order to calculate the average percent reduction of incoming refuse weight.

C. STORAGE OF REFUSE

It is accepted practice to collect refuse during the daylight hours, and since collection trucks start their rounds about the same hour, and are filled about the same hour, refuse is likely to arrive at the incinerator in cycles, with two or three peak periods during the day. Where the incinerator operates more than one shift, or more days than the collection service, the refuse collected must be stockpiled for burning over an extended period. Also, in case of incinerator shut-down for maintenance or repairs, or in the event of holidays, disasters or other causes of generation of large quantities of waste material, there is need for the incineration plant to accept and hold quantities of refuse until it can be handled by the incinerator working at its steady rating.

The most common storage device is the concrete bin, set below ground level so that trucks can dump directly into it. Bins are usually constructed of reinforced concrete and often have steel rails or facings set in the sides to resist damage from the crane buckets. Unfortunately, incinerators are often erected on otherwise marginal land which may be poorly drained or may be the site of an old refuse dump. This can lead to expensive construction of the bins as well as expensive foundations for the rest of the structure. The bins must be water proof, yet must be provided with sewers for draining of accumulated liquids or flushing water.

Bins tend to be large. For example, the bin for a 500 TPD plant with provision for one full day's storage when filled up to ground level, and one and one-half day's storage with refuse piled by the crane, might be about 75 feet long, 25 feet wide and 50 feet deep. For a 1,000 TPD plant, the change would probably be mostly in increased length.

Bins are usually carefully shaped to permit full access by overhead cranes, and to facilitate cleaning. Since dust, odors and fires have been recognized as problems, some bins are equipped with sprinklers, ventilation suction systems and doors to close them off from the drive-in and tipping areas.

The other storage method, the floor dump, is not nearly as common as the bin, and appears to be used only in smaller incinerators. It consists of a concrete or bituminous surfaced floor sheltered or enclosed by a simple structure. A bulldozer equipped with a lift bucket is used to move and pile the refuse on the floor, sometimes ten feet high, until it is fed into the incinerators. The sides of the enclosure are constructed to withstand the side thrusts of the refuse piles, and there are sewers for drainage and often sprinklers and ventilation systems to cope with dust, fire, and odor.

In case of temporary emergencies, excess refuse is sometimes piled outside the tipping floor, or is taken directly to a land fill, until floor or bin space becomes available.

D. SORTING, MIXING AND PREPARING THE REFUSE

Some communities attempt to segregate refuse during collections, while others take anything that will go into a packer truck. Still others bring furniture and large metal objects like refrigerators, stoves, bedsprings and bicycles to the incinerator. Sometimes there are commercial wastes like large packing crates, or industrial wastes like large wooden pallets, or rubber tires, or spoiled batches of foodstuffs. Occasionally, non-combustibles like concrete slabs, or china sinks or rolls of fence wire appear. Obviously, certain of these items should be kept out of an incinerator, while others must be treated in some special way to get them into and through the incinerator without causing damage.

Gross separation of objects unsuited for incineration is done by watchful weighmasters and furnace loaders. Breaking or crushing of bulky combustible items like furniture and crates is often done by the travelling crane or the bulldozer, whichever is used in the particular plant. A few incinerators are equipped with chippers, wood hogs or hammermills for disintegrating pallets, demolition lumber and logs. The resulting "chips" are then mixed in with the rest of the refuse going into the furnace. Those disintegrators that are acceptable for this severe service are very heavy duty machines provided with large throats to receive large items. They generally require more than 50 horsepower and are quite noisy. The unavoidable inclusion of metals and stone in the refuse takes a heavy toll of the knives or hammers of the machines. Nevertheless, they are very effective toward making bulky items suitable for incineration and thus saving land fill.

The problem of unusually "wet" refuse like lawn clippings, or spoiled loads of fruit; or of high heating value refuse like plastic scrap or rubber tires is handled by judicious mixing on the tipping floor or in the storage bin. The crane operator or bulldozer operator tries to "average out" the unusual loads, into a reasonably combustible mix.

E. FEEDING REFUSE TO THE FURNACE

Moving the refuse from the place it is stored to the inside of the furnace is an unusual and exacting materials handling task, for which several types of specialized equipment have been developed. The task is difficult because the material to be handled is composed of so many different sizes, shapes, weights, textures, hardnesses, slipperiness and resiliencies. There is paper in all forms, from telephone books to carton boxes to greasy garbage wrappings. There is cloth, wood, pieces of metal machinery, all shapes of cans and bottles, grass and brush clippings, earth, dust and occasionally significant amounts of waste foodstuffs. In good weather, the conglomerate waste (mostly paper) may be quite dry and fluffy, but during prolonged rainy spells, or in snow storms, the refuse received at the incinerator may be soggy wet. Also, the service imposed on the material handling equipment can only be classified as "severe".

The refuse, while generally lightweight when compared to earth or minerals, nevertheless is handled in such large volumes and by such large equipment that high tonnages must be grasped, pushed, lifted, and carried. For example, a typical crane bucket, large enough to "grab" 1,000 pounds of mixed refuse at a "bite", weighs about 5,000 pounds in itself, in order to withstand the jarring, abrasive service conditions. Hence, the crane and its drums, bearings, cables, motors, gears, brakes, etc. must all be designed to lift 6,000 pounds each time, and to do it continuously and reliably. Similarly, a tractor used to push and stack refuse on a charging floor might handle over 1,000 tons per day, in the course of feeding 500 tons per day into the furnaces.

Another requirement of the feeding system is to supply a controlled flow of refuse to the furnaces with minimum interference with air supply for combustion, and with maximum protection against flashbacks of fire or gases through the charging opening.

The most popular feeding system, by far, is comprised of a below-grade storage bin and a travelling crane with a grab bucket which lifts and carries the refuse high above the furnace, and releases it into a funnel shaped hopper which leads to a chute that allows the refuse to slide into the furnace under the action of gravity. A few smaller incineration plants use monorail hoists in which a single fixed overhead "rail" supports a "trolley" which can travel the length of the rail on wheels. The trolley contains electric motors and brakes, and drums of steel cable which suspend and raise and lower a "clamshell" type bucket or grapple, usually two to four cubic yard capacity, over the refuse storage bin. (The halves of a bucket may be visualized as two cupped hands with the fingers of each tight together, while a grapple would look like two hands with the fingers spread apart in a claw configuration.) With monorail cranes, the bin is narrow with steep sloping sides to make the refuse fall under the line of travel accessible to the bucket, and the furnace feed hoppers must also be in this line of travel, to accept the refuse from the crane.

The larger incinerators have bridge cranes in which two parallel overhead rails mutually support a cross structure, or bridge, on wheels, so the bridge can travel the length of the rails. The bridge, in turn, supports a "trolley" which suspends and operates the bucket or grapple as described above. The bucket of the bridge crane can reach any point in the area between the support rails and can therefore handle refuse in wide bins and can reach furnace charging hoppers in more locations. Usually, the crane is operated by a man in a cab mounted right on the bridge or trolley. The cabs are well ventilated, often air conditioned, and are frequently provided with communications systems, since the operator must work in an environment of dust, odor, heat and noise, yet his judgment and performance in sorting and mixing refuse, and rate of feeding the furnaces are extremely important to the successful operation of the incinerator. A few cranes are operated from a fixed "pulpit" on ground level or above, and some monorail types are controlled by a man walking on the ground alongside the trolley and using electrical switches on the end of a cable, or mechanical controls activated by a rope.

Good cranes are costly equipment because of the sophisticated controls, the severe duty and the need for reliability, since a crane stoppage shuts down the entire plant. They also require special provisions in the buildings which house them, such as strong, true mountings for the rails, headroom and side clearance for the trolleys and bridges, heavy duty, well protected electrical power source to the trolley (either the "third rail" type or festooned retractable cables), and sometimes storage space for standby bridges, trolleys and buckets.

Tractors with bulldozing blades and lifting buckets are simpler and less costly than travelling cranes, but they can only be used to feed a furnace hopper where the refuse does not have to be taken out of a below-grade bin, and lifted above the furnace. If a tipping floor is at an elevated level with respect to the furnace, as is possible with a hillside location or with a manmade ramp, the tractor operator can mix, sort and feed refuse to a bank of incinerators just as efficiently as a crane operator, and, in case of a breakdown, the machine can be quickly replaced with another tractor, or even, temporarily, with a snowplow on a truck.

Continuous chain, bucket or belt type conveyors appear to be rarely used in feeding incinerator furnaces. This is not because of inability to transport the waste material, but is perhaps due to the dismal prospect of a disabled conveyor buried 50 feet deep under 500 tons of mixed refuse, or to the inability of a single conveyor to stack and mix refuse like a crane or tractor can do. In at least one small incinerator, a tractor is used to push refuse from a tipping and sorting floor into a shallow floor trench onto an apron type metal conveyor which carries the refuse up an incline into the furnace.

In some older types of furnaces, the refuse is charged directly through an opening in the top of the furnace and falls on the firebed. Such openings are usually fitted with refractory lined horizontally sliding charging gates, often hydraulically activated, located just below the charging hopper. A load of refuse from crane, dozer, or directly from a truck is dumped into the hopper and covers the charging gate. When the gate is withdrawn horizontally, the load of refuse forms an air seal until it falls into the furnace, and then the charging gate is slid back to its closed position as quickly as possible. This type of batch feeding permits a quantity of cold air to enter the furnace with each charge and can lead to erratic combustion and smoking. A true air lock can be achieved with two sliding charging gates, one above the other, but this appears to be rarely used.

The most frequently used charging method consists of a smooth metal lined chute extending several feet down from the "throat" of the hopper into the furnace, and terminating above one end of the stoker or hearth. The resultant column of refuse forms an air seal, and the lower end of the column of refuse is exposed to the heat of the furnace for drying and ignition. The stoking action starts the ignited refuse on its way through the furnace, and new refuse from the column replaces it. The "buffer" quantity of refuse in the chute and hopper permits the actual feed rate into the furnace to be controlled by the stoker action and allows the crane to be used for stacking refuse or feeding other furnaces for reasonable intervals of time.

The end of the chute in the furnace is water cooled or refractory coated. To cope with occasional backfires of the refuse in the chute, the hoppers for these chutes are either equipped with sliding charging doors at their throats or with metal covers which can be quickly applied to seal them off.

An innovation to the gravity fed chute has been the addition of an hydraulically activated horizontal ram at the bottom of the chute to push "slugs" of mixed refuse into the furnace. This affords positive control of the feed rate and serves as the chute seal in place of the charging gate. The ram is arranged so as to push a load of refuse onto an exposed drying and ignition hearth, and in the next stroke, the new load tumbles the dried refuse over a parapet onto the actual stoker.

F. DRYING AND IGNITION OF REFUSE

Most materials that truly burn, i.e., combine with oxygen, must first be converted to their gaseous form by heating. Much of the material in mixed refuse has moisture on it (surface moisture) or absorbed in it (inherent moisture), and any heat that is applied first turns this liquid water to steam but leaves the burnable material too cool to volatilize and ignite until most of the water has been driven off. To perform the drying function and to prevent smothering a going fire with undried and non-combustible material, most furnaces have some provision for exposing newly charged material to radiant heat energy and hot gases to drive off and absorb the moisture. As previously mentioned, these provisions take the form of exposure at the bottom of a feed chute, or on a drying stoker or hearth, or brief suspension in hot gas as the refuse falls onto the stoker through the opening in the roof of an incinerator furnace.

After the moisture has been driven off, the heat radiated to the refuse by the hot gases and hot surfaces, and conveyed to the refuse by the motion of hot gases, increases the temperature of the refuse until the hydrocarbon compounds vaporize and decompose and begin to combine with oxygen. This is the ignition process which starts the burning. In most furnaces, the original ignition is done by a match or a pilot oil or gas burner, and thereafter the burning refuse ignites the incoming refuse. Subtile design features like positioning of grates with respect to heat reflecting walls, or guiding of flaming gases over the incoming refuse, are employed to ensure autoignition. In some furnaces, to ensure ignition when there are unusually wet loads, auxiliary gas or oil burners are positioned to play their flames on the incoming refuse.

During the drying and ignition phase of combustion, there are large quantities of steam and gases liberated and the fire heats and expands these to many times their original volume. Therefore, furnaces usually provide for unrestricted flow of these gases away from the ignition zone, so that fresh air can get in to supply oxygen and prevent smothering of the flame.

G. BURNING THE REFUSE

The burning process consists of the continued heating and vaporizing of the elements that will combine with oxygen until only inert minerals and metals remain as ash. Actually, there are many additional complex reactions during burning, and most of the metals actually oxidize to some extent, as do other elements like sulfur and even nitrogen in the intense heat of the furnace, but these are minor effects and would only confuse the general picture if discussed here.

The heart of the incineration system is the furnace, which consists of a chamber to contain the gaseous reaction, a stoker to transport the refuse through the furnace and agitate the refuse to expose new surface to oxygen and heat, an air supply to furnish oxygen for combustion, and a pressure differential (draft) to cause the gaseous products of combustion to flow out of the chamber.

Furnaces come in many shapes and sizes, but the three most common configurations in modern municipal incinerators are the upright cylindrical (like an oil drum), the rectangular (like a shoe box) and the multi-chamber rectangular (like two shoe boxes joined, with one lying flat and the other on end). They are generally constructed on concrete foundations with either a structural steel framework supporting inner walls and roof arch of refractory material, (supported wall and suspended arch construction) or typical masonry with bricks laid one atop another (gravity walls) and self supporting arched roofs made of keystone shaped bricks (sprung arches). The supported wall and suspended arch are almost universally used in modern incinerators. Metal or refractory hooks secure the refractory to the structural steel, and a layer of insulation and an outer sheet metal casing usually complete the wall structure.

Three different forms of refractory are used; fired refractory bricks, which are laid up with a very thin layer of refractory cement between bricks, plastic refractory which is supplied in a damp clay-like consistency and is spread and pounded into place against lath or hooks, and castable refractory which is poured into temporary molds, like concrete. The latter two forms are usually dried out at low furnace heat and then assume their final vitreous strength when the furnace is brought up to its normal operating temperature. There are many compositions of refractory material, basically clays of silica or alumina. These are called fire clays and are used in various grades for various conditions of heat, erosion, and chemical resistance. Special high performance refractories like silicon carbide or aluminum oxide are used for extremely severe duty such as furnace linings at the edges of the stoker bed where there is intense heat and severe abrasion.

In practically all municipal incinerators, the refuse rests on grates while burning. These grates are, in general, metal surfaces with holes or slots through which combustion air enters. Usually the grates are movable by mechanical means so they can move the refuse through the furnace, agitate the refuse to promote combustion, and remove the ash from the furnace. These mechanical grate systems are called stokers, since they perform the function which used to be done by men who tended the fire using long metal hoes and stoking bars. Most furnaces are equipped with doors in the sides through which manual stoking can be done when necessary.

Upright cylindrical furnaces have a floor of rocking grates above the ash pit. These rocking grates are pivoted on axles so that when they are rocked, large spaces open up for the ash to fall through. Above the floor of grates, mounted on a vertical axis, is a star shaped rabble arm which rotates slowly and spreads and tumbles the refuse on the grate during combustion. In these furnaces, new batches of refuse are dumped in from the top at intervals, and they are, therefore, classed as batch type furnaces.

The flow-through furnaces are equipped with stokers which receive refuse at one end, either continuously or in batches, and continuously move it horizontally and downward through the furnace, finally depositing the ash in a receiver at the opposite end of the furnace. During the journey through the furnace, the refuse is supplied with "underfire air" which comes up through the grates from a "windbox" under the stoker. Fine particles of ash (siftings) often fall through the holes in the stoker surface and must be caught and removed to avoid eventually clogging the windbox and the grate openings.

There are four principal types of flat-bed stokers:

1. The travelling grate stoker which is essentially a moving chain belt carried on sprockets and covered with separated small metal pieces called keys, so that the entire top surface can act as a grate while moving through the furnace, yet can flex over the sprocket wheels at the end of the furnace, return under the furnace,

and re-enter the furnace over a sprocket wheel at the front. The sprockets drive this chain conveyor, and are in turn driven by electric motors at slow speed.

2. The reciprocating grate stoker, which is a bed of bars or plates arranged so that alternate pieces, or rows of pieces, reciprocate slowly in a horixontal sliding mode and act to push the refuse along the stoker surface. These are driven through links by electric motors or hydraulic cylinders.

3. The rocking grate stoker which is a bed of bars or plates on axles so that by rocking the axles in a coordinated manner, the refuse is lifted and advanced along the surface of the grate. This type of stoker is actuated by linkage driven by hydraulic or electric motors.

4. The inertial grate stoker, which is a fixed bed of plates with the entire bed carried on rollers and activated by an electrically driven mechanical drive which draws the bed slowly back against a spring and then releases it so that the entire bed moves forward until stopped abruptly by another spring. The inertia of the refuse carries it a small distance forward along the stoker surface and then the cycle is repeated.

Each of these types of stoker may be flat or inclined down in the direction of flow, and may be used as a single stoker or as a series of two or three units arranged in stair-step array so the refuse is tumbled and agitated as it moves from one section to the next. Often the individual sections can be operated so as to advance the refuse at different speeds to control drying and burn-out of the refuse.

The grate surfaces are made of sturdy iron or steel castings, alloyed and designed to resist distortion, growth, cracking and oxidation. However, in well designed furnaces, the grate surfaces do not characteristically operate at temperatures even near that of the fire because they are protected by unignited refuse, by ash, and by the cooling underfire air passing through them. In the drying and ignition zones, the volatile combustible gases, water vapor and smoke are driven off and flow into the secondary combustion chamber where they are mixed with air and retained long enough to complete combustion. After the ignition zone of the stoker, the residual refuse burns off its fixed carbon with a clean hot flame which radiates heat energy to facilitate the proper burning of the still-combustible gases and airborne particulate matter.

The rotary kiln is really a combination furnace and stoker and is very effective in gently tumbling the burning refuse until complete combustion is achieved. The kiln is a large metal cylinder with its axis horizontal or slightly inclined. It is lined with firebrick and mounted on rollers so that electric motors can slowly rotate it about its horizontal axis. As used in municipal incinerators, the refuse is always first passed over flat bed type drying and ignition stokers in a furnace, and then, when most moisture and volatile constituents have been driven off, the burning residue is fed into the kiln for final burn-out. In such an arrangement, the volatiles driven off in the ignition chamber are led through a passage above the rotating kiln and join the hot gas effluent from the kiln in a secondary combustion chamber where combustion of the gases and airborne particulate matter is carried out.

Another kind of furnace which is acceptable to some municipalities is the tepee burner. As the name implies, this is a large sheet steel walled structure that looks like an Indian tepee with an opening at the top to let the smoke out. Instead of stokers, these have either earth or concrete floors, or sometimes fixed gratings with air supplies under them. Refuse is fed in either by a conveyor which enters the tepee half way up its side wall, or by a bulldozer which pushes the refuse in through a ground level door, to make a heap in the center of the floor. Residue is removed after the fire has burned out, by pushing it out with the bulldozer.

A few cities have recently built a specialized type of incinerator for burning logs, heavy brush and bulky objects like discarded furniture. This has taken the form of a large box-like furnace with typical furnace wall refractory and insulation construction, and large doors at one end. The floor is a simple firebrick hearth and one end of the furnace is constructed to collect the flue gases (the products of combustion) and treat them in a cleaning process before release to the atmosphere. The bulky refuse is pushed into the furnace by a bulldozer, ignited, and allowed to burn down to residual ash which is cleaned out of the incinerator by the bulldozer when the furnace has cooled.

Waterwall furnaces are one of the most recent innovations in municipal incinerator design. It was recognized that incinerator furnaces differ from other kinds of furnaces, in that ordinary industrial furnaces are built to conserve all possible heat for useful purposes. Incinerator furnaces burning American mixed refuse usually have excess heat which causes slag (melted and recrystallized ash) to accumulate on the refractory walls until it sometimes tears the walls down with its weight. To guard against slag, or other heat damage to the furnace, extra cooling air is introduced into the furnace, but this increases the total gas volume that passes out of the furnace for cleaning, and results in larger and more costly dust collectors, fans and stacks.

Waterwall construction consists of steel tubes laid side by side and welded together to form panels which are in turn formed into the walls of a furnace. Water is circulated through the tubes and absorbs heat from the incineration process. The water may turn into steam or into hot water, depending on the design, and this steam or water may be put to a useful purpose, or simply used to carry the heat away to the outside environment. This construction reduces the necessity for excess cooling air in the furnace, and as a result, the flue gas exhausting and cleaning equipment can be smaller and less costly. A layer of protective insulation and light metal sheathing is used outside the waterwalls to conserve the heat in the tubes and to protect personnel and adjacent equipment.

In contrast to the "underfire" air which enters the furnace through and around the grates, air which enters the furnace above the grates through the sides or roof of the furnace is called "overfire air". Overfire air is used to mix and burn with the combustible gases driven off from the refuse, and to cool the burning gases to temperatures which will permit reasonable furnace life. Overfire air is usually introduced in high velocity jets at specific points which vary with furnace design, and is directed so as to provide turbulence and thorough mixing of the gases for optimum combustion.

The flow of air and other gases through a furnace is caused by blowing the air in (forced draft), sucking the gases out so that atmospheric air flows in through the openings provided (induced draft), or heating the gases so they become lighter and rise (natural draft). Forced draft is generally used for underfire air and overfire air jets in modern furnaces, and is supplied by heavy duty industrial type fans driven by electric motors and controlled by dampers which are simply gates or flaps in the air ducts.

Furnace pressures are usually held slightly below atmospheric pressure so that if doors are opened, or if there are any leaks in the walls, atmospheric air will flow into the furnace, rather than permitting the hot, odorous and sometimes dangerous gases to flow out of the furnace to the surrounding workspace. This "negative draft" is maintained by sucking out slightly more gas than the air and gases that are blown in or generated in the furnace. The traditional way to do this is by natural draft, utilizing a tall stack. The heated gases in the stack are lighter than the cooler atmospheric air outside the stack, and so a positive upward gas flow is established by the same principle as sucking up liquid through a straw. Stacks are popular because they are simple and can be constructed to handle large volumes of gas and to withstand hot and corrosive gases. Also, they discharge the airborne products of combustion high in the atmosphere where the winds can quickly disperse them. After the first cost of erection, they require no further expense for power and usually need only nominal maintenance. However, there are practical limitations on the heights and costs of stacks, and these, in turn, limit the amount of suction available to draw the flue gases through efficient dust collection devices. For these reasons, the newer incinerators include induced draft fans which can provide almost any degree of suction required for good gas cleaning.

Induced draft fans, while usually less costly than a natural draft stack, are limited by their tolerance to hot and corrosive gases so that normally the gases are water cooled before the fan. The fans are usually quite large and require large electric drive motors which use considerable power. They can exhaust into relatively short lightly constructed stacks which serve only to carry the residual gases and particulates to a reasonable dispersal height. Sometimes provision is made for varying the fan speed to control the gas flow through the furnace, but more often dampers, which are less expensive, are used for this control.

The temperatures in a modern municipal incinerator furnace are controlled between reasonably close limits. Average temperatures in the burning fuel bed on the grates, and just above, may reach 2,100°F to 2,500°F. The temperature of the flaming gases falls from this level to about 1,200°F to 1,600°F in the time the gases flow through the primary and secondary combustion chambers. Generally, the average gas temperature of the furnace is kept above 1,400°F to ensure oxidation of all malodorous compounds, and below 1,800°F to prolong the furnace life.

The secondary combustion chambers in incinerators are seldom sharply defined chambers connected by passages to the primary combustion chamber. Rather, they tend to be extensions or enlargements of the primary combustion chambers sometimes set off by half-walls or baffles that cause the gases to flow in turbulent eddys for a time long enough to complete the combustion process.

H. DISSIPATING THE HEAT OF COMBUSTION

Early incinerators which had to burn refuse of low heating value were designed primarily to conserve and reflect the heat of combustion so as to dry and ignite the refuse and heat the resultant gases above the deodorizing temperature with minimum use of supplementary fuel. The acceptable limit on furnace temperature was then imposed by the durability of the refractory lining. Hot flue gases were discharged directly through masonry stacks with refractory linings, with a "settling chamber" at the base and a "spark screen" at the top as the air pollution control. Early attempts to use waste heat to generate steam were unsatisfactory because there was relatively little "waste heat".

Modern municipal incinerators, burning refuse of much higher heating value, and emitting their flue gases through sophisticated air pollution control devices, are designed to dissipate the heat of combustion so that after achieving the 1,400°F to 1,800°F necessary for complete combustion in the furnace, the flue gases are cooled to 500°F to 700°F before they enter the air pollution control devices.

The use of air cooled and water cooled furnace walls has been mentioned previously. A full water wall furnace, or a waste heat boiler consisting of an array of water tubes in the path of the hot gases, can bring the flue gases down to 600°F and even lower, thus reducing their volume as well as their temperature so that economically sized exhaust fans and electrostatic precipitators, cyclones or bag filters may be considered. The heat of combustion is transferred to the steam and the energy is made available to do work.

Air cooled refractory furnaces have thus far been used mainly to prolong refractory life and reduce slagging rather than to reduce flue gas temperatures.

The two most common methods of reducing flue gas temperatures are by dilution with ambient air and by evaporation of water directly into the gas stream. In addition, there is always some direct conduction and rediation of heat through the walls of the furnace and ducting. Direct admission of air is a simple and easily controllable operation. A damper in the ducting allows outside air to be sucked into the flue gases because the draft of the chimney or of the induced draft fan causes a lower pressure inside the gas ducts than outside. However, even though cooling the flue gases shrinks their volume, the amount of fresh air added increases the net volume so that larger and thus more costly ducts, fans, air pollution control equipment and stacks are required.

If water is mixed with, or exposed to the hot flue gas stream, the water tends to evaporate into steam, and in so doing withdraws heat from the gas. In round numbers, the evaporation of one pound of water can lower the temperature of 40 pounds of hot gas by 100°F. The total volume of the cooled gas and the steam is less than the volume of the original hot gas, so smaller fans, ducts and pollution control equipment can be utilized. However, the water usually does not entirely evaporate and the residual liquid absorbs sulfur and chlorine from the flue gases and becomes acidic and attacks the metal mechanism and structure of the gas cleaning equipment unless they are designed to resist corrosion. Often, water quenching is combined with a wet scrubber for gas cleaning, since the water supply, distribution and containment systems are common. The quenching and scrubbing water may be introduced as sprays, on wet baffles which are obstructions placed in the gas duct with water flowing in thin films over the structures, or as wet bottoms, which are simply shallow water tanks which form the bottom of sections of the flue gas ducting. The effectiveness of evaporation cooling is usually dependent upon good mixing of the gas and liquid.

I. COLLECTING, COOLING AND REMOVAL OF RESIDUAL SOLIDS

Solid residue is generated at three places in a municipal incinerator: the incombustibles that come off or through the stoker, the siftings that fall through the grate openings, and the fly ash collected from the flue gas. Each of these solids occurs in different quantities and different form, and since, on the average 20 percent to 25 percent of the weight of municipal mixed refuse is glass, rock, cans and other metals and minerals, the collection, cooling and removal of the incombustible solid residue is a significant materials handling task. Fortunately, this solid residue comprises only 5 percent to 15 percent of the average volume fed into the incinerator, the rest having been converted to gas.

The principal residue is that discharged from the stoker. This consists of broken glass and ceramics, tin cans of all shapes and sizes up to oil drums, stones, earth, assorted hardware, some fused ash (clinkers) from melted glass, metals and minerals, all surrounded by flakes and dust of the light fluffy ash that typically results from burning paper or wood. Although some incinerators do a remarkably thorough job of burning the combustibles, practical limitations of the time that the average load can be left in the furnace permit some incompletely burned refuse to appear in the stoker residue. Telephone books, catalogs, and heavy bundles of newspaper, particularly if wet, are not readily penetrated by air for direct combustion, or by radiant or convective heat for drying and volatilization, so it is not uncommon to find bits of unburned paper in the ash. Heavy timbers or green wood may pass through the average 40 to 60 minute burning cycle with a core of unburned wood still present. Certain foodstuffs containing high water content and occurring in thick sections, like watermelon rinds, carrots, apples or waste meats may char on the outside and seal in liquids, thus permitting some putrescible material to appear in the ash. All this may be aggravated by an operator pushing wet refuse through an incinerator at maximum feed rate to handle a peak load, instead of slowing the stoker to permit better drying and longer combustion time for difficult wastes.

Nevertheless, a typical "good" residue contains less than 5 percent by weight of unburned carbon and less than 1 percent of putrescible organic material.

In cylindrical batch feed type furnaces, the stoker residue falls into refractory lined metal hoppers where it is quenched, then through a gate in the bottom of each hopper, into a truck for removal to a dumping site. The residue is usually steaming and sometimes still burning locally when it is removed, because of the difficulty of reaching all the internal surfaces with the water sprays.

The larger, newer incinerators with flow-through furnaces generally use conveyor systems to remove the stoker ash. The residue is usually discharged from the stoker grates into a water filled trough where it is thoroughly quenched and cooled. A metal drag link conveyor, consisting of a pair of endless metal chains with metal bars attached between the chains, like a rope ladder, is driven by an electric motor through sprocket wheels to drag along the bottom of the ash trough and capture the residue, pull it out of the trough, up a chute and into a waiting bin or truck. These drag link conveyors are heavily constructed of heat resistant cast steel drag link parts, with corrosion resistant metal or concrete tanks and chutes for containing and guiding the wet, abrasive residue. They travel slowly, thus allowing water to drain back into the tank from residue moving up an inclined chute. The unused portion of the drag link chain which is returning from the point of discharge of the residue back to the entrance to the quenching tank may require as much supporting, guiding and protective structure as the working section of the chain.

It is common practice to position drag link conveyor paths transversely across the discharge ends of two or more rectangular furnaces so that the residue of both can be carried to a common discharge point for economy of overall structure and material of the conveyor. Because the residue removal conveyors are such vital elements of the incineration system, and because they are big, heavy, and somewhat difficult to service, they are often built in parallel pairs with a diverting chute so that each of several furnaces can direct its residue to each of two residue conveyors, to ensure reliable service.

Another type of conveyor system is a metal mesh travelling belt on which the residue falls from the stoker, and is spray quenched. Other systems, using metal apron type conveyors, vibratory conveyors and rubber belts for cooled residue are in use, but the metal drag link type is the most popular. Manual handling of residue has practically disappeared, except for a few small older incinerators.

A few incinerators have equipment for separation of residue and salvage of metal, mostly tin cans. The separation is usually done in a metal drum or barrel with holes in its sides and mounted to rotate about its horizontal axis. This tumbles the residue and the ash falls through into a hopper, while the cans finally pass out the end of the drum to another hopper. Sometimes magnetic separators are used to collect the steel from the rest of the residue. The cans are usually pressed flat or shredded to make them into salable scrap. The non-metallic ash is a dense, inert material, almost like damp earth, and is sometimes sold for road fill.

The siftings are dust-like bits of ash, often still glowing, that drop through the grate openings and cover whatever is below. The amount varies with the type of stoker and the material being burned. Certain types of plastics that melt, or greases that can run through the grate openings may accumulate in the underfire air chambers and ignite and burn unless precautions are taken. Some stokers rely on manual cleanout through doors provided for the purpose. Others provide hoppers under the grates and means ranging from mechanical and pneumatic conveyors to water sluicing to move the accumulated siftings either to an outside collection point or into the quenching tank with the other solid residue.

An innovation to combine siftings removal with stoker residue removal consists of a "wet bottom" furnace in which the entire furnace foundation is made as a concrete basin which is filled with water. A drag link conveyor as wide as the furnace runs the entire length of the furnace and drags out the grate siftings which have fallen into the water, as well as the stoker residue which falls into the quench water at one end of the foundation.

Fly ash, in a municipal incinerator, is the particulate matter which is light enough to be carried out of the furnace by the existing gas stream. Dust, ash, fine burning particles, and even sizable pieces of burnt or burning paper are released from the grate by underfire air and fuel bed agitation, so that about 2 percent of the weight of mixed refuse charged into the furnace leaves the furnace as airborne fly ash. The various air pollution control devices, to be described in another section, collect from 30 percent to 95 percent of this fly ash, either by dry collection in hoppers or by capturing it in water. As in the case of siftings, the dry fly ash is conveyed by mechanical or pneumatic conveyors, or by sluicing with intermittent floods of water through pipes, either to a storage hopper for truck loading, or to the residue quenching tank for removal with the other solid residue.

Fly ash entrained in water has been most successfully collected by the use of settling tanks or lagoons. In either case, a large quiescent body of water permits practically all of the particulate matter to settle to the bottom in time, and the relatively clear water is drawn off the top for re-use, while the particulates are discharged or dredged from the bottom. There have been several attempts to separate the particulates from scrubbing water with centrifuges, mechanical screens and filters, but there has been little sustained success.

J. CLEANING AND DISCHARGING EFFLUENT GASES AND LIQUIDS

The gaseous products of combustion, in modern municipal incinerators, usually contain fly ash which is gas borne particulate matter, mostly incombustible, as well as air, carbon dioxide, water vapor, small amounts of sulfur oxides, and traces of other gases. The water vapor and carbon dioxide are natural and acceptable constituents of the atmosphere, but the other materials, the large particles, the dust and any noxious, odorous or corrosive gases tend to pollute the atmosphere and must be controlled within acceptable limits, if they cannot be eliminated.

The smoke, generally carbon particles less than one micron (.00004 inches) in size, and the odors, generally chemical compounds formed during the process of combustion, should not exist if there are the time, temperature and mixture with oxygen for complete combustion. Unfortunately, practically complete combustion is seldom achieved in the older incinerator designs, and even in the newer ones there are transient periods of start-up and shut-down, or unusually wet loads or unusual materials like tires or roofing that can cause smoke.

The particulate matter is collected in three classes of equipment in existing municipal incinerators: subsidence chambers, mechanical cyclones, and wet scrubbers, and these are listed in the order of increasing effectiveness. The "efficiency" of dust collectors is usually simply defined as the percentage (by weight) of the particulate matter entering that is caught. For example, if one pound of dust goes in, and 0.1 pounds comes out in the "clean" gas, then 0.9 pounds was caught and the efficiency is 0.9/1.0 or 90 percent. This is an unfortunate method of rating because it makes no allowance for the variability of size, shape and weight of the gas borne particulate matter. To illustrate, if the incoming gas stream contained a brick, several scraps of paper, and a thousand grains of sand, and if the collector removed only the brick, it would be rated as 99+ percent efficient by this method. Therefore, the effectiveness (efficiency) of particulate collectors is meaningless unless all collectors are evaluated on "standard" fly ash of known density and size analysis. Such tests are tedious and expensive, and until recently, were seldom run on incinerators. Instead, the acceptability of incinerator chimney effluents was often specified and is still often judged on the basis of a Ringlemann test. This is a visual comparison of the color and opacity of the "smoke" from a stack, with various samples of grey color on a printed card, and does not differentiate between carbon fumes, fine dust, large flakes of paper ash, or visible steam from condensed water vapor, nor does it allow for different colored sky backgrounds, atmospheric conditions, or the observer's color perception.

Subsidence chambers, which are also called expansion chambers, baffle chambers or settling chambers are in principle large volumes where the gases are slowed down and retained for a while to allow some of the particulate matter to settle out to the floor of the chamber by gravity. Large heavy particles drop out of the gas stream quite readily, particularly where there are changes in gas flow direction caused by baffles. Smaller particles settle out to a degree, if the gas is not very turbulent and ample time is allowed. However, for typical incinerator fly ash, with a high percentage of particles below 50 microns (1/500 of an inch) in size, the turbulence of the flowing gas stream holds most of them in suspension until they pass out the stack. Since more than half of the total particulate matter in the typical municipal incinerator fly ash as it comes from the furnace is under 30 micron size, it is understandable that even a large subsidence chamber, which may be larger than the incinerator furnace, cannot offer very high collection efficiency. Nevertheless, this is the type of dust collection system in use in the majority of present municipal incinerators.

An improvement in collection efficiency of subsidence chambers is obtained by the use of wet bottoms or wet baffles, which, as previously described, serve to cool the hot flue gases by evaporation, while trapping and retaining the dust particles that impinge on the wet surfaces. An obvious extension of the water cooling and impingement principles is the introduction of water in sprays or cascading curtains in the ducting and subsidence chambers. However, this rudimentary wet scrubbing does not statistically bring most of the dust particles into contact with water droplets or water surface and there is only moderate improvement in collection efficiency. About 25 percent of the municipal incinerators have water augmented subsidence chambers.

Subsidence chambers, with or without water augmentation, are constructed to have low pressure drops for the large volumes of gas flowing through them, and consequently they are suitable for natural draft installation where the motive force for gas flow is provided by the rising hot gases in a tall chimney, instead of by use of a fan.

Chimneys (stacks) for municipal incinerators are usually constructed of masonry, though steel or reinforced concrete are becoming more popular. Tall stacks, often 100 to 250 feet high, are the usual "trade-mark" of municipal incinerators, towering over everything but power plant stacks, and often discharging clearly visible plumes of smoke and steam which have given incinerators a poor reputation as air polluters. Chimneys are highly specialized and costly structures, since they must be designed to withstand adverse terrestrial and atmospheric conditions, to permit access for inspection and maintenance and must be lined with heat, moisture and acid resistant materials to withstand the attack of flue gases. Tall stacks allow the discharged particulates and gases to be caught in upper air currents and dispersed, instead of settling in the immediate vicinity of the incinerator. Though more expensive in original cost than an induced draft fan installation, they do not require continuous use of power. These two features, dispersion and low operating cost, have probably led to the popularity of natural draft installations and thus have limited air pollution control devices to those that could operate with approximately one inch of water pressure drop.

Chimneys also are natural settling chambers. The flue gas usually enters through a horizontal duct (breeching) several feet above the base, and the expansion and turning of the gas as it starts to rise allows particulates to fall to the base of the stack where they can be removed through clean-out doors. Sometimes a wet base is provided in the chimney to trap particulates in water and flush them out hydraulically.

Mechanical cyclones direct the particle-carrying gas at high velocity, into cylindrical chambers which cause the gas stream to whirl around in a circular path. The heavier particles are thrown to the outside of the circle by centrifugal force and are collected in hoppers at the base of the cylinders while the cleaned gas spins out through the center of the chambers. The cyclones are usually made of steel and cast iron selected for corrosion and abrasion resistance. Occasionally, they are lined with wear-resistant refractory materials in critical sections. The smaller the diameter of the individual cyclone cylinders, the higher the centrifugal force that can be developed for a given pressure drop, but as the cylinders get much below 10 or 12 inches in diameter, the number required, the supporting and gas-guiding structure, and the number of small openings prone to plugging, all increase and so do the cost and maintenance problems. Cyclones are used with 3 to 6 inches of water pressure drop.

Well designed and properly installed cyclone systems can provide significant efficiency improvements over subsidence chambers, but it is only in the past ten years that cyclones have begun to find use in municipal incinerators. At present, fewer than ten percent of incinerators have them.

Wet scrubbers are the natural outgrowth of wet bottoms and wet baffles, in the evolution of gas cleaning systems for municipal incinerators. The principle of wet scrubbing, which is well known in the chemical processing field, is to bring all the gas into intimate contact with a liquid which can seize and hold the particulates and gases to be removed from the incoming gas stream. The liquid must then be separated from the clean gas. It should be recognized that this results in a stream of polluted liquid, but there are acceptable methods for processing liquids to remove the impurities and allow re-use of the liquids.

Almost any degree of gas particulate cleaning desired can be obtained in a properly designed wet scrubber, providing sufficient mixing energy is supplied to cause the particles to contact liquid. The energy is usually applied to breaking the liquid into droplets in various kinds of spray nozzles, or by moving the gas at high velocity through water, and in both cases turbulating the gas - water mixture long enough to statistically assure contact. Removal of the water droplets takes additional power and is done by centrifugal means (like a mechanical cyclone) or by flowing the gas through a zig - zag path between baffles which trap the droplets. For municipal incinerators, five to twelve inches of water pressure drop is usually used in the gas stream.

Wet scrubbers provide favorable conditions for dissolving gases containing sulfur, chlorine and other trace chemicals out of the flue gas stream. However, these tend to form active acids, when in water solution, and the scrubbers, ducting, fans and stacks must be constructed of materials that can withstand acid corrosion.

It is only in the past few years that true wet scrubbing systems, as differentiated from crude spray chambers or wet baffles, have been applied to municipal incinerators, and fewer than ten percent of the incinerators have them. They are usually rectangular chambers, constructed of stainless steel or lined with rubber, or cement. Various configurations of fine sprays, or bubbling the gas upward through layers of water held on perforated trays or on a bed of spheres are the methods commonly used to obtain intimate gas - liquid contact.

There have been a few attempts to combine a cyclone and a scrubber into a wet wall or wet bottomed cyclone. The results have not been satisfactory for incinerator fly ash because dampened fly ash tends to cake into a mud and bridges over openings and blocks them. It has been necessary to keep scrubber surfaces flooded with liquid to prevent "mud" build-up.

The spent liquid coming from wet bottoms, wet baffles, residue quench tanks, pit drainage, spray chambers and scrubbers in many cases presents a disposal problem because it is chemically and physically contaminated, and a water salvage problem because of the cost of water. Where water supply is no problem, and where sewers or streams are unrestricted, the older and smaller incinerators sometimes dispose of the waste water directly without any treatment.

The most common method of water treatment, though used in less than 50 percent of municipal incinerators, is the use of settling tanks or lagoons. Particulate matter can be collected from the bottom of the tank or lagoon, and relatively clear water can be drawn off through a weir at the top. A few of the more recently built plants have installed mechanical screen strainers, filters, or centrifuges to clarify the water for recirculation, but the results have been less than satisfactory.

The waste water which has been in direct contact with flue gases tends to become acidic, while the water which has leached through fly ash or siftings may be quite basic. Some of the larger metropolitan incinerators treat the waste water with neutralizing chemicals before clarification treatment.

In general, reclamation and reuse of waste water, though desirable, is troublesome in today's municipal incinerators. Corrosion, abrasion and plugging of plumbing, pumps, valves and spray nozzles are common problems unless careful attention has been paid to designing for reuse of contaminated water.

K. CONTROLLING THE PROCESS FOR SAFETY, EFFICIENCY, ECONOMY AND COMMUNITY ACCEPTANCE

A modern municipal refuse incinerator operating at rated conditions releases an awesome amount of energy under conditions that could be destructive to the plant itself and dangerous or offensive to the community if not properly controlled. Moreover, like any other chemical process, the quantities and mixture of the reactants (refuse, air and water) and the conditions of the reaction (time, temperature, turbulence) must be controlled for satisfactory results. Also, the presence of potentially hazardous elements like high temperatures, deep pits, moving conveyors, heavy trucks and cranes and lethal fumes make it imperative that there be controls to safeguard the operating personnel.

The words "instrumentation" and "control" are often linked together as a common term, but they are really quite different and the difference is important. Instrumentation is the equipment used to indicate and/or record physical conditions like weight, temperature, position, flow, time, speed, voltage, etc. Instruments give signals, but in themselves they do not change the conditions of operation. Controls are mechanisms which change conditions of operation, like a valve which can change water flow, a switch which can turn on a fan motor, or a speed-up in the rate of refuse feed which can increase furnace temperatures.

A control "system" must have four basic elements: a standard of desired performance, a sensor (instrument) to determine actual performance, an intelligence to compare actual versus desired performance (error) and to make a correction, and a control device to cause a corrective change to occur. If these elements are integrated into an automatic system that controls the process to a set standard, like a household thermostat that holds 70°F temperature, it is a closed loop or automatic feedback control system. If, on the other hand, control is effected by making a change and then observing the result (like steering a car), it is an open loop system.

Present municipal incinerators generally utilize their instrumentation in conjunction with open loop control systems, although there are increasing instances of fully automatic closed loop control systems for controlling furnace temperatures and furnace draft.

There are many types of instrumentation used in incinerators, but they can be classed as follows:

1. Temperatures

   - Optical pyrometers for flame temperatures in the range of 2,200°F to 2,500°F.

   - Thermocouples (Chromel-Alumel) for furnace temperatures in the 1,400 to 1,800°F range and iron-constantan in duct temperatures down to 100°F.

- Gas or liquid filled bulb thermometers for duct temperatures, below 1,000°F. and for ambient temperatures and water temperatures.

2. Draft Pressures

   - Usually only a few inches of water column.

   - Manometers and inclined water gauges for accurate readout close to the point of measurement.

   - Diaphragm actuated sensors where remote readouts are desired.

3. Gas or Liquid Pressures from 1 to 100 psi

   - Bourdon tube pressure gauges for direct readout.

   - Diaphragm actuated sensors for remote readout.

4. Gas Flows

   - Orifices or venturis with differential pressures measured by draft gauges.

   - Pitot tubes and draft gauges.

5. Liquid Flows

   - Orifices with differential pressure measurement.

   - Propeller type dynamic flowmeters.

6. Electrical Characteristics

   - Voltmeters, ammeters and wattmeters.

7. Smoke Density

   - Photo-electric pickup of a light beam across the gas duct.

8. Motion

   - Tachometers for speeds of fan, stoker or conveyor drives.

   - Counters for reciprocating stokers and conveyors.

9. Visual Observation

   - Vidicon cameras for closed circuit television for viewing furnace interiors, furnace loading operations or stack effluents.

   - Peep holes in furnace doors.

   - Mirror systems.

The general functions of control systems in present day municipal incinerators are:

1. To control underfire airflow despite varying furnace draft and varying restrictions to airflow through the grate openings.

2. To control overfire air as a means of controlling furnace temperature as the quantity and heating value of the charged refuse vary.

3. To control furnace pressure by varying the draft induced by the chimney or the I.D. fan.

4. To control gas temperature at the dust collectors by varying the amount of quenching water or diluting air introduced.

5. To control refuse drying and burning time by varying the conveying speed of the stoker mechanism.

Usually, the indicating and recording instrument readouts are grouped on a control panel centrally mounted on the operating floor, with a system of warning lights or bells to summon the operator when corrective action must be taken. Often, a duplicate panel of indicating instruments is placed in the plant superintendent's office for additional surveillance.

It is quite common to have recording type instruments which indicate on a removable paper chart, the conditions which exist over a 24 hour period. These records can be very useful in making statistical summaries of operating conditions, and of reviewing operating conditions which may correlate with a malfunction.

L. PROTECTING THE PERSONNEL AND EQUIPMENT

A modern municipal incinerator plant represents an investment of two million dollars or more in equipment and structure, and is expected to serve the community for about 25 years with reasonable maintenance. However, there are forces continuously at work tending to deteriorate the incinerator, namely, the environment, dangerous refuse and careless operation. The experience of engineers and operators has resulted in design features and operation procedures which serve to protect incinerators.

At the receiving bays and storage pits, clearly marked traffic lanes, high intensity lighting and heavy duty curbings and rails reduce the incidence of collisions between refuse trucks and the columns and structures of the receiving area.

Lining the concrete storage pits with steel bumping rails and attaching heavy wear-shoes to the crane bucket can greatly reduce mutual deterioration of pits and crane buckets of grapples. Enclosing the crane machinery and subduing the dust of the storage bins with ventilation and water sprays is a means to reduce crane "down time" and improve crane life. Adequate clearance room and automatic stops save damage from crane overtravels.

Storage pits are susceptible to fires from spontaneous combustion or from smoldering refuse inadvertently dumped in. Sprinkler systems or at least ready water hoses are employed in most incinerators.

Backfires in the loading hoppers of continuous feed incinerators may occur, particularly if the furnace pressure rises above atmospheric. Many incinerators provide metal covers or cut-off dampers on the loading hoppers or chutes so that backfires can be quickly contained and smothered.

Undergrate or windbox fires can be a source of damage if a slow burning meltable or powdered fuel, usually special industrial waste, is fed in large quantities. The combustible refuse may fall through large grate openings and the resultant fire from below may burn or warp stoker parts. Good grate designs and reasonable surveillance of incoming refuse are the measures usually employed to prevent this.

Overheating of the furnace chambers or hot gas ducting can cause serious damage in a short time. Multiple temperature sensors, closed loop control systems, and audible and visual alarm systems are employed to avoid this danger. Increasing overfire air, reducing underfire air and reducing refuse feed rate are control methods used to reduce furnace temperature.

Failure of the quench water supply, whether from clogged nozzles, pump failure, electrical power failure or lack of water, can be quickly disastrous to the flue gas cleaning system and fans. Auxiliary water towers and automatic bypass ducting that can dump the furnace gas directly to the stack are the usual provisions for such an emergency.

Loss of electrical power can be anything from an annoyance to a disaster, depending on the particular system involved. Several incinerators have standby auxiliary power supplies with gasoline, diesel or turbine engines.

In cold climates, freezing water can do damage to piping and to wet conveyor systems. The common practice is to enclose such sensitive systems in heated buildings, or to selectively heat sensitive lines.

Corrosion is the perpetual enemy of the metal structures and equipment of incinerators, particularly when even traces of sulfur, nitrogen and chlorine in flue gases can acidify moisture. Enclosing mechanisms in weather-proof shelters, good painting practice, use of corrosion resistant metals and stainless steel, and use of durable non-metallics where warranted, are the protective methods employed.

Much concern has been expressed over the danger of municipal incinerator explosions, but there appear to be no records of serious damage resulting from explosions of pressure cans, paints and solvents, chemicals, and even ammunition and dynamite. One reason for this seems to be that the furnace volumes are large and unconfined, so that even a sizable explosion cannot make much of a pressure wave. Furnaces are usually lined with thick layers of brick and are steel cased, and there is usually a "cushion" of several inches of porous slag on the inside surfaces. Also, many of the potentially explosive containers soften or burn before an explosive release of energy can occur.

Personnel safety and reasonably tolerable, if not attractive, working conditions are necessary to recruit and retain people competent to operate a modern incinerator efficiently. Guard rails around pits, hoppers and conveyors, good lighting, good ventilation, protective clothing and eye shields for working at furnace openings, and constructive safety training programs are to be found in the majority of installations. Also, well managed municipal refuse disposal plants are essentially odor free, clean and dry, with well appointed locker rooms, lunch rooms, reception lobbys and administrative offices. The buildings generally have pleasing and functional architectural treatment with fences and landscraping designed to make them good neighbors.

SECTION IV

FUTURE DEVELOPMENT IN MUNICIPAL INCINERATORS

In the period of 1961 to 1967, there has been a remarkable increase in the rate of evolutionary development of the art and science of municipal refuse incineration in the United States. During the 1950's, there was growing awareness that the expanding population, the increasing combustible refuse per capita, the diminishing availability of disposal land, and the dependable performance of well constructed continuous flow incinerators in cities like New York, Philadelphia, Atlanta and Chicago were pointing to incineration as a major factor in municipal refuse disposal plans for the latter half of the 20th century.

In 1961, the American Public Works Association published the first edition of "Municipal Refuse Dispsal" with a full chapter describing the engineering principles and practices of central incineration. In 1964, the first National Incineration Conference was sponsored by the American Society of Mechanical Engineers, and the published "proceedings" containing the twenty-nine technical papers of the conference became, in effect, the first American textbook on incineration design. In 1965, the International Research Group on Refuse Disposal Conference in Trento, Italy brought to the attention of American refuse disposal authorities the technical advances in municipal incinerators that had been made in Europe. In May, 1966, the Second ASME National Incinerator Conference was held and its thirty-four technical papers became part of a now sizable bibliography on the subject of incineration.

On October 20, 1965, the Solid Waste Disposal Act, "......to authorize a research and development program with respect to solid waste disposal......" became Public Law 89-272 and provided the impetus for bringing the resources of universities, research organizations, governmental bodies and industry to bear on the problems of solid waste disposal. Naturally, part of this effort is being devoted to methods of improving existing incineration equipment and performance, and toward developing ideal municipal incineration systems for the future.

A review of recently completed incinerators and specifications for others to be built, and interviews with leading consulting engineers and incinerator buying influences have revealed the following probable patterns of development and improvement.

A. RECEIVING, MEASURING AND STORING

It is expected that the principal changes in these areas will be those reflecting the ever larger quantities of refuse to be handled. Following the European developments, it is reasonable to suppose that refuse will be brought to central incinerators by larger trucks, by rail and by barge and there will be need for better methods of rapid unloading and nuisance-free storage. The bridge crane with faster travels and simplified controls will probably be supplemented by various types of conveyors, including pneumatic transportation systems. The storage pits will continue in vogue for the larger plants, but the smaller towns may go increasingly toward open floor dumping because of lower first cost. In both cases, there is likely to be better enclosure of the stored refuse, sprinklers for dust and fire control and mechanical ventilation for discharging the odorous exhaust air into the incinerator.

B. SORTING, MIXING, FEEDING

Considerable effort is being expended to improve these functions, and it is therefore likely that future municipal incinerators will include new equipment for preparing the refuse for efficient incineration. Breakers, crushers and shredders will be employed to reduce awkward size combustibles like wooden pallets, demolition lumber and furniture to smaller pieces, and obviously incombustible items like bathtubs, bicycle frames and kitchen stoves will be separated during the collection process. There are signs of growing interest in special bulky refuse incinerators for logs, brush and furniture.

It is not expected that there will be a significant trend toward pre-incineration salvage. Fairly sophisticated machinery has already been developed for this purpose for composting operations, but the salvaged materials, even when classified, are troublesome to market. "Tin cans" contain steel, tin, solder, plastics, aluminum, paper and residual food, and are not desirable as scrap. Clothes are often unsalvagable mixtures of synthetics and natural fibres, and the market for salvaged glass and even clean paper is undependable.

There is likely to be increasing interest in various types of ram and conveyor feeders as supplements to the gravity fed hopper and chute. The use of wheeled vehicles to load furnaces from floor dump operations is also expected to increase. As shredding and grinding of refuse become more common, more mechanical or pneumatic conveying of the prepared fuel into the furnace will probably be employed.

C. FURNACES

It appears that developments in municipal incinerator furnaces will proceed in several directions; refractory lined furnaces and water wall furnaces, both with conventional flow-thru stoker systems, and a number of advanced concepts. Some of these may prove to be impractical, but others may, in time, offer significant advantages.

There is a trend toward air cooled walls in refractory lined furnaces, and the use of silicon carbide or high alumina facings in the slagging and abrasion zones of the furnaces. Air cooling is accomplished by natural or forced circulation of air over the outside of the refractory lining, and often the air which has picked up heat from the lining, is discharged into the furnace as overfire air. The cooled walls seem to resist penetration by heavy glassy slags, so that the slag falls off or is easily removed, without causing spalling (breaking off layers) of the refractory surface. There is increasing recognition that with the high heating value of American refuse, it is not as necessary to heavily insulate the furnace walls to conserve all the heat of combustion. With thinner, more conductive air cooled walls, some excess heat can be directly dissipated through the furnace walls to reduce furnace temperatures and improve refractory life.

There is also likely to be increasing use of plastic and castable refractories for walls and arches (ceilings) to reduce the labor involved in the traditional methods of laying up firebrick.

Waterwall furnaces are expected to find increasing use, both as cooling surfaces to shrink gas volume so the flue gases can be more easily cleaned, and as heat absorption surface in steam generation systems. Following European incinerator practice, there may be refractory coated tubing used for corrosion resistance in critical areas of the furnace.

The stoking systems and grates used in these furnaces will probably undergo detail improvements to increase ease of servicing and durability. The new designs will tend toward controlled agitation of the residue to strike the best balance between full combustion and least generation of fly ash.

Some of the more novel approaches to incineration of municipal refuse under experimentation are suspension burning, melting with auxiliary fuel, pyrolysis, fluid bed combustion and pressurized burning. Suspension burning, which is the process widely used in power boilers, consists of blowing the finely divided fuel into a vortex pattern in a furnace chamber so that it burns while suspended in the turbulent air stream. It is efficient and can provide high heat release in a relatively small volume, without the necessity for supporting a burning fuel bed or a grate or hearth. Well controlled preparation of the refuse is required.

Melting of the incombustible residue can be accomplished if the heat release of the burning refuse is augmented by burning it with a high quality fuel like coke in a properly designed refractory chamber. The melted residue, including metals and minerals, can be run into a water bath where it solidifies and fractures into coarse crystals which are probably the ultimate in cleanliness, compactness and desirability as a residue.

Pyrolysis consists of decomposing the refuse by the application of high heat, without supplying oxygen for combustion. Theoretically, the refuse can be converted to combustible gases, fixed carbon (like charcoal) liquids and tars containing useful organic chemicals and inert ash, metals and minerals.

Fluid bed combustion is carried out in a bed of inert granular mineral (like sand) which is heated in a refractory vessel on a perforated plate. Air is blown upward through the holes in the plate at a controlled rate which churns the sand into a turbulent mass like quicksand. After preheating with a gas or oil burner, the refuse is introduced and burns while circulating in the hot sand. Theoretically, there is excellent control and complete combustion. Separation of the residue from the bed material presents a problem.

Pressurized burning may be performed by any of the above methods, in a smaller furnace than normal, by introducing the combustion air under high pressure. The same weight of air is thus contained in a smaller space, so combustion can proceed normally. The additional power required to compress the air is a drawback, but the existence of hot pressurized flue gas offers the thermodynamic possibility of directly operating a gas turbine engine to generate useful power.

D. DISSIPATION OF THE HEAT OF COMBUSTION

A fair amount of interest is being shown in the use of gas-to-air heat exchangers of tubular construction to cool and shrink the flue gases without the corrosion, mud-forming and waste water disposal problems of wet quenching. The heated ambient air can be directly released to the atmosphere without pollution problems, but the tubes must be designed so that they are not blocked or corroded by the raw flue gas emerging from the furnace.

If the heat absorbed in water walls is merely to be dissipated, it is likely that air-cooled condensers will be preferred, because they do not produce a cloud of visible steam in cold weather like cooling towers do, and they do not require large supplies of cooling water as water cooled condensers do.

Perhaps the most sensible prospect, and therefore the concept that may ultimately prevail, is to convert the incinerator furnace waste heat into steam which can be used for one or more of the following purposes.

1. For heat and power required in the operation of the incinerator plant itself.

2. For heat, power and process steam exported to nearby industry, institutions or municipal installations.

3. For power to be fed into commercial electric utility networks.

E. HANDLING OF RESIDUAL SOLIDS

As the burning process developed, there has been improvement in the "quality" of the residual materials, but the ever-increasing quantities of residue and the form of it -- dust, sludge and miscellaneous incombustibles -- make it likely that continued attention will be paid to application of modern materials handling techniques.

Hand cleanout of siftings will almost certainly disappear in favor of automatic siftings collection by mechanical, pneumatic, or sluice-type conveyors. Hot collection of stoker residue with quenching by water spray in a hopper will probably be replaced entirely by direct quenching of the residue in water filled sumps. The all metal drag-link conveyor, while presently the most popular residue handling system, is likely to see competition from the less costly European type systems of swinging metal pushers to lift the cooled residue from the quench tank, followed by rubber belts or metal plate type belts to transport it to the disposal point.

It is also probable that there will be continued efforts to separate metal cans and bulky items from the dust, sludge and minerals of the residue, not only for the possible salvage of the metal (burned out tin cans have certain value as scrap and for metallurgical processing), but to make the non-metallic residue more valuable as high quality fill. As an alternative, the cans and clinkers may be crushed or ground to reduce the volume and improve the homogeneity of the total residue.

F. AIR POLLUTION CONTROL

It is the consensus of the industry that improvements in air pollution control systems and equipment will be the most immediate significant change in the next generation of municipal refuse incinerators. Although municipal incinerators contribute only a few percent to the total air pollution of a metropolis, the clearly visible tall chimneys with their plumes of smoke, or even white steam, the lingering mental association between incinerators and smoky, odorous burning open dumps, the occasional fallout of dust and flakes of charred paper from old systems with little air pollution control equipment have made the public conscious of municipal incinerators as pollution makers rather than pollution controllers. The methods and equipment for air pollution as control to almost any degree desired are commercially available. The problem has been a lack of enforced air pollution control standards, and the desire to "economize" in the purchase and construction of central incinerators.

Engineering studies have indicated that in order to comply with the more stringent air pollution codes now in existence or being prepared, a modern municipal incinerator might require 94 percent overall collection efficiency with a fractional efficiency of about 75 percent by weight collected of all particles sized five microns and below.

These efficiencies can be obtained with high quality mechanical cyclones, wet scrubbers and filter bag collectors with a fan-powered induced draft system. With natural draft alone, they can only be achieved with electrostatic precipitators. Odors and true smokes of submicronic particles can be virtually eliminated by proper combustion control in the furnace, although bag filters and electrostatic precipitators can collect smoke particles, and wet scrubbers can dissolve out certain odorous or noxious gases.

It is expected that there will be a strong movement toward electrostatic precipitators and high performance wet scrubbers. The electrostatic precipitators operate on the principle of electrostatically charging the particles in a gas stream by passing them through the corona of a high voltage (upward of 40,000 volts) conductor. The charged particles are carried at very low velocity between oppositely charged electrical plates where they are attracted out of the gas stream and cling to the plates. At intervals, the plates are shaken and the accumulated dust falls into hoppers. Electrostatic precipitators are large and relatively expensive because they must handle large volumes of gas at low velocity. They can have difficulties if the particulates will not accept and hold the electrical charge because of high temperature or chemical composition. If the fats and greases of refuse have not been properly burned in the furnace, they can condense in the precipitator and cause malfunction and fire. Also, large flakes of burned paper can sail right through them if not otherwise trapped and collected. Nevertheless, they have been used quite successfully on European incinerators and will be used on American incinerators, both for upgrading existing installations and for new installations. Waterwall furnaces or waste heat boilers, which cool and reduce the volume of the flue gases will permit use of smaller and less costly electrostatic precipitators.

Wet scrubbers and also water quenchers, tend to saturate the hot flue gases with water vapor. As the flue gases emerge from the stack and encounter cold air, some of the water vapor condenses into visible steam. The public tends to confuse this harmless steam with smoke, so it is expected that future scrubbers will be equipped with heat exchangers to reheat the scrubbed flue gases using furnace heat, to reduce the incidence of visible steam plumes. If the scrubbing water is kept cold, the flue gases will be cooler and less moisture will be picked up in the scrubber. For this, settling ponds with spray coolers and ordinary cooling towers may be called upon to cool the recirculating water.

Mechanical cyclones should also appear in upgraded existing incinerators and in some new ones. Unfortunately, there has been some poor experience with improperly designed equipment, inadequate draft, and carried-over quench water and it will be difficult to convince the buying influences that these problems can be overcome through competent engineering.

Bag filters suck the flue gases through the woven fabric walls of special bags, like vacuum cleaner bags. A pre-coat of dust forms and thereafter catches just about all the solid matter entrained in the gas stream. The multiplicity of bags are contained in a large structure (baghouse) and equipped with automatic devices to divert the gas stream and shake the collected dust off the bags and into hoppers at appropriate intervals. Bag filter installations can do a near perfect job of dust collection, but they are expensive, and require considerable power and maintenance. It is believed that other methods of air pollution control will be accepted more readily on future incinerators.

It is also likely that there will be increased use of induced draft fans specially designed for municipal incinerator use. These will be of heavy duty, abrasion resistant and corrosion resistant construction for reliability; and will include flow control by variable speed or by efficient damper systems. Because the induced draft fans on large incinerators may require 100 or more horsepower, more attention will be given to fan efficiency and durability, rather than to lowest first cost.

G. CONTROLS AND INSTRUMENTATION

Industrial process instrumentation and controls are a highly developed art and future incinerators may be instrumented and atuomated to almost any desired degree. However, it is expected that municipal incinerators will not go very far toward fully automated or computer-controlled operation in the next few years because municipalities will continue to look toward their refuse disposal operations as sources of employment for many unskilled and semi-skilled people. Also, the fact that these people will be engaged in the operation of incineration systems will lead to the adoption of automatic controls for certain critical parameters like furnace temperature and percent of carbon dioxide in the flue gas; and very simple, perhaps color coded, "on - off" type signals and push buttons for the less critical functions. Read-out instruments giving the precise numerical value of each temperature and pressure in the system may not be considered worth their cost.

H. PROTECTION OF EQUIPMENT AND PERSONNEL

As the sophistication and cost of municipal refuse incineration system equipment increases, it is logical to suppose that continued attention will be paid to protection of the capital investment. For reasons of economy and efficiency, however, it may be that municipal incinerator structures will have less future emphasis on traditional architecture (like a town hall or a school) and tend more toward weather resistant unenclosed furnaces and ducting, and minimum functional enclosure of offices, workshops and critical equipment.

In keeping with the generally increasing social consciousness, it is expected that there will be additional safety provisions, training, comfortable work stations and uniformed technicians and skilled managers whose service to the community can be rendered with dignity and professional satisfaction.

SECTION V

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PART 5

INCINERATOR AIR POLLUTION CONTROL EQUIPMENT

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SECTION I

SUMMARY AND CONCLUSIONS

This report presents the performance capability of the major classes of air pollution control equipment. More knowledge of incinerator pollutants is required, and some application research must be conducted if this equipment is to be applied to incinerators with optimum results. Air pollution control equipment if properly designed, installed and maintained can meet stringent air pollution regulations.

Of first importance to incinerator air pollution control is proper combustion within the burning system. Under these conditions, high efficiency mechanical collectors, wet scrubbers, electrostatic precipitators, and fabric collectors can meet present and projected incinerator air pollution control regulations. However, conventional wet and dry settling chambers will usually not be satisfactory.

The relative capital and operating costs, water requirements and pressure drops for different air pollution control systems are also presented together with design charts for system selection. It is concluded that technology is not the limiting factor in controlling air pollution; rather it is the communities' willingness to finance the additional cost for sophisticated air pollution control equipment. It is estimated that present and projected emission levels can usually be obtained for a cost not exceeding 15 percent of the total plant cost.

Finally, it is concluded that visual observations are not an accurate means to determine incinerator stack emissions. Measurement of the pollution control capability of the burning system by sampling of the flue gas is recommended. Although an incinerator stack may appear reasonably clean because of the diluting effect caused by the extremely large quantities of air usually introduced into the burning system, the fly ash load in the gas may be excessive.

SECTION II

INTRODUCTION

This section of the report discusses the problem of incinerator air pollution and its control. The problem of refuse disposal is inextricably involved with the problem of air pollution regardless of the method of disposal. Incineration offers the opportunity to remove offensive odors and to reduce the bulk of the refuse to a sterile landfill, but it can be a significant contributor to the air pollution problem in an urban community. The primary air pollution concern is with particulate emission rather than gases or odors; therefore, the emphasis in this section will be on particulate emission.

There have been comments that a well run incinerator does not need particulate collection equipment. Many systems with little or no air pollution control equipment have been represented as effectively meeting dust emission requirements when they actually do not. This occurs because the excess air used for combustion and cooling is so great (200% to 500% excess air) that it dilutes the effluent to the extent that it does not appear objectionable, although excessive quantities of dust are actually emitted. With the trend toward large efficient incinerators located close to the population centers served, effective control of incinerator atmospheric pollution is extremely important.

The degree of gas cleaning to be required and the cost of the primary control equipment will be discussed in the sections to follow. Relative costs for various degrees of control will also be presented. It should be understood that data in this section is based primarily on knowledgeable technical opinions. The time and effort were not available to completely investigate all the numerous incinerator parameters affecting the stack effluent. This portion of the study addresses itself particularly to the large, continuously fed incinerator common to modern municipal practice.

SECTION III

SYSTEM EQUIPMENT CONSIDERATIONS

In an incinerator, continuous, rather than batch, feeding of the refuse can reduce air pollution. Continuous feeding permits greater control over furnace temperature and therefore influences the completeness of combustion. Other design and operating factors which insure low fly ash emission from an incinerator furnace are:

1. Excess air should be maintained between 50 and 150 percent to insure proper burning and control of furnace conditions.

2. Furnace exit temperature should be held between 1,400°F and 1,800°F to minimize slagging and to eliminate stack odors.

3. Furnace design must allow sufficient residence time for combustion to be completed.

4. Overfire air should account for from 20 to 40 percent of the total air and should be introduced into the furnace in such a manner that it insures sufficient turbulence for complete combustion.

5. Gas quenching or heat removal should be arranged so that it does not affect combustion. If water quenching is used, it should be arranged to remove some of the larger fly ash particles.

With good combustion, the limited amount of fly ash produced is very fine and is difficult to capture in the collector. It is, however, well within the capability of present technology to capture most of the particulate matter.

The advent of polyvinylchloride (PVC) and other plastics that contain a high percentage of chlorine and/or fluorine (Teflon) may subject incinerator metals to severe corrosion attack. The problem is particularly acute during periods of start-up and shutdown when the chlorine and other halogens as well as sulfur combine with the plentiful moisture in the flue gas to form highly corrosive acids. During normal operation, the higher temperature diminishes the danger of formation of the corrosive elements. If water quenching or gas scrubbing is incorporated into the incineration system, special metals must be used to handle the corrosive acids formed and the water must be treated to neutralize the acid attack. Gas quenching is necessary in U. S. incineration practice, since water walls or other heat exchangers are not normally used, and since the furnace exit temperature is usually in excess of 1,500°F, the cost of fans and fly ash collectors which could withstand these temperatures is prohibitive.

Much peripheral equipment has a direct bearing on the performance of the fly ash collection equipment. Improper gas ducts leading to the collectors can upset gas and dust distribution, thereby affecting collector performance. The collection equipment designer must analyze the flow and incorporate proper ducting.

Dust hoppers are secondary collectors or settling chambers as well as dust storage space. The hoppers must be liberally sized and not allowed to fill completely if they are to accomplish the final state of gas-dust separation as intended. Ash removal systems must be properly engineered and automatic continuous hopper emptying is preferable. Continuous hopper discharge insures maximum hopper space for dust separation.

All collector performance reported in this part of the report was obtained from tests made in accordance with methods and procedures established by the American Society of Mechanical Engineers' Power Test Codes Nos. 21 and 27. Similarly, all dust sizing data reported has been determined in accordance with ASME Power Test Code No. 28.

SECTION IV

INCINERATOR PARTICULATE EMISSION

The quantity and size of particulate emission leaving the furnace of an incinerator varies widely, depending on such factors as the refuse being fired, method of feeding, operating procedures and completeness of combustion. The information presented below includes some results obtained by Combustion Engineering, Inc., and published data from a number of other sources. This study has shown the need for more knowledge of incinerator emissions.

The rate of furnace dust emissions has been reported to vary from less than 10 pounds to as much as 60 pounds of dust per ton of refuse burned. High performance, compact, turbulent incinerators of the type considered here operate close to the middle of this range, or about 35 pounds per ton. In practice, dust loadings are reported in various ways. This 35 pounds per ton may be reported as:

3.5 pounds per million Btu (assuming 5,000 Btu per pound refuse).

2.97 pounds of dust per 1,000 pounds of flue gas adjusted to 50 percent excess air.

1.58 grains per standard cubic foot adjusted to 50 percent excess air.

These dust loadings refer to conditions "leaving the furnace". It should be understood that this means leaving the combustion zone, including any after-burner or secondary furnace, and ahead of the quench chamber.

Dust sizing, like dust loading, varies widely. Most of the same factors which affect the dust loading of the gas also affect dust sizing. Improved incinerator performance, which reduces dust quantities, also decreases the size of the individual particles. The dust is always quite heterogenous, consisting of rather typical fly ash combined with large, low density flakes. Dust density has been found to vary from an average of slightly over two grams/cc (125 $lbs./ft.^3$) to as high as 3 grams/cc (187 $lbs./ft.^3$). The dust size as determined in the BAHCO centrifugal classifier, using the methods and procedures of the ASME Performance Test Code No. 28, indicate a size range distribution as presented in Figure 1. From this figure, it is evident that on the average about 35 percent of the dust leaving the furnace is below ten microns (1 micron = 3.94×10^{-5} inches) and represents a difficult dust to collect. Settling chambers and spray chambers do not remove sufficient quantities of this dust to meet even lenient air pollution regulations, and more sophisticated equipment must be used.

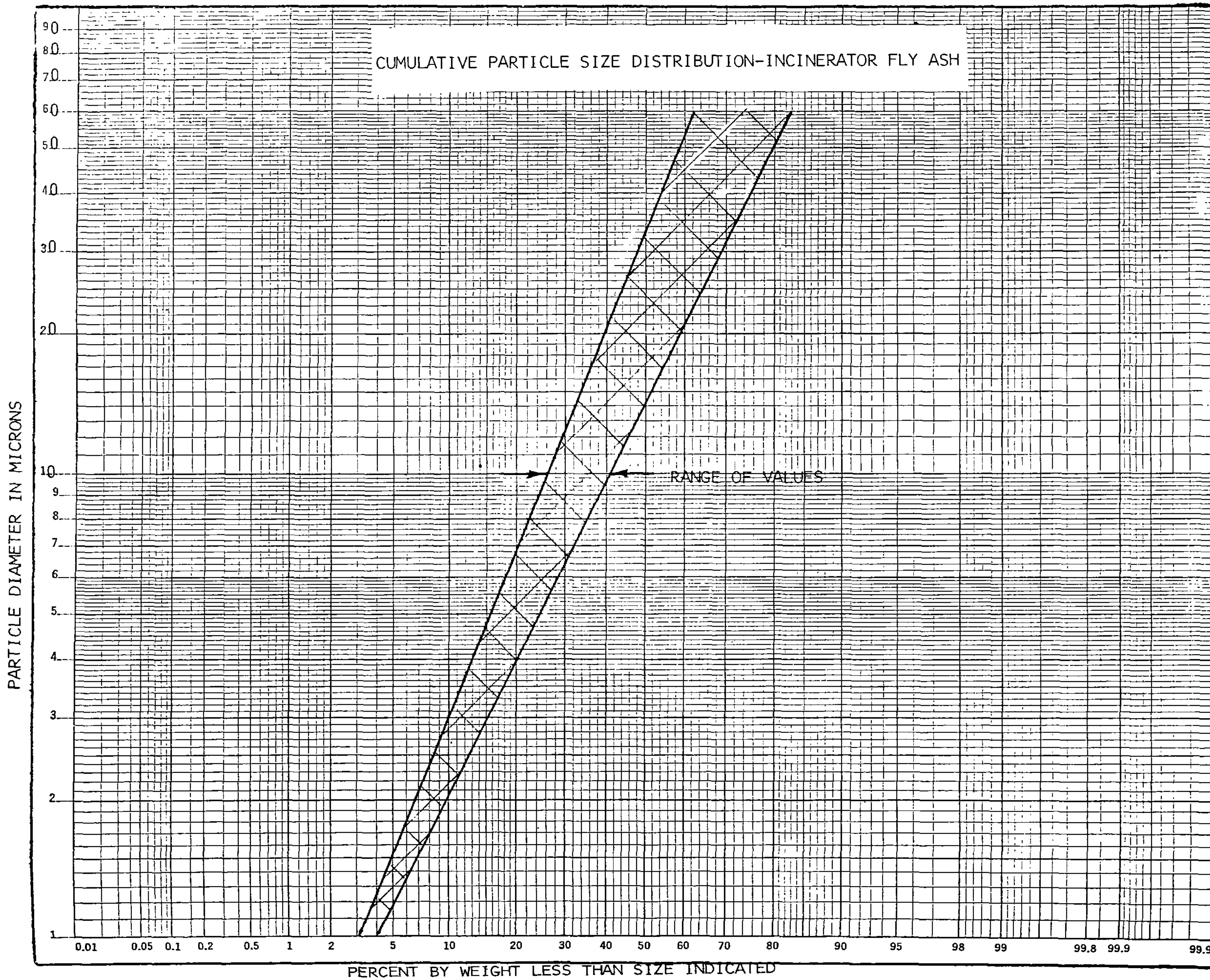

CUMULATIVE PARTICLE SIZE DISTRIBUTION-INCINERATOR FLY ASH
PARTICLE DIAMETER IN MICRONS
90
80
70
60
50
40
30
20
10
9
8
7
6
5
4
3
2
1
RANGE OF VALUES
0.01
0.05
0.1
0.2
0.5
1
2
5
10
20
30
40
50
60
70
80
90
95
98
99
99.8
99.9
99.99
PERCENT BY WEIGHT LESS THAN SIZE INDICATED

Figure 1

SECTION V

EMISSION STANDARDS

The foregoing discussion has indicated the size and quantity of the dust generated in a modern, well run incinerator. The question remains as to how much of this is to be emitted to the atmosphere. Present day good practice controls to 0.85 pounds of fly ash per thousand pounds of flue gas, adjusted to 50 percent excess air (1 pound per 10^6 Btu), as suggested in the "1949 ASME Example for a Smoke Regulation Ordinance". The ASME published a new suggested regulation in 1966 entitled "Recommended Guide for the Control of Dust Emission - Combustion for Indirect Heat Exchangers". It seems reasonable to assume that this document will receive the widespread acceptance that the earlier suggested ordinance did. Thus, one should expect future codes to lower the allowable emission from 1.0 to 0.80 pounds of fly ash per million Btu or 0.68 pounds of dust per thousand pounds of gas corrected to 50 percent excess air. This seems a reasonable level for most installations. The only exceptions might be in the larger more congested metropolitan areas or in an area with adverse topography such as the Los Angeles basin. Many of these areas may wish to adopt the recent Federal Facilities Regulations published in the Federal Register, Volume 31, No. 107, June 3, 1966. These regulations limit emissions to 0.6 pounds of dust per million Btu fired for incinerator capacities up to approximately 25 tons per day and a gradual decrease from this level with larger capacities. A 250 ton per day unit would only be allowed 0.4 pounds of fly ash per million Btu. Figure 2 has been included to illustrate these various control standards.

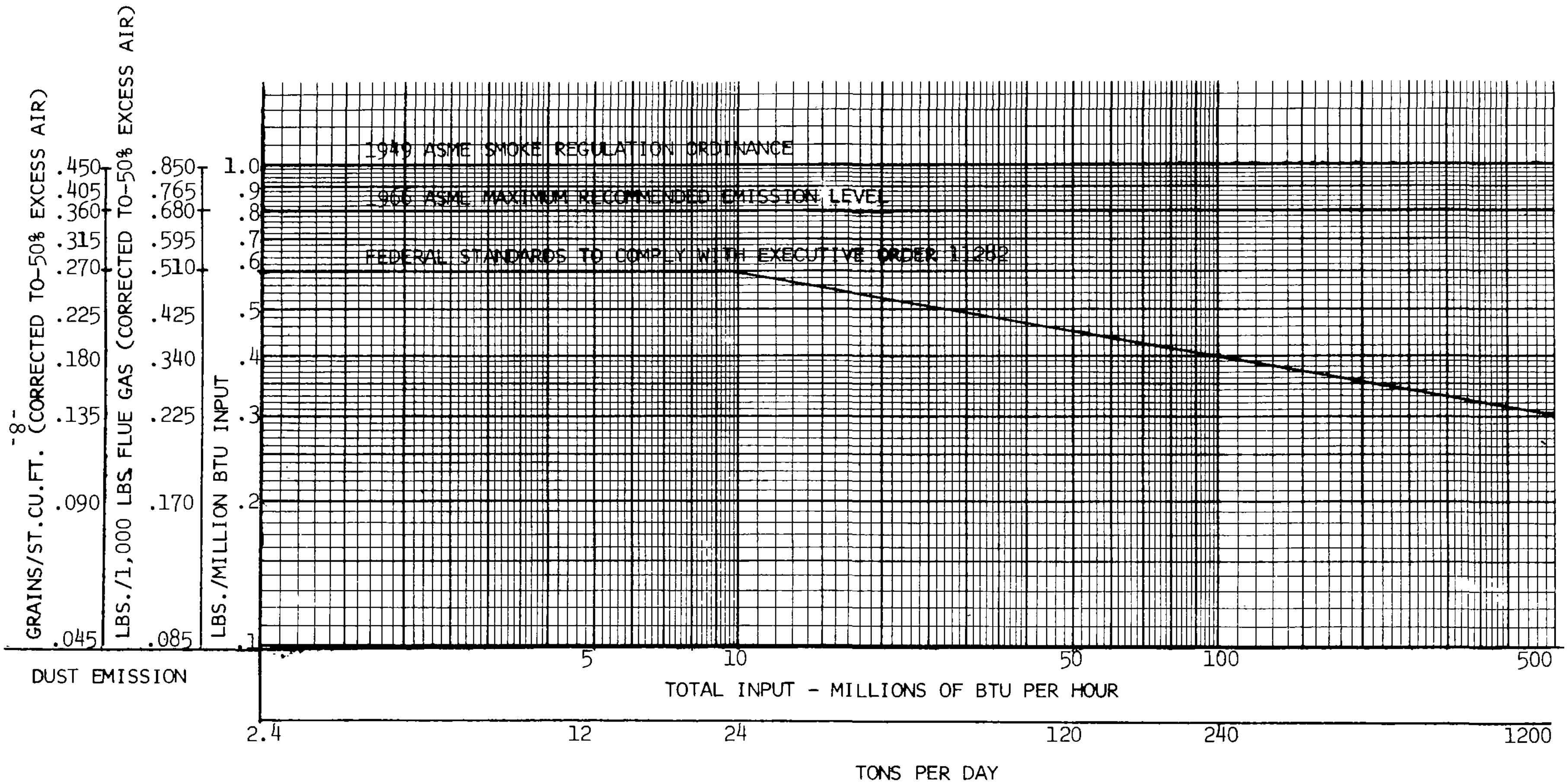
Since particulate emissions from large incinerators are of major concern to the community, there exists a trend to tighten regulations and this is being spearheaded by certain communities. Among them are the following:

	Maximum Allowable Emission	
Community*	Lbs./10^6 Btu	Lbs./10^3 Lbs. of Corrected Flue Gas**
New York City	0.77	0.65
Detroit, Michigan	0.35	0.30
Cincinnati, Ohio	0.47	0.40
San Francisco Bay Area	0.44	0.38

* Reference: "A Compilation of Selected Air Pollution Emission Control Regulations and Ordinances", H.E.W. Report A65-34.
** Corrected to 50 percent excess air.

These codes have the added advantage that they do not relate the allowable emission to the pounds of refuse burned. This is considered poor practice because the refuse varies widely in composition and heating value. It is much more desirable to know the heating value and relate the permissible

MAXIMUM ALLOWABLE PARTICULATE EMISSION
FOR COMBUSTION UNITS



FUEL:
STOKER - FIRED REFUSE
HHV - 5000 BTU/LB.

EXTRACTED FROM:
FEDERAL REGISTER, VOL. 31, NO. 107, 6-3-66
ASME STANDARD, NO. APS-1, 6-15-66

Figure 2

emissions to the Btu input. Most codes also include opacity or optical density of smoke limits. These had considerable value at the turn of the century when an effort was underway to improve combustion and to reduce the objectionable unburned effluent. This is no longer the case, and if an incinerator plume exhibits more than a number one Ringelmann[1] reading, the plant is probably being improperly operated and this should be corrected. Dust collecting equipment can not be expected to compensate for faulty operation.

Opacity regulations should not be used in a quantitative manner because the measurement is empirical in nature and has definite limitations. The apparent opacity of a stack plume depends upon:

1. Concentration of particulate matter.

2. Size of particulate matter being transported.

3. Color of particulate matter.

4. Variation in stack outlet velocity.

5. Depth of plume (stack diameter).

6. Natural lighting conditions including intensity and background.

7. Direction of the sun relative to the observer.

8. Amount of excess air employed.

9. Water vapor in the plume.

10. Training of the observer.

In place of the opacity requirements, the following factors should be given consideration in developing air pollution regulations:

1. A safe emission level for the size of plant and the topography about the plant should be established.

2. All allowable emissions should be applied to the operational level of the plant and not to the plant's design point.

3. The maximum size of particle to be emitted should be limited.

4. Regulations should be based on heat input or corrected to standard conditions.

5. Adjustments for stack height should be allowed.

The projected levels of emission discussed here are all within the capability of present technology; it is essentially a matter of economics. If the community is willing to establish and police rigorous standards and to pay for the necessary gas cleaning equipment, the incinerator can be a good neighbor.

SECTION VI

INCINERATOR AIR POLLUTION CONTROL EQUIPMENT

The previous paragraphs made reference to the ability of modern technology to cope with more stringent air pollution control regulations. Equipment capable of accomplishing this task will now be discussed. Air pollution control of incinerators is a unique field with many peculiar problems which must be solved. Before the various devices and their capabilities are discussed, it should be noted that equipment performance is significantly affected by the completeness of combustion, operating procedures and the adequacy of maintenance. The following presentation assumes a modern, properly designed, operated and maintained incinerator plant.

The early steps toward the reduction of particulate matter emitted from an incinerator stack included the use of a settling chamber or combined settling chamber-spray coolers. Dry settling chambers on normal incinerator fly ash approach 20 percent efficiency if they are properly designed and are large enough to sufficiently reduce the gas velocity. The combined settling chamber-water spray gas cooler, when correctly designed, can remove 30 percent of the fly ash leaving the furnace. This combination gained popularity because they offered additional volume to complete combustion. Before the advent of modern incinerators with their controlled refuse feed and large furnace volumes, settling chambers gave a needed additional combustion volume and removed the large unburned flakes, or "blackbirds". Today, the secondary chamber is smaller or non-existent. It may be much smaller if its essential purpose is water quenching of the gas to a temperature acceptable to the air pollution control equipment (APCE) and induced draft fans. The temperature of gases leaving such spray chambers is usually about 600°F. If, on the other hand, the gas shrinking and cooling is accomplished by indirect heat exchange, such as in a boiler or gas to air heat exchanger, no settling chamber is required. Because the large settling chamber requires considerable space and is insufficient for the complete gas cleaning task, it is not expected to be used as frequently in the future.

The mechanical (cyclone) collector is the next step up the ladder of air pollution control equipment performance and cost. It usually consists of either of two basic types -- the multi-cyclone or the large involute cyclone. The multi-cyclone units are made up of numerous axial inlet (vaned) mechanical collecting tubes which vary in diameter from 6 to 10 inches and are arranged in a tube sheet to receive the incoming dirty gas. The inlet spinner vanes impart a swirl to the gas which creates a strong vortex within the main tube. This vortex centrifugally separates the dust from the gas stream and allows the clean gas to proceed up the outlet tube which connects to a second tube sheet. This sheet separates the inlet dirty gas from the leaving clean gas. Separated dust moves down to the lower outlet and settles in the dust hopper.

Multi-cyclones are in common use in industry today and most of their performance parameters are known. This type of collector is extremely efficient on large particles, but performance drops off rapidly for dust sizes smaller than 20 microns (78.74×10^{-5} inches) and they are not very satisfactory on dust sizes less than 10 microns where about 35 percent of the incinerator fly ash falls (see Figures 1 and 3). Flow through the dust hopper caused by gas flowing out of one tube and into another can seriously affect performance. This is always present unless inlet gas distribution is perfect and no tubes are plugged. Sticky or wet dust will plug the inlet spinner vanes causing cross hopper flow. When all tubes are clean and the vortex is sufficiently strong (3 1/2 in. w.c.* pressure drop) the multi-cylcone dust collector can attain 80 percent collection efficiency on incinerator fly ash, but if about a third of the tubes become plugged, the efficiency may drop to as low as 20 percent.

The second type of mechanical collector, the large (over two feet in diameter) involute type cyclone, operates on the same basic principle as the multi-cyclone. Its performance is usually similar to that of the multi-cyclone except when it is equipped with a flow splitting inlet manifold and separate dust hoppers. This arrangement is usually free of plugging and cross-hopper flow problems. There is a place in modern incinerator design for mechanical collectors, but the designers must consider the device's shortcomings as well as its simplicity and cost.

The next most popular class of air pollution control equipment used in incinerators is the wet gas scrubber. Scrubbers have received wide acceptance as gas cleaners by industry. This would seem to be part of the natural evolution in cleaning the gaseous effluent from an incinerator, since the use of the combined settling-spray chamber has been so popular. Although this may be true, it has hurt the proper adaptation of scrubbing principles to incinerators. There is widespread misunderstanding when spray chambers, wet baffle collectors and scrubbers are discussed. There has been adequate data and study in the science of dust collection to dramatically illustrate the ineffectiveness of a simple spray chamber type dust collector. The simplest form of true scrubber is a properly designed impingement wet baffle unit with fine sprays. A scrubber of this design can obtain over 90 percent collection efficiency if the energy expended in scrubbing is sufficient (6 to 8 in. w.c. pressure drop).

To better understand what is involved in true gas scrubbing, the following brief theoretical analysis is offered. Many workers have investigated the various configurations and methods used to scrub particulate from gases, and certain important facts are known. First, the dust particle must impact on the water droplet to be removed and the impaction efficiency was found to be a function of the non-dimensional group $\frac{(Vr.Vs)}{Dg}$, where:

(Vr) is the relative velocity between the water droplet and the dust particle.

(Vs) is the settling velocity for the dust particle.

(D) is the diameter of the water droplet in microns.

(g) is the acceleration due to gravity.

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* Water column

Since (g) and (Vs) are constant for a particular dust particle of a given size, impaction efficiency is essentially a direct function of the relative velocity and an inverse function of the droplet diameter. If collection efficiency is vitally dependent on relative velocity and droplet size, then collection efficiency must be a function of the power supplied to the unit. This fact has been verified by Semrau[2], who found efficiency to have little relation to scrubber design or geometry, but to be dependent on the properties of the dust and on the contacting power. In a later paper[3] he developed the "contacting power rule", which states that the efficiency of a scrubber on a given dust is essentially dependent only upon the power per unit of volumetric gas-flow rate that is dissipated in the gas-liquid contacting process.

This means that very fine sprays must be developed and introduced in such a manner that there is a maximum relative velocity between the dust particles and the spray. Various types of scrubbers are in use which capitalize on these principles. The venturi type produces the spray by drawing the water and gases through a narrow venturi section at high velocities. Since the spray is produced by the high velocity gas while the water and flue gases are in contact, fly ash collection efficiency is high.

Another type of scrubber is the flooded plate type in which the flue gases pass upward through holes in the first plate and impinge on a grid directly above. By maintaining a water seal over the holes, the ash is separated by a combination of impingement and wetting. There are many other types of scrubbers, but those discussed are sufficient to illustrate the difference between gas spraying and scrubbing and the application of the fundamental principles of scrubbing.

The wet scrubber has been used in a few municipal incinerators operating in the area of 6.0 to 8.0 inches w.c. pressure drop, and having a fly ash removal efficiency in the range of 90 to 97 percent. It has the advantage of relative compactness and relatively low first cost when compared with other high efficiency collectors. In order to meet the high particulate removal efficiencies indicated, the equipment normally produces a flue gas which is saturated at the wet bulb temperature of the recirculating water. The specific humidity of the stack effluence is therefore relatively high. A characteristic, then, of the wet scrubber installation is an almost continuous vapor plume at the top of the stack. While this plume is not an air pollutant per se, it has the appearance of being one. The trend in opacity requirements in air pollution regulations may require the elimination of the plume. To accomplish this, the gas must be subcooled to condense out the water and then must be reheated to obtain a dry plume with sufficient buoyancy.

Water rates required in scrubbers are high, and this may introduce a disposal problem. If in the interest of economy recirculation of the scrubber water is practiced, the recirculated water must be suitably conditioned. Indications are that the necessary chemical treatment is complicated and to date few incinerator scrubber systems have performed satisfactorily with recirculation. Even with chemical treatment, scrubber maintenance problems may be affected by the absorption of gaseous acid forming products of combustion by the scrubbing water. Unless materials of construction are carefully selected, maintenance costs and down time may be high, both for the scrubber induced-draft fans and other components in contact with the gas stream. It should be noted that scrubbers are high efficiency dust collection devices; they are non-selective as to the particle composition, and they are capable of removing certain gaseous air pollutants.

In summary, scrubbers are subject to corrosion and expensive metals or metal protection is required. The stack steam plume may be objectionable, but scrubbers have the added advantage in that they will absorb certain gases that would otherwise be emitted from the incinerator. In the past, the pressure drop, along with the problems of corrosion, purification of contaminated water prior to disposal, and costs have militated against their use. They are, however, an attractive enough device that further research on their application to incinerators shoud be given a high priority. Scrubbers of a variety of designs can be successfully applied to incinerators because collection efficiency is a function of the scrubbing energy applied. The energy requirements for efficiencies in the range of 90 to 97 percent vary from 6 in. to 8 in. w.c. pressure drop.

The next class of air pollution control equipment to be considered is the electrostatic precipitator. This device has been used in industry for some fifty years and has built an enviable reputation. In spite of this, the fact remains that there are no precipitators operating on incinerators in the United States at this time. New York City has recently purchased two precipitators for incinerators, and their successful operation may signal a new era for the electrostatic precipitator on American incinerators.

Before discussing a few of the major factors to be considered in the selection of an electrostatic precipitator, it is best to understand the process fundamentals. Simply stated, a precipitator operates by inducing an electrostatic charge on the dust particle by means of a high voltage corona discharge and by passing the charged dust-ladened gas through an electrical field where the charged dust particle is attracted to the grounded collecting surface and the cleaned gas passes to the clean gas outlet. This basic theory sounds simple enough, but the performance of a precipitator is affected by complex relationships with a great number of interrelated parameters.

The strength of the electric field is one of the utmost importance and factors that influence it affect collection efficiency. Another factor is the charging voltage which can range from about 40,000 to over 70,000 volts.

Other factors which seriously affect the dust migration to the collecting plates are dust resistivity, gas temperature, moisture content of the gas, percent of design rating (gas velocity), flow distribution and carbon content of the fly ash.

It has been found that for proper collection efficiency, the fly ash resistivity should be between 1×10^5 ohm-centimeters and 2×10^{10} ohm-centimeters. Dusts with a resistivity less than 1×10^5 ohm-centimeters are difficult or impossible to precipitate, while dust with resistivity greater than 2×10^{10} ohm-centimeters may be collected if the gas is treated to reduce the resistivity.

The general conclusion has been drawn that particles of low resistivity, on making contact with the collector electrode, rapidly part with their charge and acquire a heavy charge of the same polarity as the electrode. When this happens the dust particle is driven back into the gas stream. If on the other hand, resistance of the dust is too high, a back corona forms which interrupts the normal precipitating action and leads to loss in efficiency.

Once the charged particle has been deposited on the collection plate, several processes may be used to remove the dust to the hopper. These include washing, vibrating and rapping. The dislodged particles are agglomerated into large lumps of dust and easily settle into the collection hopper. Experience indicates that incinerator fly ash is fine and fairly sticky and can accumulate on discharge and collecting electrodes and in hoppers normally used for fly ash collection. Special provisions for removal of collected material must be provided.

One might question why the electrostatic precipitator has received such favorable acceptance in industry and why it is considered to hold great promise for incinerators, if it has some of the noted drawbacks. The main reasons for acceptance are the facts that precipitators can be designed for nearly any efficiency required, can operate over a broad spectrum of fly ash concentration and size, and require a nominal draft loss of only about 1/2 to 1 in. w.c.

On properly operating incinerators, precipitators have the potential of collecting more than 95 percent of the dust emitted from the furnace and they collect sub-micron size particles with nearly the same facility as 100 micron particles. Thus the electrostatic precipitator can effectively remove entrained fly ash from incinerator gases and an evaluation is possible between the degree of collection and the relative size and cost of the equipment, allowing the purchaser to match his equipment to the predicted control requirements.

The electrostatic precipitator should definitely be considered for high efficiency air pollution control on incinerators. It is capable of high efficiency operation if it is properly designed for the widely differing service encountered in incineration practice. It is therefore reasonable to predict that this country will follow European practice where precipitators are extensively used on incinerators.

The final class of air pollution control equipment to be discussed is the fabric filter collector. Application of the fabric collector to incinerators is still in the preliminary stage of development because of the high temperature gases and the characteristics of the fly ash. The fabric collector is one of the original cleaning devices, and much experience is available in other industries. In fabric filters the gas passes through the fabric which is usually arranged as tubular bags. The accumulated filter cake on the fabric filter removes the fly ash from the gas stream. Various methods are used to clean the filter -- mechanical shaking, reverse jet blowing, bag collapse, and reverse flow backwash. The released filter cake falls to the dust hopper for removal. In one type of fabric filter collector, the dust-laden gas enters through the top, passes through the bag filter giving up the dust, and the clean gas proceeds to the stack. Filter efficiencies approach 100 percent, but their overall pressure loss may be as high as 5 to 7 inches of water.

Cloth filtration is probably the oldest and most reliable method of removing a high degree of fine solid particulate matter from gases. It has the ability to remove 99.9 percent of the particulate matter, thus insuring practically complete elimination of the plume opacity and making it a very desirable air pollution control system. The filterhouse has not been considered sooner because both the cost of the initial filterhouse and the bag replacements have been prohibitive. Newer materials which guarantee long filter life at higher temperatures have opened the way to the practical application of filter collectors to incinerators. For example, glass cloths allow operation at 500°F. Some research and development work will, however, be required to insure the desired results and incinerator purchasers will have to become accustomed to the higher cost and space requirements for this type of air pollution control equipment. The application of these collectors to incinerators will require even greater control of combustion and moisture to prevent the formation of sticky soot which blinds the filter cloth. Cooling of the gases must be carefully controlled to avoid formation of moisture on the fabric. Either evaporative spray cooling to 700°F with no wetting of the spray chamber followed by cool air dilution to 500°F, or indirect heat exchange to 500°F are feasible methods of gas conditioning. At present, filter collectors are not being used, but the increase of combustibles in refuse and the development of continuous high temperature incinerator operation indicates there is a future potential application for fabric filters in incineration.

To insure proper collection performance with any of the systems discussed, frequent thorough inspection and maintenance of air pollution control equipment is required. If frequent maintenance is not performed, design performance as an operating criterion is meaningless. As a further check on normal operation, some form of pollution survey should be conducted occasionally to see if local air-quality levels affected by a particular unit are up to expectations and are maintaining the desired level of control. Spot checks of dust fall and air conditions at critical locations should be conducted.

This discussion pertains to incinerator emissions, but other polluting activities at the surface level can be very important. Refuse handling systems often present dust problems and must be corrected by wetting agents, and dust-tight handling systems. Ash handling can be another cause for concern if not properly maintained.

Each of the major collection devices has been briefly discussed, and it might be well to ask if the different types can be combined to achieve improved performance at reduced cost. Present practice seems to indicate that there is little advantage of combining collection systems. The type of unit most frequently combined with one of the other collection units is the mechanical collector. It has been used with all three of the other types of collectors, but it is most successfully combined with the electrostatic precipitators. The use of this combination has diminished recently since it has been found that the mechanical collector can either aid or hinder the precipitator's performance, depending on the properties of the ash.

In conclusion, it may be stated that means are available to limit the emission from an incinerator to any desired level, and that incinerator installations of the future can meet community requirements if the community is willing to shoulder the expense.

SECTION VII

INCINERATOR AIR POLLUTION CONTROL EQUIPMENT PERFORMANCE

Now that each of the major classes of air pollution control equipment have been discussed, their performance will be studied in greater depth. Particulate collection equipment performance may be classified in a number of ways, but the most widely accepted criterion is the weight efficiency. The weight efficiency relates the quantity of dust collected to the dust that enters the collector with the gas. This number is only meaningful under conditions similar to those entering the collector during the test, including the given dust size distribution, the entering gas dust loading, the collector energy level, the inlet gas temperature, etc. The results can sometimes be related to other applications if the dust density, size distribution, dust resistivity (if precipitator), collector energy level, and gas condition are known.

A second important collector performance criterion is the fractional efficiency curve (see Figure 3). This is sometimes called the size or grade efficiency curve. It represents the performance of the particular collector on each size of dust particle of a given dust density, for a given collector energy level, gas temperature and dust resistivity (if a precipitator).

The two efficiencies are related and can be computed one from the other if the dust size distribution is known. This is a very important fact since most air pollution control equipment manufacturers would prefer to guarantee the known fractional efficiency performance for their equipment and allow the purchaser to compute the efficiency for his particular dust.

Dust size determinations are now well accepted and follow the method and procedures presented in the American Society of Mechanical Engineers - Performance Test Code No. 28 -- "Determination of the Properties of Fine Particle Matter". Once the size distribution of the dust to be collected is known, the collector weight efficiency on the dust can be computed in the following manner: First, the size distribution data must be broken into size fractions -- 5 microns increments are usually satisfactory, then the average fractional efficiency over this size range is determined from the fractional efficiency curve and the product of the two then produces the percent of the dust in each fraction that the unit is capable of collecting. The sum of the computed percentages is the overall weight efficiency that can be expected of the collector on this dust. The following example illustrates the method, using the fractional efficiency curve given in Figure 3 and the approximate mean size distribution for incinerator fly ash as presented in Figure 1.

Size Fraction	Weight Percent	Fractional Efficiency	Percent Collected
0 - 5	20%	25 %	5.0%
5 - 10	13%	56 %	7.3%
10 - 20	16%	90 %	14.4%
20 - 30	9%	99.5%	9.0%
> 30	42%	100 %	42.0%
		Collector Efficiency	77.7%

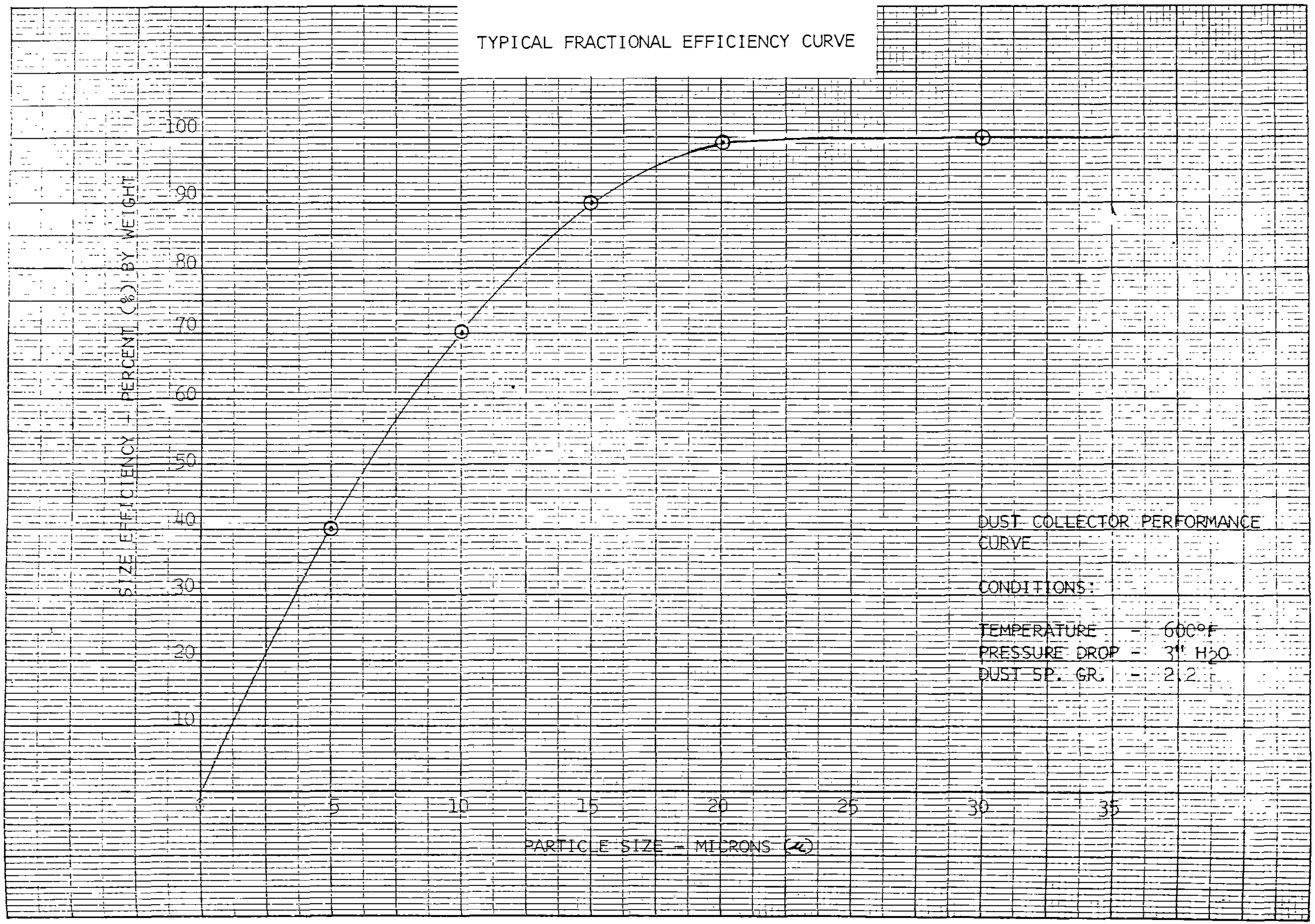
TYPICAL FRACTIONAL EFFICIENCY CURVE
SIZE EFFICIENCY - PERCENT (%) BY WEIGHT
100
90
80
70
60
50
40
30
20
10
0
5
10
15
20
25
30
35
PARTICLE SIZE - MICRONS (μ)
DUST COLLECTOR PERFORMANCE CURVE
CONDITIONS:
TEMPERATURE - 600°F
PRESSURE DROP - 3" H2O
DUST SP. GR. - 2.2

Figure 3

Therefore, the collector whose fractional efficiency is given in Figure 3 would have an efficiency of about 77.7 percent on an average incinerator fly ash. For more details on this method, see ASME's Performance Test Code No. 21. It should be pointed out that average fly ash is like the psychologist's normal man, i.e. very rare. It is, however, a good starting point for an incinerator designer who must design a plant before any fly ash can be generated.

The size and composition of incinerator fly ash and the extremely large quantities of air used in incineration mask the real pollution potential. As a result, stack observations are no measure of an incinerator's pollution control. An accurate determination of the stack emissions can be obtained only by actual test based on samples taken in the duct leaving the air pollution control equipment. It is suggested that test connections be designed into the ducting before and after the primary dust collection equipment. This will permit the accurate determinations of the particulate emission from the stack and the testing of the primary air pollution control equipment to determine if it is functioning properly. Improperly performing pollution control equipment is one major cause of much air pollution. These test connections can be used to verify that the collection equipment is meeting its design criteria and as proof that the stack emissions are within acceptable levels. The necessary connections must be designed into the unit; a makeshift arrangement to accommodate sampling at a later date is at best a compromise.

In an earlier paragraph, mention was made of the present and projected particulate emission standards, and in the foregoing paragraphs various collectors and their efficiencies on a standard incinerator fly ash were discussed. These collector performances are presented in summary form in Figure 4 for ready reference and comparison. The local emission standards may be used as an entry to the graph, and the efficiency required read on the left ordinate while the right ordinate presents the class of air pollution control equipment that could be designed to meet this requirement. As an illustration, if the ASME 1966 maximum emission level from Figure 2 is used, one can enter Figure 4 with the 0.8 pounds of dust per million Btu and read 77 percent efficiency on the left ordinate and on the right ordinate note that a mechanical collector could be designed for this service. Once again, the reader is cautioned that this data is for a properly designed and maintained collector on gas from an incinerator with good combustion conditions. The ranges of performance presented on the right ordinate of this figure indicate areas in which it is reasonable to expect each class of equipment to perform if designed for the service and if proper operating conditions are maintained. It also assumes the equipment is in good order and sufficient energy has been used to obtain the performance. In most cases, the 35 pounds of dust per ton of refuse leaving the furnace assumed as a basis for this graph is a satisfactory starting point. If, for a certain type of incinerator, the designer knows the furnace emission to be greater or less than the assumed 35 pounds per ton, a second line can be drawn radially from the 100 percent efficiency point to the expected furnace emission on the zero efficiency line, and the graph used as before for these new conditions.

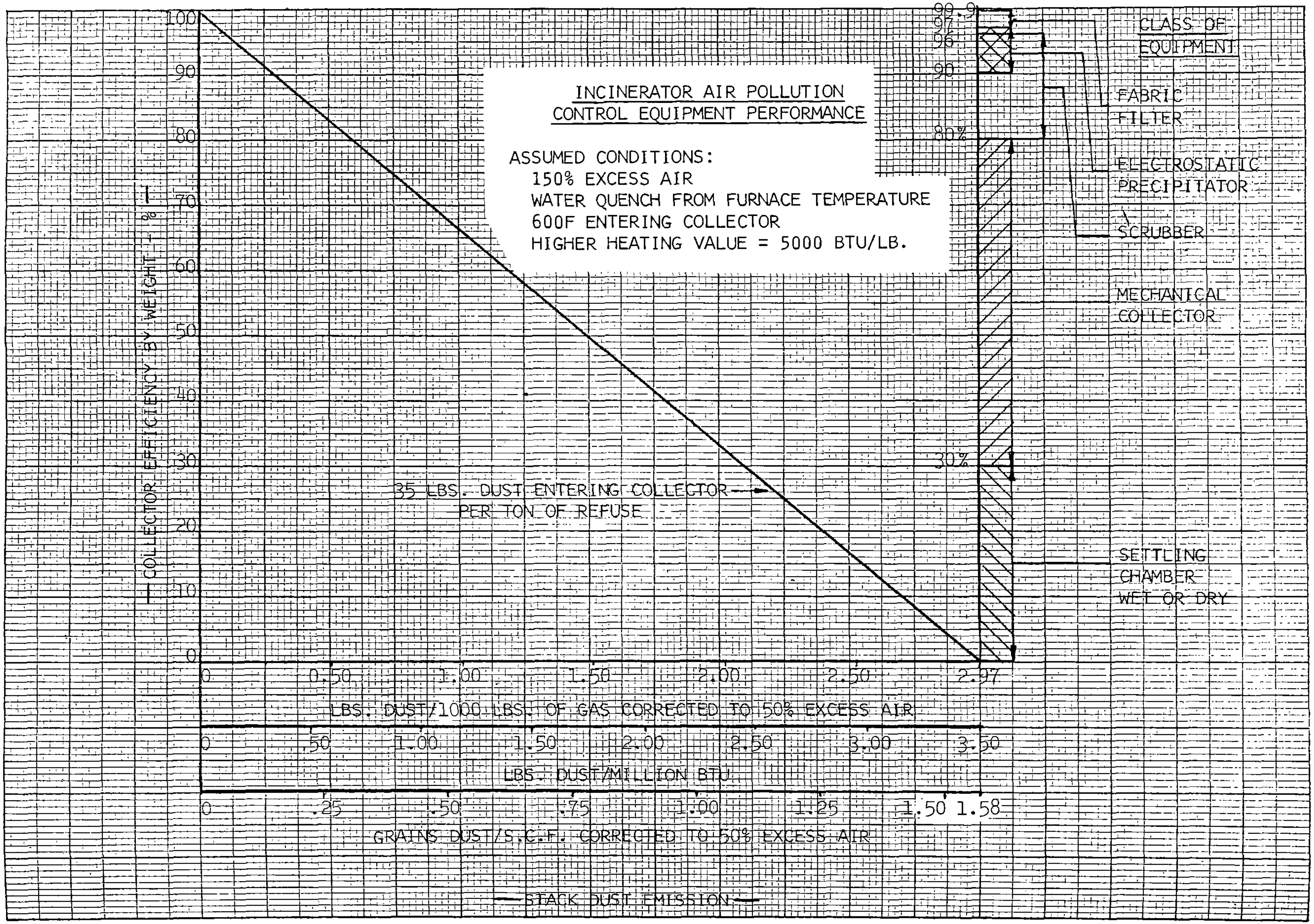
INCINERATOR AIR POLLUTION
CONTROL EQUIPMENT PERFORMANCE
ASSUMED CONDITIONS:
150% EXCESS AIR
WATER QUENCH FROM FURNACE TEMPERATURE
600F ENTERING COLLECTOR
HIGHER HEATING VALUE = 5000 BTU/LB.
COLLECTOR EFFICIENCY BY WEIGHT - %
35 LBS. DUST ENTERING COLLECTOR PER TON OF REFUSE
CLASS OF EQUIPMENT
FABRIC FILTER
ELECTROSTATIC PRECIPITATOR
SCRUBBER
MECHANICAL COLLECTOR
SETTLING CHAMBER WET OR DRY
99.9
97
96
90
80%
30%
LBS. DUST/1000 LBS. OF GAS CORRECTED TO 50% EXCESS AIR
LBS. DUST/MILLION BTU
GRAINS DUST/S.C.F. CORRECTED TO 50% EXCESS AIR
STACK DUST EMISSION

Figure 4

This graph illustrates that with today's technology, good pollution control is possible on modern incinerators. As mentioned earlier, the highest efficiency collectors may require additional development to achieve their full potential, but are available to the industry today.

SECTION VIII

COST OF AIR POLLUTION CONTROL EQUIPMENT FOR INCINERATORS

Now that incinerator emissions have been discussed, the projected emission regulations reviewed, and the equipment to meet these regulations presented, the cost to incorporate these various collectors into an incineration system will be studied. It is extremely difficult to precisely pinpoint the price of a particular class of air pollution control equipment. Prices vary substantially from one vendor to another, and with conditions such as the prestige potential of the job or a lack of sufficient vendor backlog. In addition to these factors, certain improvements in performance and reliability cost more than a less sophisticated design of the same class of control equipment. Therefore, all values presented in this section must be considered estimates representative of a range of possible values. Relative costs given here are reported for uninstalled bare equipment, f.o.b. the factory. It is nearly impossible to quote "designed and erected" values because local construction uncertainties and costs are unpredictable. The local architect-engineer involved in a particular design is best equipped to estimate the cost of the air pollution control equipment for a given plant. A very rough estimate of the erected price of the air pollution control equipment only, minus any ancillary equipment, may be obtained by doubling the f.o.b. prices. This factor of two should be recognized as a probable median value from a range of values that begin around 1.5 and may go as high as three.

The approximate relative cost per ton per day presented on Figures 5 and 6 was developed on the basis of the following assumptions:

1. A 600°F inlet gas temperature to the device.

2. One hundred fifty percent excess air used to burn the refuse.

3. A 5,000 Btu/pound refuse burned.

The first assumption of 600°F was selected because this temperature allows the use of fairly standard air pollution control equipment, I.D. fans and duct designs. It also insures adequate buoyancy at the stack outlet to assist in the dispersion of the flue gas. One hundred fifty percent excess air was assumed because it is felt that the continued use of some air quenching of the gas will be practiced. With air in excess of 150 percent, there may be insufficient furnace temperature and residence time to eliminate smoke and odors. A refuse with a 5,000 Btu/pound heating value was used because this is very near the present average value of mixed refuse and the trend is to even higher values in the future. Corrections for variations in heating value are presented elsewhere in this report, and they may be applied to this work, if adjusted to correct for the specific plant applications. These assumptions reduce to approximately 520 CFM per ton per day of capacity if the gas cooling is accomplished with water quenching from the refractory lined furnace exit temperature to 600°F. If the cooling is performed indirectly by water heating or steam generating surfaces, or by an air heating device, the quantity of gas to be handled is substantially reduced (See Figure 7).

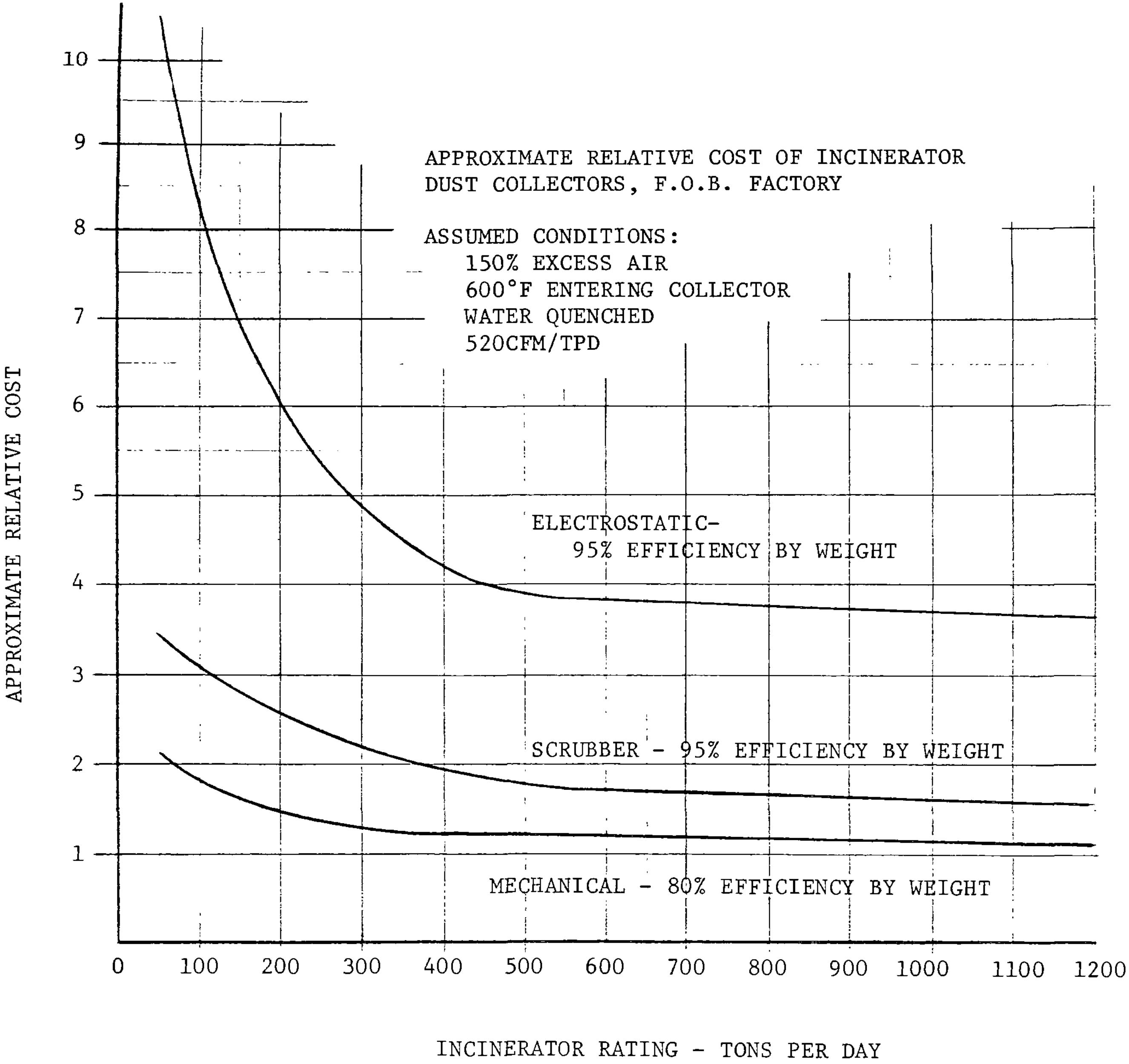
APPROXIMATE RELATIVE COST OF INCINERATOR
DUST COLLECTORS, F.O.B. FACTORY
ASSUMED CONDITIONS:
150% EXCESS AIR
600°F ENTERING COLLECTOR
WATER QUENCHED
520CFM/TPD
ELECTROSTATIC-
95% EFFICIENCY BY WEIGHT
SCRUBBER - 95% EFFICIENCY BY WEIGHT
MECHANICAL - 80% EFFICIENCY BY WEIGHT
APPROXIMATE RELATIVE COST
10
9
8
7
6
5
4
3
2
1
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
INCINERATOR RATING - TONS PER DAY

Figure 5

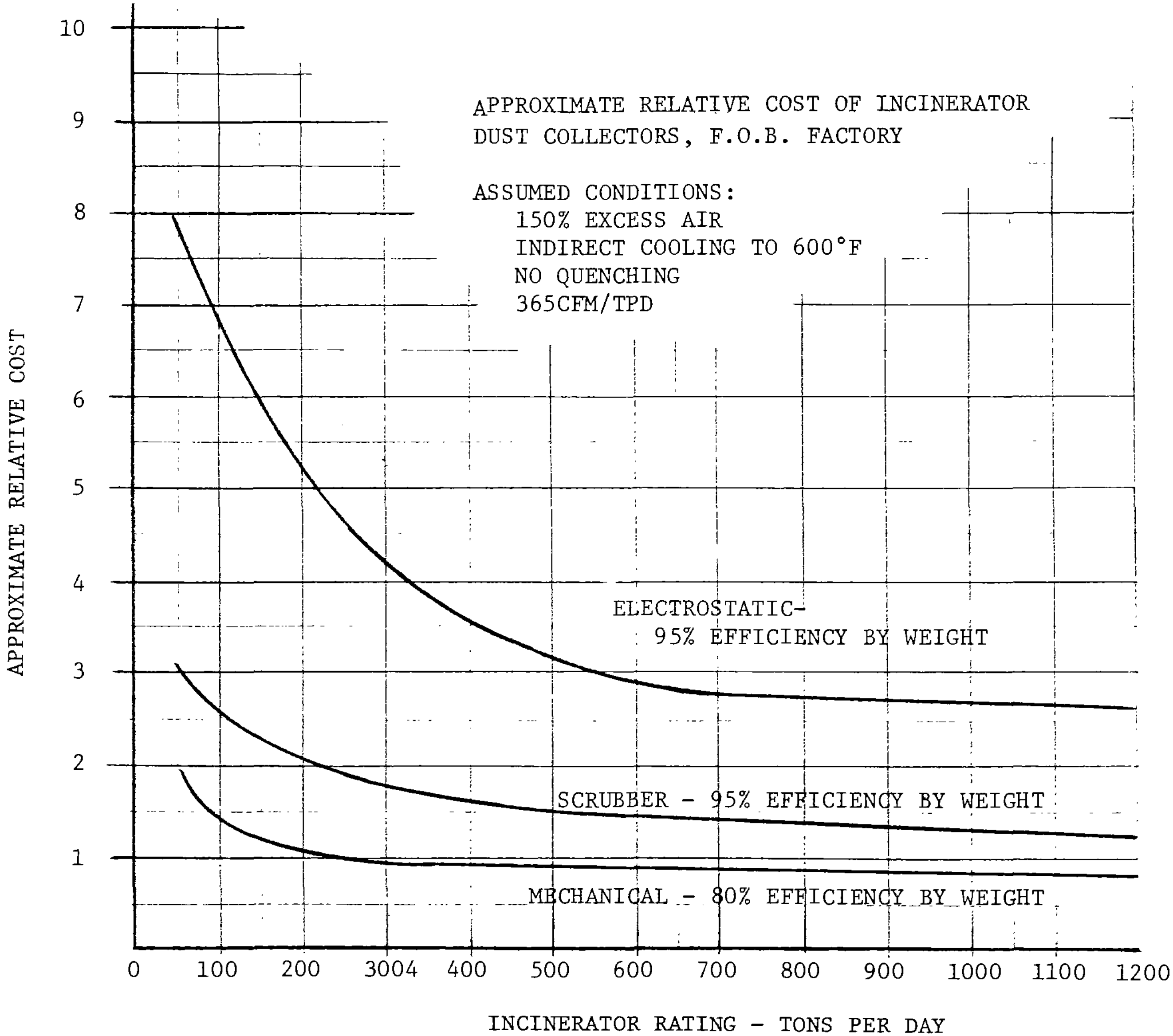
APPROXIMATE RELATIVE COST OF INCINERATOR
DUST COLLECTORS, F.O.B. FACTORY
ASSUMED CONDITIONS:
150% EXCESS AIR
INDIRECT COOLING TO 600°F
NO QUENCHING
365CFM/TPD
ELECTROSTATIC-
95% EFFICIENCY BY WEIGHT
SCRUBBER - 95% EFFICIENCY BY WEIGHT
MECHANICAL - 80% EFFICIENCY BY WEIGHT
APPROXIMATE RELATIVE COST
10
9
8
7
6
5
4
3
2
1
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
INCINERATOR RATING - TONS PER DAY

Figure 6

The volume of gas to be handled in this latter case is only approximately 365 CFM per ton per day of capacity. If combustion is completed with 50 percent excess air and steam generating surface is used to control furnace temperatures and cool the gas to 600°F, the volume of gas is reduced to approximately 220 CFM per ton per day of capacity.

Figures 5 and 6 present the best estimates of relative f.o.b. factory prices for high efficiency mechanical collectors (η = 80%) and 95 percent efficient incinerator precipitators and scrubbers of varying capacities. Scrubbers are veiled in the misunderstandings mentioned earlier, but for the type suggested in this section, the price should be approximately the relative values given in Figures 5 and 6.

No fabric filter unit has been considered for installation to date, and it is difficult to estimate the probable price for the various sizes of incinerators. This study developed information that indicates that the factory cost of a fabric filter would be nearly the same as that of a precipitator. So, by reading the precipitator values from Figures 5 and 6, fabric filter prices may be approximated.

Figure 7 graphically presents the advantage in capital cost reduction for the air pollution control equipment, I.D. fan, ducting and stack when the flue gas is cooled indirectly. The difference is nearly directly related to the difference shown on this graph since dust collectors are sized by actual volume rate of gas to be handled. This difference justifies serious consideration of the utilization of heat generated in an incinerator. If the energy released were used to supply the power to run the incinerator plant, or to heat the plant and surrounding buildings, this energy saving could offset the additional cost of the converting equipment and the operating savings could possibly reduce the cost of incinerating the refuse. Another alternative would be to generate hot water, steam or hot air and dissipate the heat to the atmosphere. The steam and hot water systems would require another piece of heat exchange equipment such as a condenser or air cooler. It is believed that there are excellent opportunities in the field of incineration heat utilization, but more research is needed if it is to develop its full potential.

A reduction in flue gas temperature to 600°F was assumed for the work presented here, but a further reduction in size and cost of gas handling equipment is possible if the flue gas is cooled even further allowing increased volume reduction. Indications are that it may be possible to reduce the incinerator flue gas temperature to 350°F or less before release to the atmosphere. This would decrease the gas volume to be handled by nearly another 15 percent. It also allows additional heat recovery which could make energy utilization even more attractive. As was mentioned, indications are that this is possible, but its complete acceptance will require the expenditure of research and development effort.

If the projected emission regulations are to be met, many existing incinerator installations must be revamped and more sophisticated air pollution control equipment systems installed. This is a costly undertaking, and some of the earliest units, especially those dating back before World War II will not be upgraded. Their designs make it difficult to improve combustion sufficiently

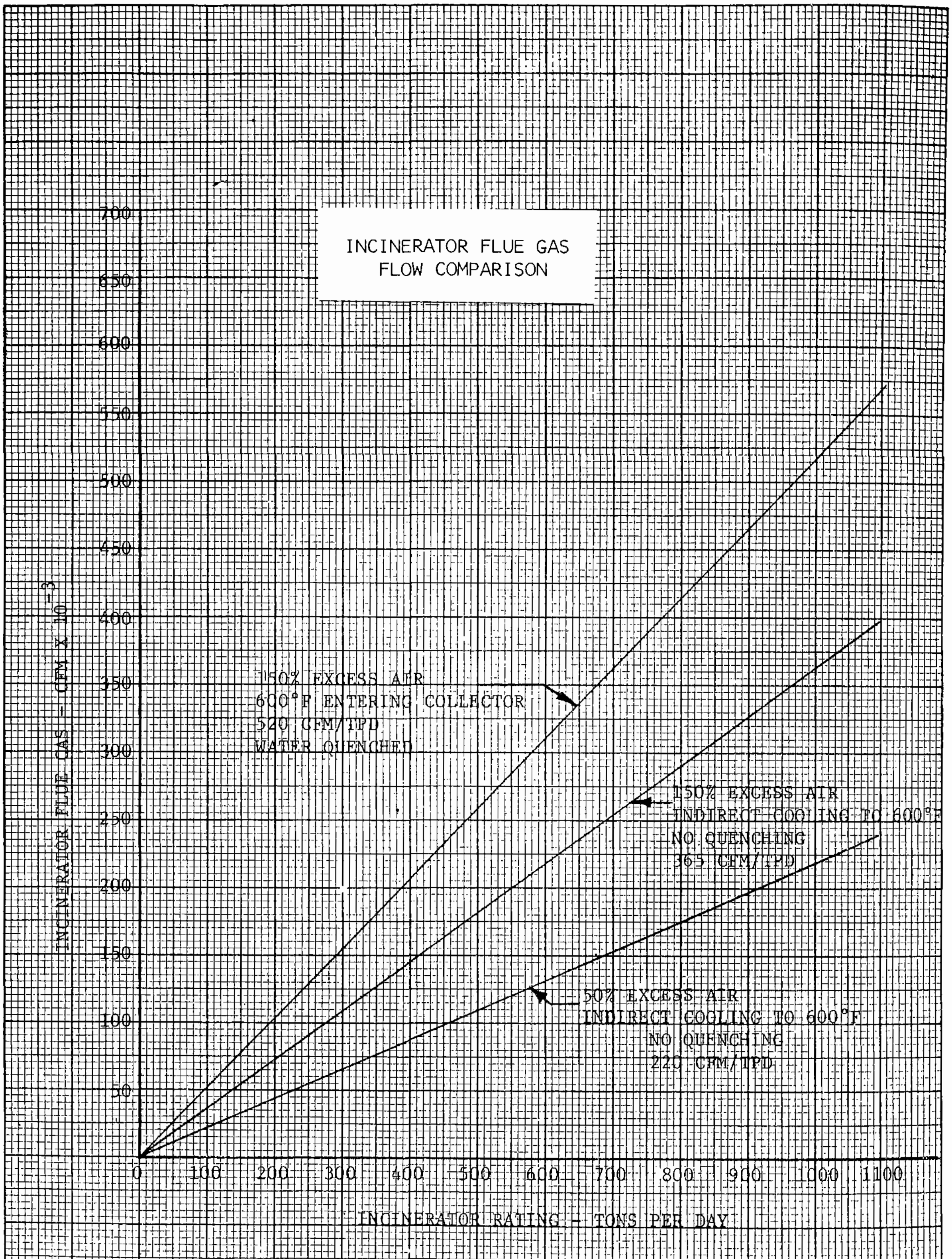
INCINERATOR FLUE GAS
FLOW COMPARISON
700
650
600
550
500
450
400
350
300
250
200
150
100
50
0
INCINERATOR FLUE GAS - CFM x 10^-3
150% EXCESS AIR
600°F ENTERING COLLECTOR
520 CFM/TPD
WATER QUENCHED
150% EXCESS AIR
INDIRECT COOLING TO 600°F
NO QUENCHING
365 CFM/TPD
50% EXCESS AIR
INDIRECT COOLING TO 600°F
NO QUENCHING
220 CFM/TPD
100
200
300
400
500
600
700
800
900
1000
1100
INCINERATOR RATING - TONS PER DAY

Figure 7

to eliminate smoke and odor problems, and obtain sufficient burn-out. In addition, they are usually too small to economically justify anything but replacement. Where combustion is good, and overloading is not a problem due to either increased refuse or refuse heating value, and where there is sufficient space, a revamp to reduce fly ash emission will be a logical solution. The cost of this upgrading can only be estimated on the basis of individual installations because of the uniqueness of the various installations. It certainly would cost more than similar equipment incorporated into a new installation.

Table I is presented to show the interrelationship and comparison of the various air pollution control equipment systems. This presentation is essentially as it has already been discussed. The second column introduces a new and important parameter -- the space required by each class of system. Efficiency is repeated in Column three. If water is used, it is noted with the quantity required in Column four. At various times, the energy required has been mentioned, and the major constituent is pressure drop. The only real exception to this is the precipitator and its electrical requirements; therefore, this gauge to the unit's energy requirements is presented in Column five. Column six presents a very important factor that is frequently overlooked -- a comparison of the relative operating cost between the various systems. Many communities buy their units on a lowest capital cost basis without regard for the continuing operating expense. On such a basis, it would be difficult to justify a unit with improvements such as indirect heat exchange. Units of this type, even when energy credits are not included, are at best on a cost par with the simpler systems. The only criterion should be that the proposed system meets all the projected incinerator requirements at a minimum cost per ton of refuse when all factors are taken into account.

TABLE I

COMPARATIVE AIR POLLUTION CONTROL DATA FOR MUNICIPAL INCINERATORS						
COLUMN	1	2	3	4	5	6
COLLECTOR	RELATIVE CAPITAL COST FACTOR (F.O.B.) FACTORY	RELATIVE SPACE	COLLECTION EFFICIENCY	WATER TO COLLECTOR PER 1000 CFM	PRESSURE DROP INCHES WATER COLUMN	RELATIVE OPERATING COST FACTOR
SETTLING CHAMBER	NOT APPLICABLE	60%	0-30%	2-3 GPM	0.5-1	0.25
MULTI-CYCLONE	1	20%	30-80%	NONE	3-4	1.0
CYCLONES TO 60 IN. DIA. TANGENTIAL INLET	1.5	30%	30-70%	NONE	1-2	0.5
SCRUBBER*	3	30%	80-96%	4-8 GPM	6-8	2.5
ELECTROSTATIC PRECIPITATOR	6	100%	90-97%	NONE	0.5-1	0.75
FABRIC FILTER	6	100%	97-99.9%	NONE	5-7	2.5

* Includes Necessary Water Treatment Equipment

SECTION IX

INCINERATOR ODOR AND GASEOUS EFFLUENTS

Modern incinerators are relatively free of odor and emit only minor amounts of noxious gases when properly operated. A number of investigators have attested to these facts and the results are quite understandable when one appreciates the nature of refuse and the modern design practice of providing sufficiently high temperature for complete combustion in the municipal incinerator.

The flue gas from an incinerator is made up of carbon dioxide, oxygen, nitrogen and water vapor which are non-pollutants and traces of carbon monoxide, hydro-carbons, sulfur dioxide, nitrogen oxides, aldehydes and traces of other gases which may be considered pollutants. If a particular unit is burning material which generates these noxious gases in objectionable quantities, a scrubber may be employed which includes a washing solution capable of absorbing the gases. This is one of the few proposed solutions to the noxious gas problem. No practical and efficient system for the removal of noxious gases has been developed to date. If the increased use of plastics creates a noxious gas problem for incinerators, research effort will have to be devoted toward a practical solution. The incinerator is not unique in this problem, and other industries with the problem may obtain a solution before the incinerator requires one.

SECTION X

TALL STACKS AND DISPERSION

The manner of discharge of the flue gases to the atmosphere affects the concentration of suspended dust in the ambient atmosphere and consideration of this fact must be taken into account when designing an incinerator. The stack is an integral part of any air pollution control system. In other words, air pollution control is not entirely a question of the quantity of pollutants emitted, but is also related to the atmosphere's ability to assimilate these pollutants without adverse effects. Emission control by dispersion effectively utilizes the atmosphere's capacity for such assimilation. It provides for the optimum combination of such factors as stack height, buoyancy, meteorology, and topography. To accomplish this, it is necessary to study atmospheric conditions surrounding the plant and to determine air flow patterns and ventilating capabilities of the region. Model studies have been found to provide very valuable assistance. What is desired is an ability to predict the dispersion of combustion products over a sufficiently wide area so as to reduce pollution concentrations at any location to amounts well within any projected air quality control level.

The term "dispersion" for purposes of this discussion refers to the movement of a polluted parcel of gases, either vertically or horizontally, and its simultaneous dilution with fresh air.

Pollutants are dispersed horizontally by movement and mixing with air as the parcel moves parallel to the earth's surface with the existing wind. Vertical dispersion results from an exhaust stack discharging a warm polluted parcel which moves upward while mixing with fresh air at higher elevations. Certain phenomena restrict these activities and must be taken into consideration when evaluating plant dispersion capability. One of the most severe natural impediments to proper dispersion is thermal inversion of the atmosphere. This atmospheric condition is defined as a temperature increase with height rather than the normal decrease in temperature. This restricts the vertical dispersion of the polluted parcel, and since this condition is nearly always accompanied by low wind velocity, it tends to trap and concentrate pollutants.

The previous discussion dealt primarily with level terrain. Often it is further complicated by adverse topography, such as confined valleys in which the increased pollution concentration can reach dangerous levels. Hilltops always present a problem because air flow patterns about them can cause the pollutant to be returned to the floor of the valley as well as cause fumigation of the area at the top of the hill. In addition to this, the top of the inversion will frequently be at or near the height of the surrounding hill tops.

High stacks have been successfully applied to large steam boilers and could offer a final degree of protection for incinerators when they are operating under adverse conditions. The physical height of the stack is usually specified, but in actual practice, this height is augmented by a high stack exit velocity. This factor, coupled with the buoyancy of the hot flue gas, produces an effective stack height which is substantially greater than the physical stack height. The effective stack height is the sum of the actual stack height plus the height effects due to velocity and buoyancy.

If the effective stack height is great enough, the effluent can "penetrate" an inversion and disperse at higher elevations. The ability to pierce any inverted layer and to flow aloft above it parallel to the earth's surface, while clearing all obstructions, is a highly effective means to insure adequate dispersion of pollutants.

A recommended minimum incinerator stack height should be based on air quality criteria, surrounding land use and meteorological, topographical, aesthetic and operating factors. This minimum will not be dictated so much by the normal incinerator operation as by the unusual operation, those periods when the air pollution potential of a municipal incinerator is at its greatest -- such as during start-up, burn-down, low furnace temperatures, wet refuse and breakdowns. Most authorities agree that the physical stack height above grade for gases from a combustion source should be at least twice the height of the tallest surrounding building. Usually, this is the incinerator plant itself, but it can be any adjacent tall building. It becomes clear that a stack of the correct height should be part of every incinerator installation.

SECTION XI

REFERENCES

1. Bureau of Mines, Ringelmann Smoke Chart, Information Circular IC 8333.

2. Semrau, K. T. Journal of the Air Pollution Control Association, Volume X, 1960.

3. Semrau, K. T. Journal of the Air Pollution Control Association, Volume XIII, 1963.

PART 6

POTENTIAL ENERGY CONVERSION ASPECTS OF REFUSE

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SECTION I

SUMMARY

Incineration of refuse offers an excellent solution for the volume reduction required since this method produces energy in a form which can be readily harnessed and utilized to offset the cost.

Some of the prospects are:

1. Regenerative feedwater heating
2. District heating
3. District air conditioning
4. Refrigeration
5. Desalination
6. Separately fired superheaters
7. Incinerator gas turbine

The control of off gases and waste water and the removal of their contaminants can be accomplished and managed through process engineering applications. However, there are many problems and the solutions are complex. A fresh creative approach to come up with optimum solutions in each particular instance is required.

SECTION II

INTRODUCTION

The total quantity of solid waste that is generated in the United States is given in Volume I, Municipal Inventory as 7.2 pounds per capita per day. Based on our population, this would amount to approximately 525 billion pounds per year. This is enough to cover the states of New Jersey 1 3/4 inches deep or Connecticut 3 inches deep. Simply stated, with quantities of this order of magnitude, communities are running out of land for waste disposal. (Economics dictates a more efficient use of land.) Waste is being generated at a rate faster than the population increase and emphasis, by both Federal and State Governments, is being placed on more efficient methods of disposal.

While many methods of solid waste disposal and reduction have been proposed and are currently being considered, incineration appears to satisfy more of the basic needs than other methods. It is a method which reduces the refuse to a minimum volume, destroys the bulk of the noxious odors and putrescible substances, and leaves a sterile landfill.

Modern incineration is used for disposal of a wide variety of wastes, the characteristics of which have changed because of new processing and packaging techniques. In the past, refuse contained approximately 65 percent garbage by volume, often resulting in an overall moisture content in excess of 50 percent. This approaches the point where auxiliary fuel is required to sustain combustion with suitable furnace temperatures. Today refuse may average 10 percent or less garbage, with an overall moisture content of 15 to 20 percent. It is characterized by large quantities of paper bags, crates, and similar dry, combustible material. Although much bulkier, it is more easily burned in incinerators of adequate design.

Industrial refuse has also changed, especially with the increased use of plastics and other synthetic materials, many of which have high heating values with little or no moisture or ash. The variable appearance of refuse is belied by chemical analysis which is quite uniform, as much of it is produced from wood and similar cellulose raw materials. Laboratory tests, as well as theoretical calculations, show that the average heating value of such cellulose by-products is about 8,000 to 9,000 Btu per pound of combustible. The major variables are the moisture and ash or inert ingredients, and these are not difficult to determine on a test basis.

Incineration is a thermal reduction process and, as such, is a series of dependent and independent variables. If we were to establish overall parameters without being hampered by present prejudices, we could approach incineration by analysis without dimension. Many factors would fall out and three functional dependent variables would remain -- refuse storage and handling, furnace and auxiliary equipment, and residue handling. These in varying degrees, fix the equipment size, loading, and arrangement.

While recognizing the interplay of the variables, this section will discuss some of the untapped potential for an integrated buring system. It will also present a few energy utilization schemes that offer probability of sound economic trade-offs.

SECTION III

POTENTIAL ENERGY AVAILABLE

With the increase in heat content of refuse, the reduction of the temperature of flue gases (or off gases) has become an extremely difficult and expensive problem. Currently, large quantities of quenching water and air are usual solutions to this problem. These techniques have certain disadvantages. Quench water is quite expensive with respect to the quantities required -- over 2 pounds of water per pound of refuse to quench to 600°F from usual furnace exit temperatures. If the entire temperature reduction is accomplished by air dilution, the "tail end" equipment, including ducting, air pollution control equipment, I.D. fan, and stack, becomes extremely large and expensive. Air dilution requires approximately 12 pounds of air per pound of refuse to quench to 600°F.

If the energy in the flue gas is considered as a useful by-product instead of the current wasteful heat dissipation, how much energy might be available, and how do we harness this heat source and extract useful work in an economical manner?

In order to compute the energy available, certain assumptions must be made. Mixed refuse has a heating value approaching 5,000 Btu per pound as fired, and this can be expected to increase in the future due to increased use of paper and plastics in packaging. A refuse heating value of 5,000 Btu per pound was assumed for the purpose of our calculations. This is equivalent to 10 million Btu per ton of refuse. Ninety-five percent of the combustibles were assumed to be completely burned. Thus, at least 4,750 Btu per pound of refuse are liberated in the furnace for potential use as by-product energy. To determine how much of this heat could be reasonably converted to a more useful form of energy, it was assumed that the inlet air temperature was 80°F and that 50 percent excess air was used in the combustion process.

To compute the quantities of air and flue gas involved, the ultimate analysis of the 5,000 Btu per pound mixed refuse must be known, and the following composition was chosen:

Carbon	27.0 percent
Hydrogen	4.5 percent
Oxygen	22.0 percent
Moisture	23.0 percent
Non-Combustibles	23.5 percent

It was assumed that the combustion exhibits a hydrogen preferential and that the 5 percent unburned combustible is entirely attributable to carbon. Thus, the unburned carbon reduces the heating value by 250 Btu per pound.

The unburned carbon percentage was calculated to be 1.7 percent based on a higher heating value of carbon, 14,500 Btu per pound. This quantity was subtracted from the carbon percentage in the ultimate analysis to give the net carbon available for composition:

$$27.0 - 1.7 = 25.3 \text{ percent}$$

The amount of combustion air used was computed next, and it was found that 0.86 pounds of O_2 per pound of refuse was required. This is equivalent to 3.72 pounds of air per pound of refuse.

The quantity of flue gas, produced by the combustion process, was determined from the foregoing results:

Carbon burned	0.253 lb./lb. of refuse
Hydrogen	0.045 lb./lb. of refuse
Oxygen	0.220 lb./lb. of refuse
Moisture	0.230 lb./lb. of refuse
Combustion air (50% Ex. Air)	5.580 lb./lb. of refuse
Flue gas (W_{FG})	6.328 lb./lb. of refuse

The energy available may now be computed if the exit gas temperature is chosen. A temperature of 600°F was assumed because it is the most common value found in incinerator design today. It should be pointed out that this value could be as low as 350°F and that as much as 15 percent more energy could be made available at this lower temperature.

The heat loss to the stack because of the moisture content of the flue gas was computed as follows:

0.045 (Hydrogen) x 9 = 0.405 pounds moisture per pound refuse

Moisture in fuel = 0.230 pounds moisture per pound refuse

Neglecting the moisture in the air, the pounds of moisture in the flue gas (W_m) is:

0.635 pounds moisture per pound refuse

Heat loss in the flue gas (Q_m) is:

$$Q_m + W_m \, (H_{s600} - H_{f80})$$

where:

H_{s600} = Enthalpy of steam at 600°F and 1 psi

H_{f80} = Enthalpy of water at 80°F

$\therefore Q_m$ = 0.635 (1335.7 - 48.0) = 816 Btu per pound refuse

Next the dry gas loss was determined:

Total flue gas	= 6.328 pounds per pound refuse
Moisture	- 0.635 pounds per pound refuse
Dry flue gas	= 5.693 pounds per pound refuse

The dry gas heat loss (Q_{dg}) is:

$$Q_{dg} = W_a \ (H_{g600} - H_{g80})$$

where:

H_{g600} = Enthalpy of gas at 600°F (approximated as air)

H_{g80} = Enthalpy of gas at 80°F

$\therefore Q_{dg}$ = 5.693 x 126.9 = 720 Btu per pound refuse

The sum of these two losses equals 1,550 Btu per pound refuse. This value was adjusted for radiation and other unaccounted losses, and the total heat loss in the flue gas was approximated at 1,600 Btu per pound refuse. The energy available for use as a by-product may now be determined:

Btu liberated	= 4,750	Btu per pound refuse
Flue gas loss	- 1,600	Btu per pound refuse
Energy available	= 3,150	Btu per pound refuse

This is equivalent to 6.3 x 10^6 Btu per ton of refuse, and when related to a 400 ton per day incinerator (16.7 tons per hour), it represents 105 million Btu per hour. Steam generation usually requires about 1,050 Btu per pound; therefore, the available energy can generate approximately 100,000 pounds of steam per hour. If this steam is used in a steam power cycle, with an efficiency of 25 percent, it can produce 7,300 kwhr of electricity.

These values indicate that there is the potential of substantial return to the incinerator operator, i.e., about 6,500 kwhr available for sale after the incinerator requirements are met. Should the incinerator be in a municipal complex which could use this electricity, it might be valued at $.01 per kwhr. At this rate, it would represent a $1,560 per day credit to the incinerator, and if the incinerator's own power requirement is included, the value increases to $1,685 per day. If the decision was made to sell the steam to a nearby district heating system, process plant, or similar customer, the value might be as much as $.50 per 1,000 pounds. This would represent a $1,200 per day income or about $360,000 per year. These are rather attractive figures, and it seems reasonable to assume that the future will see increasing numbers of heat recovery systems incorporated into incinerator designs. The remainder of this paper will discuss various schemes for the utilization of incinerator heat.

SECTION IV

HEAT UTILIZATION METHODS

By atomizing oil, grading coal, or pulverizing coal, we recognize and exploit the advantages of selective surface enlargement in terms of the combustion process. With this surface enlargement, smaller particles can meet and combine more readily with oxygen. In addition to the advantage of surface enlargement mentioned above, refuse is taken from a hetrogeneous mixture to at least a partially homogenized mixture.

Figure 1 illustrates a proposed burning system which provides the unique features of thermal drying and maximum heat utilization. This system requires refuse preparation and is based on all refuse being reduced to 2 inches or below (including metals). The refuse may be burned alone or in combination with other fuels. With this method, the principle of over-feed firing is employed and the refuse is fed into the furnace through distributors or burner registers located high enough to allow drying of the refuse before it reaches the grate at the bottom of the furnace. Turbulence is provided by blowing tangentially directed streams of preheated air at high velocity through rows of nozzles at various furnace levels. Overfire air and underfire air are proportioned in accordance with the volatile content of the refuse. All of the refuse passes the rows of nozzles at the various furnace levels. When the refuse enters this highly turbulent high-temperature gas zone, a portion will burn rapidly in suspension and the larger particles will be dried and prepared for complete reduction when they fall to the grate. Figure 2 illustrates the turbulent zone through which the refuse falls and dries.

The furnace envelope for this method of refuse burning is completely water cooled and there is a continuous ash discharge grate. The entire burning process is carried out at temperatures high enough to destroy all of the noxious odors and putrescible refuse.

The boiler is the conventional once-through type (non-baffled). To minimize corrosion and erosion, velocities in the boiler bank must be kept low. The overall advantages of this system are: (1) permits operation at lower excess air and (2) takes advantage of the heat absorption in the furnace. The excess air requirement will be approximately 50 percent as compared with 150 to 200 percent in the present conventional incinerator units. With the smaller quantities of air to handle, fan requirements, boiler draft loss, and fly ash carry-over will be reduced. The selection of high efficiency air pollution control equipment is, therefore, more economical and higher burning rates and more complete combustion can be accomplished. With proper heat recovery equipment, unit efficiencies in excess of 80 percent can be realized.

Equipment similar to this has been in satisfactory operation for many years, burning millions of pounds of cellulose materials annually.

SIDE ELEVATION OF UNIT DESIGNED FOR COMBUSTION FIRING OF REFUSE, NATURAL GAS, OIL AND COAL

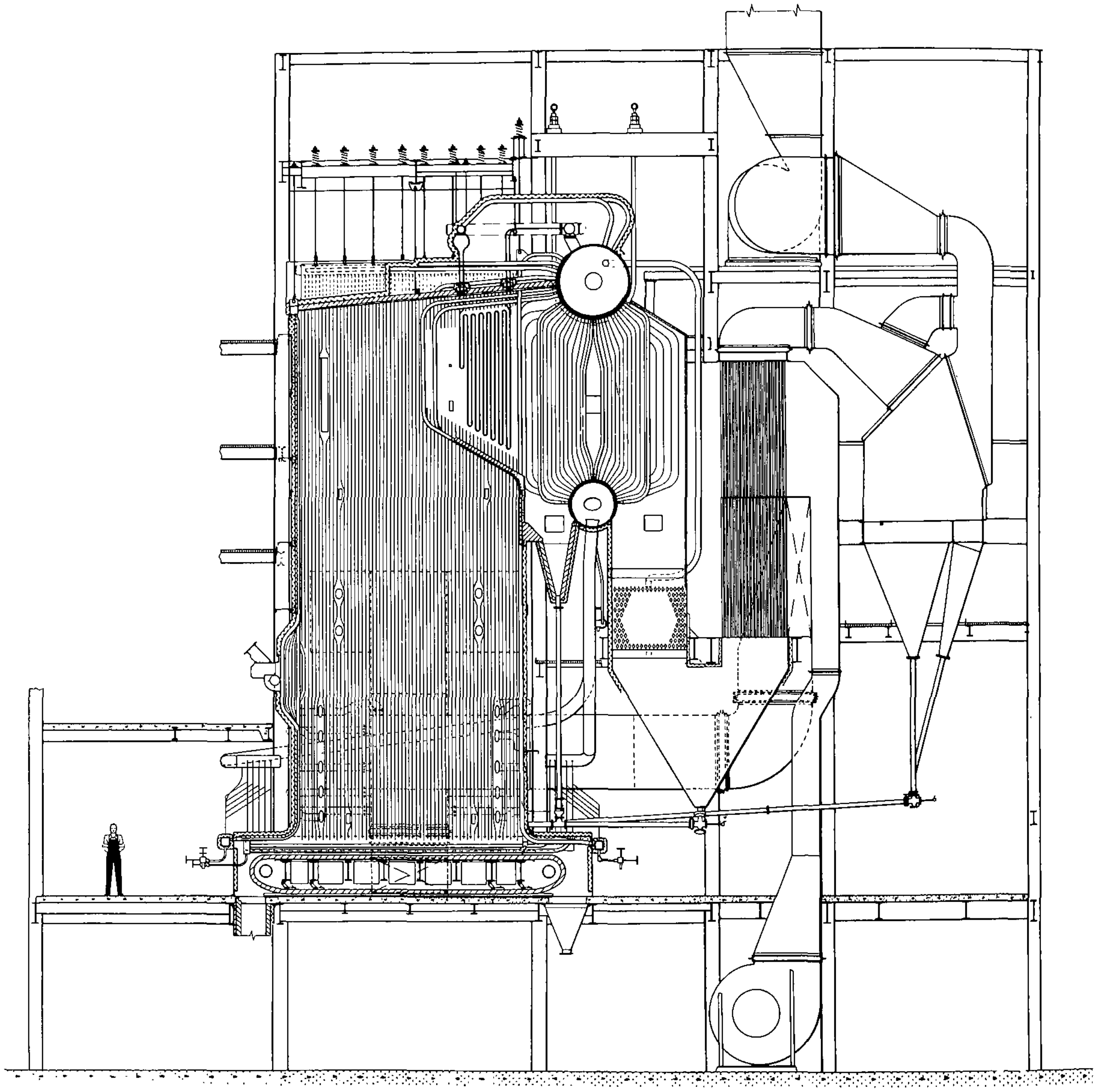


Figure 1

TURBULENT ZONE OF FURNACE OF REFUSE BURNING BOILER

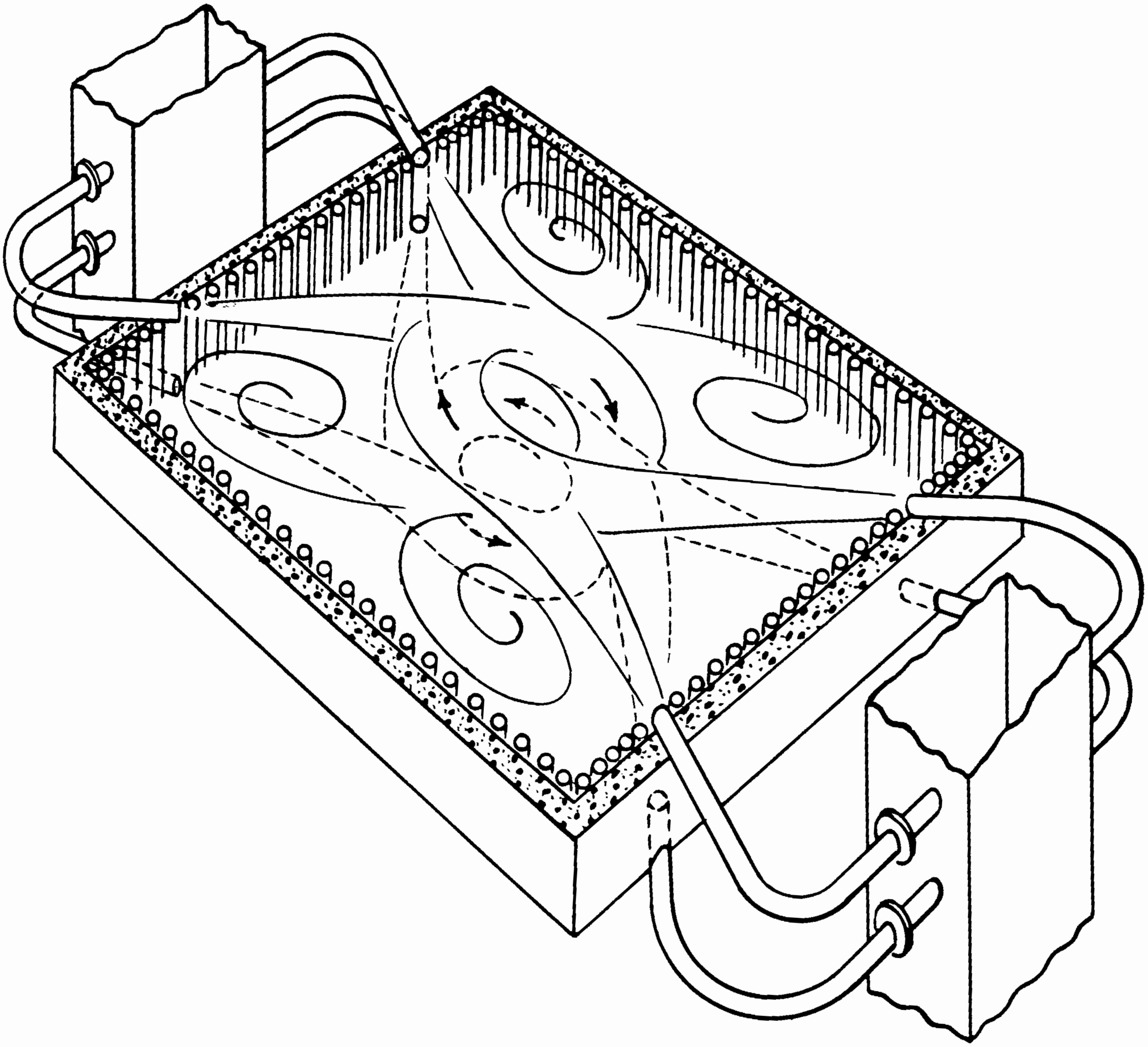


Figure 2

Figure 3 illustrates another very similar method of firing; the major difference, however, is that the refuse must be reduced to a size below 3/4 of an inch. The refuse is fed by high pressure - low volume air to centrifugal drying towers where hot air from the regenerative type Ljungstrom air heat dries the refuse. It is then transported and fired tangentially to utilize maximum heat absorption in the furnace.

As mentioned previously, this system requires preparation of all refuse to a small size and, in addition, metal recovery prior to injection in the furnace should be considered. The bottom of the furnace is the well known Coutant type. A very small grate is available to collect material (less than 5 percent) which might fall in this zone.

The conveying system is a proven system, capable of transporting properly sized material. Actual systems are in successful operation conveying cellulose material, such as wood chips and barks many miles. The ability to convey this material may also open up the possibility of locating the firing equipment at a source removed from the refuse inlet position.

Because of the varying nature of refuse, its energy conversion systems are probably best suited to base-load applications. The irregularity of flow and variable heat content would impose serious feed and control problems for process applications. These require close temperature and pressure control.

Figure 4 is a schematic of a proposed method by which water cooled furnaces can be used to affect a trade-off with air pollution devices without use of the by-product steam or hot water. By utilizing a completely water cooled furnace, low excess air can be achieved. Furnace exit temperatures will probably be around 1,500°F, thus minimizing the size of other heat absorbing equipment in the system. Water spraying or a gas turbine could be utilized to reduce the furnace exit gas temperature from 1,500°F to a manageable 600°F. The quantity of gas requiring temperature reduction is lower, i.e., 50 percent excess air as compared with 150 to 200 percent in a conventional incinerator and, therefore, if spraying is used, the quantity of water required is less.

The heat absorbed would be approximately 100 Btu per pound of water circulated in the water cooled furnace. The heat absorbed in the water must be dissipated by heat exchangers, such as water to water or water to air (fin-fan coolers) heat exchangers.

In a simple expansion of the system, convectors may be substituted for the heat exchangers and we now have a modern high-temperature hot water heating system. This system is being used to satisfy many heating and air conditioning requirements. It lends itself to large area heating and all that is proposed here is consideration of the source of energy - refuse rather than fossil fuel.

PNEUMATIC TRANSPORT SYSTEM FOR FIRING SOLID FUELS

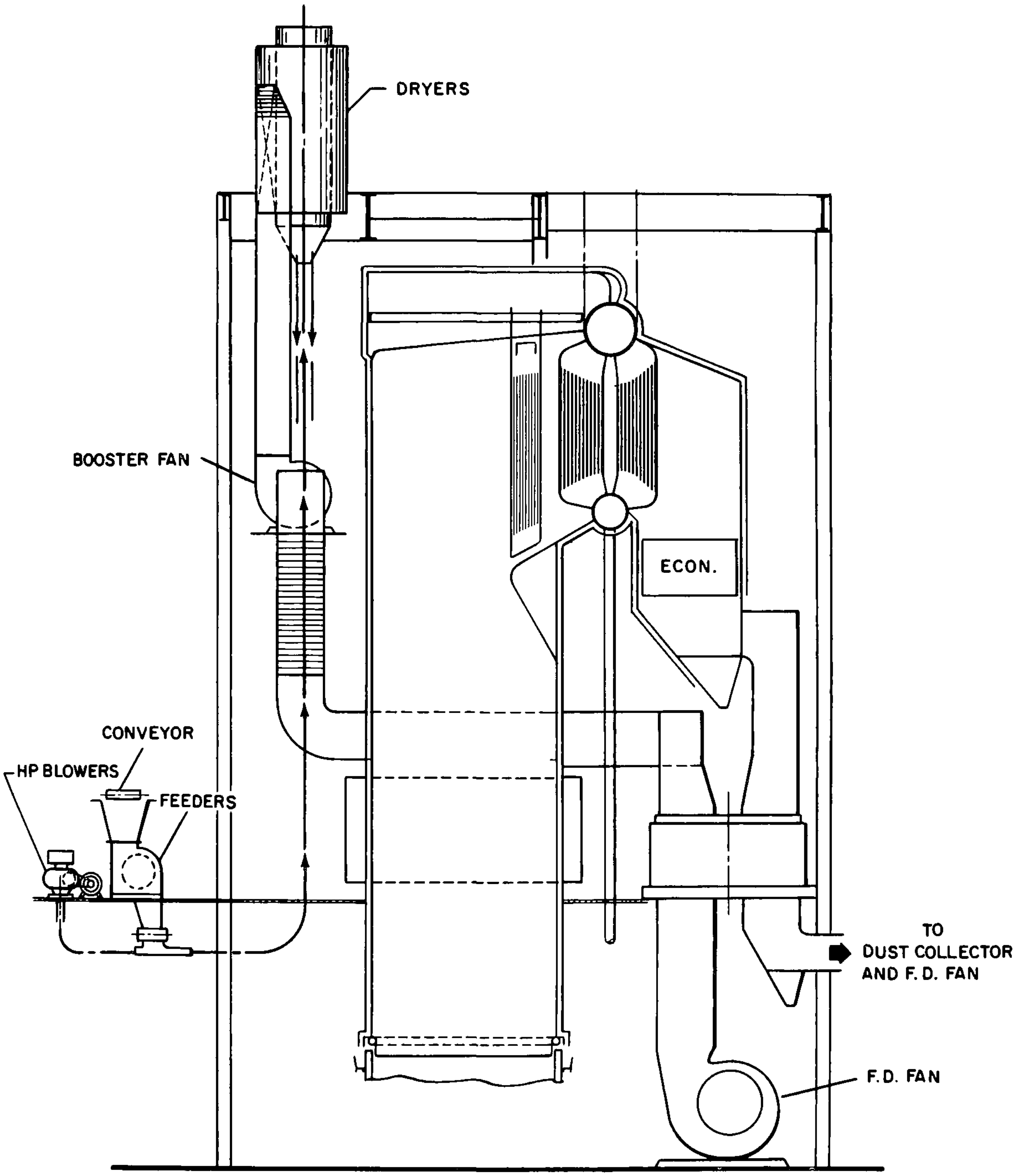


Figure 3

WATER FLOW SCHEMATIC

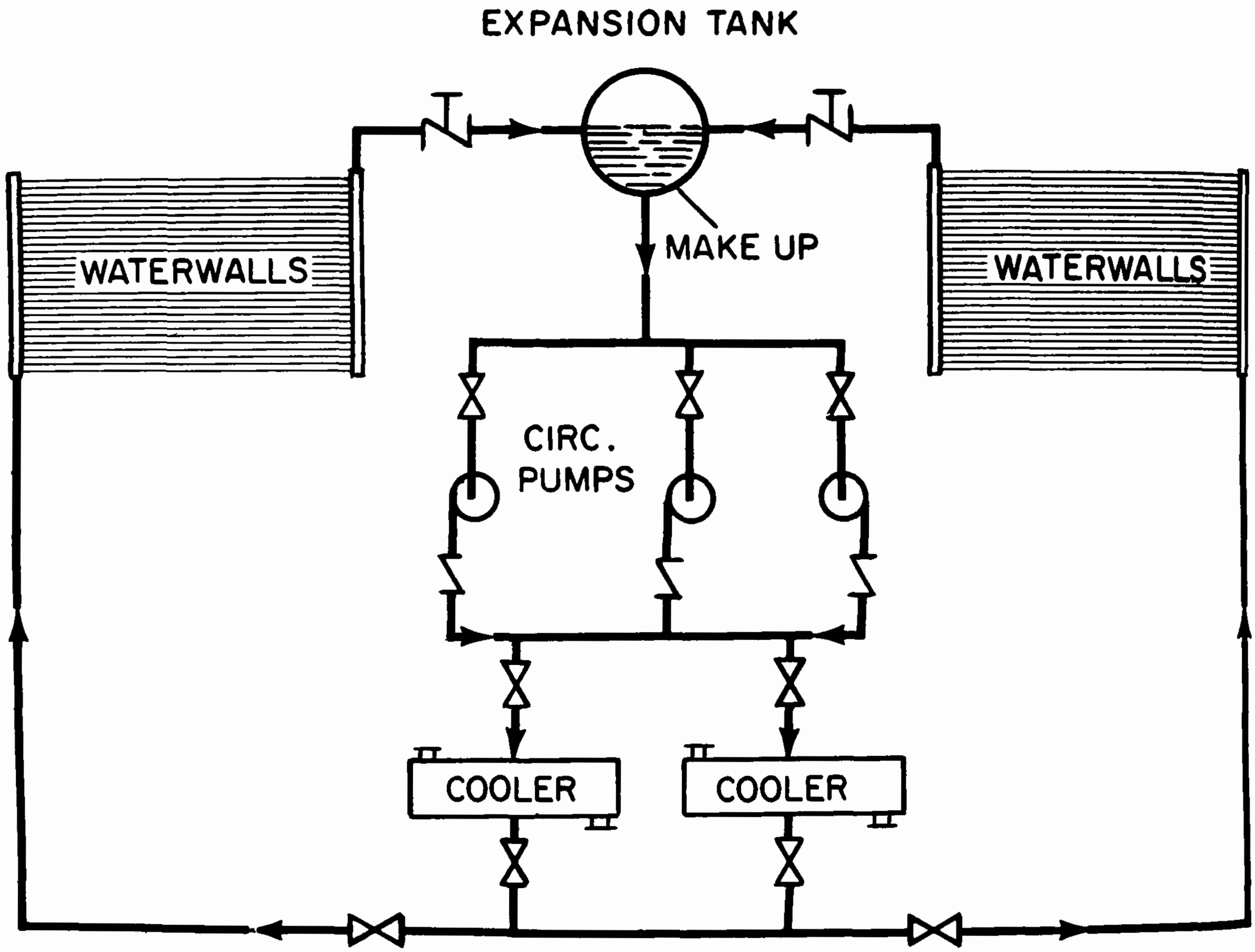


Figure 4

SECTION V

STEAM USAGE

In the previous paragraphs, the quantity of heat available and methods for producing steam with the heat were mentioned. Possible uses of the steam will now be discussed.

In the section on potential energy available in an incinerator, a few possibilities were mentioned for the sale of by-product steam. These included the production of power and the sale of steam to a nearby district heating system or process plant. Power production is one of the most obvious and often suggested uses for the incinerators' heat. Incinerator power generation is not without drawbacks. Knowledge of incinerator combustion is not complete and there are corrosion problems which are somewhat unpredictable because of inconsistency of the fuel and the frequent presence of unusual substances in the refuse. Factors such as these raise questions as to the availability, on a continuous basis, of energy from an incinerator plant. At the present state of development, down-time might conceivably limit the application of incinerator heat to straight power generation.

The power industry is studying these problems and without a doubt, solutions will be found. It should be recalled that about forty years ago when the use of pulverized coal was first inaugurated its availability was rather limited, but at the present time a major portion of the world's power is generated with it. A parallel development is certainly possible in incineration.

If it is considered advisable to sell steam to a power company rather than get involved in electrical distribution systems, certain possibilities are available. The steam at a specified temperature and pressure could be supplied to the steam electrical generating station and used in the regenerative feedwater heating portion of the power plant cycle. This would free the main cycle steam from the heating task and full steam flow could be utilized in the turbine to generate power. This would isolate the two steam flows which is particularly attractive because power plant operation requires very exotic water conditioning, while the incinerator system does not impose such severe water restrictions. In a similar scheme, the power plant could use the incinerator's steam to preheat combustion air. Steam coil air heaters are not new, but the use of incinerator steam to preheat combustion air is. The steam air heater could even be enlarged sufficiently to allow a substantial increase in the economizer. An enlarged economizer would do all of the feedwater heating, once again releasing the main cycle steam to power generation.

The use of incinerator by-product steam or hot water in district heating systems or process plants has been mentioned. This is another possible use for the steam, and should be given prime consideration.

Thinking should not be rigorously restricted to the sale of steam or hot water. Steam can produce chilled water in an absorption or evaporative type cooling system, and the sale of chilled water for summertime air conditioning or year-round refrigeration is a distinct possibility. With the trend toward air conditioning, a heating and cooling system would have certain distinct advantages. The same pipes that transport hot water in the winter could be used for chilled water in the summer.

The modern municipal complex, including the sewage treatment plant, municipal garage, incinerator, and possibly the office building and water works, requires both space and water heating as well as some process steam. Therefore, consideration should be given to the use of incinerator steam to accomplish these tasks.

Another possibility is condensation of the steam. This would accomplish the first objective of incinerator steam generation, that of shrinking the flue gas volume to be handled, but if the incinerator is situated by the sea this introduces the further possibility of sea water desalination. (This has been successfully applied so details will not be presented here.) With fresh water as a by-product, a neighboring power plant could be supplied with make-up water needed for the steam cycle, saving the cost of producing such water. Also the municipal complex has a need for considerable fresh water, and the incinerator-desalinator could be established as this source.

Another logical use of the fresh water produced from an incinerator-desalinator plant would be the municipal water system. This use of incinerator heat is most attractive, particularly if unit availability happens to be a problem. The water system reservoir would then ensure that demand matched supply. Since desalination shrinks flue gas volume which in turn reduces the cost of primary incinerator equipment, the marriage of incineration and water supply seem natural and should be given increased study in the immediate future.

If the incinerator installation incorporates a scrubber instead of dry dust collection, the gas shrinking may be partially accomplished by water walls and convection steam generating equipment. The heat absorbed can then be used to reheat the cool clean gases leaving the scrubber. In such a system, however, the scrubber water would have to be cooled in a spray pond or cooling tower and recirculated to the scrubber ensuring a proper heat balance around the unit.

Most of the systems discussed here have been suggested before in one form or another, but convention should not restrict thinking. As an example, the nuclear power plants presently being designed are penalized because of the lack of superheating. Separately fired superheaters have been installed, but fuel costs have been a problem. If waste incinerator heat was used to superheat nuclear cycle steam, the combination might produce even lower cost nuclear power.

We have discussed trade-offs in more conventional steam-water systems. A different approach is considered in the next section.

SECTION VI

INCINERATOR-GAS TURBINE

Direct hot gas powering of a prime power might seem possible if the incinerator were pressurized, except that dust contamination would be detrimental to the dynamic parts of any prime mover to say nothing of the corrosion problems inherent in incinerator operation. An easy solution to these problems might be an extra heat exchanger circuit, such as has been discussed in the various steam and hot water designs. This may not be the best solution, but is worth investigation. In the discussion that follows, the use of gas-to-gas heat exchanger with a gas turbine as the prime mover will be outlined.

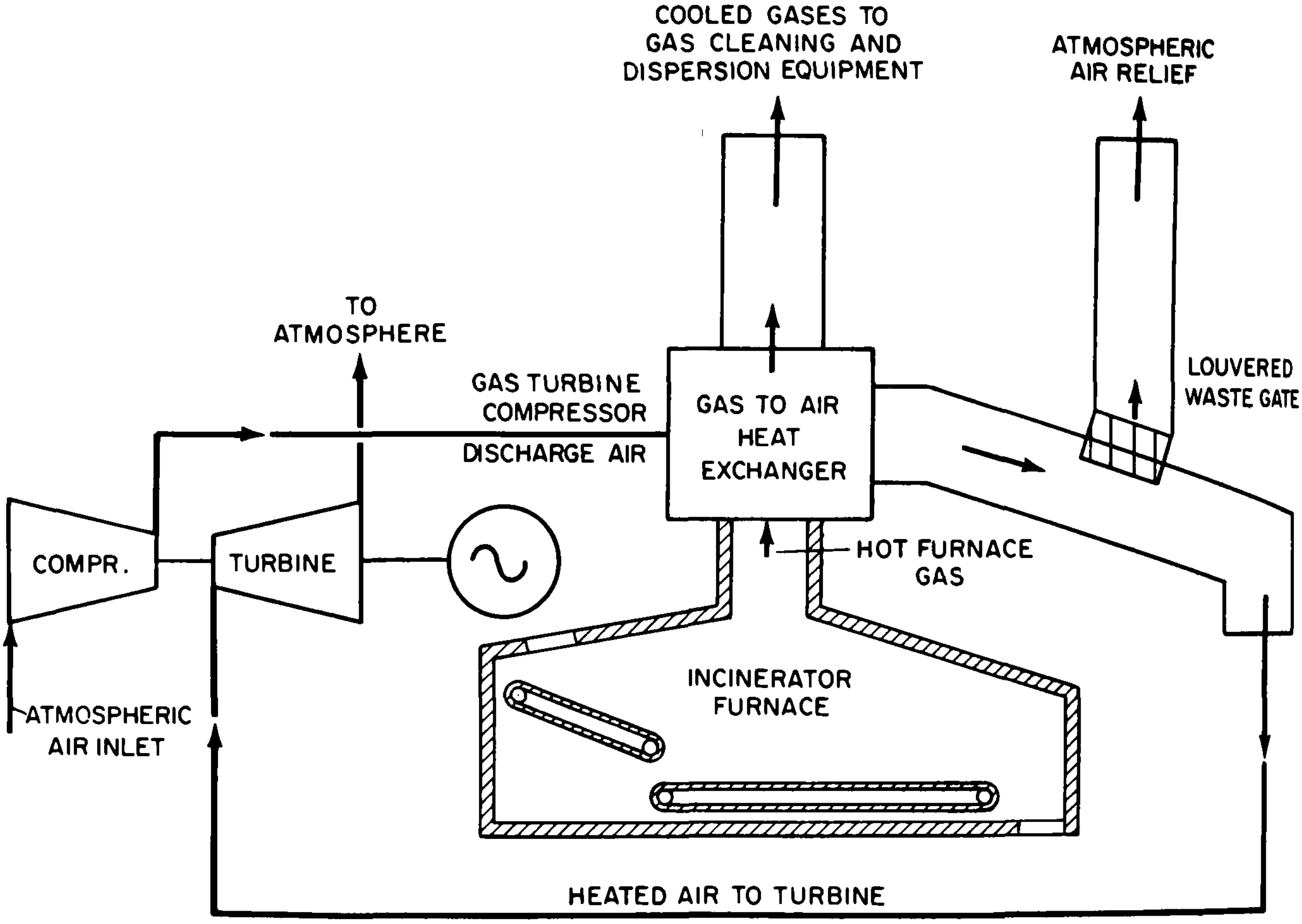
The system (Figure 5) uses a standard incinerator of modern design capable of good combustion and a gas discharge temperature from the furnace of 1,500°F. An air heater reduces the gas volume and temperature as desired, with a minimum use of water. To accomplish this and still use a minimum of water may require that the furnace incorporate waterwall cooling and steam generation, or a similar solution. What is important here is that these two requirements -- complete combustion and approximately a 1,500°F exit temperature -- can easily be met with present day technology.

The hot flue gas from the incinerator furnace transfers most of its heat to the air in the heat exchangers. Gas leaves the heat exchanger at approximately 600°F, a temperature considered earlier as reasonable, and is routed to the pollution control equipment. The remainder of the gas circuit would be similar to a conventional modern unit.

On the air side of this system, ambient air is compressed to about 90 pounds per inch^2 absolute and 500°F. The air is then heated to about 1,100°F in the incinerator heat exchanger, and flows to the turbine for expansion to ambient back pressure. The low pressure discharge air from the turbine, which is still at a very high temperature of about 700°F, can then be discharged to the atmosphere or used in another heating system. (A portion of the air may be used in the incinerator furnace as the overfired air.) In flowing through the turbine, the air gives up much of its energy and the turbine develops considerable power. Most of this power will, however, be used to drive the air compressor and sustain the cycle, but a small quantity of net energy is available to generate power, or drive the I.D. fans. If D.C. power is generated, control of fan speed would be optimum and system conditions could be easily matched with a minimum of control. It should be noted that the hot air line between the heat exchanger and the turbine contains a waste gate. This louvered opening can be used to release some of the hot high-pressure air to the atmosphere to match the power demand on the turbine. This could be accomplished while still offering complete gas cooling to the incinerator system.

This system offers certain advantages -- size, minimum quantity of water required, and design within the state of the art. For these reasons, the system offers potential in future incinerator designs. The scheme could be the forerunner of a completely self-sustained incinerator plant.

INCINERATOR – GAS TURBINE



INCINERATOR - GAS TURBINE
HEAT UTILIZATION

Figure 5

PART 7

THE EFFECTS OF MUNICIPAL REFUSE VARIABILITY ON INCINERATOR EXHAUST GAS, WATER AND AIR FLOWS AND BURNING CAPACITY

Prepared

Peter W. Kalika
Project Engineer
Product Diversification Department

November 1, 1967

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LIST OF TABLES AND FIGURES

SECTION I

SUMMARY

The results of a computer study to assess the effects of the variability of municipal refuse are presented in the form of graphs, tables and detailed discussion.

It was determined that the probable variability of the characteristics of municipal refuse can potentially cause large increases in required air, gas and water flows at a given incinerator burning rate. These required increases are likely to exceed the growth potential included for these factors in today's incinerator designs, and can therefore cause potentially serious reductions in the burning rate capacity of large incinerators.

Heat absorption equipment, if designed to provide variable absorption, offers a potential means for compensating the effects of refuse variability.

It is recommended that a study be conducted to develop the means to project changes in refuse composition and heating value.

SECTION II

INTRODUCTION

A large, well designed incinerator, incorporating the latest air pollution control equipment must be considered one of the best means available for the safe and economical disposal of the large quantities of refuse generated in densely populated areas. Incinerators such as these are actually sophisticated fuel burning systems. The compacted incinerator residue requires far less landfill volume, and a properly processed residue requires no cover material to assure control of insects and rodents.

One of the many problems encountered in the design of such fuel burning systems is the variability of municipal refuse. It is a mixture of virtually every imaginable object discarded by society and can be considered one of the most difficult fuels to burn effectively. The refuse composition and heating value vary from day to day and exhibit trends over periods of time.

The design calculations leading to the sizing of the fuel burning system include heat and material balances[1] which depend upon the chemical composition of the refuse and on the heat content. The chemical composition and the refuse burning rate determine the rate of combustion gases which are released (carbon dioxide, sulfur dioxide and water vapor) and the theoretical rate at which combustion air is required. The heat content and the refuse burning rate determine the quantity of excess combustion air required to maintain the temperature of the combustion gases at predetermined levels. Thus, both characteristics of the refuse influence the quantities of the exhaust (flue) gas and combustion air. The quantity of air or water required for cooling of the exhaust gases is also influenced by the refuse characteristics.

The designer usually sizes the incinerator and its auxiliary equipment on the basis of some "typical" refuse, which may or may not be truly typical of the region where the system will operate. The characteristics he assumes will usually not be based on actual test, but more than likely will be "national averages"[2] perhaps "adjusted" for local conditions. The designer uses this assumed refuse in conjunction with the desired burning rate, or capacity, and bases the size of the combustion system, furnace, ducts, fans, pumps, valves, controls and air pollution control equipment on the calculated air, water and gas flows which result.

The designer expects that, when refuse departs markedly from these assumed characteristics, the incinerator operator will adjust the burning rate to compensate for these occasional, or even day-to-day variations. Thus, if the refuse is either excessively wet or dry as compared to the design conditions, the operator must lower or raise the burning rate, and in effect, change his capacity. These fluctuations are expected to be temporary, and when conditions are normal, full capacity is expected to be restored.

The procedure described would be entirely satisfactory, if the refuse characteristics used were truly a typical average (plus or minus some reasonable tolerance) for the refuse to be delivered to the incinerator and if these characteristics were constant over the entire life of the system. Since actual sampling of refuse characteristics is the exception, rather than the rule, and since there has been a definite uptrend in the combustible portion of the refuse in the past twenty years, many incinerators may be operating today at burning rates significantly below the design capacity established, for example, ten years ago. Projections as to future increases in heating value are largely guess work, but increased use of plastics could push the average heating value to as high as 7,000 Btu/pound.

The graphs and tables presented and discussed in this report are based on the results of a computer program developed in part under Combustion Engineering auspices and partly under Contract #Ph 86-66-163. They explore the effects of variations in the composition and heating value of municipal refuse in terms of exhaust (flue) gas weight and volume flow, air weight and volume flow, excess air, heat loss by radiation and waste heat utilization and quench water flow. The extent to which these effects influence incinerator capacity is discussed. The results are based on an assumed table of refuse compositions and heating values which are considered typical of current and projected municipal refuse.

The work presented in this section was conducted by Peter W. Kalika of the Product Diversification Department. The computer program was prepared by Myron Holmes of the Programming Department.

SECTION III

CONCLUSIONS

A. The probable variability of the characteristics of municipal refuse can result in potentially serious reductions in the burning rate capacity (tons per hour) of large incinerators.

B. Potential increases in the required combustion airflow, exhaust gas flow, and quench water flow due to refuse variability, are likely to exceed the growth potential included for these factors in today's incinerator designs. The only compensation the operator can apply to maintain operation within design limits is a reduction in burning rate.

C. Heat absorption equipment offers a potential means for compensating the effects of refuse variability, if the equipment is designed to permit a controlled variation of the quantity of heat absorbed.

D. The procedure described, and the resultant computer output, graphs and tables may be used as valuable design tools in assessing the effects of refuse variability. The sizing of fans, ducts, stacks, pumps, valves, controls, air pollution control equipment and heat absorption equipment may be significantly aided by the techniques described. If an estimate of the variation of refuse composition with time is available, the designer can weigh his selections in terms of their significance over the operating life of the system.

SECTION IV

RECOMMENDATIONS FOR FUTURE ACTIVITIES

Although the techniques described in this report are a valuable aid in assessing the effects of the variability of municipal refuse, they do not provide a means to predict such variability. It is recommended that the feasibility of providing a means to project the changes in refuse composition and heat content be studied.

SECTION V

DISCUSSION OF RESULTS

A. METHOD OF ANALYSIS

In order to assess the interrelationships among incinerator design variables such as refuse heating value and composition, percent excess air and percent of total heat release lost by radiation or absorbed by waste heat utilization, a large number of calculations were made. Hand calculations were made initially for a number of cases, and the procedure was programmed for computer evaluation to permit consideration of sufficiently narrow increments of refuse characteristics. In order to provide the results which are independent of incinerator size, the calculations were based on a burning rate of one ton per hour (2,000 lb./hr.). Larger capacities may be evaluated by direct multiplication. All parameters were given in percentages to maintain generality.

A table of refuse higher heating values and compositions was developed in increments of 200 Btu per pound between 4,000 and 8,000 Btu per pound. The carbon (C), hydrogen (H), oxygen (O), moisture (H_2O), and non-combustibles (nonC) were determined for each heating value by means of equation:

Eq. (1) $$HHV = 141\ (\%C) + 610\ (\%H - \%O/8)$$

where:

(%C) = the percentage carbon on the "as fired basis"

(%H) = the percentage hydrogen on the "as fired basis"

*(%O) = the percentage oxygen on the "as fired basis"

*(Assumed to be entirely combined with hydrogen to form moisture.)

This equation is based on the individual heating values of the carbon and hydrogen in the refuse, and is similar to the well known Dulong formula[3] except that it neglects the contribution to heating value by any sulfur present in the fuel. Since the sulfur content of refuse is usually low, the potential error incurred by this assumption is insignificant. The Dulong formula has been shown to be an accurate means for approximating the heating value of most coals, probably within 2 to 3 percent, but its application to other fuels, even to some coals, has resulted in significant deviations. Deviations are caused by a number of factors, including the combination of the hydrogen and carbon as hydro-carbons. The heating value of such combinations can be significantly different from what it would be if the carbon and hydrogen existed separately, because the heat of combination or of dissociation would have to be considered. The value of the constants in the Dulong equation would then have to be adjusted to account for this factor. An example of this consideration is given by cellulose, $C_6H_{10}O_5$, whose chemical composition is such that there is not net hydrogen, and whose percentage of carbon by weight is 44.4 percent. The heating value of cellulose is 7,526 Btu/pound. If these facts were inserted into Equation 1 with the coefficient for carbon as the unknown quantity, it would be calculated at 169.5, instead of the 141 given in the equation.

Mr. Elmer Kaiser[4] has suggested that since municipal refuse contains substantial quantities of cellulose, an empirical relationship similar to Equation 1 be used for refuse, with a coefficient of 160 to 162 used for the carbon percentage. Mr. Kaiser has conducted several sampling analyses of refuse[2, 5] and if the suggested procedure is applied to the heating value and chemical composition results of these analyses, a coefficient for the carbon percentage between 150 and 160 is obtained. However, this procedure assumes that the heat released by the dissociation of the carbon-hydrogen bonds may be entirely lumped into the coefficient for the carbon percentage. There is no experimental basis for this assumption. Johnson and Auth[3] indicate that the presence of the heat of dissociation makes questionable the heat value of a portion of the carbon and probably all of the hydrogen.

There doubtless exists for typical municipal refuse an equation of the form of Equation 1, with different values than those shown for the carbon and hydrogen coefficients. The empirical establishment of such an equation will require the accumulation of substantial data on refuse chemical composition and heating values. Equation 1, based on the individual heating values of carbon and hydrogen, permits the convenient development of refuse compositions and will provide results which are conservative in predicting gas, air and water flows.

Table I lists the assumed refuse compositions and heating values based on Equation 1. The results presented by this report are based on these characteristics. Increasing heat content is achieved primarily through reduction in moisture and non-combustibles, with a steady increase in both the net hydrogen (hydrogen which is not combined with oxygen in the fuel, but which is burned with the oxygen in the air) and carbon. The decreasing carbon to net hydrogen ratio indicates that the net hydrogen increases more rapidly than the carbon. The use of "as fired" compositions, as opposed to the moisture-free or moisture-and-ash-free versions was used because it is what is actually placed in the furnace.

A trial computer run, using a factor of 162 substituted for the 141 in Equation 1, and using the same moisture, non-combustible and net hydrogen percentages as for the compositions in Table I, gave new compositions with lower carbon and higher oxygen percentages. Gas, air and water flows calculated on the basis of these new compositions were 5 to 10 percent lower than those based on Equation 1. Equilibrium gas temperatures were up to 7 percent higher. These deviations are not excessive. Thus, Equation 1 may be used to develop preliminary estimates of the relationship between refuse composition and heating value, and it provides a basis for analyzing the effects of the potential variability of refuse. The computer program can, of course, be used to analyze the air, gas and water flows and temperatures for known refuse compositions and heating values, as well as for hypothetical ones as discussed.

Equation 1 also neglects the heat released by the oxidation of metals in the non-combustibles. Mr. Kaiser[5] has indicated that this could amount to approximately 2 to 3 percent of the total heating value. Although the heating value calculated by Equation 1 will be slightly low due to the exclusion of this contribution, the analysis is simplified by the assumption and the important trends are unaffected. This was verified by a trial run on the computer, using heating values 200 Btu/pound higher than those given by Equation 1. The results indicate that a one percent change in higher heating value will result in, at most, a one percent change in temperature and gas flows, and a 1.2 percent change in quench water requirements.

Figure 1 is a moisture-and-ash-free plot of higher heating value versus the C/(H) (carbon to net hydrogen) ratio for constant percentage values of carbon. The compositions developed as input (Table I) to the computer program are shown with x's; note that there is only approximately a 5 percent range in the moisture-and-ash-free percentage of carbon. Thus, the increasing heating value is primarily due to increases in net hydrogen as shown by the decreasing C/(H) ratio. This is an expected trend in municipal refuse due to the addition of greater quantities of plastics and other hydrogen bearing materials. The proposed table of higher heating values and municipal refuse compositions is considered typical of current and expected municipal refuse compositions.

The computer program, given a refuse composition and heating value, a percent excess air, and a percent heat loss, calculates the products of combustion for a 2,000 pound per hour burning rate. It then generates a table of specific heats and enthalpies for the products, and performs a heat balance to determine the equilibrium gas temperature. This calculation assumes complete combustion, except for an assumed percentage of unburned carbon in the residue, and that equilibrium conditions are achieved. Sensible heat in the residue and fly ash is relatively small and is neglected. The hot gases are then water quenched to 1,000°F, 750°F, 500°F, 250°F, and to saturation. The program calculates the quench water requirements for each of these steps, and determines the weight and volume flow at each point. The quench water calculated is the theoretical quantity and assumes complete evaporation. The program is also given as input characteristics of the combustion air and quench water characteristics are incorporated within the program by means of the heat of vaporization. Table II illustrates a typical computer output.

Twenty-one refuse compositions are considered; eleven values of excess air from 40 to 300 percent, and ten heat loss percentages from 2 to 60 percent. Thus, 2,310 separate cases are considered, leading to some 70,000 items of information for the twenty-one refuse compositions calculated.

A typical means for presenting this type of information is to plot air, gas and water quantities in terms of "millions of Btu input", or as it is referred to in this report, "millions of Btu, total heat release". Thus, the 2,000 pounds per hour burning rate assumed in the study, multiplied by the higher heating value, gives the total heat release in Btu/hour. If this is then divided into the gas, air and water quantities, information such as pounds of air per million Btu, or pounds of exhaust gas per million Btu can be developed. This representation has become the accepted procedure in furnace design practice, because it permits general information to be developed independent of specific fuel compositions.

Since this study was primarily undertaken to investigate the effects of very specific variations in fuel composition and heating value, the "million Btu" representation of data was not used. In this study, gas, air and water quantities were plotted against higher heating value, temperature and heat loss percentage for the assumed one ton per hour burning rate.

However, the relationship of these quantities to millions of Btu of heat released may readily be obtained from the curves which are plotted. This is illustrated by Table III. Conversion of any of the curves to the million Btu basis is easily accomplished by simple manipulation of the given conditions.

B. EFFECTS OF REFUSE VARIABILITY ON EXHAUST GAS FLOW

Figures 2 through 9 illustrate one means by which the bulk of output information can be greatly reduced. These figures are plots of exhaust gas weight and volume flow versus temperature. All percentages of excess air are included on one graph, but each combination of heating value and percent heat loss will require a separate graph.

Exhaust gas weight and volume flows are plotted on the ordinates and exhaust gas temperatures on the abscissas. Furnace exit equilibrium temperatures are the extreme right ends of the curves and are circled. Saturation conditions are the extreme left ends of the curves and are boxed. Saturation is achieved entirely by water quench and no other form of cooling is introduced between the furnace exit and the saturation condition. Note that the circled points at the right extremity of each curve form a "locus" of furnace exit conditions. If it is desired to maintain a furnace exit temperature which falls between two of the points, then the required value of excess air percentage and the corresponding cooling curve may be interpolated.

Examination of several of the curves will serve as an example of their use. Note that the ordinate are in "thousands" of pounds per hour or CFM.

Figure 2 provides the weight and volume flow versus temperature for the combustion of one ton per hour of the 5,200 Btu/pound refuse when the heat loss is 2 percent. This is considered typical of current practice with uncooled refractory furnace enclosures. If 100 percent excess air is used, the furnace exit gas temperature will be 1,840°F and the gas flow will be 17,400 pounds per hour or 16,800 CFM. If the temperature is reduced to 600°F by means of water quenching, the weight flow increases to 22,300 pounds per hour, which means that 4,900 pounds per hour or 9.8 GPM of quench water have been added to achieve the 600°F temperature. The volume flow, however, has been reduced to 11,700 CFM.

If Figure 3 is consulted, the conditions are for 5,200 Btu per pound refuse and 30 percent heat loss. In this case, 100 percent excess air results in a furnace exit temperature of 1,290°F, a volume flow of 12,800 CFM and a weight flow of 17,500 pounds per hour. Note that the use of heat absorption equipment to the extent of 30 percent heat loss has greatly reduced the temperature and volume flow of gases leaving the furnace. This is an excellent illustration of the saving in the size of ducts and air pollution control equipment available from waste heat utilization, since this equipment must be sized on the basis of volume flow. Note that as expected, weight flow leaving the furnace is unaffected by heat loss. The conditions at 600°F are 10,000 CFM and 20,000 pounds per hour. Thus, the water requirement is reduced to 2,600 pounds per hour or 5.2 GPM from 9.8, also a saving attributable to the waste heat utilization.

Referring to Figure 4, the conditions are for 5,800 Btu/pound refuse and 2 percent heat loss. Examination of the 100 percent excess air case for this combination will give us an indication of the effects of a significant increase in contemporary heating values on incineration equipment typical today. The furnace exit temperature is 1,890°F, the volume flow is 18,900 CFM, and the weight flow is 19,200 pounds per hour. At 600°F, the volume flow is 12,800 CFM and the weight flow is 24,700 pounds per hour. Thus, 5,500 pounds per hour, or 11 GPM of water was added to quench to 600°F. Comparison of these results with those described for Figure 2 indicates that the 600 Btu/pound increase in HHV (11.5%) results in an increase of 50°F (2.7%) in furnace exit gas temperature, a 2,100 CFM (12.5%) increase in volume flow at T_G, and an 1,800 pound per hour (10.3%) increase in weight flow at T_G.

At 600°F, there is a 2,400 pound per hour (10.8%) increase in weight flow and a 1,100 CFM (10.3%) increase in volume flow. The water requirement increases by 1.2 GPM (12.3%). Thus the assumed increase in heating value can cause significant increases in the load on the exhaust gas handling and quench water systems, and could necessitate a lower burning rate if the over-capacity is not built into fans, etc. Since furnace exit gas temperature is usually maintained at a constant value by dilution with excess combustion air, the exhaust gas volume and weight flows would be increased even further if the exit temperature were to be maintained at the original 1,840°F. Examination of the locus of furnace exit conditions of Figure 4 shows that the excess air would have to be increased to approximately 110 percent.

Since furnace exit gas temperature is usually maintained at some constant value by dilution with excess air, a more realistic representation of the data is a plot of gas flows versus temperature for constant values of furnace exit gas temperature rather than constant values of percent excess air. In order for the computer program to accomplish this, the excess air corresponding to assumed values of 1,500, 1,600, 1,700, 1,800 and 1,900°F furnace exit temperatures were determined by iteration, and then all desired data were calculated at these new values of excess air. Figures 10 through 17 illustrate this representation of the data. From these graphs it is possible to determine the effects of heating value and heat loss variations while furnace exit gas temperature is maintained constant.

Another example will illustrate the value of these graphs. Figure 14 gives the conditions of 2 percent heat loss and a 6,400 Btu/pound refuse. If it is desired to maintain 1,600°F at the furnace exit, the gas volume flow is 22,900 CFM and the flow at 600°F is determined by following the 1,600°F curve down to 600°F where the volume flow is seen to be 16,400 CFM. Comparisons with the results at different heating values and heat losses may be accomplished in the same manner as was described for the other graphs. The effects of increasing or decreasing the setting of the temperature controller is immediately evident by merely moving from one constant temperature graph to another. Thus, at 6,400 Btu/pound, an increase in the temperature setting from 1,600°F to 1,700°F causes a decrease from 22,900 to 22,300 CFM.

The information shown on Figures 10 through 17 may be represented in other ways to illustrate the relationships among the variables. Additional graphs may be cross-plotted to show other characteristics not clearly evident from the original curves. Figures 18 and 19 show the exhaust gas volume at T_G plotted versus furnace exit gas temperature for various constant higher heating values, and each graph is for a constant heat loss percentage. Figures 20 through 24 show the exhaust gas volume at T_G plotted versus higher heating value for various percentages of heat loss, and each graph is for a constant furnace exit gas temperature. Figures 25 and 26 show the exhaust gas volume at T_G, at 500°F, and at saturation plotted versus higher heating value for various constant furnace exit gas temperatures, and each graph is for a constant heat loss.

C. EFFECTS OF REFUSE VARIABILITY ON AIRFLOW

Figures 27 and 28 give the air weight and volume flow (at 80°F) corresponding to each of the heating values given on Table I, plotted versus excess air percentages. These curves represent the entire data for airflow since they are independent of heat loss percentage. In the example given in Section B, at 100 percent excess air, the increase in airflow when heating value increases from 5,200 to 5,800 Btu/pound is from 3,500 to 3,900 CFM. This is an 11.4 percent increase in the output required from the combustion air fans. If constant temperature were to be maintained, an additional increase is required. This is shown on Figure 29. At 5,200 Btu/pound, the furnace exit gas temperature was 1,840°F. If this were maintained when the heating value was raised to 5,800 Btu/pound, the air volume flow is increased to 4,050 CFM, compared to 3,900 CFM if the temperature had been allowed to increase to 1890°F. Thus the increase in air volume flow would actually be 550 CFM or 15.7 percent. The excess air percentages corresponding to these conditions may be read from Figure 31. As expected for 1,840°F and 5,200 Btu/pound, the excess air is 100 percent; for 5,800 Btu/pound and 1,840°F, it is 107 percent.

Note that airflow and excess air percentage are not independent of heat loss percentage when gas temperature is constrained to constant values. Increased heat loss allows the constant temperature to be maintained with less cooling (excess) air, thereby illustrating that waste heat utilization reduces gas volume by reducing temperature without air or water quenching. For example, at 5,200 Btu/pound, and at a constant temperature of 1,840°F, the increase in heat loss from 2 percent to 30 percent reduces the required air volume flow from 4,050 CFM to 2,300 CFM, a reduction of 41.7 percent. Excess air is reduced to less than 30 percent (see Figures 30 and 32).

The curves of airflow versus the constant values of T_G for various values of heating value and heat loss percentage also give the opportunity to evaluate to some extent, the combination of air quenching and waste heat utilization. If at a given heating value gas temperature is achieved by a certain airflow, the gas temperature may be reduced by air quenching by following the line of constant HHV to the lower temperature. Figures 29 through 32 limit this procedure to a bottom temperature of 1,500°F, but Figures 2 through 9 allow for lower temperatures corresponding to a maximum dilution of 300 percent excess air. Further cooling may then be assessed on the basis of water quenching, following the excess air curve which gave the required amount of air quenching.

D. EFFECTS OF REFUSE VARIABILITY ON WATER FLOW

As discussed in Section B, Figures 2 through 17 assume that cooling below the furnace exit gas temperature is accomplished by water quenching. The water quantities required to achieve any temperature between T_G and saturation may be deduced by subtraction on the weight flow versus temperature curves (Figures 2 through 9). The water quantities involved are theoretical, assuming complete evaporation, whereas in actual practice, greater quantities will be required, depending upon the means used to inject the water. The use of Figures 2 through 9 to determine water requirements is limited in that interpolation between the given values of excess air will often be required. Figures 33 through 36 do away with this difficulty by plotting water requirements against furnace exit gas temperatures between 1,500°F and 1,900°F for various heating values and each graph is for a constant heat loss percentage. Figures 33 and 34 give the water requirement to quench to 500°F and Figures 35 and 36 the water requirements to quench to saturation.

Examination of the graphs for quenching to 500°F shows that, as expected, the quench water increases with increasing heating value. As the furnace exit gas temperature is controlled at higher values, the water requirement increases further, despite reduced airflow requirements at the higher temperatures. As the heat loss percentage is increased, this effect is less evident and the curves flatten out. The heat absorption reduces the airflow requirement more strongly than does the increasing furnace exit gas temperature.

The graphs for quenching to saturation show that the water required is essentially independent of the furnace exit gas temperature. This is due to a balance between the reduction in gas weight flow and the increase in gas enthalpy with increasing temperature. The number of Btu's which must be absorbed by the quench water is relatively constant. As expected, increasing heat absorption reduces the quench water requirement substantially. For example, with 5,800 Btu/pound refuse (Figure 35), the quench water requirement (to saturation) per ton burned is 17.6 GPM at 2 percent heat loss. At 30 percent heat loss (Figure 36), it is 11.7 GPM. This is a reduction of 33.4 percent. The reduction in quench water to 500°F from a T_G of 1,800°F is from 12.3 GPM to 8.2 GPM, also 33.4 percent. On an incinerator with a 240 ton per day, or 10 ton per hour capacity, this is a saving of 59,000 gallons of water per day. The use of the quench water graphs in conjunction with the other information discussed in Sections B and C will permit "trade-off" studies to be accomplished among waste heat utilization, water quenching and air quenching.

E. EFFECTS OF REFUSE VARIABILITY ON GAS TEMPERATURE

The results already discussed under Sections B and C indicate that variations in refuse characteristics tend to have a marked effect on the temperature of the gases exiting from the furnace. This temperature is normally controlled to a constant value by air dilution, and these effects are not always apparent in operation. However, when refuse characteristics suddenly exhibit a drastic change, as would occur if an excessively dry charge enters the furnace, the temperature controller often cannot compensate quickly enough, and a large increasing temperature excursion may occur. The combustion air dampers would open to their maximum area in an effort to exert control. As the charge burns down, this excess air provides too much cooling and an under temperature excursion occurs. If the operator continues to charge the dry material, the cycle repeats and the temperature recorder shows a highly cyclic pattern, and the excursions could reach 200 to 300°F. If a sufficiently dry refuse is charged continuously, the temperature controller may be incapable of exerting sufficient control, and the temperature may increase despite maximum airflow. Under these conditions the operator may find it necessary to reduce the burning rate and mix his charge with wetter refuse. It may even become necessary to deliberately wet the refuse.

Figures 2 through 9 may be used to illustrate the effects of increased refuse heating value on furnace exit temperature when excess air percentage is held constant. For example, at 2 percent heat loss, if heating value increased from 5,200 Btu/pound to 6,400 Btu/pound at 120 percent excess air, the furnace exit temperature increases from

1,720°F to 1,800°F, and the airflow from 3,900 to 4,790 CFM. If the air system must increase airflow further to hold temperature at 1,720, the excess air setting would be increased to 133 percent, and the airflow to 5,040 CFM (See Figures 29 and 31). Thus, in order to maintain the constant temperature with the sudden charge of dry refuse, the combustion air system must increase its output from 3,900 to 5,040 CFM, an increase of 1,140 CFM, or 29 percent. If the incinerator had originally been designed for normal operation with 5,200 Btu/pound refuse, it is unlikely that the designer would have built an overcapacity of almost 30 percent into the air system.

It is more likely that the air system will not even be capable of maintaining the original 120 percent excess air. For example, assuming that an overcapacity of only 15 percent was designed into the air system, the maximum output would be 4,490 CFM. This will result in a furnace exit gas temperature of 1,890°F (See Figure 29), or 172°F hotter than normal, and corresponds to 106 percent excess air for the 6,400 Btu/pound refuse (See Figure 31). If the operator persists in running the system under these conditions, he will probably encounter severe slagging and rapid deterioration of his refractory walls. His only means for compensating is to reduce the burning rate. It should be noted that the foregoing discussion has assumed that sufficient overcapacity exists in his exhaust gas system to handle the additional gas volume flow at T_G which has increased by 23 percent (See Figure 18).

The hypothetical situation described is based on a sudden, rather severe change in refuse characteristics, to which the operator usually will respond by temporarily depressing his burning rate. It also illustrates clearly the potential effects of long term variations. When the burning rate is permanently reduced below the design value to maintain safe operating conditions, the operator is faced with accumulating refuse due to increasing refuse quantities, additional shifts, weekend operation, and ultimately, acquisition of additional equipment must result.

If the designer decides to include a certain increment of overcapacity to accommodate the long term increases, he must provide different overcapacity factors for each of the gas air and water handling systems. This was illustrated in the example, where a 15 percent overcapacity in the air system resulted in a requirement for a 23 percent overcapacity in the exhaust gas handling system.

The output data from the computer study also gave the exhaust gas flows at various temperatures below the furnace exit gas temperature, down to saturation. These intermediate temperatures of 1,000°F, 750°F, 500°F and 250°F were achieved entirely by water quench. Of these, 500°F is probably of greatest interest, since mechanical and electrostatic air pollution control equipment is most likely to operate at about this temperature. Saturation conditions are of interest in systems that use scrubbers for air pollution control equipment. At 500°F, there is a progressive increase in volume flow of exhaust gas with increasing heating value, while increasing heat loss reduces the volume flow. The lower the controlled furnace exit gas temperature, the higher the gas flow at 500°F. These relationships are well illustrated by Figures 25 and 26. For example, at 5,200 Btu/pound and 2 percent heat loss and T_G = 1,600°F, the volume flow at 500°F is 12,100 CFM. With 5,800 Btu/pound refuse at the same conditions, the volume flow becomes 13,800 CFM. If heat loss percentage is increased to 30 percent, the volume flow at 5,200 Btu/pound would be 8,000 CFM. If T_G were increased to 1,700°F, the volume flow at 5,200 Btu/pound and 2 percent heat loss would be 11,600 CFM and at 5,800 Btu/pound it would be 13,100 CFM. At 30 percent heat loss these figures would be 7,600 CFM and 8,700 CFM.

Saturation temperature does not vary drastically over the range of heating values and other conditions studied. However, this is primarily due to the steep slope of saturation line on a humidity versus temperature chart. There will be a large variation in saturation humidity of the gases, but only a slight variation in the saturation temperature. For example, over the practical range of conditions studied, the saturation temperature does not fall outside the range from 165 to 185°F, and the saturation humidity varies from .35 to .85 pounds water vapor per pound of dry gas.

F. EFFECTS OF REFUSE VARIABILITY ON WASTE HEAT UTILIZATION

Waste heat utilization (or waste heat absorption without subsequent utilization) offers many advantages in addition to the obvious ones involved in reclaiming some of the energy in the refuse. If heat absorption equipment is capable of varying the amount of heat it removes from the gases, then compensation for the effects of refuse variability is possible. Decreases in heating value cause increases in air and gas volume flows and quench water requirements. The removal of more heat from the gases can compensate for these increases. Examination of Figures 20 through 24 shows that a constant exhaust gas volume flow at T_G may be maintained by progressive increases in heat loss percentage, regardless of increases in refuse heating value. Similar graphs may be cross-plotted from data already presented to illustrate how volume flow at other temperatures, airflow and water requirements may also be held constant with increasing heating value, by approximate manipulation of the waste heat absorbed. The data with regard to heat absorption within the furnace while furnace exit gas temperature is maintained between 1,500 and 1,900°F, does not account for further heat absorption equipment which may be installed downstream of the furnace and which can be used to replace the water quenching equipment to achieve various temperatures below T_G. This option was not considered in the computer study except to the extent that Figures 2 through 9 illustrate the combinations that result in furnace exit gas temperatures below 1,500°F.

SECTION VI

REFERENCES

1. Kaiser, E. R. Combustion and Heat Calculations for Incinerators. Proceedings of 1964 National Incinerator Conference.

2. Kaiser, E. R. Refuse Composition and Flue Gas Analyses from Municipal Incinerators. Proceedings of 1964 National Incinerator Conference.

3. Johnson, A. J. and G. H. Auth. Fuels and Combustion Handbook. 1951.

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5. Kaiser, E. R. Chemical Analyses of Refuse Components. Proceedings of 1966 National Incinerator Conference.

SECTION VII

NOMENCLATURE AND DEFINITION OF TERMS

HHV	Higher heating value -- Btu per pound
%C	Percentage by weight carbon, as fired
%H	Percentage by weight hydrogen, as fired
%O	Percentage by weight oxygen, as fired
$\%H_2O$	Percentage by weight moisture, as fired
% Non-comb.	Percentage by weight non-combustibles, as fired
%NH	Percentage by weight net hydrogen
T_G	Equilibrium exhaust gas temperature -- °F
T_{sat}	Saturation temperature of exhaust gas -- °F
CFM	Volume flow of exhaust (flue) gas -- cubic feet per minute
CFM_{air}	Volume flow of combustion air -- cubic feet per minute
GPM_{quench}	Volume flow of quench water -- gallons per minute
Percent Heat Loss	Percentage of total heat release (higher heating value x burning rate) which is lost by radiation and/or absorbed by heat recovery equipment.
Carbon to Net Hydrogen Ratio	The ratio of the percentage by weight of carbon (%C) to the percentage by weight of net hydrogen (%NH). The ratio equals %C/(%H-%O/8).
Percentage Unburned Carbon in Residue	The percentage of the non-combustibles which are made up of unburned carbon.
Exhaust Gas Flow	The weight or volume flow of all gaseous products of combustion, including moisture in the fuel and in the combustion air, moisture resulting from combination of oxygen and hydrogen and all quench water added to achieve any particular temperature.

TABLE I

REFUSE COMPOSITIONS USED IN REFUSE VARIABILITY

COMPUTER PROGRAM (PARTIAL LISTING)

(PERCENT BY WEIGHT)

HHV Btu per lb.	C%	H%	O%	H_2O%	NonC%	Carbon to Net Hydrogen Ratio C/(H)
4,000	24.0	3.5	20.0	30.0	22.5	24.00
4,600	27.3	4.0	22.0	24.2	22.5	21.82
5,200	30.4	4.5	24.0	21.1	20.0	20.26
5,800	32.5	5.25	26.0	18.3	18.0	16.23
6,400	35.7	5.5	26.0	16.0	16.8	15.84
7,000	37.7	6.0	26.0	16.0	14.3	13.72
7,600	39.8	7.0	30.0	12.0	11.2	12.25
8,000	40.5	7.5	30.0	11.0	11.0	10.80

TABLE II

TYPICAL COMPUTER OUTPUT, REFUSE VARIABILITY PROGRAM

Influence of Refuse Characteristics

Refuse HHV = 5,400 Btu per pound   Combustion Rate = 2,000 pound/hour

Moisture	Carbon	Hydrogen	Oxygen	Non-Combustible
18.3%	30.7%	5.0%	26.6%	20.0%

Carbon unburned	= 4.0% (of non-combustible)
Excess air	= 100.0%
Air flow	= 16,170 pound/hour or 3,665 CFM (at 80°F)
Heat loss (absorption and radiation)	= 10.0%
Equilibrium gas temperature	= 1,706.7°F
Saturation temperature	= 175.3°F
Total dry products	= 16,488 pound/hour
Saturation humidity	= 0.535 pounds/pound DG

Temperature	1,706.7°F	1,000°F	750°F	500°F	250°F	175°F
Wet exhaust gas,* lb./hour	17,964	20,508	21,668	23,010	24,595	25,316
Wet exhaust gas,* CFM	16,325	14,078	12,611	10,867	8,759	8,150
Moisture content,* lb./hour	1,476	4,020	5,179	6,522	8,106	8,827
Moisture content,* GPM	2.95	8.04	10.36	13.04	16.21	17.65
Quench water added, lb/hour	-	2,544	3,703	5,046	6,631	7,351
Quench water added, GPM	-	5.09	7.41	10.09	13.26	14.70

Water at 80°F necessary to quench from 500°F to saturation at 100 percent efficiency = 2305 pounds/hour or 4.62 GPM.

* Including quench water, moisture from air and from refuse combustion.

TABLE III

INFORMATION FROM REFUSE VARIABILITY COMPUTER

PROGRAM ON "MILLION Btu" BASIS

HHV Btu/lb.	Fuel (lb./10^6 Btu)	Theoretical Air (lb./10^6 Btu) (Figure 27)	% Excess Air To Maintain 1,600°F (Figure 31)	Actual Air (lb./10^6 Btu)	Exhaust Gas (lb./10^6 Btu) (Figure 21)
4,000	250	751	118	1,637	1,830
4,600	218	751	133	1,751	1,920
5,200	192	755	143	1,835	1,990
5,800	172	745	150	1,863	2,004
6,400	156	749	156	1,917	2,047
7,000	143	747	161	1,951	2,073
7,600	132	740	165	1,960	2,077
8,000	125	738	168	1,976	2,086

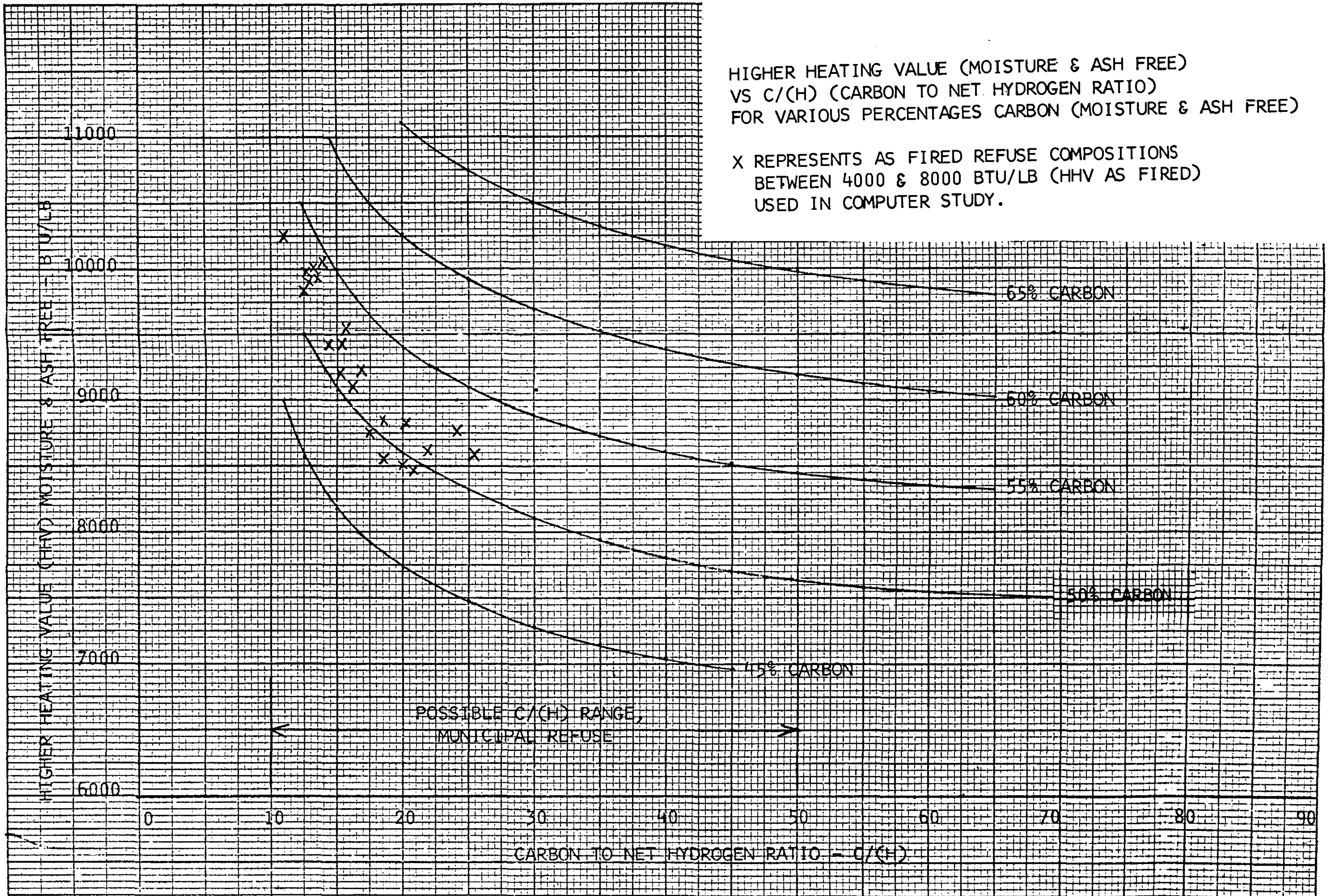
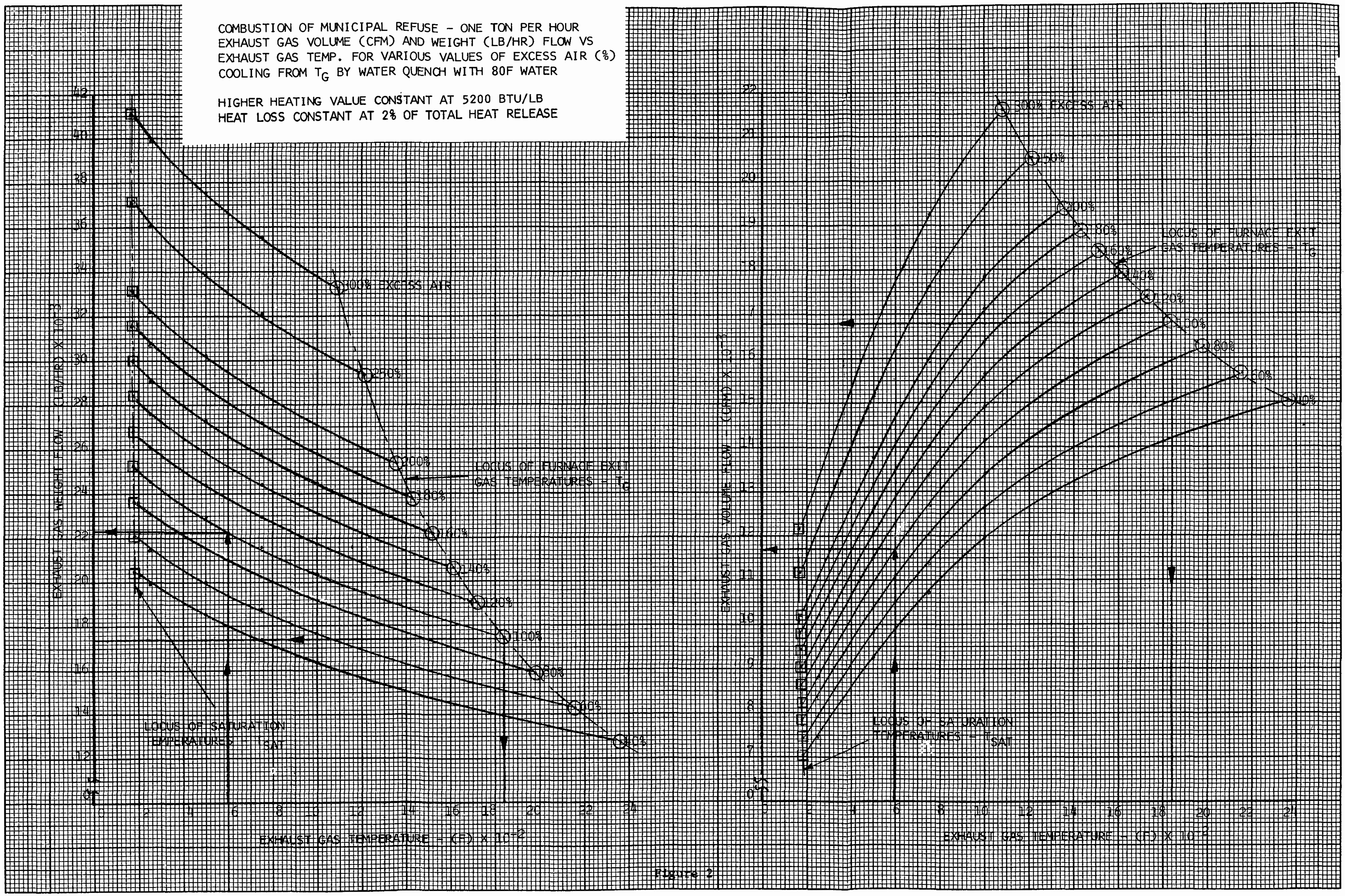

HIGHER HEATING VALUE (MOISTURE & ASH FREE)
VS C/(H) (CARBON TO NET HYDROGEN RATIO)
FOR VARIOUS PERCENTAGES CARBON (MOISTURE & ASH FREE)
X REPRESENTS AS FIRED REFUSE COMPOSITIONS
BETWEEN 4000 & 8000 BTU/LB (HHV AS FIRED)
USED IN COMPUTER STUDY.
HIGHER HEATING VALUE (HHV) MOISTURE & ASH FREE - BTU/LB
11000
10000
9000
8000
7000
6000
65% CARBON
60% CARBON
55% CARBON
50% CARBON
45% CARBON
POSSIBLE C/(H) RANGE,
MUNICIPAL REFUSE
0
10
20
30
40
50
60
70
80
90
CARBON TO NET HYDROGEN RATIO - C/(H)

Figure 1



COMBUSTION OF MUNICIPAL REFUSE - ONE TON PER HOUR
EXHAUST GAS VOLUME (CFM) AND WEIGHT (LB/HR) FLOW VS
EXHAUST GAS TEMP. FOR VARIOUS VALUES OF EXCESS AIR (%)
COOLING FROM T_G BY WATER QUENCH WITH 80F WATER
HIGHER HEATING VALUE CONSTANT AT 5200 BTU/LB
HEAT LOSS CONSTANT AT 2% OF TOTAL HEAT RELEASE
EXHAUST GAS WEIGHT FLOW (LB/HR) X 10^{-3}
300% EXCESS AIR
250%
200%
180%
160%
140%
120%
100%
80%
60%
40%
LOCUS OF FURNACE EXIT GAS TEMPERATURES - T_G
LOCUS OF SATURATION TEMPERATURES - T_{SAT}
EXHAUST GAS TEMPERATURE - (F) X 10^{-2}
EXHAUST GAS VOLUME FLOW (CFM) X 10^{-3}
300% EXCESS AIR
250%
200%
180%
160%
140%
120%
100%
80%
60%
40%
LOCUS OF FURNACE EXIT GAS TEMPERATURES - T_G
LOCUS OF SATURATION TEMPERATURES - T_{SAT}
EXHAUST GAS TEMPERATURE - (F) X 10^{-2}

Figure 2

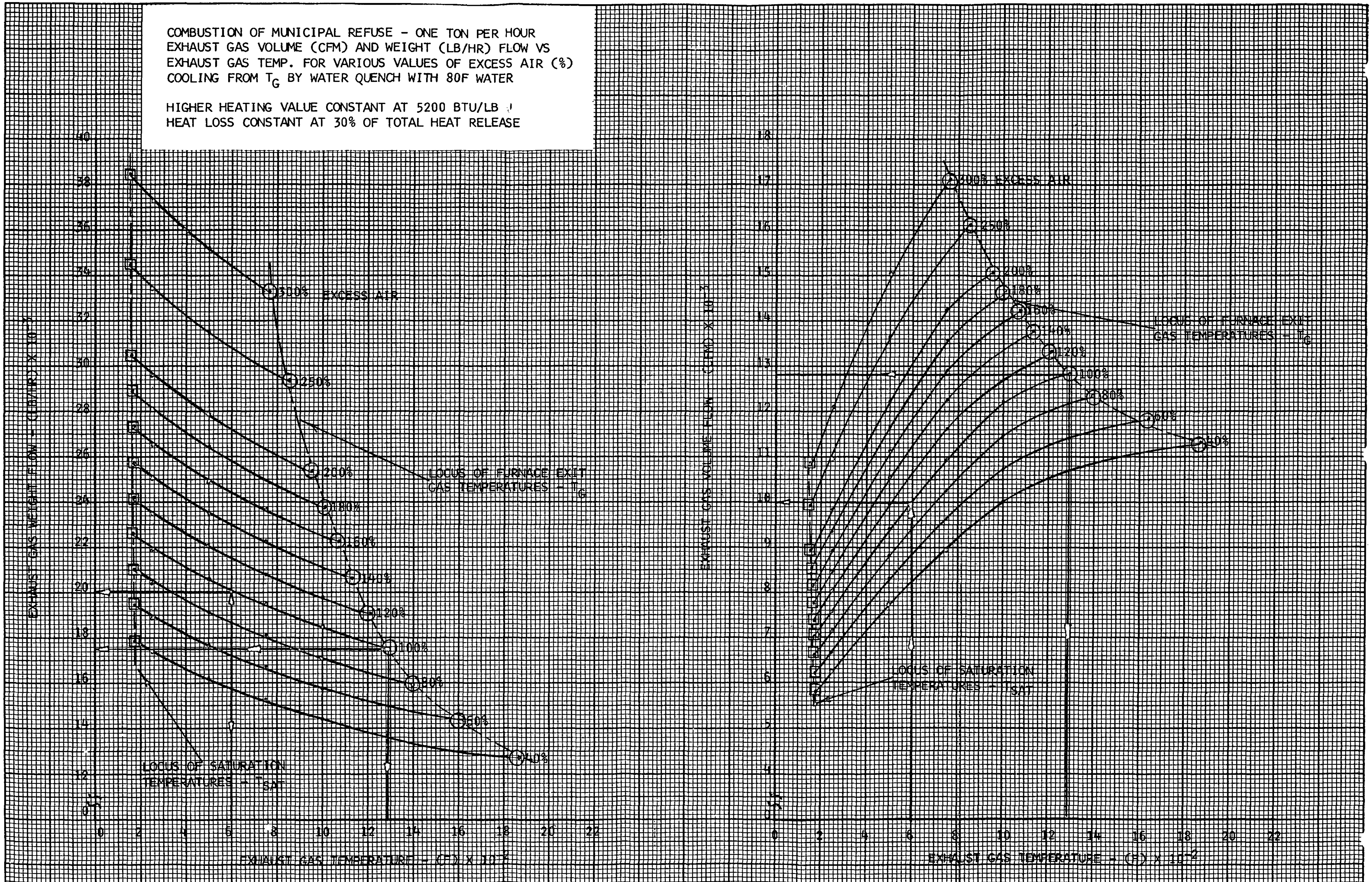

COMBUSTION OF MUNICIPAL REFUSE - ONE TON PER HOUR
EXHAUST GAS VOLUME (CFM) AND WEIGHT (LB/HR) FLOW VS
EXHAUST GAS TEMP. FOR VARIOUS VALUES OF EXCESS AIR (%)
COOLING FROM T_G BY WATER QUENCH WITH 80F WATER
HIGHER HEATING VALUE CONSTANT AT 5200 BTU/LB
HEAT LOSS CONSTANT AT 30% OF TOTAL HEAT RELEASE
EXHAUST GAS WEIGHT FLOW - (LB/HR) X 10^{-3}
300% EXCESS AIR
250%
200%
180%
160%
140%
120%
100%
80%
60%
40%
LOCUS OF FURNACE EXIT GAS TEMPERATURES - T_G
LOCUS OF SATURATION TEMPERATURES - T_{SAT}
EXHAUST GAS TEMPERATURE - (F) X 10^{-2}
EXHAUST GAS VOLUME FLOW - (CFM) X 10^{-3}
300% EXCESS AIR
250%
200%
180%
160%
140%
120%
100%
80%
60%
40%
LOCUS OF FURNACE EXIT GAS TEMPERATURES - T_G
LOCUS OF SATURATION TEMPERATURES - T_{SAT}
EXHAUST GAS TEMPERATURE - (F) X 10^{-2}

Figure 3

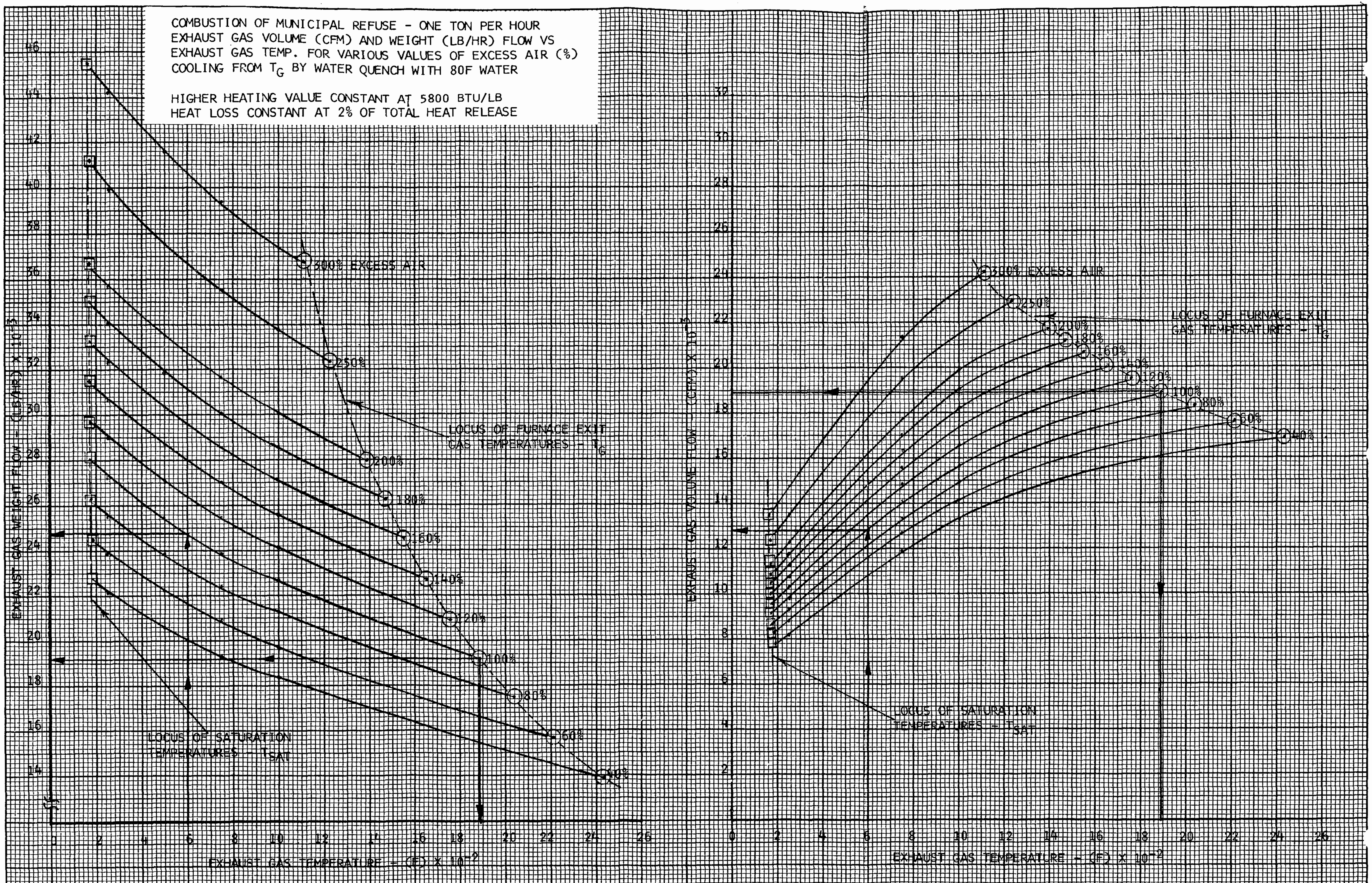

COMBUSTION OF MUNICIPAL REFUSE - ONE TON PER HOUR
EXHAUST GAS VOLUME (CFM) AND WEIGHT (LB/HR) FLOW VS
EXHAUST GAS TEMP. FOR VARIOUS VALUES OF EXCESS AIR (%)
COOLING FROM T_G BY WATER QUENCH WITH 80F WATER
HIGHER HEATING VALUE CONSTANT AT 5800 BTU/LB
HEAT LOSS CONSTANT AT 2% OF TOTAL HEAT RELEASE
EXHAUST GAS WEIGHT FLOW - (LB/HR) X 10^{-3}
300% EXCESS AIR
250%
200%
180%
160%
140%
120%
100%
80%
60%
40%
LOCUS OF FURNACE EXIT GAS TEMPERATURES - T_G
LOCUS OF SATURATION TEMPERATURES - T_{SAT}
EXHAUST GAS TEMPERATURE - (F) X 10^{-2}
EXHAUST GAS VOLUME FLOW - (CFM) X 10^{-3}
300% EXCESS AIR
250%
200%
180%
160%
140%
120%
100%
80%
60%
40%
LOCUS OF FURNACE EXIT GAS TEMPERATURES - T_G
LOCUS OF SATURATION TEMPERATURES - T_{SAT}
EXHAUST GAS TEMPERATURE - (F) X 10^{-2}

Figure 4

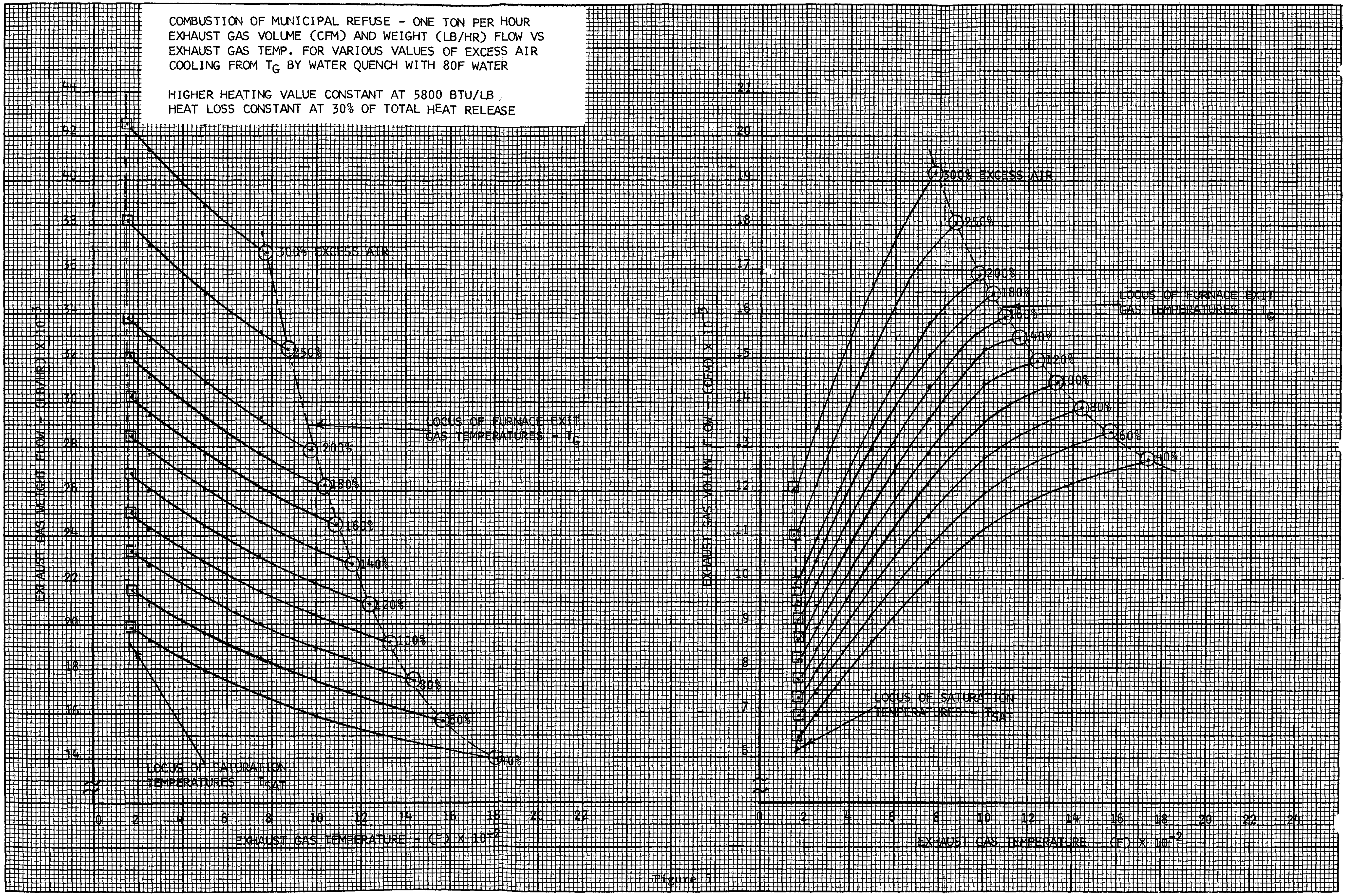
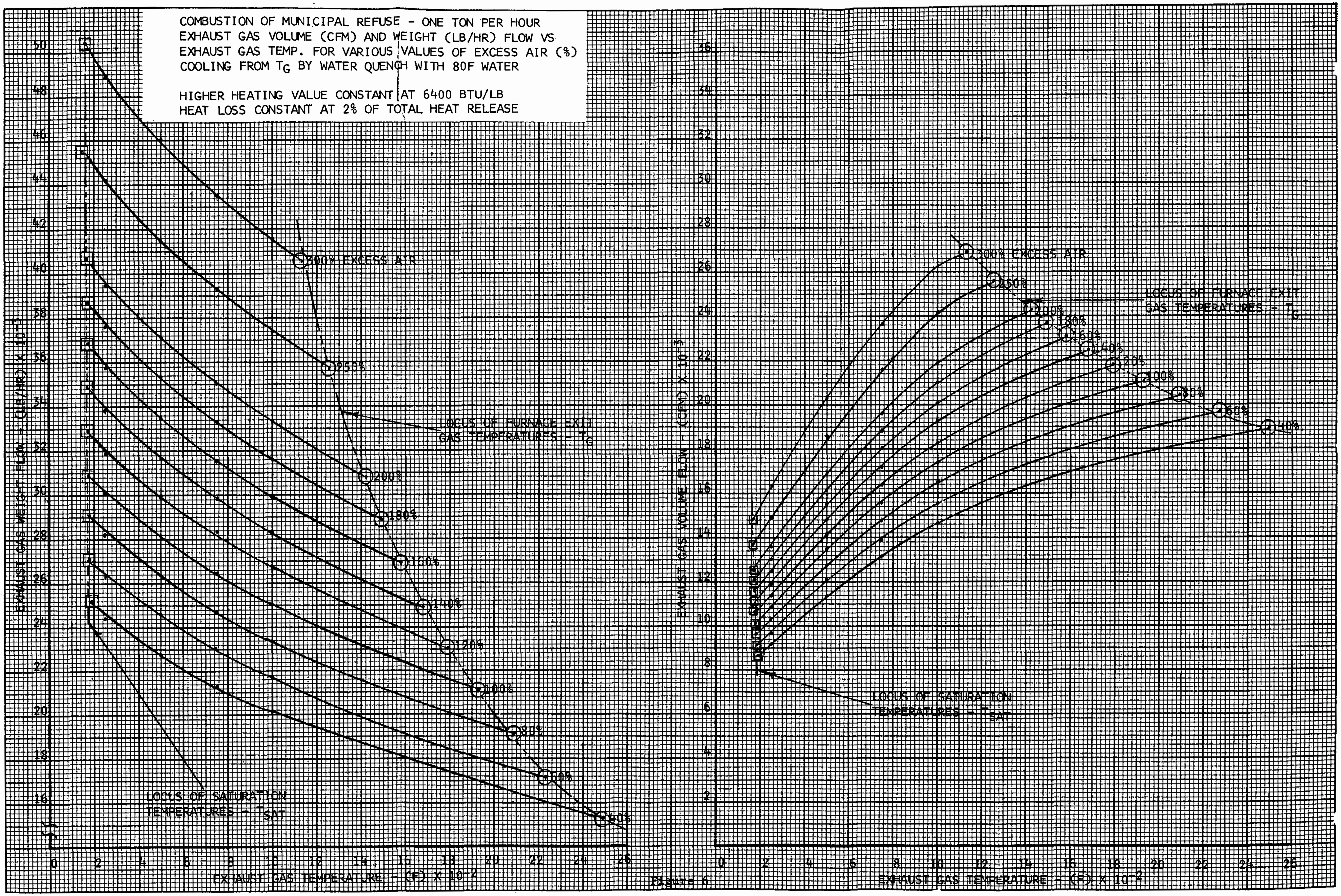

COMBUSTION OF MUNICIPAL REFUSE - ONE TON PER HOUR
EXHAUST GAS VOLUME (CFM) AND WEIGHT (LB/HR) FLOW VS
EXHAUST GAS TEMP. FOR VARIOUS VALUES OF EXCESS AIR
COOLING FROM T_G BY WATER QUENCH WITH 80F WATER
HIGHER HEATING VALUE CONSTANT AT 5800 BTU/LB
HEAT LOSS CONSTANT AT 30% OF TOTAL HEAT RELEASE
EXHAUST GAS WEIGHT FLOW - (LB/HR) X 10^{-3}
300% EXCESS AIR
250%
200%
180%
160%
140%
120%
100%
80%
60%
40%
LOCUS OF FURNACE EXIT GAS TEMPERATURES - T_G
LOCUS OF SATURATION TEMPERATURES - T_{SAT}
EXHAUST GAS TEMPERATURE - (F) X 10^{-2}
EXHAUST GAS VOLUME FLOW - (CFM) X 10^{-3}
300% EXCESS AIR
250%
200%
180%
160%
140%
120%
100%
80%
60%
40%
LOCUS OF FURNACE EXIT GAS TEMPERATURES - T_G
LOCUS OF SATURATION TEMPERATURES - T_{SAT}
EXHAUST GAS TEMPERATURE - (F) X 10^{-2}

Figure 5



COMBUSTION OF MUNICIPAL REFUSE - ONE TON PER HOUR
EXHAUST GAS VOLUME (CFM) AND WEIGHT (LB/HR) FLOW VS
EXHAUST GAS TEMP. FOR VARIOUS VALUES OF EXCESS AIR (%)
COOLING FROM T_G BY WATER QUENCH WITH 80F WATER
HIGHER HEATING VALUE CONSTANT AT 6400 BTU/LB
HEAT LOSS CONSTANT AT 2% OF TOTAL HEAT RELEASE
300% EXCESS AIR
250%
200%
180%
160%
140%
120%
100%
80%
60%
40%
LOCUS OF FURNACE EXIT GAS TEMPERATURES - T_G
LOCUS OF SATURATION TEMPERATURES - T_{SAT}
EXHAUST GAS WEIGHT FLOW - (LB/HR) X 10^{-3}
EXHAUST GAS TEMPERATURE - (F) X 10^{-2}
EXHAUST GAS VOLUME FLOW - (CFM) X 10^{-3}

Figure 6

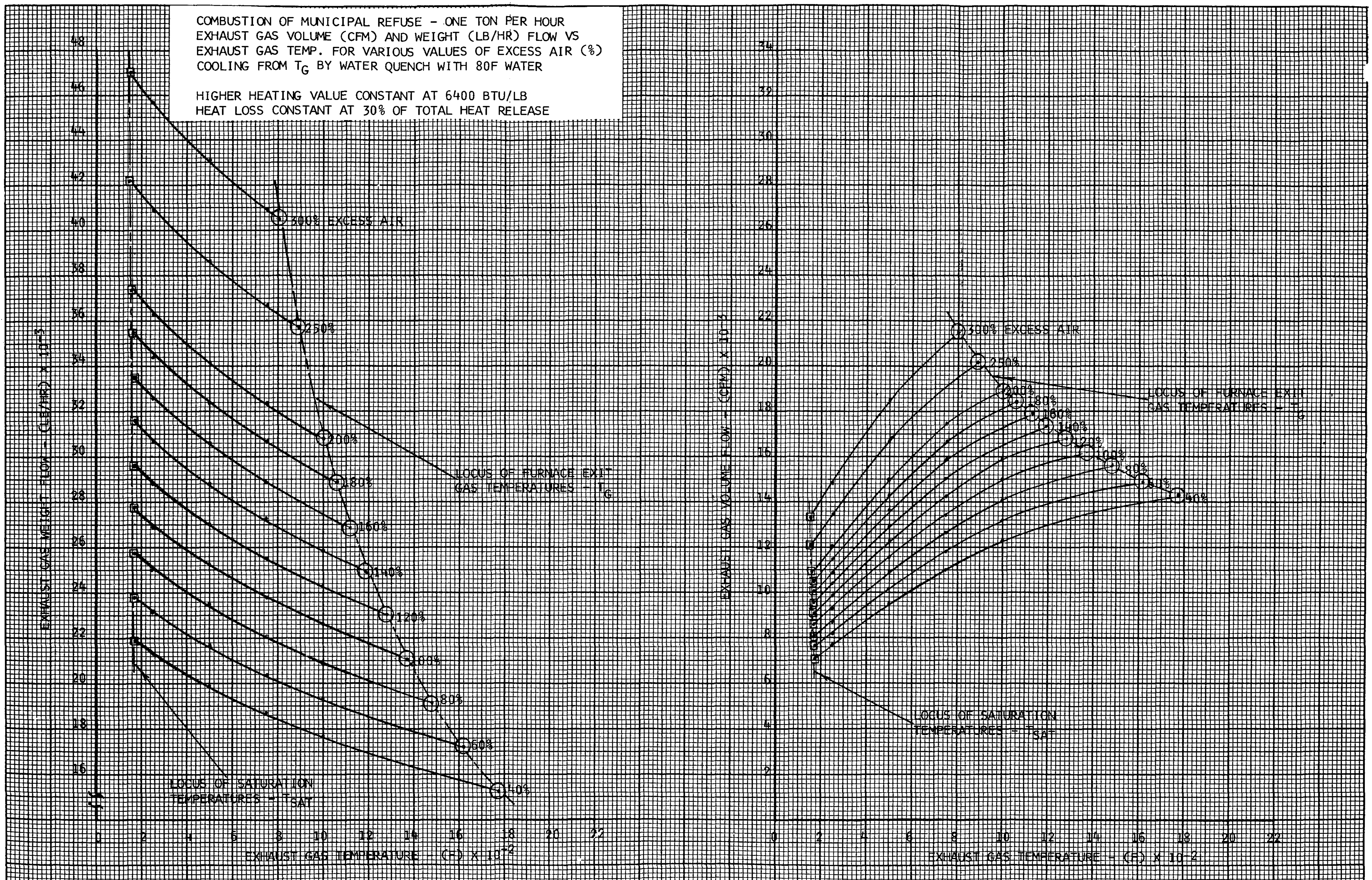
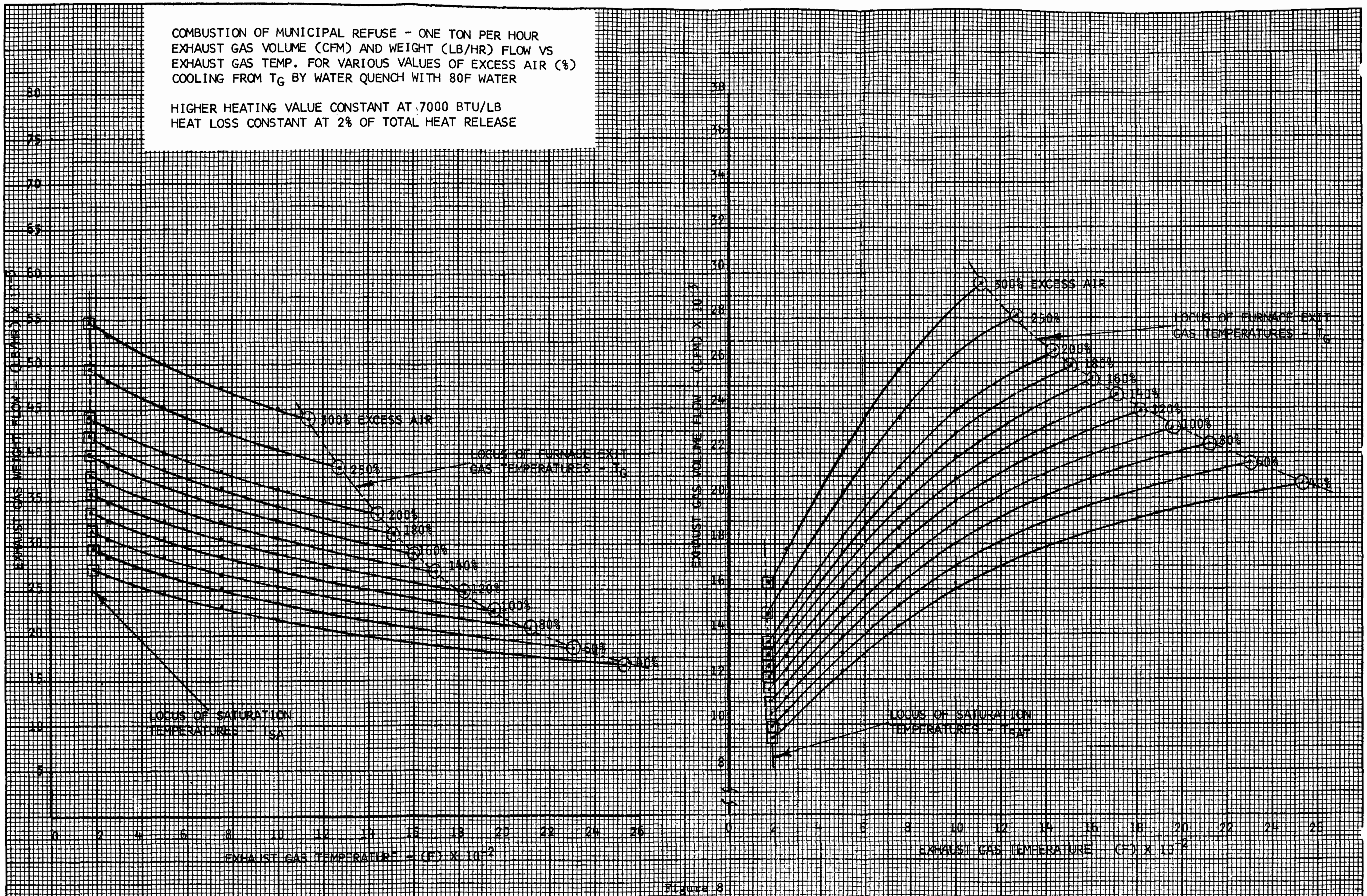

COMBUSTION OF MUNICIPAL REFUSE - ONE TON PER HOUR
EXHAUST GAS VOLUME (CFM) AND WEIGHT (LB/HR) FLOW VS
EXHAUST GAS TEMP. FOR VARIOUS VALUES OF EXCESS AIR (%)
COOLING FROM T_G BY WATER QUENCH WITH 80F WATER
HIGHER HEATING VALUE CONSTANT AT 6400 BTU/LB
HEAT LOSS CONSTANT AT 30% OF TOTAL HEAT RELEASE
EXHAUST GAS WEIGHT FLOW - (LB/HR) x 10^{-3}
300% EXCESS AIR
250%
200%
180%
160%
140%
120%
100%
80%
60%
40%
LOCUS OF FURNACE EXIT GAS TEMPERATURES - T_G
LOCUS OF SATURATION TEMPERATURES - T_{SAT}
EXHAUST GAS TEMPERATURE - (F) x 10^{-2}
EXHAUST GAS VOLUME FLOW - (CFM) x 10^{-3}
300% EXCESS AIR
250%
200%
180%
160%
140%
120%
100%
80%
60%
40%
LOCUS OF FURNACE EXIT GAS TEMPERATURES - T_G
LOCUS OF SATURATION TEMPERATURES - T_{SAT}
EXHAUST GAS TEMPERATURE - (F) x 10^{-2}

Figure 7



COMBUSTION OF MUNICIPAL REFUSE - ONE TON PER HOUR
EXHAUST GAS VOLUME (CFM) AND WEIGHT (LB/HR) FLOW VS EXHAUST GAS TEMP. FOR VARIOUS VALUES OF EXCESS AIR (%)
COOLING FROM T_G BY WATER QUENCH WITH 80F WATER
HIGHER HEATING VALUE CONSTANT AT 7000 BTU/LB
HEAT LOSS CONSTANT AT 2% OF TOTAL HEAT RELEASE
EXHAUST GAS WEIGHT FLOW - (LB/HR) x 10^{-3}
300% EXCESS AIR
250%
200%
180%
160%
140%
120%
100%
80%
60%
40%
LOCUS OF FURNACE EXIT GAS TEMPERATURES - T_G
LOCUS OF SATURATION TEMPERATURES - T_{SAT}
EXHAUST GAS TEMPERATURE - (F) X 10^{-2}
EXHAUST GAS VOLUME FLOW - (CFM) X 10^{-3}

Figure 8

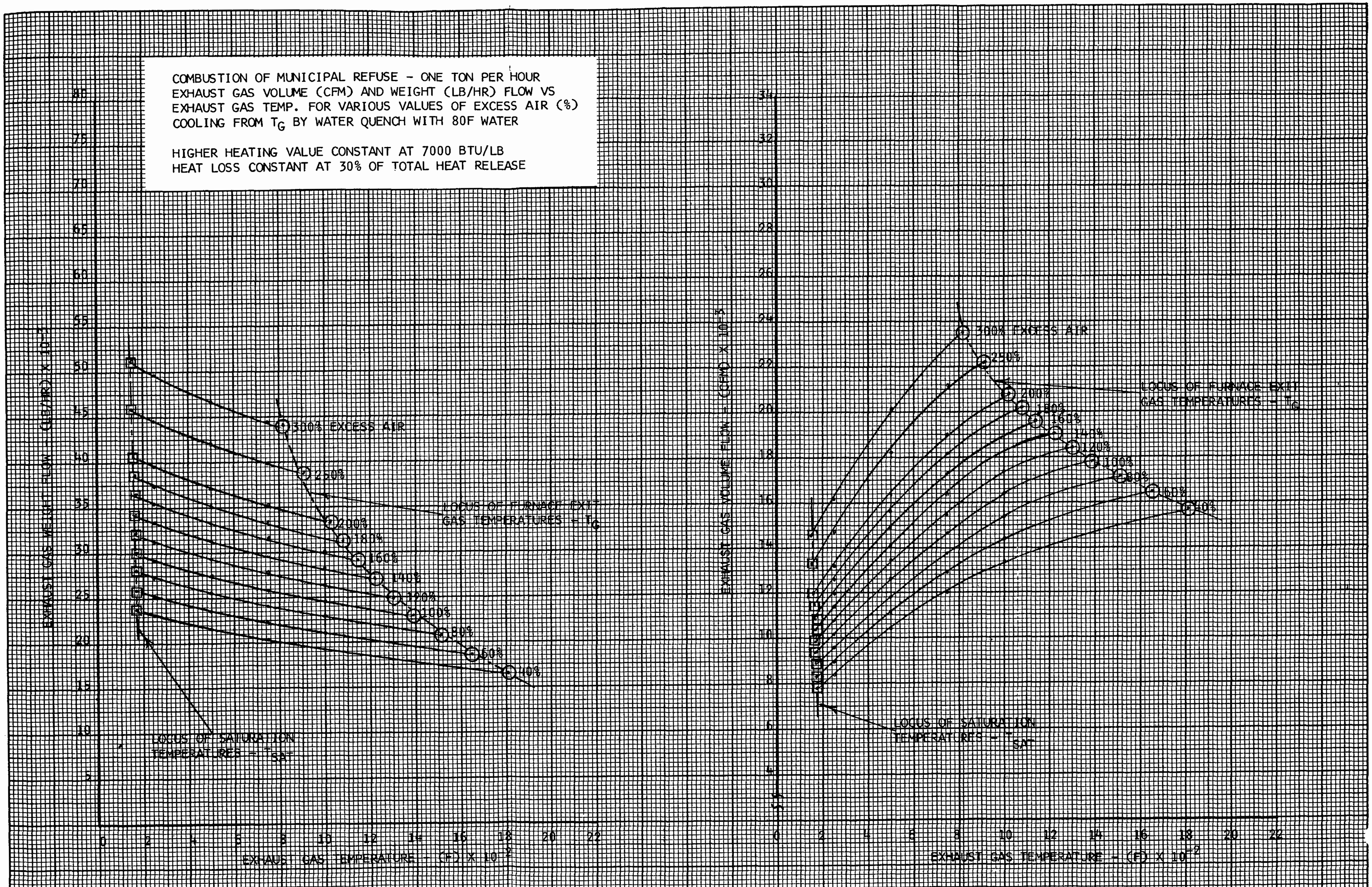
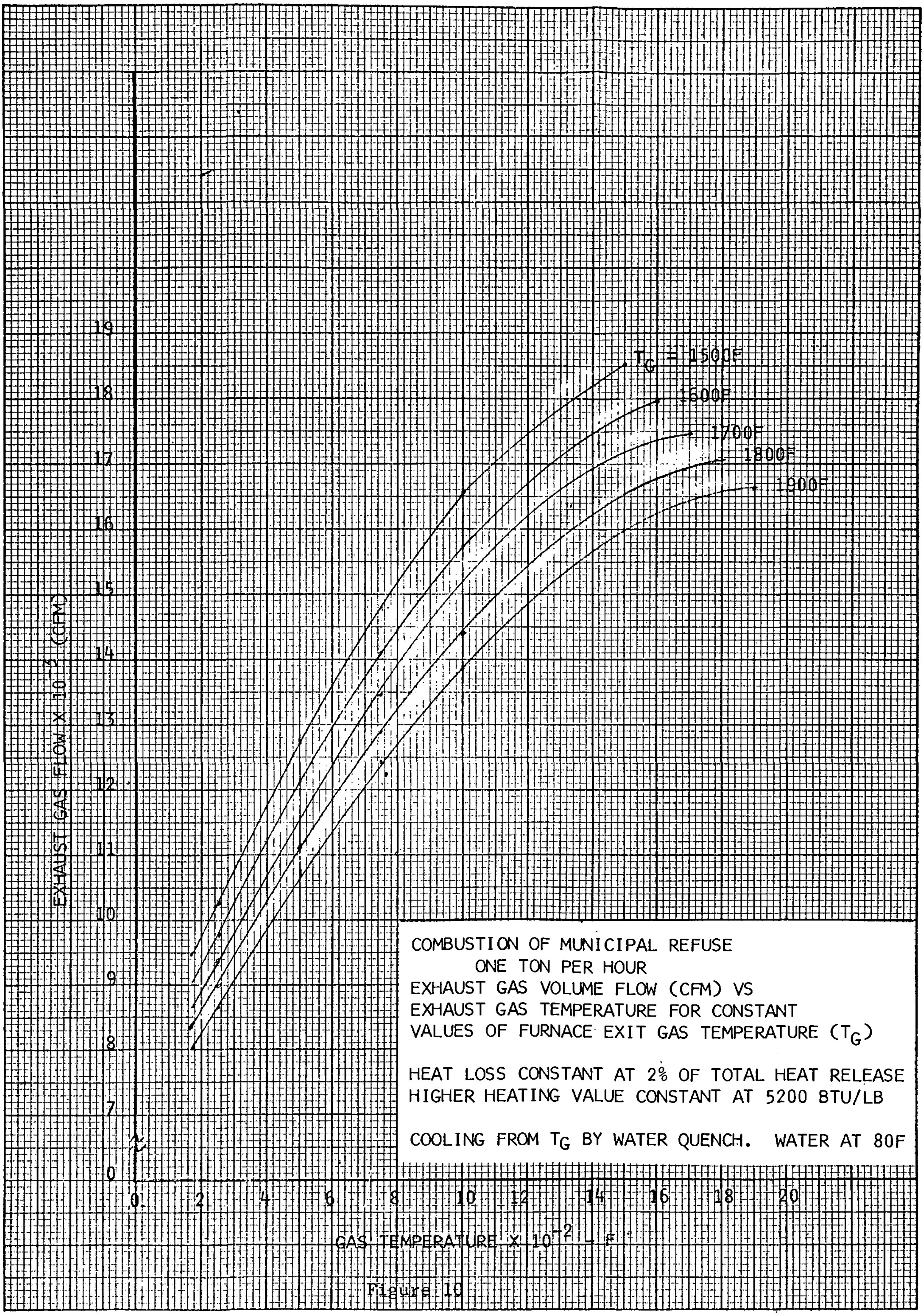

COMBUSTION OF MUNICIPAL REFUSE - ONE TON PER HOUR
EXHAUST GAS VOLUME (CFM) AND WEIGHT (LB/HR) FLOW VS
EXHAUST GAS TEMP. FOR VARIOUS VALUES OF EXCESS AIR (%)
COOLING FROM T_G BY WATER QUENCH WITH 80F WATER
HIGHER HEATING VALUE CONSTANT AT 7000 BTU/LB
HEAT LOSS CONSTANT AT 30% OF TOTAL HEAT RELEASE
EXHAUST GAS WEIGHT FLOW - (LB/HR) X 10^{-3}
300% EXCESS AIR
250%
200%
180%
160%
140%
120%
100%
80%
60%
40%
LOCUS OF FURNACE EXIT GAS TEMPERATURES - T_G
LOCUS OF SATURATION TEMPERATURES - T_{SAT}
EXHAUST GAS TEMPERATURE - (F) X 10^{-2}
EXHAUST GAS VOLUME FLOW - (CFM) X 10^{-3}

Figure 9



EXHAUST GAS FLOW X 10^-3 (CFM)
GAS TEMPERATURE X 10^-2 - F
T_G = 1500F
1600F
1700F
1800F
1900F
COMBUSTION OF MUNICIPAL REFUSE
ONE TON PER HOUR
EXHAUST GAS VOLUME FLOW (CFM) VS
EXHAUST GAS TEMPERATURE FOR CONSTANT
VALUES OF FURNACE EXIT GAS TEMPERATURE (T_G)
HEAT LOSS CONSTANT AT 2% OF TOTAL HEAT RELEASE
HIGHER HEATING VALUE CONSTANT AT 5200 BTU/LB
COOLING FROM T_G BY WATER QUENCH. WATER AT 80F

Figure 10

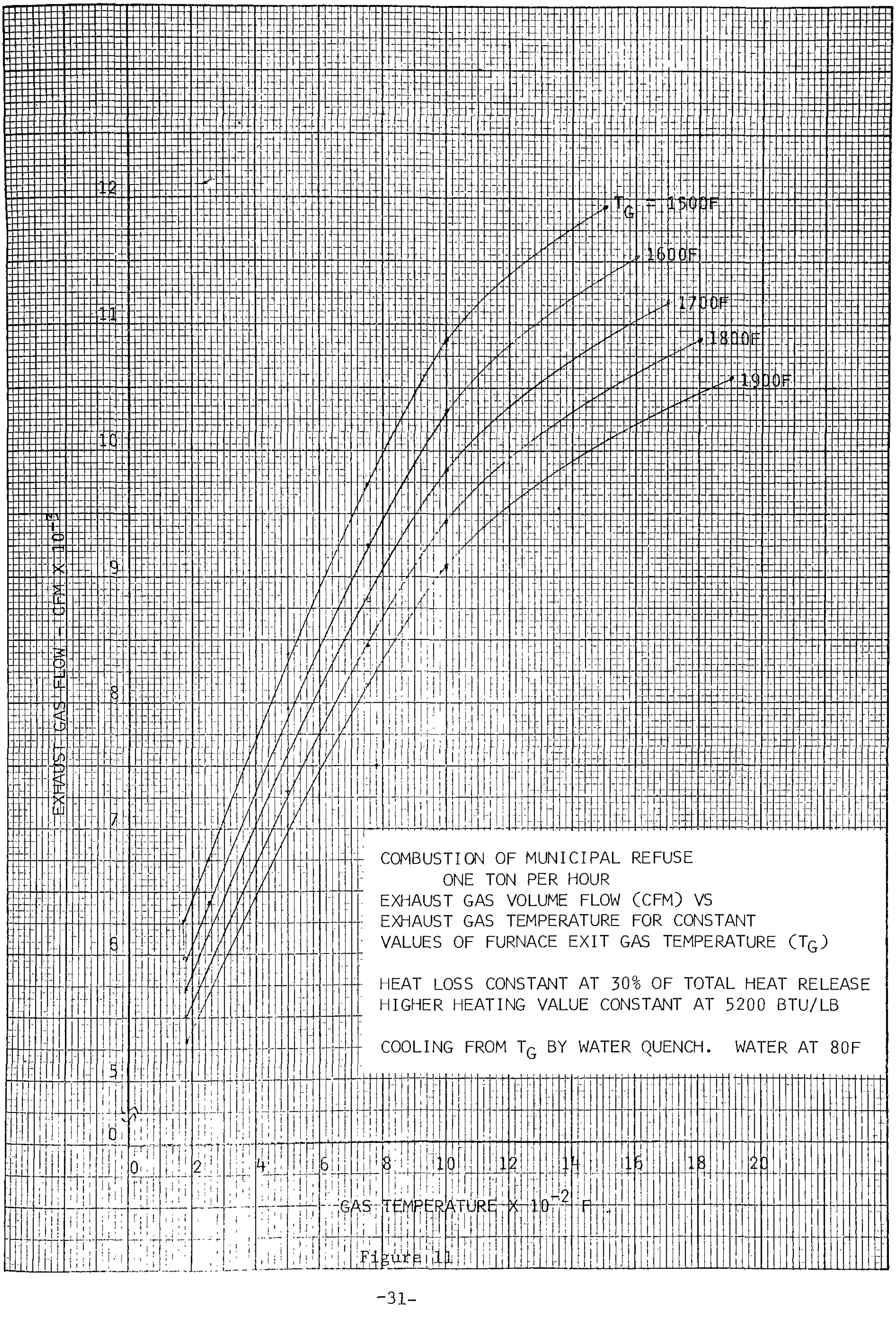

EXHAUST GAS FLOW - CFM X 10^-3
12
11
10
9
8
7
6
5
0
0
2
4
6
8
10
12
14
16
18
20
GAS TEMPERATURE X 10^-2 F
T_G = 1500F
1600F
1700F
1800F
1900F
COMBUSTION OF MUNICIPAL REFUSE
ONE TON PER HOUR
EXHAUST GAS VOLUME FLOW (CFM) VS
EXHAUST GAS TEMPERATURE FOR CONSTANT
VALUES OF FURNACE EXIT GAS TEMPERATURE (T_G)
HEAT LOSS CONSTANT AT 30% OF TOTAL HEAT RELEASE
HIGHER HEATING VALUE CONSTANT AT 5200 BTU/LB
COOLING FROM T_G BY WATER QUENCH. WATER AT 80F

Figure 11

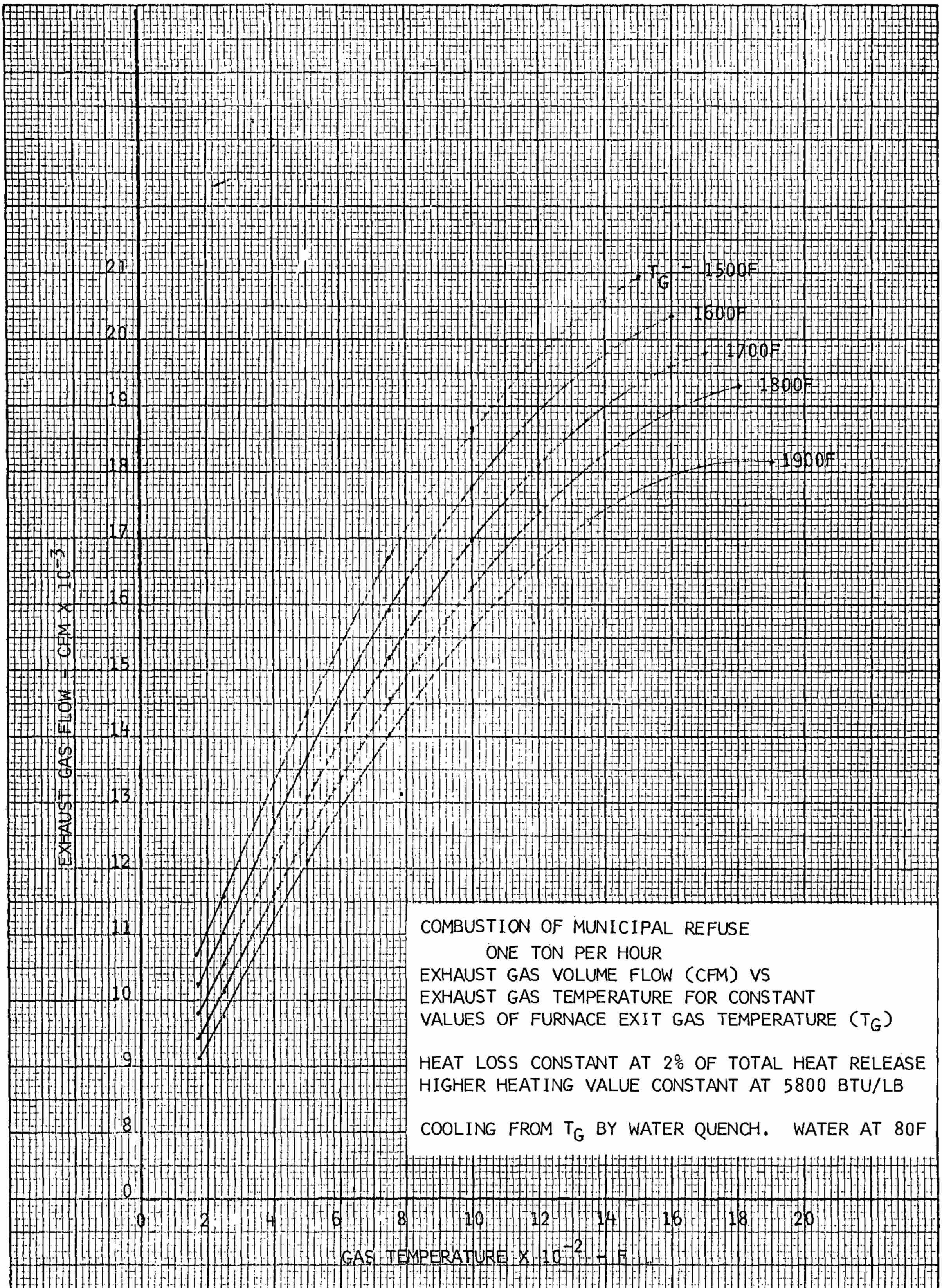
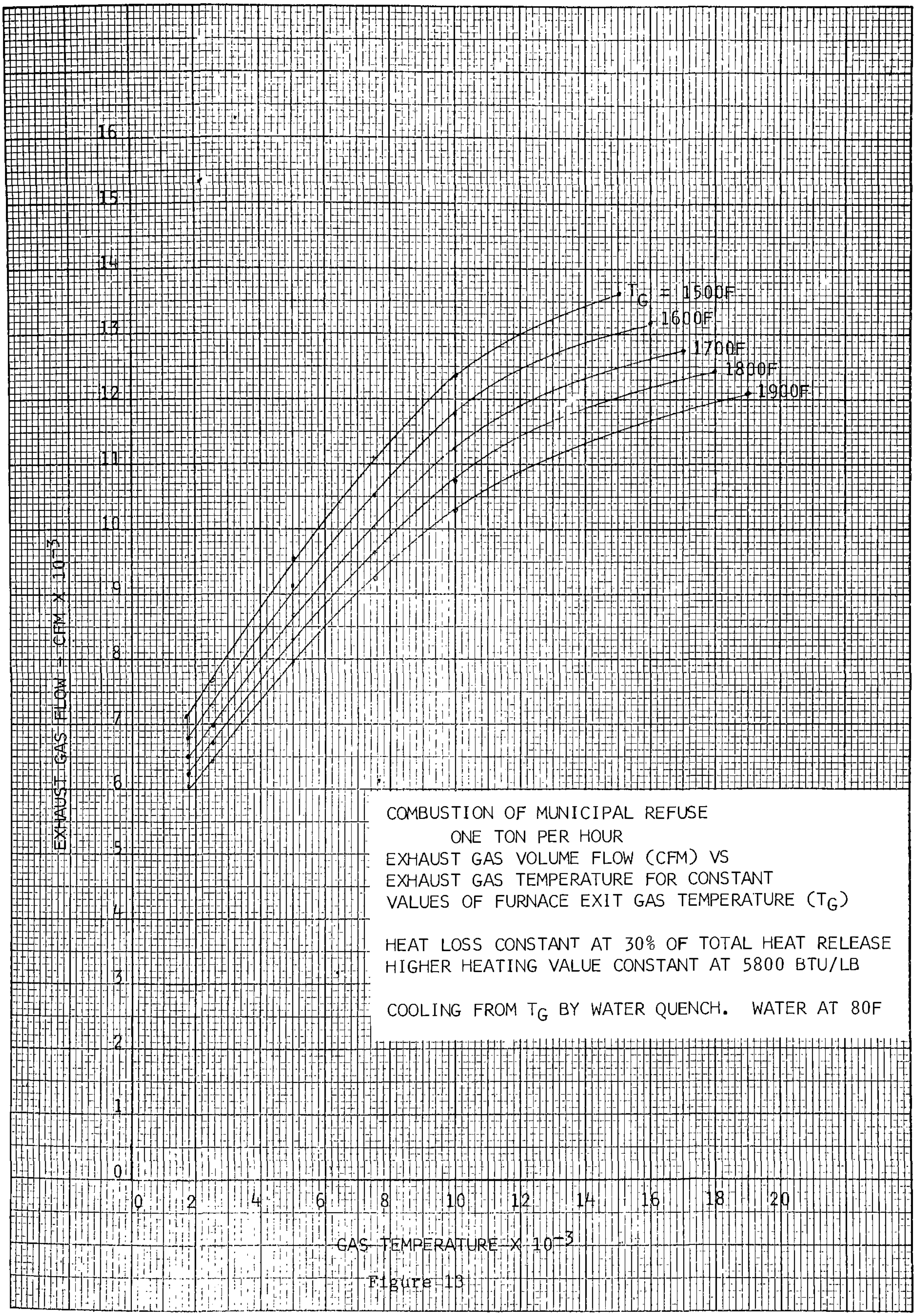

T_G - 1500F
1600F
1700F
1800F
1900F
EXHAUST GAS FLOW - CFM X 10^-3
GAS TEMPERATURE X 10^-2 - F
COMBUSTION OF MUNICIPAL REFUSE
ONE TON PER HOUR
EXHAUST GAS VOLUME FLOW (CFM) VS
EXHAUST GAS TEMPERATURE FOR CONSTANT
VALUES OF FURNACE EXIT GAS TEMPERATURE (T_G)
HEAT LOSS CONSTANT AT 2% OF TOTAL HEAT RELEASE
HIGHER HEATING VALUE CONSTANT AT 5800 BTU/LB
COOLING FROM T_G BY WATER QUENCH. WATER AT 80F

Figure 12



EXHAUST GAS FLOW - CFM X 10^-3
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
T_G = 1500F
1600F
1700F
1800F
1900F
0
2
4
6
8
10
12
14
16
18
20
GAS TEMPERATURE X 10^-3
COMBUSTION OF MUNICIPAL REFUSE
ONE TON PER HOUR
EXHAUST GAS VOLUME FLOW (CFM) VS
EXHAUST GAS TEMPERATURE FOR CONSTANT
VALUES OF FURNACE EXIT GAS TEMPERATURE (T_G)
HEAT LOSS CONSTANT AT 30% OF TOTAL HEAT RELEASE
HIGHER HEATING VALUE CONSTANT AT 5800 BTU/LB
COOLING FROM T_G BY WATER QUENCH. WATER AT 80F

Figure 13

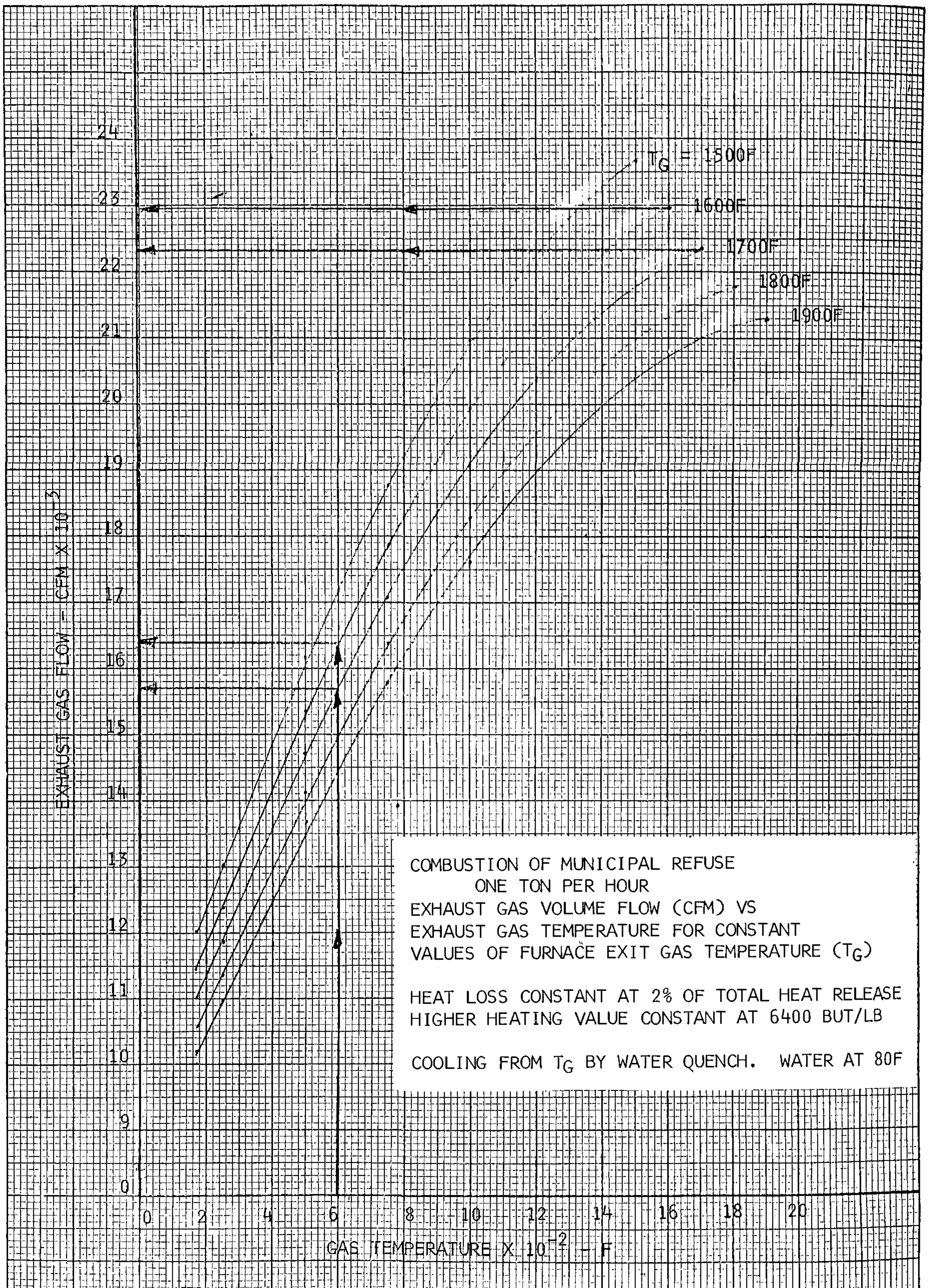

EXHAUST GAS FLOW - CFM X 10^-3
24
23
22
21
20
19
18
17
16
15
14
13
12
11
10
9
0
TG = 1500F
1600F
1700F
1800F
1900F
0
2
4
6
8
10
12
14
16
18
20
GAS TEMPERATURE X 10^-2 - F
COMBUSTION OF MUNICIPAL REFUSE
ONE TON PER HOUR
EXHAUST GAS VOLUME FLOW (CFM) VS
EXHAUST GAS TEMPERATURE FOR CONSTANT
VALUES OF FURNACE EXIT GAS TEMPERATURE (TG)
HEAT LOSS CONSTANT AT 2% OF TOTAL HEAT RELEASE
HIGHER HEATING VALUE CONSTANT AT 6400 BUT/LB
COOLING FROM TG BY WATER QUENCH. WATER AT 80F

Figure 14

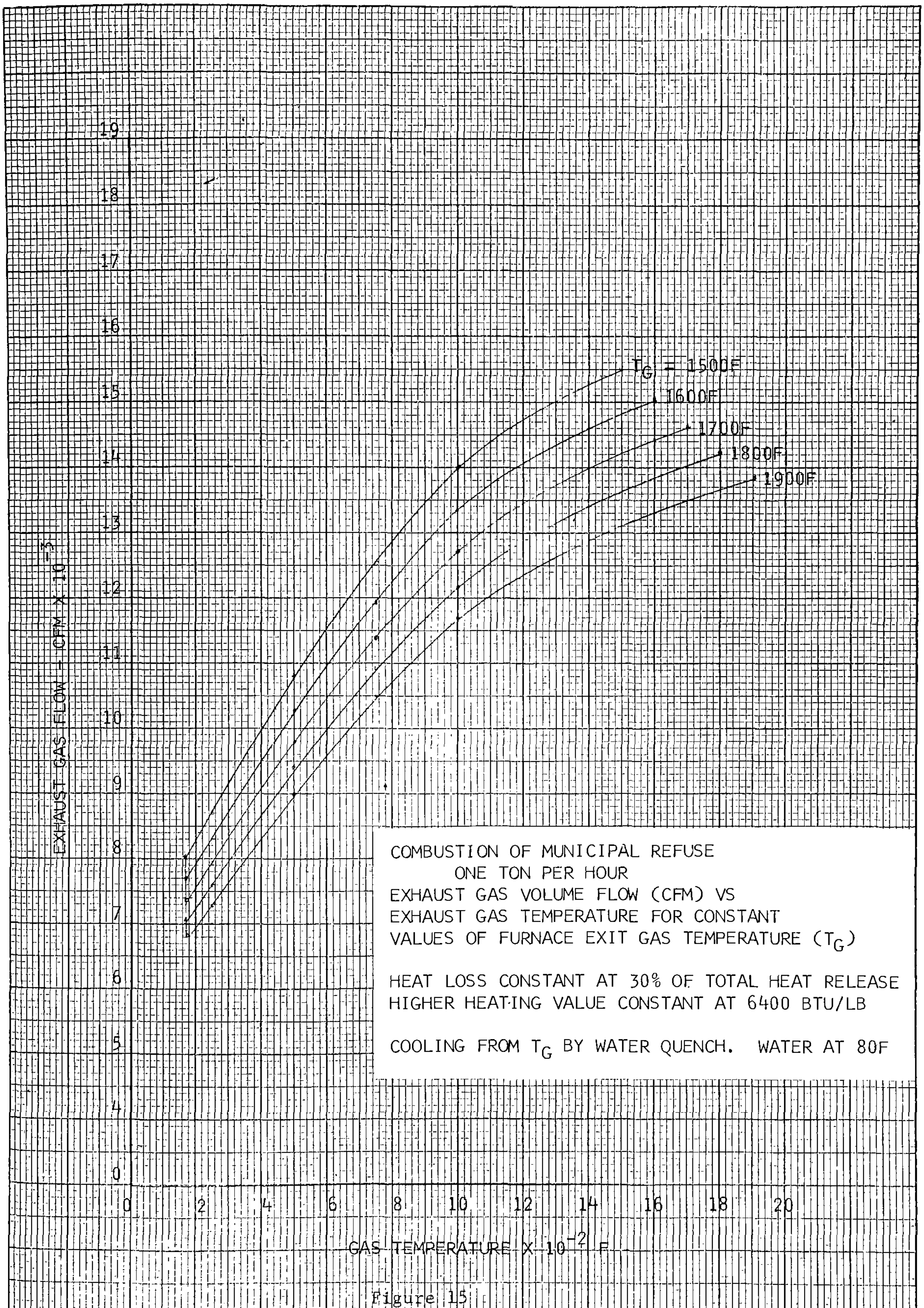
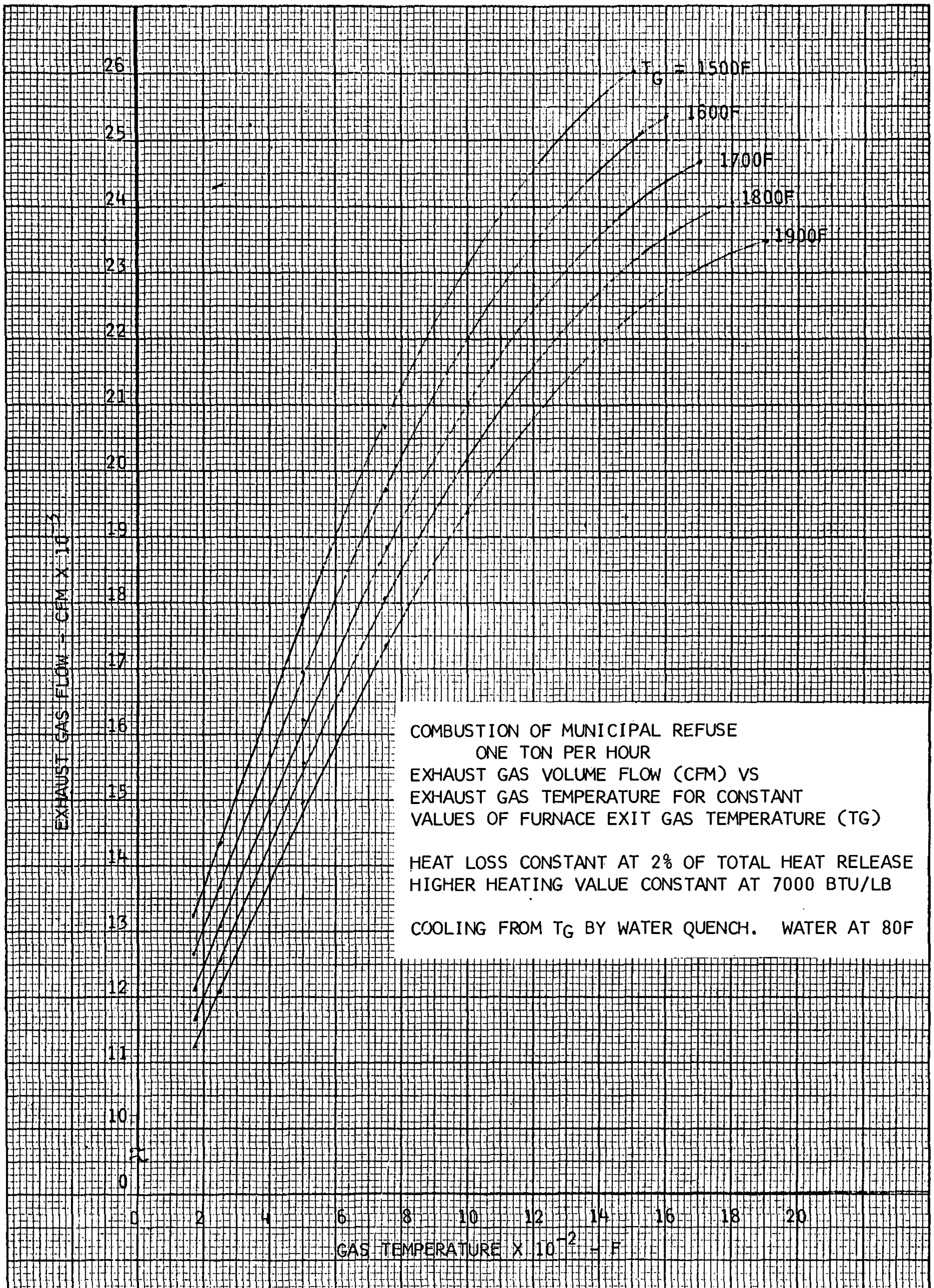
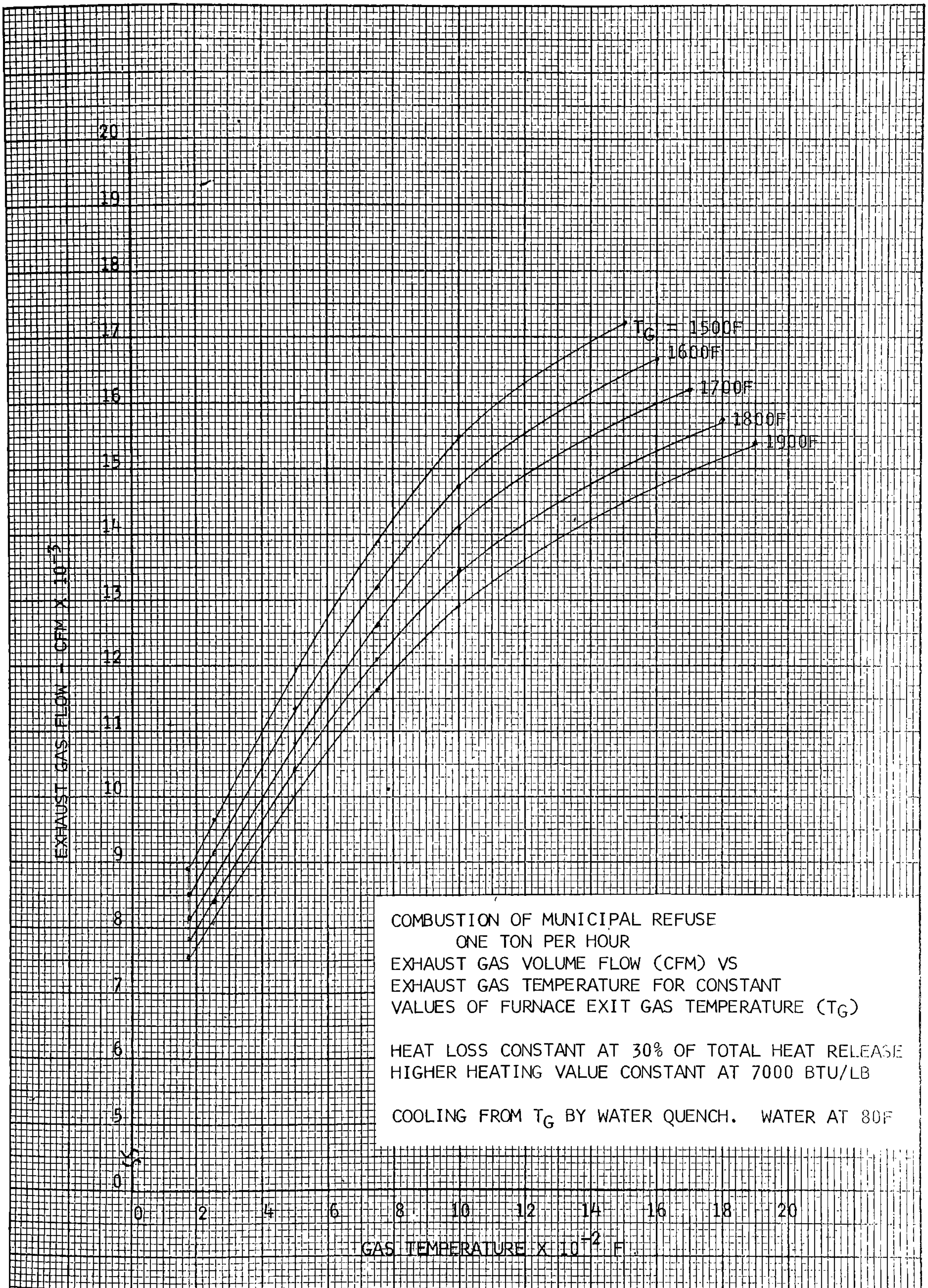

COMBUSTION OF MUNICIPAL REFUSE
ONE TON PER HOUR
EXHAUST GAS VOLUME FLOW (CFM) VS
EXHAUST GAS TEMPERATURE FOR CONSTANT
VALUES OF FURNACE EXIT GAS TEMPERATURE (T_G)
HEAT LOSS CONSTANT AT 30% OF TOTAL HEAT RELEASE
HIGHER HEATING VALUE CONSTANT AT 6400 BTU/LB
COOLING FROM T_G BY WATER QUENCH. WATER AT 80F
T_G = 1500F
1600F
1700F
1800F
1900F
EXHAUST GAS FLOW - CFM X 10^{-3}
GAS TEMPERATURE X 10^{-2} F
0
2
4
6
8
10
12
14
16
18
20
4
5
6
7
8
9
11
13
15
17
19

Figure 15



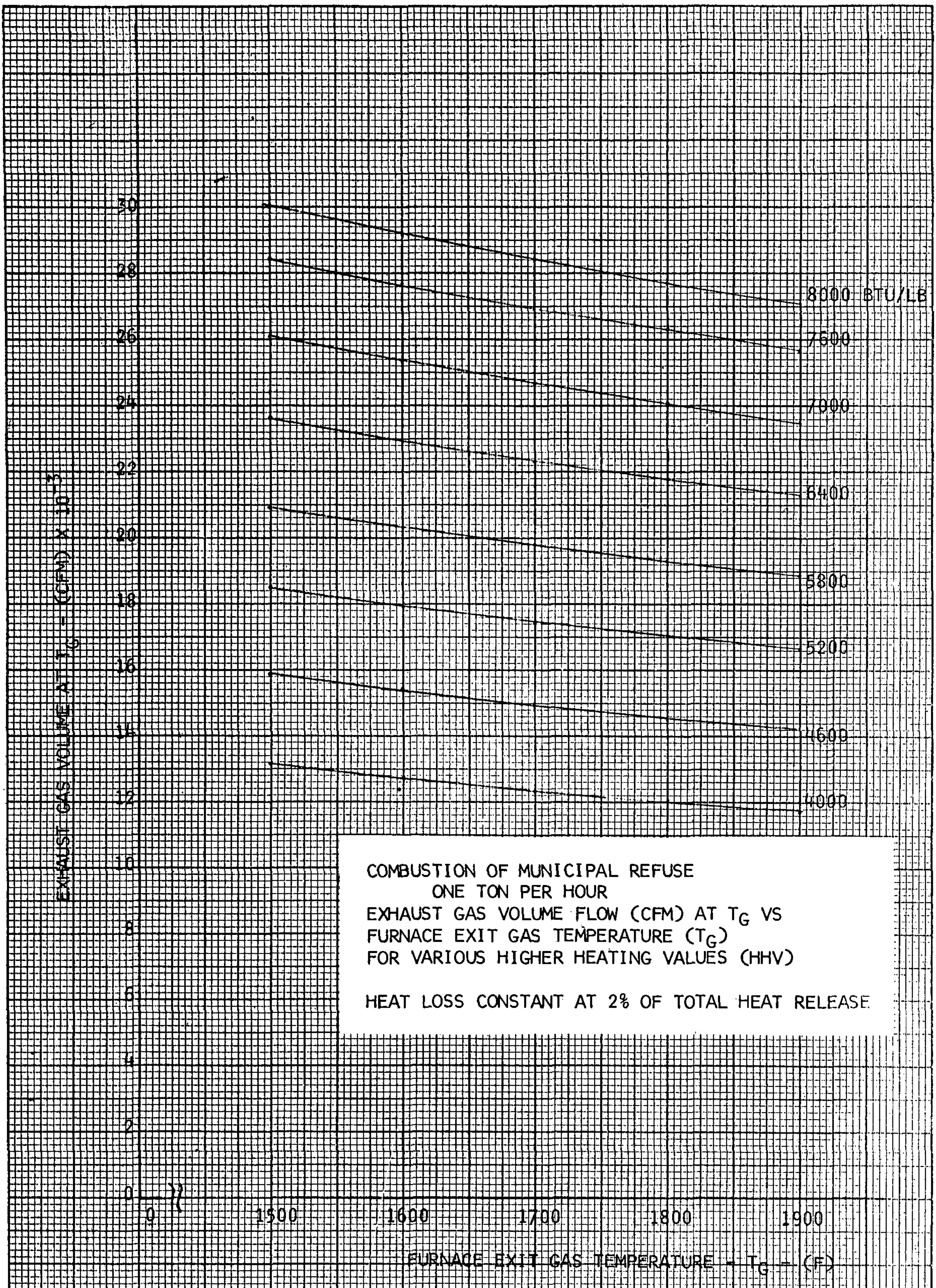
T_G = 1500F
1600F
1700F
1800F
1900F
COMBUSTION OF MUNICIPAL REFUSE
ONE TON PER HOUR
EXHAUST GAS VOLUME FLOW (CFM) VS
EXHAUST GAS TEMPERATURE FOR CONSTANT
VALUES OF FURNACE EXIT GAS TEMPERATURE (TG)
HEAT LOSS CONSTANT AT 2% OF TOTAL HEAT RELEASE
HIGHER HEATING VALUE CONSTANT AT 7000 BTU/LB
COOLING FROM T_G BY WATER QUENCH. WATER AT 80F
EXHAUST GAS FLOW - CFM X 10^{-3}
GAS TEMPERATURE X 10^{-2} - F
0
2
4
6
8
10
12
14
16
18
20
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26

Figure 16



EXHAUST GAS FLOW - CFM X 10^-3
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
0
0
2
4
6
8
10
12
14
16
18
20
GAS TEMPERATURE X 10^-2 F
T_G = 1500F
1600F
1700F
1800F
1900F
COMBUSTION OF MUNICIPAL REFUSE
ONE TON PER HOUR
EXHAUST GAS VOLUME FLOW (CFM) VS
EXHAUST GAS TEMPERATURE FOR CONSTANT
VALUES OF FURNACE EXIT GAS TEMPERATURE (T_G)
HEAT LOSS CONSTANT AT 30% OF TOTAL HEAT RELEASE
HIGHER HEATING VALUE CONSTANT AT 7000 BTU/LB
COOLING FROM T_G BY WATER QUENCH. WATER AT 80F

Figure 17



EXHAUST GAS VOLUME AT T_G – (CFM) x 10^{-3}
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
8000 BTU/LB
7600
7000
6400
5800
5200
4600
4000
COMBUSTION OF MUNICIPAL REFUSE
ONE TON PER HOUR
EXHAUST GAS VOLUME FLOW (CFM) AT T_G VS
FURNACE EXIT GAS TEMPERATURE (T_G)
FOR VARIOUS HIGHER HEATING VALUES (HHV)
HEAT LOSS CONSTANT AT 2% OF TOTAL HEAT RELEASE
0
1500
1600
1700
1800
1900
FURNACE EXIT GAS TEMPERATURE – T_G – (F)

Figure 18

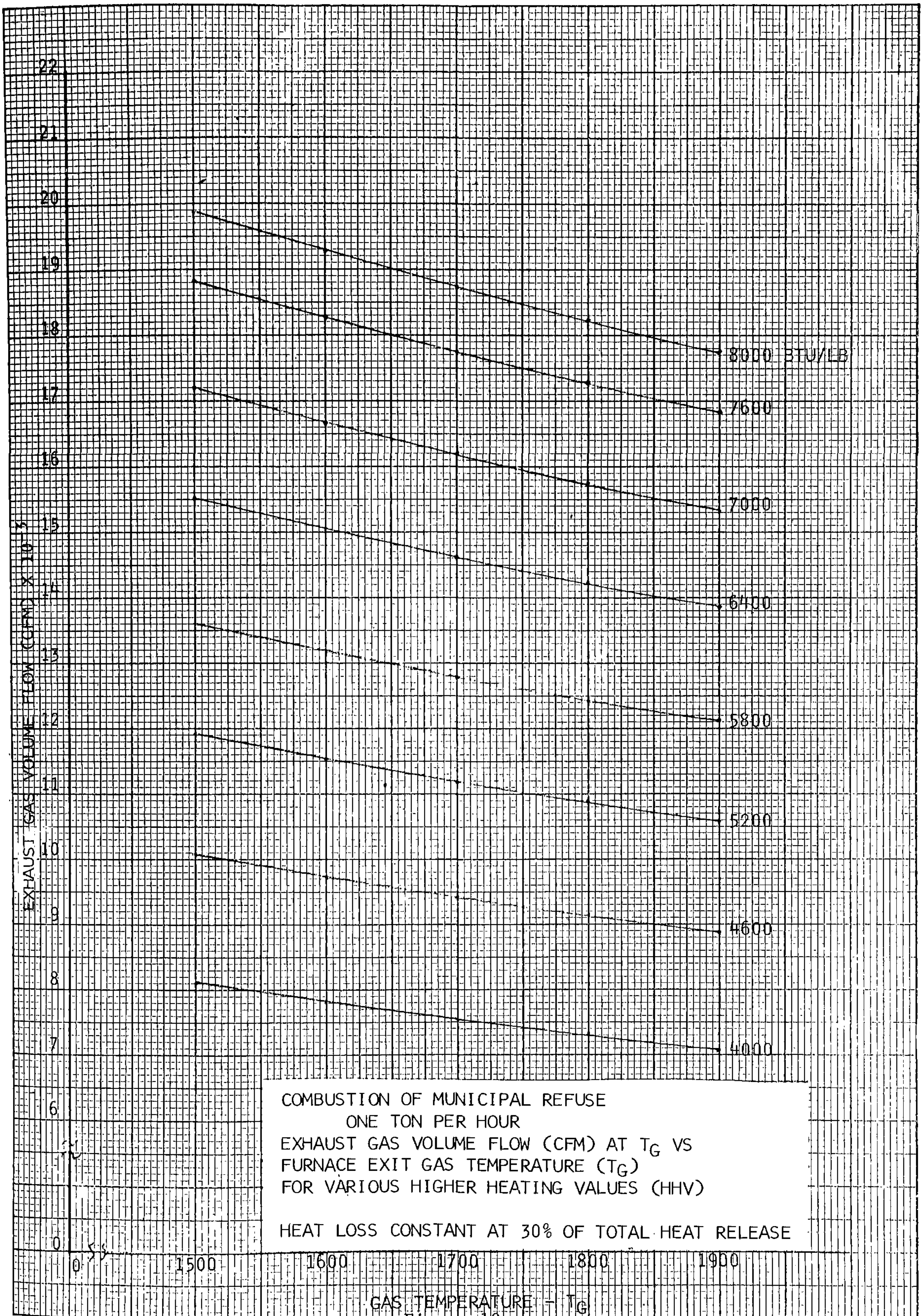

EXHAUST GAS VOLUME FLOW (CFM) X 10^-3
22
21
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
0
0
1500
1600
1700
1800
1900
GAS TEMPERATURE - T_G
8000 BTU/LB
7600
7000
6400
5800
5200
4600
4000
COMBUSTION OF MUNICIPAL REFUSE
ONE TON PER HOUR
EXHAUST GAS VOLUME FLOW (CFM) AT T_G VS
FURNACE EXIT GAS TEMPERATURE (T_G)
FOR VARIOUS HIGHER HEATING VALUES (HHV)
HEAT LOSS CONSTANT AT 30% OF TOTAL HEAT RELEASE

Figure 19

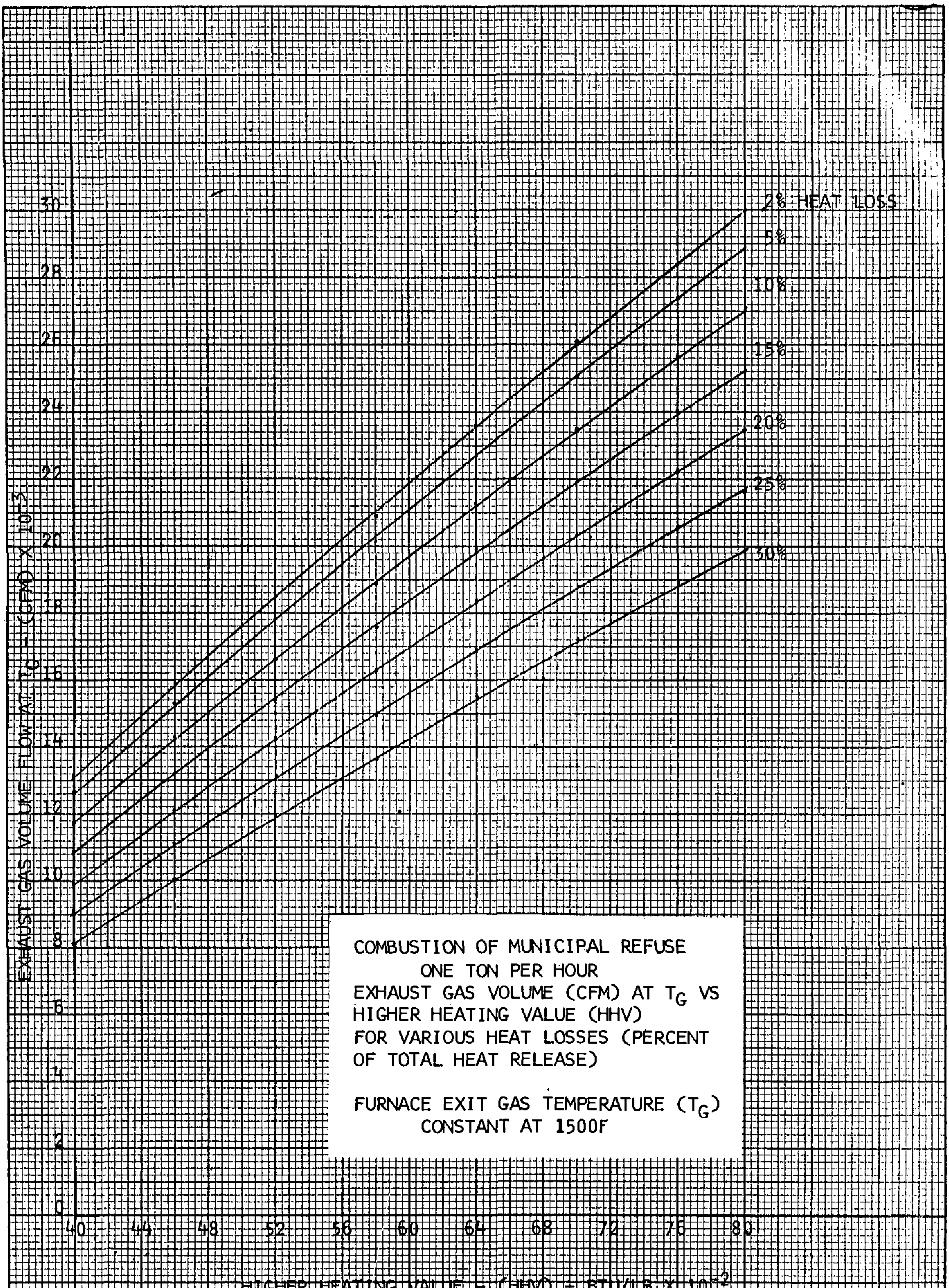

2% HEAT LOSS
5%
10%
15%
20%
25%
30%
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
40
44
48
52
56
60
64
68
72
76
80
EXHAUST GAS VOLUME FLOW AT T_G – (CFM) X 10^{-3}
HIGHER HEATING VALUE – (HHV) – BTU/LB X 10^{-2}
COMBUSTION OF MUNICIPAL REFUSE
ONE TON PER HOUR
EXHAUST GAS VOLUME (CFM) AT T_G VS
HIGHER HEATING VALUE (HHV)
FOR VARIOUS HEAT LOSSES (PERCENT
OF TOTAL HEAT RELEASE)
FURNACE EXIT GAS TEMPERATURE (T_G)
CONSTANT AT 1500F

Figure 20

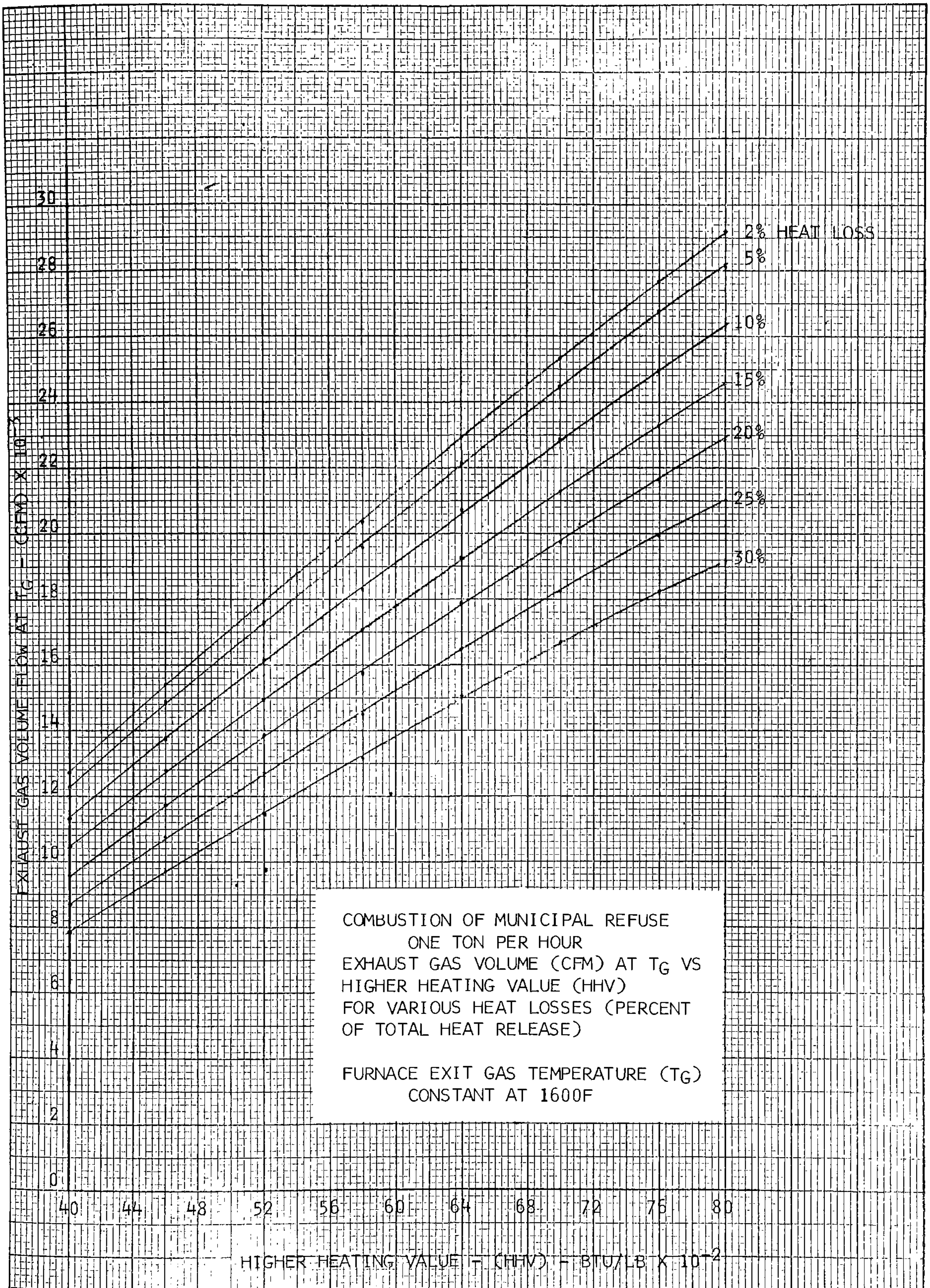
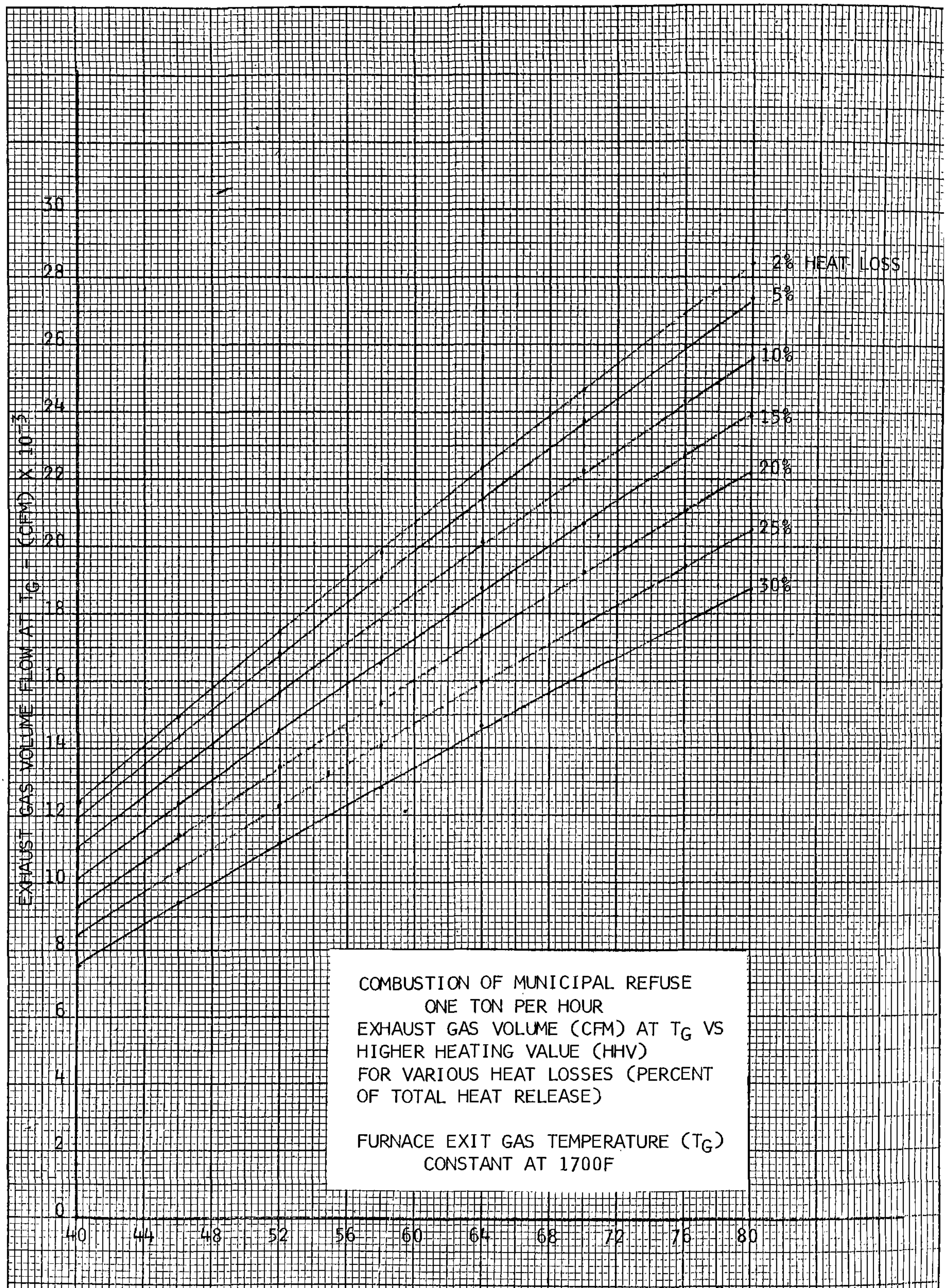
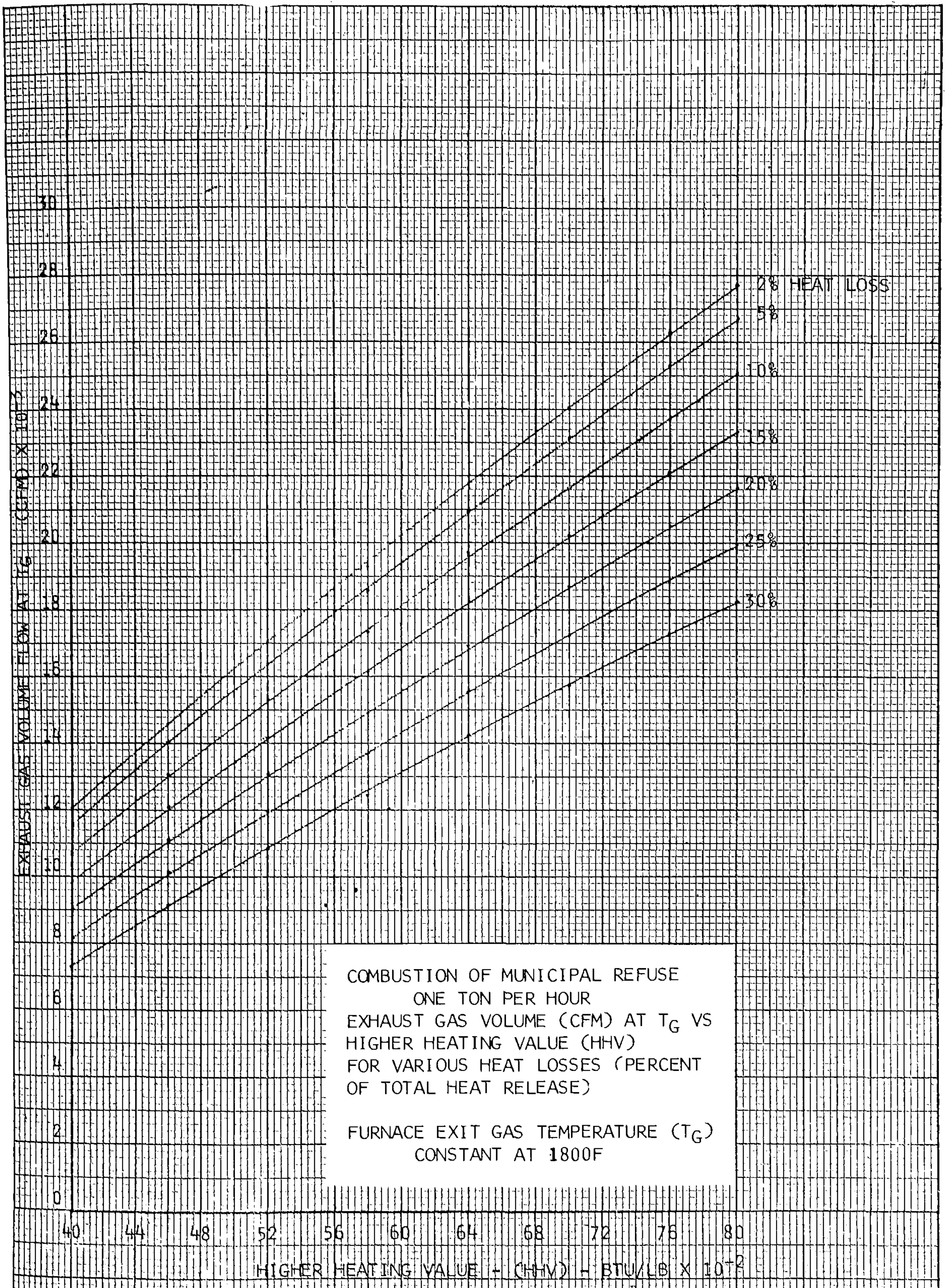

COMBUSTION OF MUNICIPAL REFUSE
ONE TON PER HOUR
EXHAUST GAS VOLUME (CFM) AT T_G VS
HIGHER HEATING VALUE (HHV)
FOR VARIOUS HEAT LOSSES (PERCENT
OF TOTAL HEAT RELEASE)
FURNACE EXIT GAS TEMPERATURE (T_G)
CONSTANT AT 1600F
2% HEAT LOSS
5%
10%
15%
20%
25%
30%
EXHAUST GAS VOLUME FLOW AT T_G - (CFM) X 10^{-3}
HIGHER HEATING VALUE - (HHV) - BTU/LB X 10^{-2}
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
40
44
48
52
56
60
64
68
72
76
80

Figure 21



EXHAUST GAS VOLUME FLOW AT T_G - (CFM) X 10^{-3}
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
40
44
48
52
56
60
64
68
72
76
80
HIGHER HEATING VALUE - (HHV) - BTU/LB X 10^{-2}
2% HEAT LOSS
5%
10%
15%
20%
25%
30%
COMBUSTION OF MUNICIPAL REFUSE
ONE TON PER HOUR
EXHAUST GAS VOLUME (CFM) AT T_G VS
HIGHER HEATING VALUE (HHV)
FOR VARIOUS HEAT LOSSES (PERCENT
OF TOTAL HEAT RELEASE)
FURNACE EXIT GAS TEMPERATURE (T_G)
CONSTANT AT 1700F

Figure 22



2% HEAT LOSS
5%
10%
15%
20%
25%
30%
EXHAUST GAS VOLUME FLOW AT T_G (CFM) X 10^{-3}
HIGHER HEATING VALUE - (HHV) - BTU/LB X 10^{-2}
COMBUSTION OF MUNICIPAL REFUSE
ONE TON PER HOUR
EXHAUST GAS VOLUME (CFM) AT T_G VS
HIGHER HEATING VALUE (HHV)
FOR VARIOUS HEAT LOSSES (PERCENT
OF TOTAL HEAT RELEASE)
FURNACE EXIT GAS TEMPERATURE (T_G)
CONSTANT AT 1800F

Figure 23

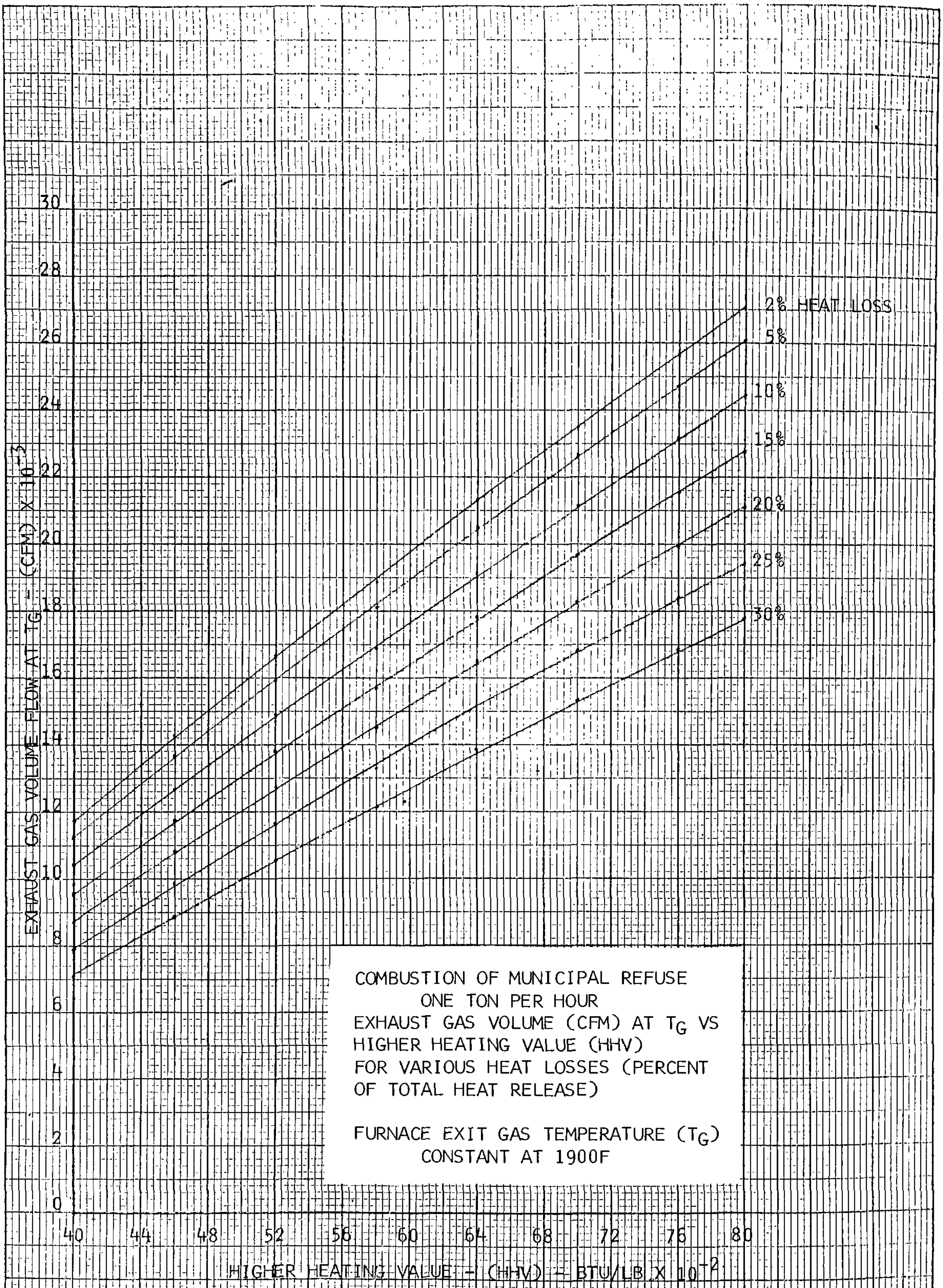

EXHAUST GAS VOLUME FLOW AT T_G - (CFM) X 10^{-3}
HIGHER HEATING VALUE - (HHV) - BTU/LB X 10^{-2}
2% HEAT LOSS
5%
10%
15%
20%
25%
30%
COMBUSTION OF MUNICIPAL REFUSE
ONE TON PER HOUR
EXHAUST GAS VOLUME (CFM) AT T_G VS
HIGHER HEATING VALUE (HHV)
FOR VARIOUS HEAT LOSSES (PERCENT
OF TOTAL HEAT RELEASE)
FURNACE EXIT GAS TEMPERATURE (T_G)
CONSTANT AT 1900F

Figure 24

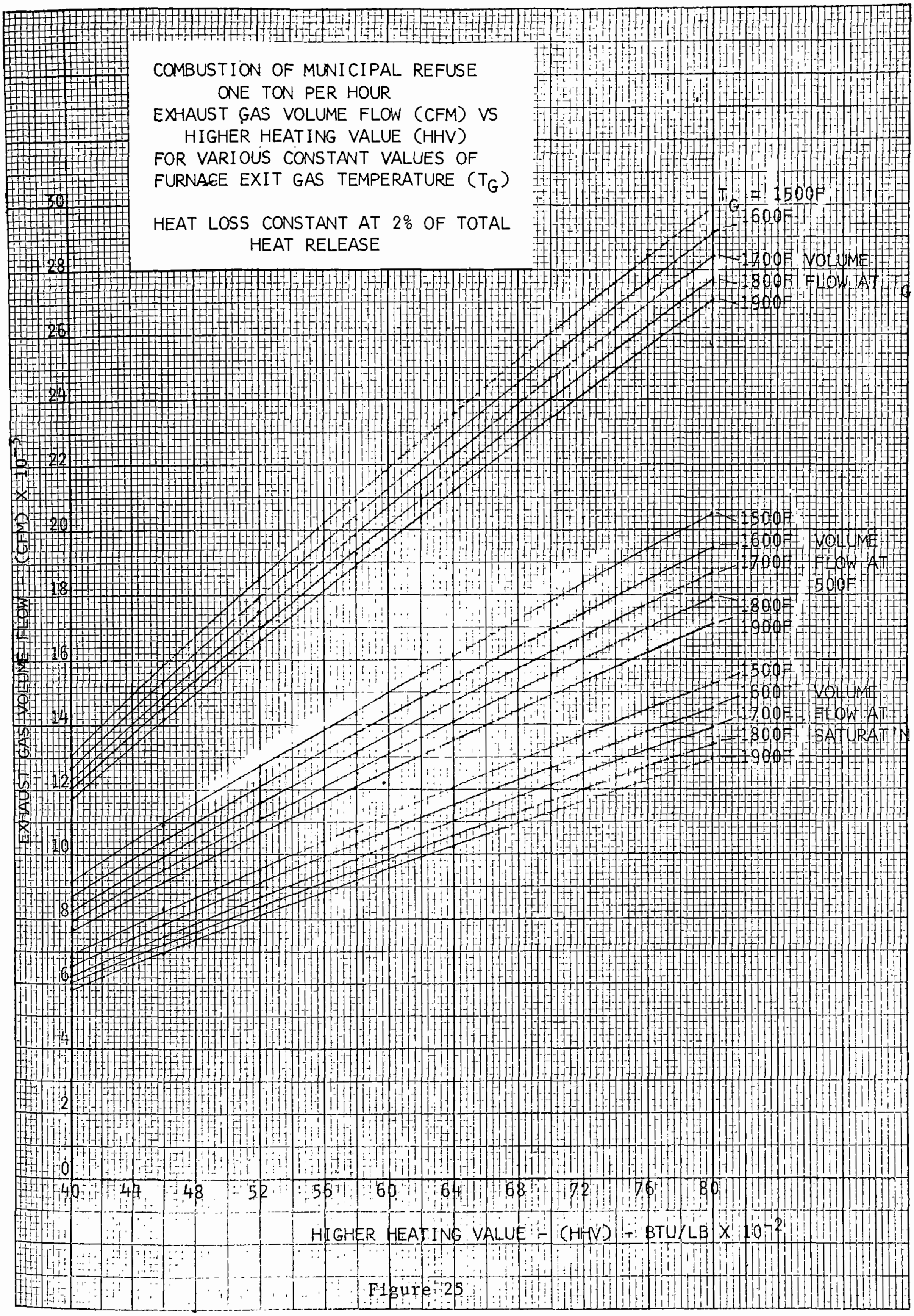

COMBUSTION OF MUNICIPAL REFUSE
ONE TON PER HOUR
EXHAUST GAS VOLUME FLOW (CFM) VS
HIGHER HEATING VALUE (HHV)
FOR VARIOUS CONSTANT VALUES OF
FURNACE EXIT GAS TEMPERATURE (T_G)
HEAT LOSS CONSTANT AT 2% OF TOTAL
HEAT RELEASE
T_G = 1500F
1600F
1700F
1800F
1900F
VOLUME FLOW AT T_G
1500F
1600F
1700F
1800F
1900F
VOLUME FLOW AT 500F
1500F
1600F
1700F
1800F
1900F
VOLUME FLOW AT SATURAT'N
EXHAUST GAS VOLUME FLOW - (CFM) X 10^{-3}
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
40
44
48
52
56
60
64
68
72
76
80
HIGHER HEATING VALUE - (HHV) - BTU/LB X 10^{-2}

Figure 25

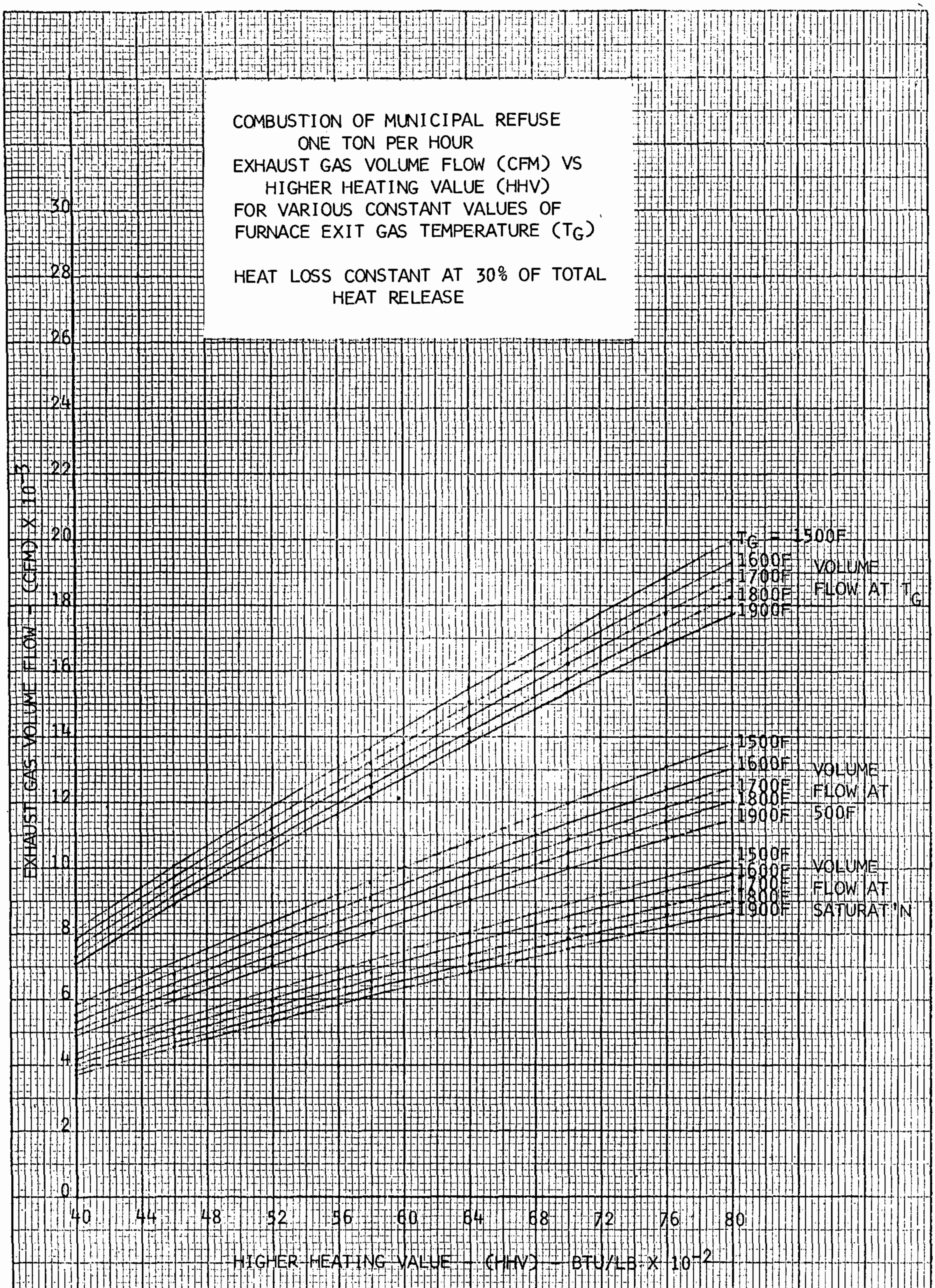
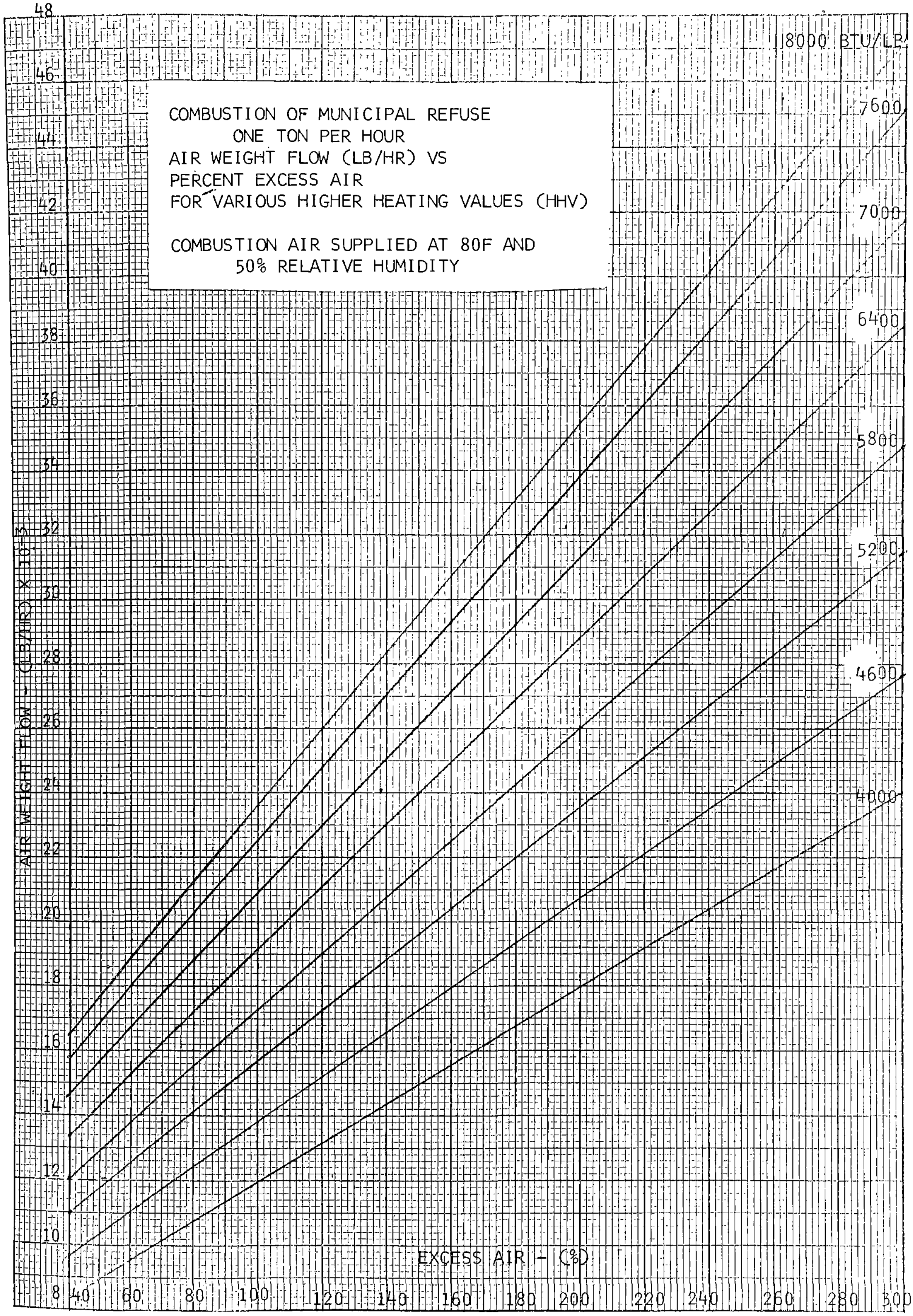

COMBUSTION OF MUNICIPAL REFUSE
ONE TON PER HOUR
EXHAUST GAS VOLUME FLOW (CFM) VS
HIGHER HEATING VALUE (HHV)
FOR VARIOUS CONSTANT VALUES OF
FURNACE EXIT GAS TEMPERATURE (T_G)
HEAT LOSS CONSTANT AT 30% OF TOTAL
HEAT RELEASE
T_G = 1500F
1600F
1700F
1800F
1900F
VOLUME FLOW AT T_G
1500F
1600F
1700F
1800F
1900F
VOLUME FLOW AT 500F
1500F
1600F
1700F
1800F
1900F
VOLUME FLOW AT SATURAT'N
EXHAUST GAS VOLUME FLOW - (CFM) X 10^{-3}
HIGHER HEATING VALUE - (HHV) - BTU/LB X 10^{-2}
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
40
44
48
52
56
60
64
68
72
76
80

Figure 26


COMBUSTION OF MUNICIPAL REFUSE
ONE TON PER HOUR
AIR WEIGHT FLOW (LB/HR) VS
PERCENT EXCESS AIR
FOR VARIOUS HIGHER HEATING VALUES (HHV)
COMBUSTION AIR SUPPLIED AT 80F AND
50% RELATIVE HUMIDITY
AIR WEIGHT FLOW - (LB/HR) X 10-3
EXCESS AIR - (%)
8000 BTU/LB
7600
7000
6400
5800
5200
4600
4000
48
46
44
42
40
38
36
34
32
30
28
26
24
22
20
18
16
14
12
10
8
40
60
80
100
120
140
160
180
200
220
240
260
280
300
Figure 27

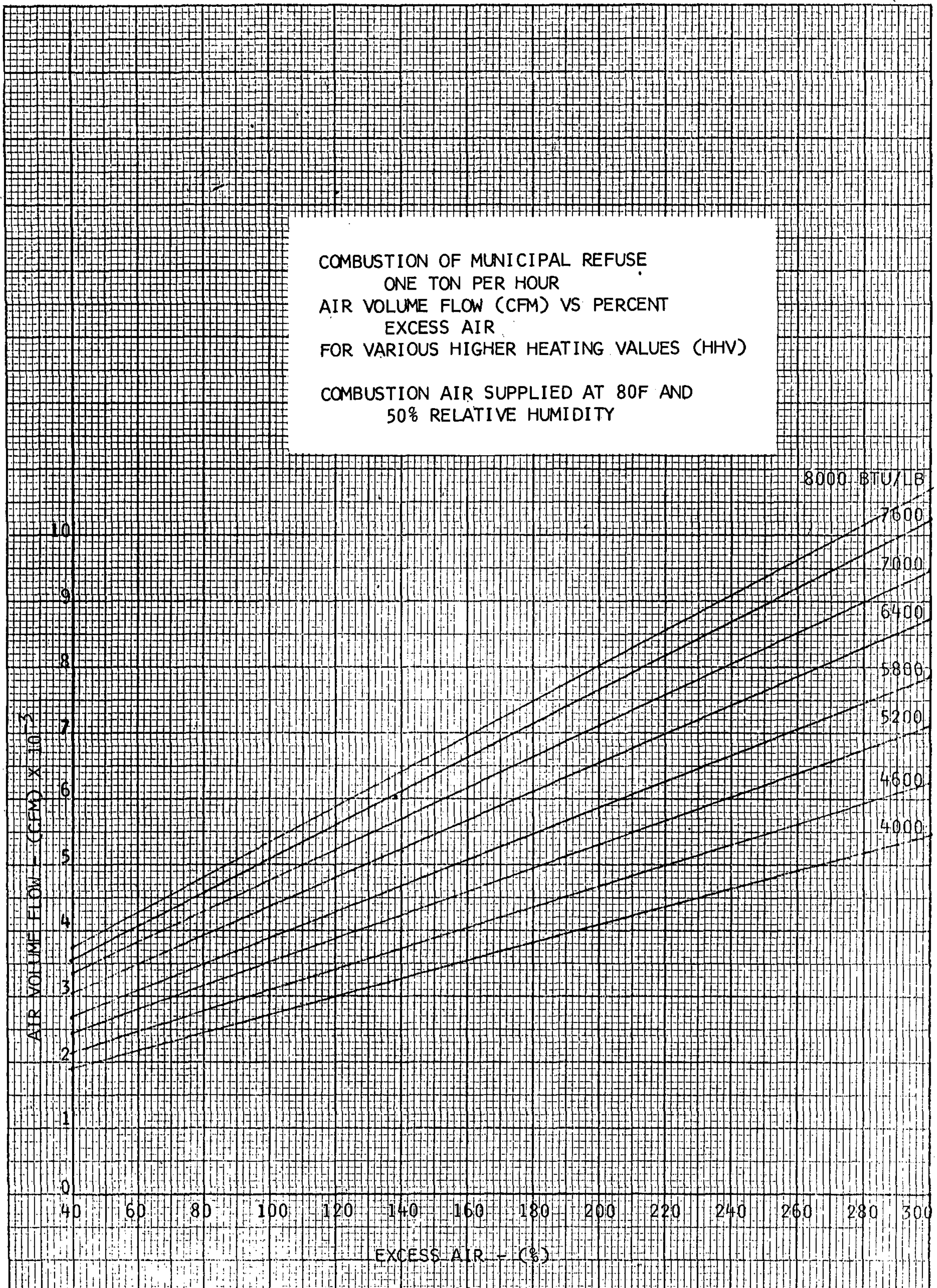

COMBUSTION OF MUNICIPAL REFUSE
ONE TON PER HOUR
AIR VOLUME FLOW (CFM) VS PERCENT
EXCESS AIR
FOR VARIOUS HIGHER HEATING VALUES (HHV)
COMBUSTION AIR SUPPLIED AT 80F AND
50% RELATIVE HUMIDITY
8000 BTU/LB
7600
7000
6400
5800
5200
4600
4000
AIR VOLUME FLOW - (CFM) X 10-3
0
1
2
3
4
5
6
7
8
9
10
40
60
80
100
120
140
160
180
200
220
240
260
280
300
EXCESS AIR - (%)

Figure 28

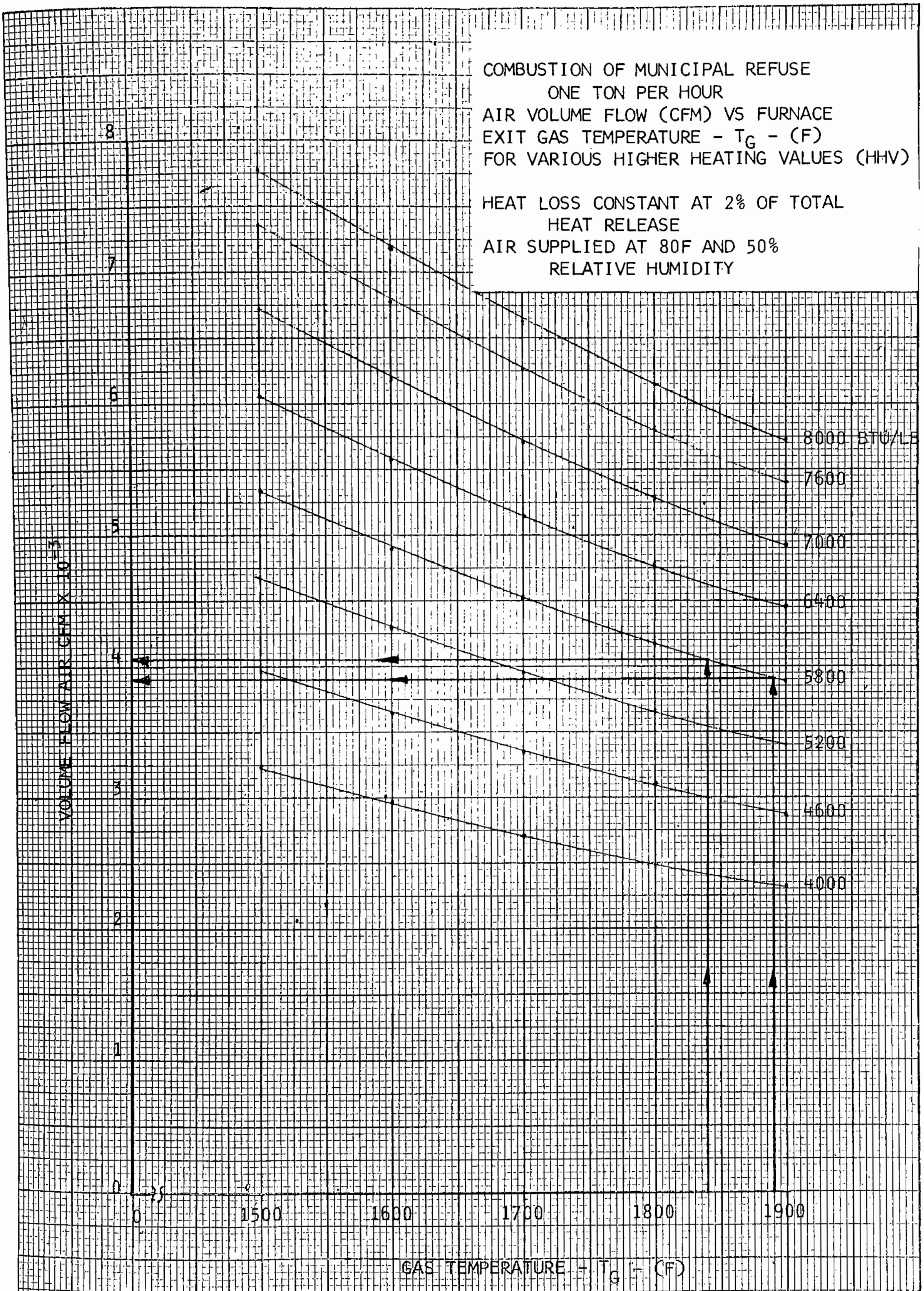
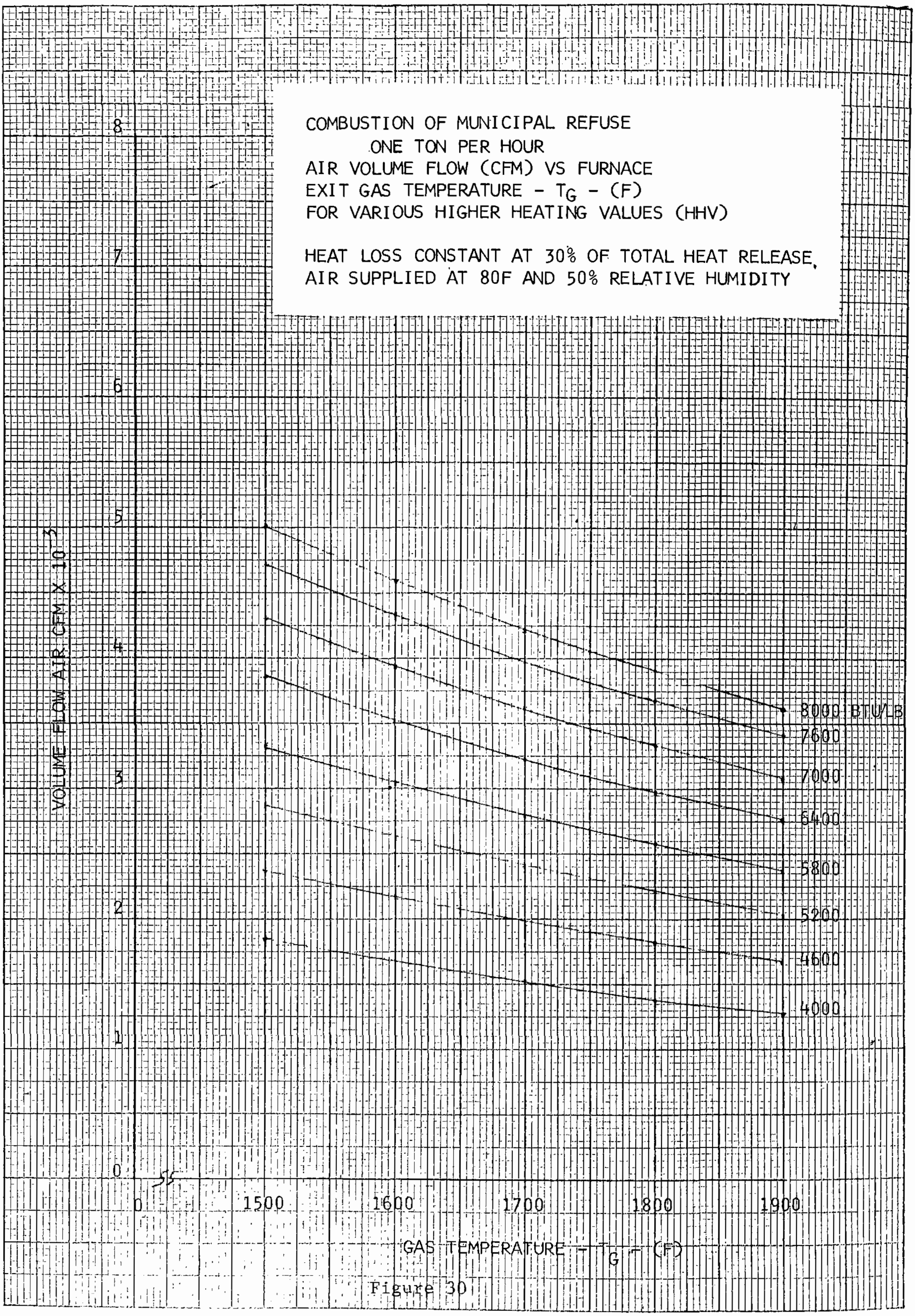
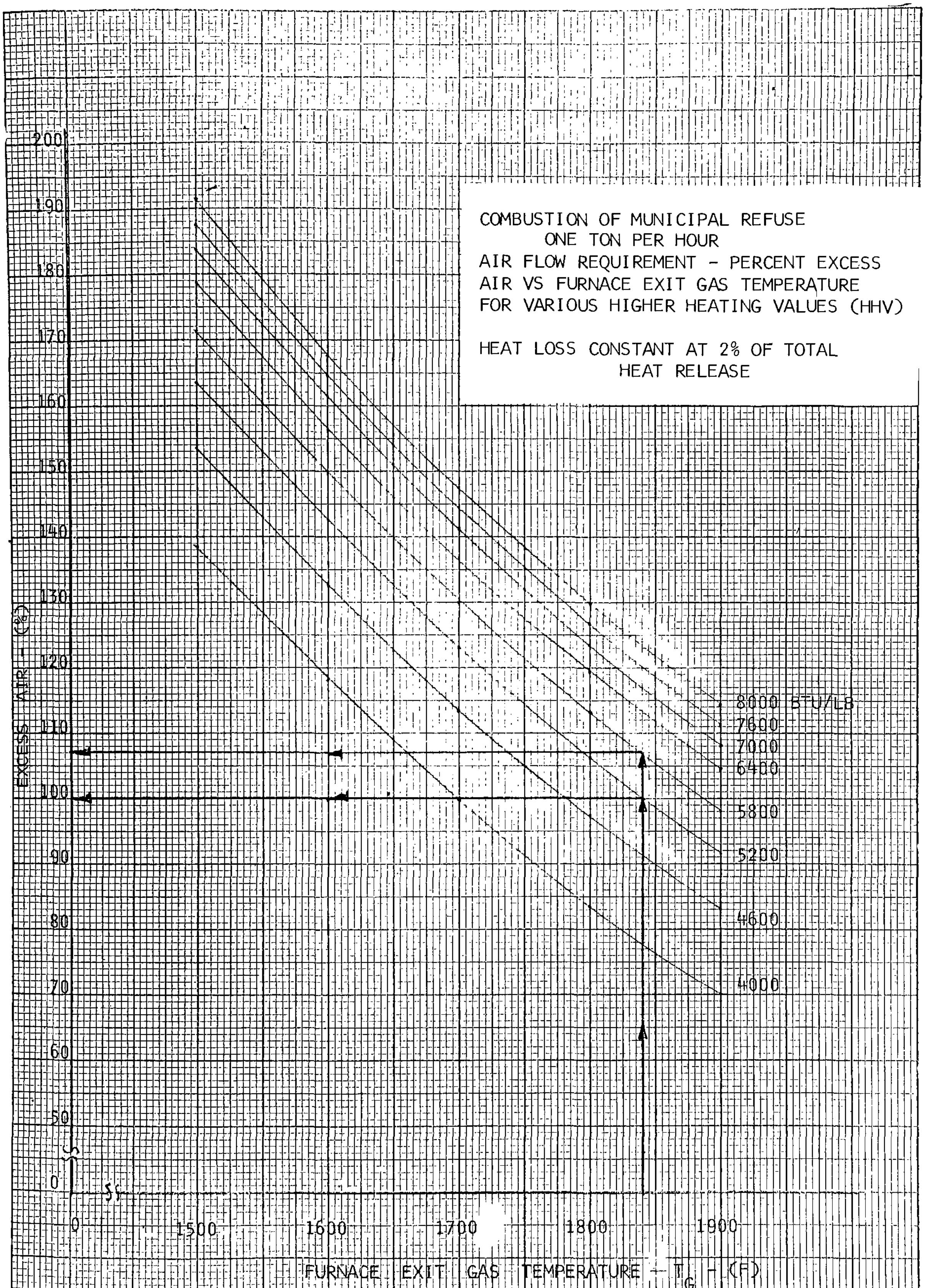

COMBUSTION OF MUNICIPAL REFUSE
ONE TON PER HOUR
AIR VOLUME FLOW (CFM) VS FURNACE
EXIT GAS TEMPERATURE - T_G - (F)
FOR VARIOUS HIGHER HEATING VALUES (HHV)
HEAT LOSS CONSTANT AT 2% OF TOTAL
HEAT RELEASE
AIR SUPPLIED AT 80F AND 50%
RELATIVE HUMIDITY
8000 BTU/LB
7600
7000
6400
5800
5200
4600
4000
VOLUME FLOW AIR CFM X 10^{-3}
0
1
2
3
4
5
6
7
8
0
1500
1600
1700
1800
1900
GAS TEMPERATURE - T_G - (F)

Figure 29



COMBUSTION OF MUNICIPAL REFUSE
ONE TON PER HOUR
AIR VOLUME FLOW (CFM) VS FURNACE
EXIT GAS TEMPERATURE - T_G - (F)
FOR VARIOUS HIGHER HEATING VALUES (HHV)
HEAT LOSS CONSTANT AT 30% OF TOTAL HEAT RELEASE.
AIR SUPPLIED AT 80F AND 50% RELATIVE HUMIDITY
VOLUME FLOW AIR CFM X 10^{-3}
8
7
6
5
4
3
2
1
0
0
1500
1600
1700
1800
1900
GAS TEMPERATURE - T_G - (F)
8000 BTU/LB
7600
7000
6400
5800
5200
4600
4000

Figure 30


COMBUSTION OF MUNICIPAL REFUSE
ONE TON PER HOUR
AIR FLOW REQUIREMENT - PERCENT EXCESS
AIR VS FURNACE EXIT GAS TEMPERATURE
FOR VARIOUS HIGHER HEATING VALUES (HHV)
HEAT LOSS CONSTANT AT 2% OF TOTAL
HEAT RELEASE
EXCESS AIR - (%)
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
0
8000 BTU/LB
7600
7000
6400
5800
5200
4600
4000
0
1500
1600
1700
1800
1900
FURNACE EXIT GAS TEMPERATURE - T_G - (F)
Figure 31

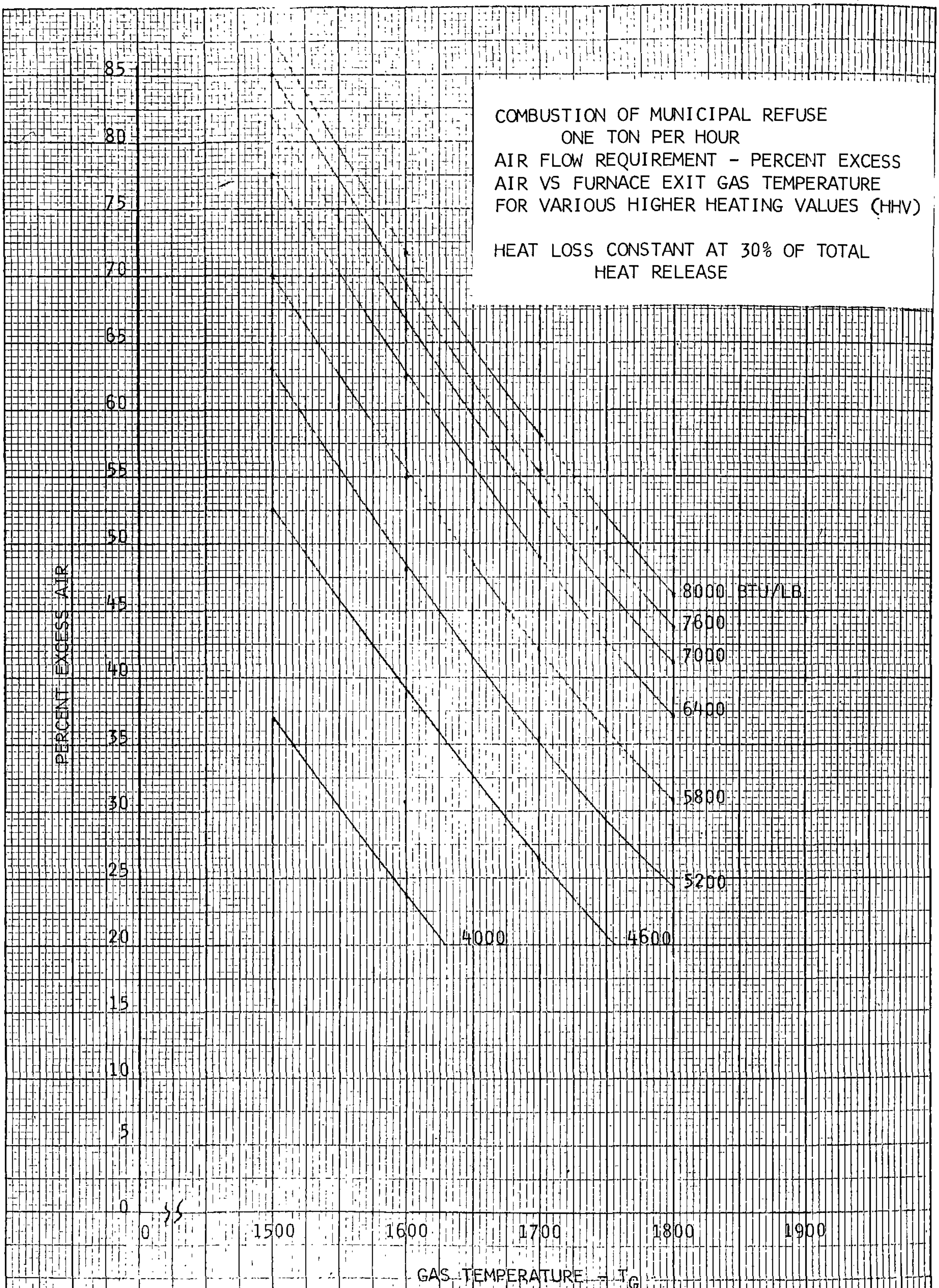
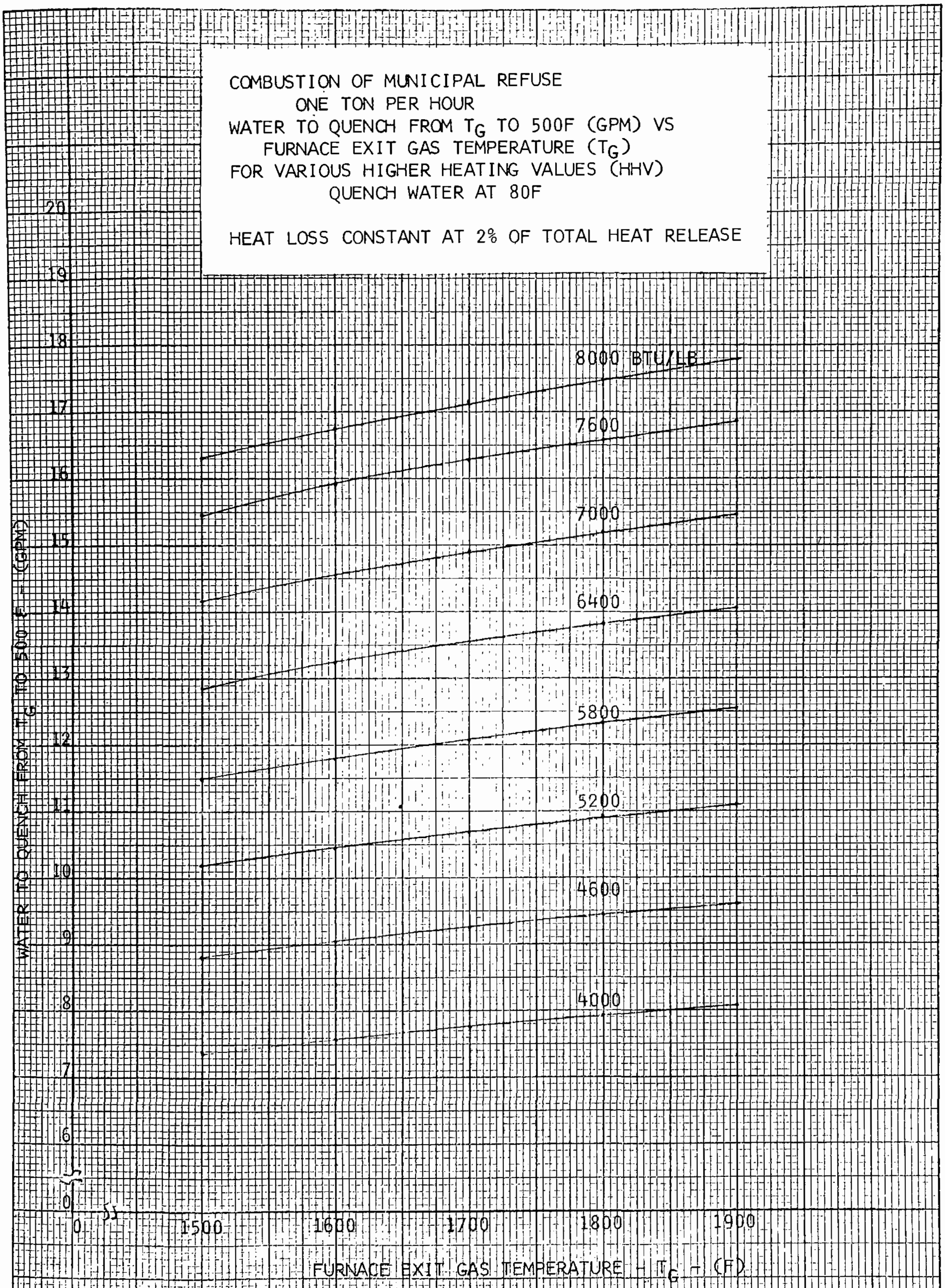
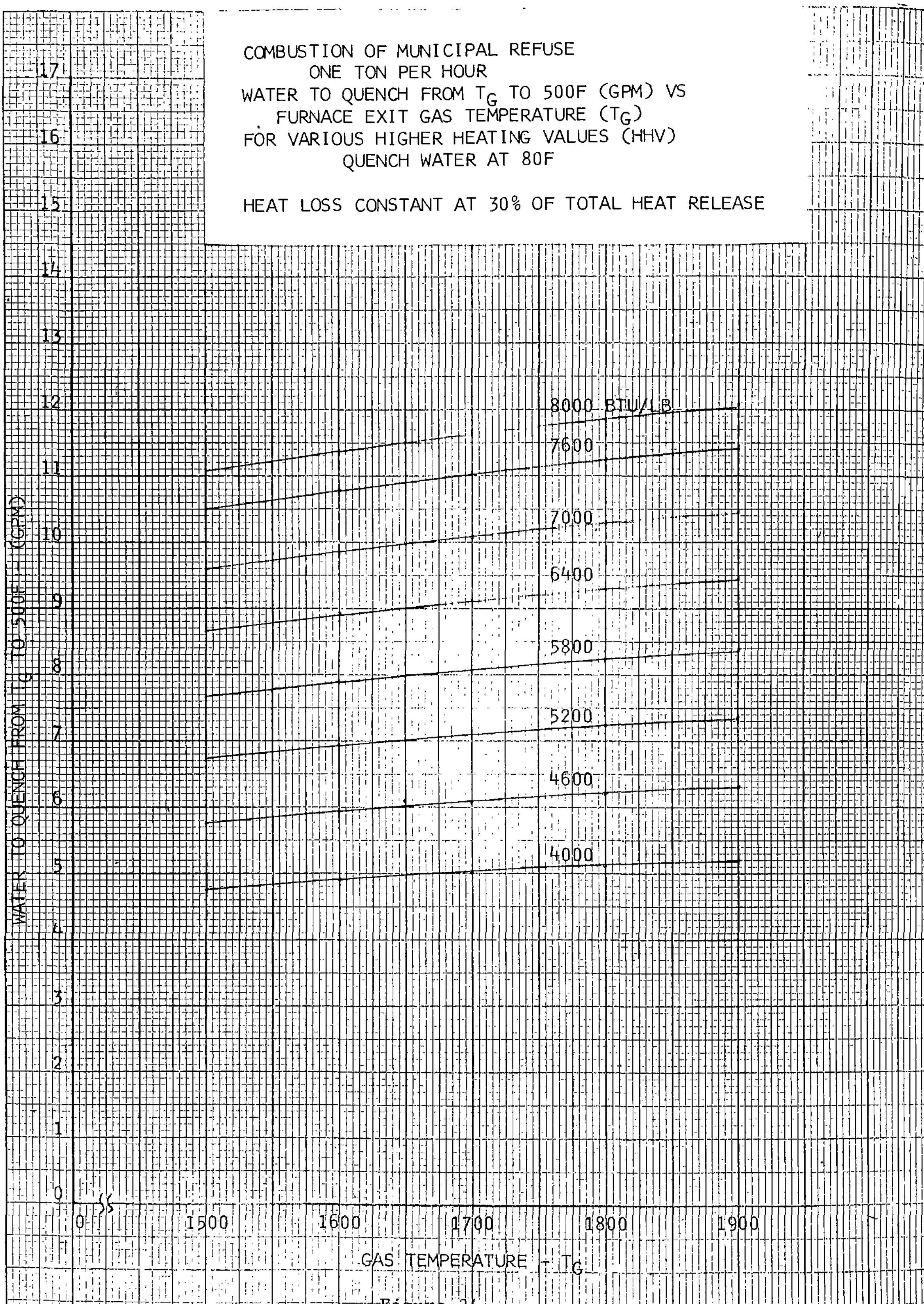

COMBUSTION OF MUNICIPAL REFUSE
ONE TON PER HOUR
AIR FLOW REQUIREMENT - PERCENT EXCESS AIR VS FURNACE EXIT GAS TEMPERATURE FOR VARIOUS HIGHER HEATING VALUES (HHV)
HEAT LOSS CONSTANT AT 30% OF TOTAL HEAT RELEASE
PERCENT EXCESS AIR
85
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
8000 BTU/LB
7600
7000
6400
5800
5200
4600
4000
0
1500
1600
1700
1800
1900
GAS TEMPERATURE - T_G

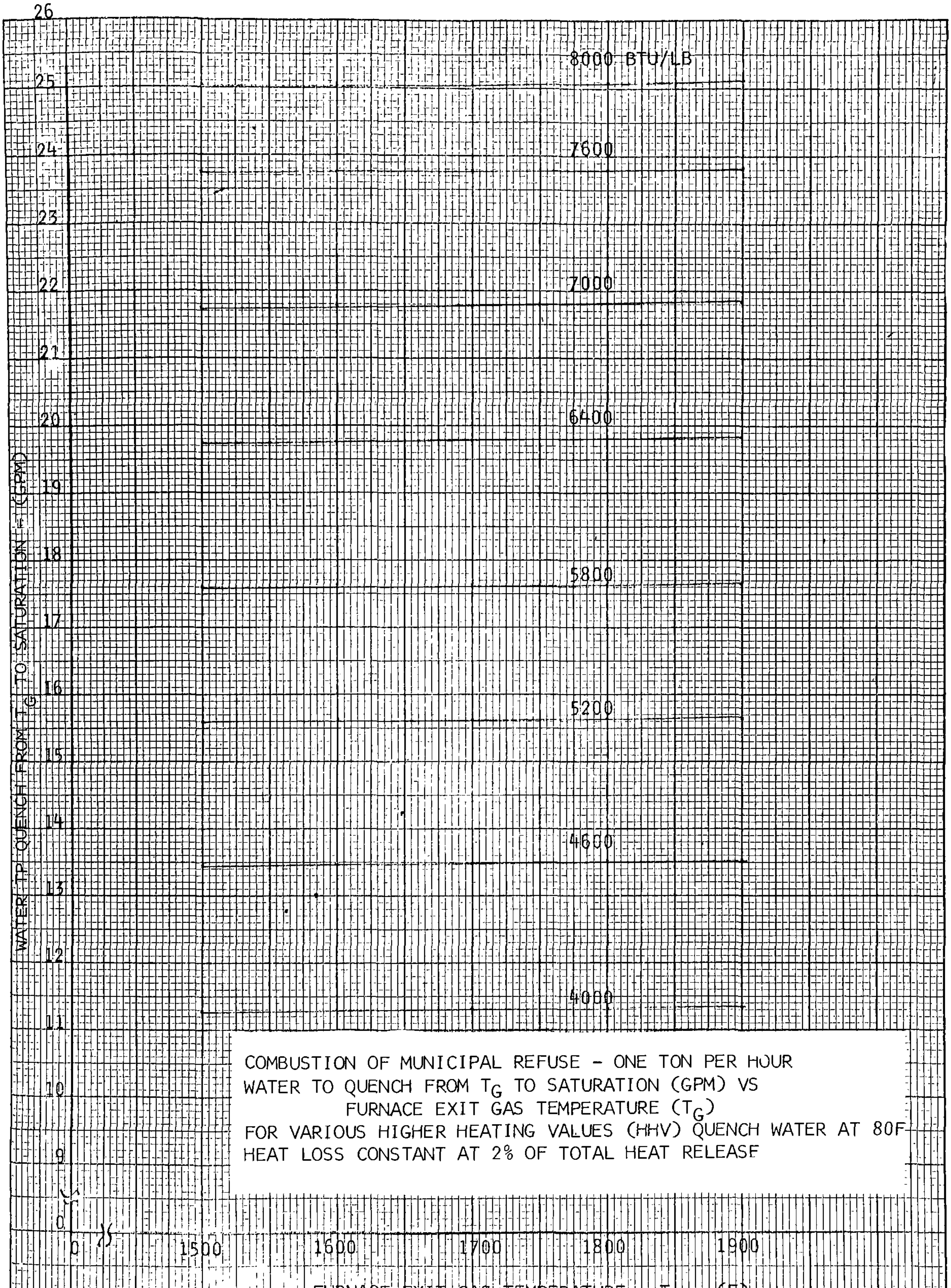
Figure 32

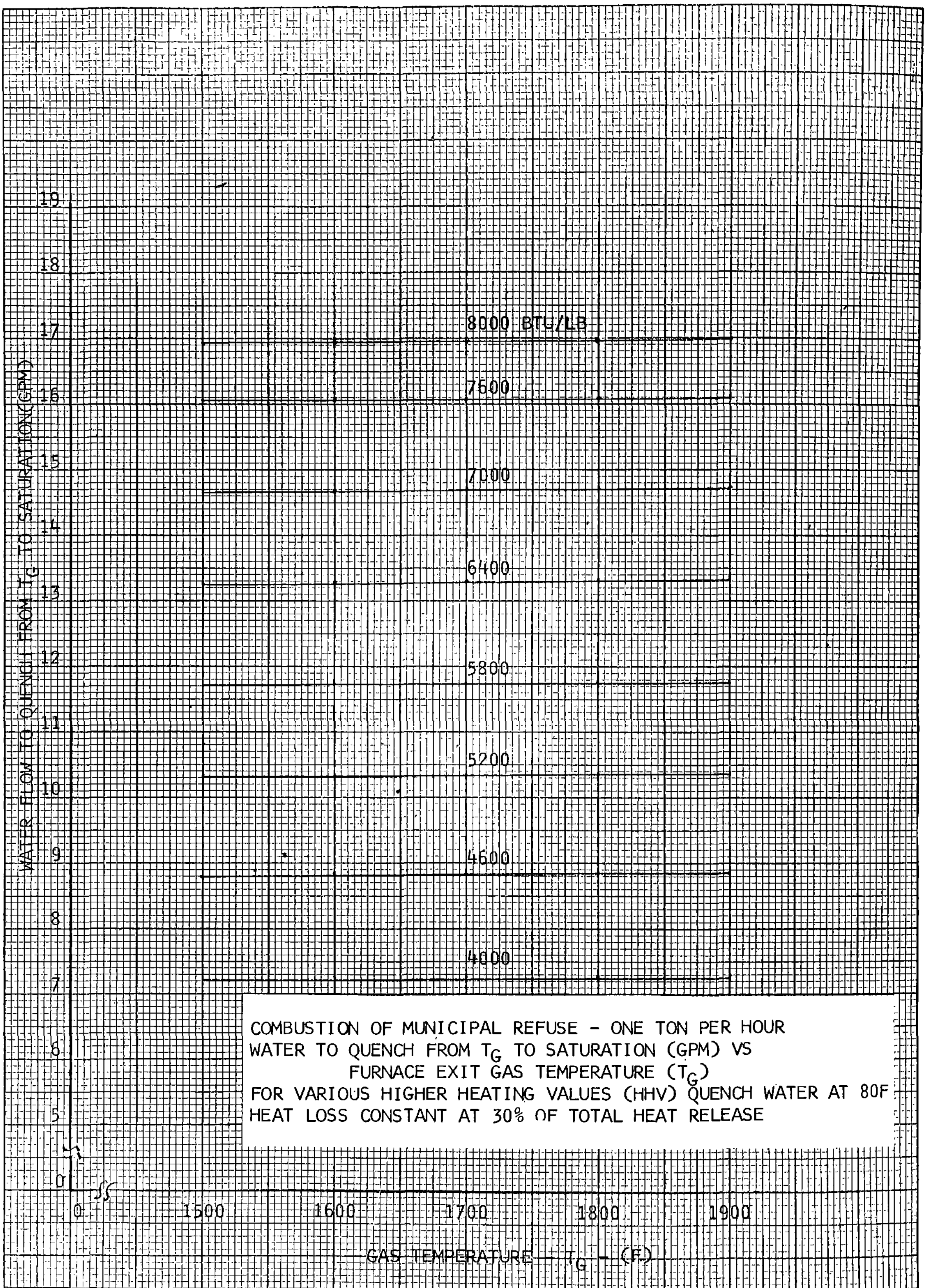


COMBUSTION OF MUNICIPAL REFUSE
ONE TON PER HOUR
WATER TO QUENCH FROM T_G TO 500F (GPM) VS
FURNACE EXIT GAS TEMPERATURE (T_G)
FOR VARIOUS HIGHER HEATING VALUES (HHV)
QUENCH WATER AT 80F
HEAT LOSS CONSTANT AT 2% OF TOTAL HEAT RELEASE
8000 BTU/LB
7600
7000
6400
5800
5200
4600
4000
WATER TO QUENCH FROM T_G TO 500 F - (GPM)
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
0
0
1500
1600
1700
1800
1900
FURNACE EXIT GAS TEMPERATURE - T_G - (F)

Figure 33


COMBUSTION OF MUNICIPAL REFUSE
ONE TON PER HOUR
WATER TO QUENCH FROM T_G TO 500F (GPM) VS
FURNACE EXIT GAS TEMPERATURE (T_G)
FOR VARIOUS HIGHER HEATING VALUES (HHV)
QUENCH WATER AT 80F
HEAT LOSS CONSTANT AT 30% OF TOTAL HEAT RELEASE
8000 BTU/LB
7600
7000
6400
5800
5200
4600
4000
WATER TO QUENCH FROM T_G TO 500F - (GPM)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
0
1500
1600
1700
1800
1900
GAS TEMPERATURE - T_G
Figure 34


8000 BTU/LB
7600
7000
6400
5800
5200
4600
4000
COMBUSTION OF MUNICIPAL REFUSE - ONE TON PER HOUR
WATER TO QUENCH FROM T_G TO SATURATION (GPM) VS
FURNACE EXIT GAS TEMPERATURE (T_G)
FOR VARIOUS HIGHER HEATING VALUES (HHV) QUENCH WATER AT 80F
HEAT LOSS CONSTANT AT 2% OF TOTAL HEAT RELEASE
WATER TP QUENCH FROM T_G TO SATURATION - (GPM)
26
25
24
23
22
21
20
19
18
17
16
15
14
13
12
11
10
9
0
0
1500
1600
1700
1800
1900
FURNACE EXIT GAS TEMPERATURE - T_G - (F)
Figure 35



WATER FLOW TO QUENCH FROM T_G TO SATURATION (GPM)
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
0
8000 BTU/LB
7600
7000
6400
5800
5200
4600
4000
0
1500
1600
1700
1800
1900
GAS TEMPERATURE — T_G — (F)
COMBUSTION OF MUNICIPAL REFUSE - ONE TON PER HOUR
WATER TO QUENCH FROM T_G TO SATURATION (GPM) VS
FURNACE EXIT GAS TEMPERATURE (T_G)
FOR VARIOUS HIGHER HEATING VALUES (HHV) QUENCH WATER AT 80F
HEAT LOSS CONSTANT AT 30% OF TOTAL HEAT RELEASE

Figure 36

PART 8

THE COSTS OF CONVEYING SOLID WASTES BY RAIL

Prepared by

Louis Koenig

Dr. L. Koenig
Louis Koenig Research
San Antonio, Texas

November 1, 1967

TABLE OF CONTENTS

SECTION I

INTRODUCTION

A parametric cost study was undertaken on the conveyance of solid wastes by rail. This was preliminary in nature in order to establish the general levels of the costs involved and the effect of certain parameters on these costs. The method generated in the study is capable of more intensive application to assess the effect and importance of various parameters and cost components, but only a few of these assessments are worked out in the present report.

The conveying of solid waste by rail is a quite new development and the New York Central Railroad has been pioneering the concept. Grateful acknowledgement is made to the New York Central for the information and data supplied and for access to their plans and certain cost figures. While the physical concept was developed by the New York Central in conjunction with a progressive solid waste contractor, and while some of the basic price data and physical relationships are those of the New York Central system, the costs and conclusions reached in this report may or may not reproduce in specific instances the quotations which the New York Central Railroad might tender for those situations. The pricing of railroad operations is extremely complicated and noted for discontinuities in prices which arise because of the rules of regulatory agencies or the procedures set up with labor unions. As a simple example, there is a discontinuity in labor costs for mainline hauling which arises from the rule that eight hours or 100 miles constitutes a day's work for the crew. This means that the labor cost for 110 miles might be twice the labor cost for 90 miles. In the present study, these discontinuities were not taken into account because the computations would become extremely complicated.

The basis of the New York Central system, explored here, comprises a unitized train service originating at transfer stations and having as destination an ultimate disposal or reduction facility (UDR) located along the railroad line. The transfer station receives the refuse from the collection vehicles and compresses it into long containers of rectangular cross-section which are transferred by overhead crane to a train of flat cars. The train departs at a regular time each day, conveying the full containers to the ultimate disposal site where they are unloaded from the train and the empty containers from the day before's haul are put back on the train. The train then returns to the transfer station in time for the next day's operation. At the ultimate disposal site, during the next day the loaded containers are emptied, cleaned and placed back in position for loading onto that evening's train. The present concept is that the community will own the transfer station and the containers, the ultimate disposal contractor will own the disposal facility including the unloading equipment at the site, and the railroad will supply the train of flat cars, locomotives and crew, plus a few gondola cars for bulky items. The community will pay a freight charge to the railroad and an unloading and disposal charge to the refuse contractor. In addition, they will incur the costs of owning and operating the transfer station and the containers. The operations studied in this report start with the delivery of collected wastes to the transfer station and end at the unloading and loading siding just short of the disposal facility itself. The costs for the sanitary landfill or the incinerator at the destination must be added to the rail haul costs presented in this report. The study is geared to the viewpoint of the community so that charges incurred by virtue of owning and operating in community owned facilities are termed "costs" while charges incurred by the community by virtue of using the facilities of others are termed "prices". Where prices are arrived at by the route of computing the operator's costs, an appropriate mark-up is added to convert operator's costs to customer's prices.

SECTION II

CONTAINER AND CRANE COSTS

The container cost and the crane cost must be considered together for they are interrelated via a derived parameter the return interval:

T = return interval, hours-time elapsed between departure of train from transfer station with loaded containers and return of the same train to transfer station with empty containers.

The return interval is composed of the outgoing haul time between train departure from transfer station and train arrival at UDR facility, the container unloading time, the loading time for the empty containers, and the incoming haul time.

The model of the operating system comprises that collection trucks will begin delivery to the transfer station in the morning, utilizing some of a reserve supply of containers later to be mentioned. The bulk of the delivery, however, will occur between some morning deadline and some afternoon deadline, so that it is required that the empty containers from the UDR site be on the side track at the transfer station by the morning deadline of each day. The filled containers resulting from transfer station operation will depart the transfer station at the p.m. deadline and will arrive at the UDR facility at an hour given by the p.m. deadline plus the one-way haul time, by definition. The containers are immediately unloaded from the train and simultaneously the cleaned empty containers from a previous trip are loaded onto the train. The train departs the UDR facility at such an hour as to arrive back at the transfer station by the morning deadline. During the daylight hours of the second day in this model the full containers at the UDR facility are emptied, cleaned, and returned to position for reloading on an incoming train.

This system of operation requires a number of containers in service, that is being conveyed in any one day's train load, sufficient to contain one day's waste. If the train leaving at the p.m. deadline can bring back a set of empty containers by the a.m. deadline the next day, then there will be required two sets of containers. If the train cannot make the deadline then the system requires that there be an empty set of containers ready at the transfer station at noon. This means that three sets of containers would be required, and one additional set of containers for each additional 24 hours in the return interval.

Let:

D = haul distance miles, and

V = average origin-to-destination on-line velocity for train, miles/hour

Then the haul-time portion is $\frac{2D}{V}$. Obviously, if $\frac{2D}{V}$ is greater than 24 hours minus the a.m. to p.m. deadline interval, the system cannot get by with only two sets of containers, but must have three or more. If 2 D/V is greater than 48 hours, minus the deadline interval, it must have four or more sets.

Let:

B = number of containers in one set, i.e. to handle the one day solid waste design quantities.

τ = average time required for unloading one container from cars, taken equal to average time required for loading one empty container back onto cars, hours, = 1/2 time to load and unload a set of containers on the car.

N_k = number of unloading cranes in service at UDR facility required for design day solid waste quantities

Then:

$2\ B\tau/N_k$ = time required for unloading and loading operation for one day's containers at UDR facility, hours.

Then:

$$T = 2\ D/V + 2\ B\tau/N_k, \text{ hours}$$

We have already shown that if the haul time alone is greater than a definable critical duration it is not possible to get by with two sets of containers. However, if the haul time is less than this, there is a possibility that two sets of containers will suffice if the loading and unloading time at the UDR facility is small enough such that the return interval is less than the critical value. In the model to be taken, the unit loading time, τ, is one of the fixed parameters but the total loading and unloading time can be varied by varying N_k the number of cranes. It is in this way that the cost of containers and the cost of cranes are interrelated.

Define:

L = inter-deadline interval, hours - in the a.m. to p.m. deadline interval.

Then:

The critical return intervals are:

24-L, 48-L, ... etc.

Consider what happens as the haul distance increases. As the distance increases, the return interval will increase. When the return interval reaches (24-L) hours, then the next increment of haul distance would require an additional set of containers. However, this necessity can be held off to a certain extent by increasing the number of cranes in service and thus reducing the unloading time. Consider firt the case in which the annual cost of a set of containers in several fold the annual cost associated with the operation of a single crane. Then at some distance slightly over a (24-L) hour return interval it would be possible to reduce this return interval to less than (24-L) hours by adding a single crane, and this would avoid the necessity of adding a complete set of containers. Thus it would be economic.

If the distance is then again increased, it would come about that even with the additional crane the return interval becomes greater than 24-L hours when the same decision is again faced.

A series of critical times may be mathematically expressed as:

$$T = 24(S-1)-L \text{ hours}$$

where:

S - Sets of containers in service - 2, 3, sets.

Now:

$S = (1 + \frac{T + L}{24})^*$ where $(X)^*$ signifies "the least integer equal to or greater than "X", or in words: X if X is an integer, the next integer higher than X if it is not.

Regardless of the haul time, or of the inter-deadline interval, there must be at the minimum enough cranes to perform the unloading-loading operation in a span of 24 hours. Otherwise each day's consignment could not be handled. Thus there is a minimum number of cranes:

$$N_{k(Min.)} = (2\tau B/24)^* = (\tau B/12)^*$$

The load-unload time with say 2 sets of containers and this minimum number of cranes will be $2\tau B/N_{k(Min.)}$, and the return interval will be:

$$2 D/V + 2B \tau/N_{k(Min.)}$$

Suppose this happens to be less than the critical interval 24 (S-1) - L, or in this illustration with 2 sets (24-L). Then consider what will happen as the distance, that is the in-and-out haul time 2 D/V is increased. As this is done, there will come a point at which $2 D/V + 2 B \tau/N_{k(Min.)}$ becomes greater than 24-L. Then the train could not meet the morning deadline. This situation could be remedied by increasing the number of sets of containers to 3. But considering for the moment a case in which the cost of a set of containers is much greater than the cost of a single crane, then the situation could be remedied by adding a single crane. This would augment the cost by less than the cost of a set of containers and yet would reduce the value $2\tau B\ /N_{k(Min.)}$ to $2\tau B\ /(N_{k(Min.)} + 1)$.

As the distance now continues to be hypothetically increased this process could be repeated adding 1 additional crane each time. But finally there would come an additional crane which would bring the total cost of the cranes added to a figure greater than the cost of an additional set of containers which could operate now on a 2-day cycle with only $N_{k(Min.)}$ cranes.

Now Let:

a_c = annual incremental cost of owning and operating 1 set of containers, \$/yr.

a_k = annual incremental cost of owning and operating 1 crane under the intended conditions of service, \$/yr.

Then the maximum number of cranes that may be added and still remain economic over the alternative of an additional set of containers is:

$$\Delta N_{k(Max.)} = \left[\left[\frac{a_c}{a_k}\right]\right]$$

where the symbol [[X]], read "double bracket X" signified "the greatest integer X", or in words: X if X is an integer, the next integer lower than X if it is not.

There is no need to add a number of cranes greater than this limit, since the cost would be greater than adding an extra set of containers and dropping back to $N_{k(Min.)}$ cranes.

In the original working out of this concept there was included in the incremental cost of owning and operating cranes a variable to account for a number of shifts of crane operation per day and also the concept that operating labor would amount to 8 hours per shift regardless of the length of the shift. This is indeed likely to be the real situation, but it presented difficulties in computation which were insurmountable without an electronic computer whereas the amount of computation to be carried out in this preliminary study did not warrant the use of an electronic computer. Accordingly, the concept was relieved of the labor and it was taken that labor costs would be incurred only during the actual hours in which the cranes were in operation, in this being mathematically similar to fuel and supplies. Accordingly, there remains in the a_c and a_k terms only the fixed costs.

Let:

P_c = investment for 1 container
P_k = investment for 1 crane

The parameters for translating investment into annual cost are as follows:

i = interest rate, fraction/year
j = insurance rate, fraction/year
g = tax rate, fraction/year
m = maintenance repair and minor replacement, fraction/year
r = capital recovery factor, year-end repayments, corresponding to i and V, fraction/year
V = amortization period, years, taken as equal to useful life
$(rjgm)$ = fixed cost rate on capital equipment = $r + j + g + m$, fraction/year

Then:

$$\Delta N_{k(Max.)} = \left[\!\left[\frac{BP_c (rjgm)_c}{P_k (rjgm)_k} \right]\!\right]$$

When the computations are performed for a series of increasing distance, relations are obtained as shown in Figure 1. All the terms used in this Figure, as well as in the actual computations, have been reduced to one-way haul time D/V, for ease in the computations, with corresponding changes to "half return interval", half load-unload time (which equals load time), etc. The bottom portion of the Figure shows the relation with respect to the number of cranes, taking N min. as 1. Starting at D/V = 0, the number of sets of containers used is two, with one crane. This condition continues for an extended period until at the time $12(S-1) - \frac{L}{2} - \frac{B\tau}{N_{k(Min.)}}$ it is necessary to add a second crane in order not to exceed the critical half-return interval. As D/V increases cranes are added stepwise until there is reached the time:

$$\frac{D}{V} = 12(S-1) - \frac{L}{2} - \frac{B\tau}{N_{k(Min.)} + \Delta N_{k(Max.)}}$$

At this point the mathematics dictates to add still an additional crane, in this illustration the fourth addition crane. However, the economics dictates that it would be cheaper to add a third set of containers and revert to a single crane. This operation is diagramed by the vertical line falling back to $N_k = 1$. In the next interval three sets are used rather than 2 and the stepwise pattern is identical with the first stepwise pattern. Thereafter the whole diagram is repetitive, both in D/V intervals and in N_k intervals, following that for three sets.

The upper portion of the diagram indicates the cost of these steps. The cost of adding each additional crane is a uniform amount. But when it comes to the step of adding the fourth crane, the diagram shows at the point labelled "see text" that the cost of going to an additional set and dropping back to one crane is less than the cost of adding another crane. The cost now with three sets of containers again plateaus for a long interval of D/V before repeating the stepwise pattern in cost. The cost pattern is also repetitive both in D/V and in cost except of course that each starting point is higher than the last, incidentally by an amount equal to the cost of adding one set of containers.

OPTIMUM NUMBER OF CRANES AND CONTAINER SETS IN SERVICE, $N_{kmin} = 1$

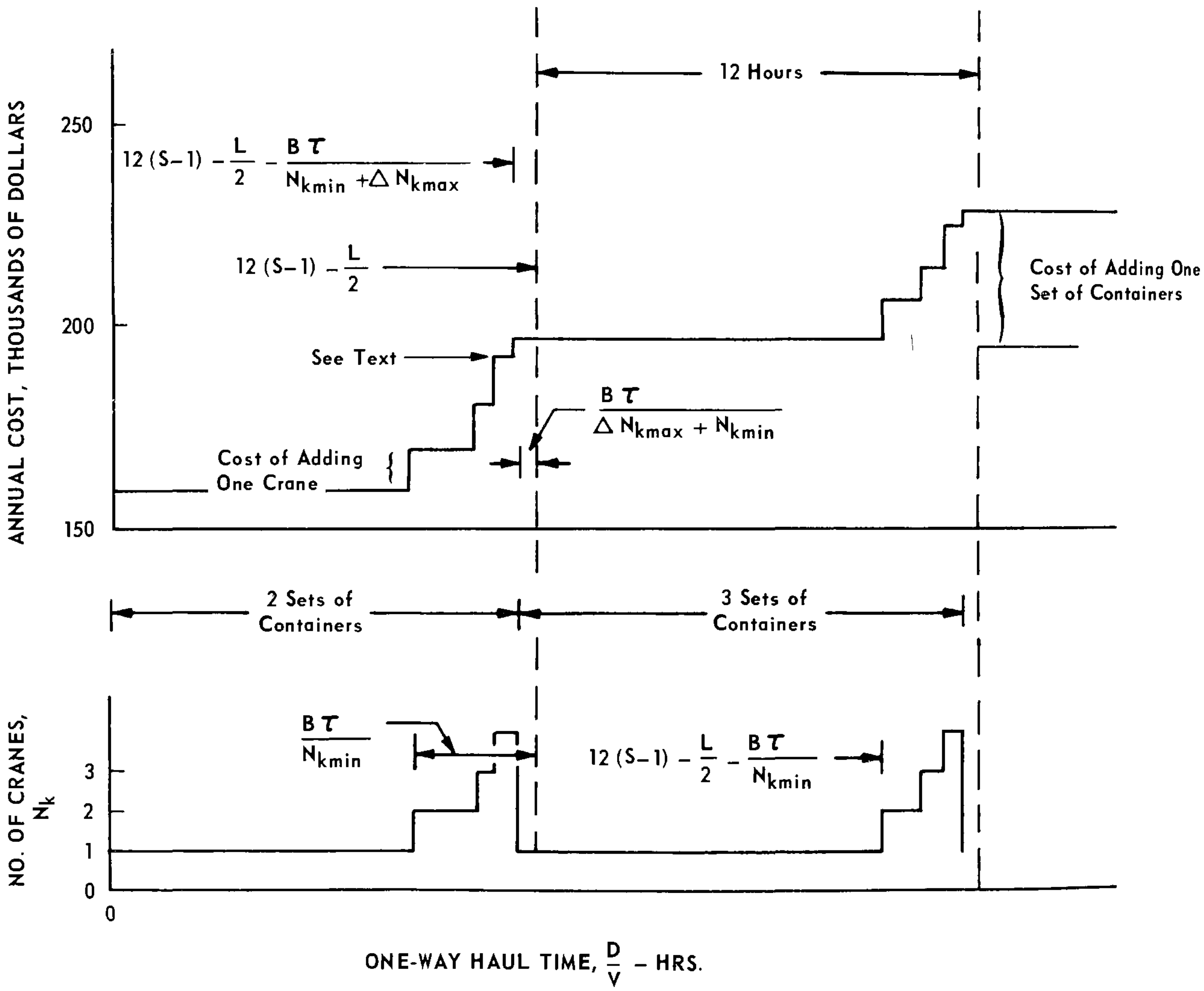


Figure 1

Adding the following parameters not previously defined:

E = men per crew on crane, number

α = cost of fuel and supplies per hour of crew operation, \$/hr

β = fraction of one set of containers in reserve

the cost quantities of interest are as follows:

Number of set of containers in use, S =

$$\left(\frac{\frac{L}{2} + \frac{D}{V} + \frac{B\tau}{N_{k(Min.)} + \Delta N_{k(Max.)}} + 12}{12} \right)^*$$

Number of cranes in use, $N_k = \left(\frac{B\tau}{12\,(S-1) - \frac{L}{2} - \frac{D}{V}} \right)^*$

Crane price at 20% markup, \$/ton handled =

$$1.20 \; \frac{\overbrace{N_k P_k \,(rigm)_k}^{\text{Fixed}} + \overbrace{624\, U\, B\tau\, (P_1 E + \alpha)}^{\text{Labor and Supplies}}}{312\, QU}$$

Container cost, #/ton handled =

$$\frac{B(S + \beta) P_c (rigm)_c}{312\, QU}$$

SECTION III

RESULTS WITH FIXED PARAMETERS

In working out the exemplary cases for this report, the fixed parameters have been given the values listed below. By fixed parameters are meant those parameters in the equations which are maintained fixed from case to case as the situations parameters are varied. Such fixed parameters include container prices, labor prices, etc. As distinguished from these fixed parameters, there are the variable or situation parameters which are primarily:

- Q daily capability
- U utilization factor
- D haul distance

Certain of the fixed parameters are included as variable parameters on occasion principally in order to demonstrate the relative insensitivity of the costs to variations in values of certain fixed parameters. The price of land is one of these. The equations provide for any set of values for both the fixed and the variable or situation parameters, but in the exemplary cases, the following values have been taken for the fixed parameters:

- t tonnage capacity of container = 30 tons
- P_c price of such containers, \$6,000
- P_k price of crane, \$100,000
- T one-half of load - unload time at UDR facility - 0.0333 hrs.
- r_c capital recovery factor on containers, 0.1666 corresponding to 7 years life at 4%
- j_c insurance rate on containers, 0.01
- g_c tax rate on containers, 0.01
- m_c maintenance and minor repair rate on containers, 0.05
- r_k capital recovery factor on cranes, 0.1666 corresponding to 7 years at 4%
- g_k tax rate on cranes, 0.01
- m_k maintenance and minor repair rate on crane, 0.05
- P_l labor price, 3.50 \$/man-hr.
- E number of men on crane crew = 2
- i_k insurance rate on cranes, 0.02

α_k cost of supplies and fuel for cranes = 1.25 $/hr.

β reserve containers, fraction of one set = 0.50

L inter-deadline interval = 7.0 hours, i.e. transfer station to be in operation from 9 a.m. to 4 p.m.

Mark-up on crane costs, fixed, labor and supplies = 20%

Mark-up on turn-around costs = 25%

The results of the numerous cases computed are too many for presentation here since the final costs are presented in the section of this report entitled "Computation Method", container costs being shown as Cost Schedule 2, and crane price as Cost Schedules 3 and 4. The price for the siding at the UDR facility is shown as Cost Schedule 5.

A. TRANSFER STATIONS

The transfer station comprises the installation at which the refuse is transferred from the collection vehicles to the containers and the containers loaded on the train. It consists of access way, building, loading floor, hoppers into which the refuse is dumped, hydraulic mechanism to compress the dumped refuse into the containers, and overhead crane to transfer containers to the train, a siding to hold the train being loaded, and winch or other mechanism for moving the train along as loading proceeds. The hourly capability of an individual hopper-press unit is remarkably high, but the daily utilization factor is low, so that a single hopper-press unit has a capability of 125 tons per day (td). Cost estimates on these transfer stations have been made in the range from four hoppers to twelve hoppers.[1]

The investment in the New York area for such stations is well represented by the equation:

$$C_{IS} = 300{,}000 + 253.33\ Q_S$$

where C_{IS} = New York region investment for transfer station

Q_S = capability of station, td

This equation becomes somewhat higher than the reference data above Q_S = 2,000, but the equation is taken as preferable over the reference because the reference shows an incremental unit cost for the 13th and 14th units which is substantially less than the incremental cost for units 11 and 12 in which themselves the trend is rising.

The acres of land required is given in Reference 1 for Q_S = 500, 1,000, and 1,500. These figures are approximated by the equation:

$$L = (Q_S/100)^{0.5}$$

where:

L = acres of land required

Reference 1 estimates do not include a fence around the installation. Provision is made in this study for a 6 foot chain link fence. Assuming the land is in the shape of a rectangle with one side twice the other, the perimeter is $885 \cdot L^{0.5}$. Thus, the fence investment is:

$$C_{IF} = 885\ (Q_S/100)^{0.25}\ P_F$$

where:

C_{IF} = fence investment

P_F = unit price of fence \$/linear feet

This reduces

$$C_{IF} = 280\ P_F\ (Q_S)^{0.25}$$

using subscripts as follows:

S = station

L = land

F = fence

The total investment then is:

$$C_{ISLF} = 300{,}000 + 253.33\ Q_S \quad \text{station}$$
$$+ \frac{P_L}{10}\ (Q_S)^{0.25} \quad \text{land}$$
$$+ 280\ P_F\ (Q_S)^{0.25} \quad \text{fence}$$

, dollars

The annual costs are:

$$C_{ASLF} = (rigm)_S\ (300{,}000 + 253.33\ Q_S) + (igj)_L\ \frac{P_L}{10}\ (Q_S)^{0.25} \quad \text{, dollars/yr.}$$

where:

C_{ASLF} = annual cost, \$/yr.

Since the purpose of the present study is primarily to explore the effect of tonnage and distance on the rail haul cost, for most cases the capital fractions will be standardized as follows. Capital recovery on the station since it is to be owned by the municipality will be taken as 20 years and 4% for capital recovery factor $r_S = 0.0736$. Insurance and taxes or payments in leiu of taxes will be taken at 1% for fractions $j_S = 0.01$, $g_S = 0.01$. Maintenance will be taken as 5% per year, $m_S = 0.05$.

The total $(rjgm)_S$ is 0.1436. The same values will be used for the fence. For the land there is no depreciation, but the interest is taken at 4%, for i - 0.04. Taxes or payments in lieu of taxes are taken at 0.01, g_L, and insurance at 0.005. The $(ijg)_L$ is 0.055.

With capital cost parameters fixed in this way, the annual fixed cost on capital becomes:

$$C_{ASLF} = 43,080 + 36.378\, Q_S \qquad \text{station}$$

$$+ \frac{P_L}{181.82} (Q_S)^{0.5} \qquad \text{land}$$

$$+ 40.208\, P_F\, (Q_S)^{0.25} \qquad \text{fence}$$

The relative importance of these three cost components may be assessed by inserting certain values for price of fence and price of land. If price of fence is taken at 7.5 $/linear foot which is a proper estimate for the type of fence planned, and if land is taken at $1,000 per acre in order to maximize the contribution of fence, it is found that the fence contribution is only of the order of 1 - 2% of the total of the fixed costs on capital for the transfer station installation, being at the lower figure for the maximum capability and at the higher figure for the minimum capability. Likewise, if land is taken at the highest reasonable price of $40,000 per acre, it is found that the contribution of land is in the range 4 - 6% being the lower at the lower capability. Since these percentage contributions will be diluted even further when the costs other than for the transfer station installation are added, such as crane and container cost, rail freight, etc., it is clear that fence can be neglected as a cost component and taken care of by adjusting the station component upwards by 1.5% giving:

$$C_{ASLF} = 43,726 + 36.924\, Q_S \qquad \text{station}$$

$$+ \frac{P_L}{181.82} (Q_S)^{0.5} \qquad \text{land}$$

The same argument applies to land contribution; this is discussed in Section V.

In addition, there will be required at the transfer station a siding for handling the cars, in length twice the length of the train. This cost will probably have to be borne by the community.

As discussed in the section on cranes and containers, if each car handles three containers, the number of cars required is:

$$\left(\frac{B}{3}\right)^*$$

Thus, with 89 foot cars, the length of the siding is:

$$2 \times 89 \times \left(\frac{B}{3}\right)^*, \text{ feet}$$

With a 20 foot right-of-way, the acres required for the siding is:

$$.08172 \left(\frac{B}{3}\right)^*$$

If it is taken that this siding land may be purchased for the same price as the main acreage and that the annual fixed factor is the same as the main land, then the annual cost of land for the siding becomes:

$$0.4792 \left(\frac{B}{3}\right)^* \frac{P_L}{1000}$$

The cost of the track for the siding itself is taken as $7 per foot[1] and with the annual cost factor the same as for the station itself (i.e. 0.1436) the annual cost for the siding track becomes:

$$178.9 \left(\frac{B}{3}\right)^*$$

It is noted that the same length of siding will be required as part of the facilities at the UDR site, taken as a cost of the UDR contractor.

This completes the fixed costs for the transfer station. The operating costs are derived from basic data in Reference 1 which provides estimates of labor type and cost for 500, 1,000 and 1,500 ton per day stations in New York City area. The labor breakdowns and the utilities cost were extended by estimation at 125 and 2,000 tons per day. The utilities include light, water, gas, phone, heating and electric energy for compression and hoisting. The labor comprises superintendent, crane operator, loader and winch operator, hopper operator and general laborers.

Because the larger stations do not require all of these categories in proportion to the capability the labor mix varies with Q, as does the average price of labor per man-hour of the labor mix. These basic figures are shown in Table I for information. However, only the totals, labor dollars per 312 days and utilities dollars per year, were used in the computations at the discrete Q_S values computed. The estimates and extentions were plotted on log - log paper and extrapolated to the 3,000 and 6,000 tons per day.

Recognizing the difficulty of achieving a variable labor load in a municipal type operation, it will be taken that the labor requirement is independent of U. The utilities cost will be only slightly influenced by U, here taken as proportional to $U^{0.25}$.

The results for the transfer stations including the station itself, the land, the siding and the fencing are shown in the section of this report entitled "Computation Method" as Cost Schedule 1.

TABLE I

UTILITIES AND LABOR COSTS

TRANSFER STATIONS

Q_S	Man-Hours Mixed Labor Per Day / Q_S	$ Per Man-Hour Labor Mix	Labor Cost $/362 Days	Utilities Cost $/Year
124	D .160	4.10	25,789	2,000
300	D .103	4.10	39,499	2,500
501	D .080	4.10	51,271	3,000
1002	D .0563	4.00	70,340	4,000
1500	D .0461	3.92	84,708	4,900
3000	D .0326	3.62	110,448	6,900
6000	D .0230	3.29	141,710	9,700

B. FREIGHT COSTS

When the subject of hauling waste solids was studied in 1961[2], it was observed that railroads would be included to assess ICC Class 13 rates to this service, but that possibly commodity rates could be negotiated. In the 1967 investigation of this project[1], it was confirmed that the railroads would tend to assess something of the order of Class 13 rates. However, for municipal refuse, rail hauling in general seems to have such an economic advantage over other methods that it appears unlikely that the railroads would be agreeable to a lower commodity rate.

The general method of constructing a rate table is described in Reference 2 and is shown here for the Eastern rail territory in Table II.

Rate base miles (also termed short-line miles) is the official mileage established by the ICC between any two railroad points and on which the quoted rates are based. It is the actual railroad distance by the shortest combination of connecting lines between the two points. Route-miles is the actual mileage traveled by the train between the two points. In many cases, this is the same as the short-line miles, but in some cases it is more convenient for the railroads to use a longer route in order to take advantage of a heavily traveled line. Straight-line miles is the straight-line distance measured on a map between the two points. Straight-line miles is the datum used in the present study since it is the statistical geographical parameter which can be easily measured for any situations. An analysis for a few dozen actual rates showed that for the nation as a whole, the average ratio of rate base or short-line miles to straight-line miles was 1.30.

TABLE II

RATE TABLE FOR EASTERN TERRITORY, CLASS 13 (1961)

By actual quotation:

Rate Base Miles	Straight Line Miles	Dollars per Ton
1309	1040	15.00
999	760	12.50
778	560	10.90
632	410	9.70
477	280	8.30
89	89	4.10

By ICC Schedules:

Rate Base Miles	Straight Line Miles	Dollars per Ton
300	253	5.84
200	168	4.92
100	84	3.74
0	0	1.81

Smooth Curve:

Rate Base Miles	Straight Line Miles	Dollars per Ton
	0	1.80
	25	2.65
	50	3.20
	75	3.60
	100	3.95
	150	4.15
	200	5.25
	250	5.80
	275	6.10
	275	8.10
	300	8.30
	400	9.55
	500	10.65

Some judgement must be used in assigning straight-line miles for long routes in reading the table. For example, if one were concerned with a New York City - Utica trip, one would probably more closely approximate the correct rate by taking the sum of the straight-line distance New York Albany and Albany - Utica rather than the hypotenuse New York - Utica.

From a plot of the data in Table II there have been taken smooth curve values shown in the bottom portion of that table. The curve has a break at 275 miles honoring the ICC schedule below this and the actual quotation above.

The rail rates actually used in the computations were those shown in Table III. These are derived from two schedules, Schedule A and Schedule B. Schedule A is the ICC and actual quotation Class 13 rates just discussed. Schedule B was constructed from quotations made by the New York Central Railroad in particular instances and for particular distances and tonnages using the unitized train, plus a statement that for X tons per day, the incremental cost of the next 100 miles would be Y¢/ton. This figure, Y, was adjusted upwards by 25% to include overhead and profit. Then it was adjusted to different ton/day figures by assuming that the incremental cost in dollars on the additional 100 miles changed very little with reasonable changes in tonnage. In other words, the cost of operating the unitized train was almost the same regardless of the number of cars. It had been indicated that the railroad could not afford to undertake a unitized train operation with less than 1,000 tons/day. Nevertheless, this limit was extended downward to cover 510 tons/day in a unitized train using some judgement to place the rates at certain mileages corresponding to the mileages estimated for the other tonnages.

The resulting rates from Schedule B obtained by this method were plotted on the same sheet with the Schedule A rates, and from these plots the figures in Table III were read off at round number mileages. The two figures given at 275 miles in the Class 13 rates section represent the break which occurs in Schedule A at about that distance, below that distance being from ICC schedules and above that distance from actual quotations for long distance service on solid waste in regular trains.

It is re-emphasized here that these possible rates are entirely the construction of the author based on the indicated information and do not represent figures which can be compared with actual quotations that individual railroads may give. Various railroads may have different cost structures than those upon which Table III is based, and furthermore, as has been explained rail rates between particular points are highly dependent upon the individual characteristics of the run, and are subject to arbitrary discontinuities.

Furthermore, rate making for unitized train service on refuse conveyance is a new art on which little experience is available. As experience is gained in the future such rates as assigned here may either increase or decrease. The rates in Table III are based on design capability, tons/day,

TABLE III

POSSIBLE RAIL FREIGHT RATES FOR CONTAINERIZED SOLID WASTE HAULING

$/ton handled

	UNIT TRAIN RATES Schedule B				CLASS 13 RATES Schedule A		
Tons/Day Miles	3000 6000	1500	990	510	510	300	124
10	1.50	1.50	1.50	1.80		2.10	2.10
50	1.95	2.05	2.10	2.55		3.20	3.20
20	2.15	2.25	2.35	3.00		3.50	3.50
100	2.35	2.65	2.90	4.15	3.95	3.95	3.95
150	2.65	3.25	3.80	5.95	4.15	4.15	4.15
200	2.95	3.90	4.20	7.65	5.25	5.25	5.25
250	3.30	4.50	5.65	9.50	5.80	5.80	5.80
275					6.10, 8.10	6.10, 8.10	6.10, 8.10
300	3.60	5.10	6.15		8.30	8.30	8.30
400	4.20	6.25	8.50		9.55	9.55	9.55
500	4.90	7.75	10.65		10.65	10.65	10.65

on the grounds that the railroad has to have the cars, locomotives and crew available to meet the peak day regardless of the actual tonnage hauled. After the railroads have gained some operating experience with this as a regular feature, they may find that the rates can be reduced to reflect some of the savings, whatever their magnitude may be, brought about by hauling an average tonnage which is of the order of one half the design tonnage, taken throughout an entire year.

It should also be mentioned that if a community seeks to use a single-car conveyance system on a regular way train, it must have a situation in which there is a regular way train leaving each day at the proper time, that is, in the late afternoon, and another regular train returning from the UDR facility at some proper time during the night. Furthermore, the interval between the arrival and the departure at the UDR facility must be at least equal to the full turn-around time required for the unloading-loading operation on the containers.

1. TURN-AROUND PRICE

An uncertain factor in the total price charged by the railroad is the turn-around time. This is the time during which the engine and train crew are waiting at the UDR facility for the unloading and loading process to be completed. This turn-around time varies from situation to situation depending on the optimization of the crane-container system. A certain amount of this turn-around time is presumably contained in the freight rates already developed, but the railroads would probably have to increase these rates in situations where the turn-around time becomes excessive. Accordingly, this turn-around time is costed as a separate item.

An 89 foot flat car will take three 27 foot 30 ton containers and accordingly, the number of cars in a unit train is:

$$C = \left(\frac{B}{3}\right)^{*}$$

A single 2,500 HP diesel unit will handle 50 cars, and one additional will be required for each fraction of 50 beyond this. The number of diesel units involved therefore is:

$$\left[\!\left[\frac{C}{50}\right]\!\right] + 1$$

The full turn-around time is:

$$\frac{2\ B\tau}{N_k}\ \text{hrs.}$$

While idling a 2,500 HP diesel will consume 7.5 gallons of fuel per hour[3] and the average price bid by railroads for diesel fuel in 1965 was 9.37 ¢/gal.[4]

The working life of such a diesel unit is 15 years with an average of 335 days per year operating, 30 days being taken out for regular and special maintenance. The capital recovery factor will be taken for 15 years at 6%, insurance at 3%, taxes at 1% and maintenance at 1%, taken when idling. The total fixed cost factor is 0.1530 fraction per year. This computes to a fixed cost of 4.758 \$/hr. per unit, or with the fuel 5.461 \$/hr. There is a five-man crew on the train irrespective of the number of diesel units and this becomes 5 P_1 dollars per hour per train for labor.

To the total of the fixed cost and labor cost for turn-around time, there is added 25% for general overhead and profit to yield a price for turn-around of:

$$\frac{\$}{\text{Year}} = 1.25 \left[5.461 \left(\left[\!\left[\frac{C}{50}\right]\!\right] + 1\right) + 5\,P_1\right] \frac{(2\,B\tau \times 312)}{N_k}$$

$$\frac{\$}{\text{Ton}} = \frac{2.50}{QU} \left[5.461 \left(\left[\!\left[\frac{C}{50}\right]\!\right] + 1\right) + 5\,P_1\right] \frac{B\tau}{N_k}$$

2. SWITCHING PRICE

When the conveyance system comprises a single car or a group of single cars hauled on a regular way train a charge will be incurred for switching the car on to and off of the train. There will be four such switching events, one to switch the car on to the train at the transfer station, one to switch it off the train at the UDR facility, one to switch it on to the train returning the empty, and one to switch it off of the train at the transfer station. A normal charge for this switching operation accomplished in a way train having a switching crew is \$7.50/switch. However, this can vary considerably with the switching circumstances. For example, if an inter-line switch should be involved in a large city, the cost might be as much as \$90/switch. However, assuming that the situations covered here involve transfers between an origin point and a destination point on a single rail line, the unit price will be taken as \$30 - (4 x \$7.50) per car.

The switching price will be incurred only for cars actually transferred; that is, it will be approximately proportional to U. On any particular day characterized by a tonnage Q and a number of cars (B/3)*, the switching price will be:

$$\text{Switching price, \$/ton} = \frac{30\left(\frac{B}{3}\right)^{*}}{Q}$$

or

$$\text{Switching price, \$/ton} = \frac{30}{QU}\left(\frac{QU}{3t}\right)^{*}$$

With 30 ton containers and without the integer restrictions, this quantity equals 0.333 $/ton for any tonnage. However, with the integer restrictions the quantity varies with Q and also with U, where U indicates the utilization factor for a particular day. Table IV shows the switching price at the various Q values and at U = 0.3, 0.5 and 1.0.

TABLE IV

SWITCHING PRICE, $/TON HANDLED

(at $7.50 per switch, 30 ton containers)

Q	U 0.3	U 0.5	U 1.0	Average of 3
120	.833	.500	.500	.611
300	.333	.400	.400	.444
510	.382	.353	.353	.366
990	.404	.364	.333	.367
1500	.333	.360	.340	.344
3000	.333	.340	.340	.338
6000	.333	.340	.335	.336

If in achieving an overall annual utilization factor, U = 0.5 the U on each day were 0.5, then the switching prices would be as shown in the 0.5 column.

However, an annual U of 0.5 is composed of individual days having various daily utilization factors some probably as low as 0.3 and others possible as high as 1.0. The actual overall average switching price per ton handled depends upon the frequency distribution of daily tonnage and can only be accurately obtained by integrating such a relation. However, this relation is not known, was not explored in this study and will be approximated by taking the integral as equal to the average of the three U values in the table.

C. UTILIZATION FACTOR

No general study on utilization factors for refuse systems was available so the choice of a typical parameter value for U was made from information made available in Reference 1. The utilization factor involved is the daily utilization factor:

$$U = \frac{\text{average daily genration throughout the year, tons/day}}{\text{design capability, tons/day}} = \frac{\bar{Q}}{Q}$$

The design capability, Q, must be such as to accommodate the peak day in the year.

From the available information, for Westchester County, 1964 - 1965, the highest days occurred in June and July, several days having ratios $\frac{Q}{\bar{Q}}$ such as 1.72, 2.24, 1.77, 2.13, etc. If the installation is designed to handle peak days of the order of 2.0 x the average generation, then over the entire year it will operate at a utilization factor U = 0.50. This figure applies to a system designed to handle this year's load and operated under this year's conditions.

Subject to the conclusions of the overall project if it be assumed that the installation is set up now with a capability to handle the load ten years from now and the increase in waste generation over that period is 30%, then that system designed for ten years hence would in its first year be operating at U = 0.38, in its tenth year at 0.50 and over the ten year period at something a little less than 0.44.

SECTION IV

COMPUTATION METHOD

On the following pages, there is reproduced a form sheet for computing rail haul costs according to the system herein developed, and to be used in conjunction with the cost schedules, numbered 1 to 8, which provide the information on the various cost components in terms of the variable parameters Q, U, D. The form as a computing program is self-explanatory. It includes adjustments for the price of land, and for utilization factors different from the standard 0.5.

One example is worked out in Table V so that the reader may follow the procedure step-by-step.

TABLE V

SAMPLE CALCULATION

FORM SHEET FOR COMPUTING RAIL HAUL COSTS

Variable parameters given				Line No.
Capability	Q, tons/day*	3,000		(2)
Utilization factor	U, fraction	.4		(3)
Distance	D, miles	100		(4)
Travel velocity	V, miles/hour	30		(5)
Land price	PL, $/acre	20,000		(6)
Derived variable parameter	DV, hours	3.333		(7)
Transfer facility. Read Cost Schedule 1 @ Q and PL=1000		.592		(9)
PL adjustment: $\frac{PL - 1000}{10^6}$ x (9) .019 x .592		.007		(10)
Adjusted for PL: (9) + (10)		.599		(12)
Adjusted for U: (12) x 0.5/U		.750		(13)
Containers. Read Cost Schedule 2 @ Q and D/V		.758		(14)
Adjusted for U: (14) x 0.5/U		.945		(15)
SUB-TOTAL: COMMUNITY'S COSTS (13) + (15)			1.695	(16)
Cranes. Labor and supplies. Read Cost Schedule 3		.022		(17)
Adjust for non-integer: (17) x $\left[1 + \left(\frac{Q}{t}\right)^* - \frac{Q}{t}\right]$		.022		(18)
Fixed. Read Cost Schedule 4 @ Q and D/V		.063		(19)
Adjust for U: (19) x 0.5/U		.079		(20)
UDR siding. Read Cost Schedule 5 @ Q		.017		(21)
Adjust for U (21) x 0.5/U		.021		(22)
SUB-TOTAL: UDR CONTRACTOR PRICE: (18) + (20) + (22)			.122	(23)
Freight. Freight rate price. Read cost schedule 6 @ Q + D		2.350		(24)
Turn-around (unitized only) Read cost schedule 7 @ Q + D/V		.127		(25)
Adjusted for U: (25) x 0.5/U		.159		(26)
Switching (waytrain only) Read cost schedule 8 @ Q				(27)
SUB-TOTAL: RAILROAD PRICE: (24) + (26) or (27)			2.509	(28)
TOTAL RAIL HAUL COST (16) + (23) + (28)			4.326	(30)

*For values of Q not given in the schedules obtain appropriate approximate values by interpolating between tabulated values.

COST SCHEDULE 1

TRANSFER FACILITY COST

Variable parameters controlling: QUP_L

For use where U = 0.5 and P_L = 1,000 and 40,000

Q	P_L = 1,000	P_L = 40,000
124	3.910	4.170
300	1.077	2.158
510	1.477	1.540
990	.989	1.060
1500	.817	.854
3000	.592	.618
6000	.457	.476

To adjust approximately for land prices, subtract from the above 40,000 figures:

$$\frac{40{,}000 - P_L}{10{,}000} \text{ percent of the tabulated value}$$

or add to the 1,000 figures:

$$\frac{P_L - 1{,}000}{10{,}000} \text{ percent of the tabulated value}$$

Example: For P_L = 20,000 at 510 tons per day:

$$-\frac{20{,}000}{10{,}000} \times \frac{1}{100} \times 1.540 = -\ .031$$

$$1.540 - .031 = 1.504 \text{ \$/ton}$$

The correct computed value for P_L = 20,000 is 1.508 dollars per ton.

To adjust quite accurately for U, multiply the tabulated costs by 0.5/U.

Example: Q = 510, P_L = 40,000, U = .40 and U = .60

$1.540 \times \frac{0.5}{0.4} = 1.925$; the correct computed value is 1.922

$1.540 \times \frac{0.5}{0.4} = 1.283$; the correct computed value is 1.284

COST SCHEDULE 2

CONTAINER COST

Variable parameters controlling: Q, U, D expressed as Q, U, D/V

Values at U = 0.5, \$/ton handled

Q = 120 tons/day

D/V Range	0 to 8.367	8.367 to 20.367	20.367 to 22.367	32.367 to 44.367
Cost, \$/Ton	0.758	1.062	1.365	1.668

Q = 300 tons/day

D/V Range	0 to 8.167	8.167 to 20.167	20.167 to 32.167
Cost, \$/Ton	.758	1.062	1.668

Q = 510 tons/day

D/V Range	0 to 7.934	7.934 to 19.934	19.934 to 31.934	31.934 to 42.934
Cost, \$/Ton	.767	1.067	1.374	1.677

Q = 990

D/V Range	0 to 7.950	7.950 to 19.950	19.950 to 31.950
Cost, \$/Ton	.763	1.066	1.369

Q = 1,500 tons/day

D/V Range	0 to 7.945	7.945 to 19.945	19.945 to 31.945
Cost, \$/Ton	.758	1.062	1.366

COST SCHEDULE 2, Cont.

Q = 3,000 tons/day
Q = 6,000 tons/day

D/V Range	0 to 7.834	7.834 to 19.834	19.834 to 31.834
Cost, $/Ton	.758	1.061	1.364

Precise values of $/ton at other U's: Multiply above by $\frac{0.5}{U}$.

COST SCHEDULE 3

CRANE PRICE

Crane Price, Labor and Supplies

Variable parameters controlling: Q but only via B, i.e. $(\frac{Q}{t})^*$. For values of Q such that Q/t is an integer crane labor and supplies is independent of Q and has the value 0.022 \$/ton. For other values of Q it is:

$$0.022\ (1 + (\frac{Q}{t})^* - \frac{Q}{t}),\ \$/\text{ton}$$

a term which varies linearly with Q between 0.022 and 0.044.

COST SCHEDULE 4

CRANE PRICE, FIXED

Variable parameters controlling: Q, U, D expressed as: Q, U, D/V

Values at U = 0.5

	Q = 120	Q = 300	Q = 510
D/V Range	0 to ∞	0 to ∞	0 to ∞
Crane Price, Handled $/Ton	1.581	0.632	.372

Q = 990

D/V Range	0 to 7.401	7.401 to 7.950	7.950 to 19.401	19.401 to 19.950	19.950 to 31.401	31.401 to 31.950
Crane Price	.192	.383	.192	.383	.192	.383

Q = 1,500

D/V Range	0 to 6.835	6.835 to 7.667	7.667 to 18.835	18.835 to 19.667	19.667 to 19.945	19.945 to 30.835
Crane Price	.127	.254	.380	.254	.380	.127

Q = 3,000

D/V Range	0 to 5.170	5.170 to 6.835	6.835 to 7.390	7.390 to 7.667	7.667 to 7.834	7.834 to 17.170	17.170 to 18.835	18.835 to 19.390	19.390 to 19.667
Crane Price	.063	.126	.190	.253	.316	.063	.126	.190	.253

repetitive at D/V + 12

COST SCHEDULE 4, Cont.

Q = 6,000

D/V Range	0 to 1.840	1.840 to 5.170	5.170 to 6.280	6.280 to 6.835	6.835 to 7.168	7.168 to 7.390	7.390 to 7.549	7.549 to 7.668	7.668 to 7.760	7.760 to 7.834	7.834 to 13.840	13.840 to 17.170
Crane Price	.032	.063	.095	.126	.158	.190	.221	.253	.285	.316	.032	.063

etc. repetitive at D/V + 12

Precise values of crane price, handled for other U's: Multiply above \$/ton by $\frac{0.5}{U}$.

COST SCHEDULE 5

UDR SIDING PRICE
(track only, not land)

Variable parameters controlling: Q, U

Values for U = 0.5

Q	$/ton
120	.024
300	.020
510	.018
990	.017
1500	.017
3000	.017
6000	.017

Precise values for other U's: multiply above by $\frac{0.5}{U}$

COST SCHEDULE 6

FREIGHT RATE PRICE

Variable Parameters Controlling: Q, D

$/TON HANDLED

	SINGLE CAR			UNITIZED TRAIN			
D	Q 120	300	510	510	990	1500	3000 6000
10	2.10	2.10		1.80	1.50	1.50	1.50
50	3.20	3.20		2.55	2.10	2.05	1.95
70	3.50	3.50		3.00	2.35	2.25	2.15
100	3.95	3.95	3.95	4.15	2.90	2.65	2.35
150	4.15	4.15	4.15	5.95	3.80	3.25	2.65
200	5.25	5.25	5.25	7.65	4.70	3.90	2.95
250	5.80	5.80	5.80	9.50	5.65	4.50	3.30
275	6.10	6.10	6.10				
275	8.10	8.10	8.10				
300	8.30	8.30	8.30		6.15	5.10	3.60
400	9.55	9.55	9.55		8.50	6.25	4.20
500	10.65	10.65	10.65		10.65	7.75	4.90

COST SCHEDULE 7

TURN-AROUND PRICE

Unitized Train Only

Variable parameters controlling: Q, U, D expressed as Q, U, D/V

Values at U = 0.5.
Pattern between vertical lines repetitive by adding 12 hours to each listed D/V value.

	Q = 120	Q = 300	Q = 510
D/V Range	0 to ∞	0 to ∞	0 to ∞
Price, $/Ton	0.127	0.127	0.127

Q = 990

D/V Range	0 to 7.401	7.401 to 7.950	7.950 to 19.401	19.401 to 19.950
Price, $/Ton	.127	.064	.127	.064

Q = 1,500

D/V Range	0 to 6.835	6.835 to 7.667	7.667 to 7.945	7.945 to 18.835	18.835 to 19.667	19.667 to 19.945
Price, $/Ton	.127	.064	.042	.127	.064	.042

Q = 3,000

D/V Range	0 to 5.170	5.170 to 6.835	6.835 to 7.390	7.390 to 7.667	7.667 to 7.834	7.834 to 17.170	17.170 to 18.835	18.835 to 19.390
Price, $/Ton	.127	.064	.042	.032	.025	.127	.064	.042

COST SCHEDULE 7, Cont.

Q = 6,000

D/V Range	0 to 1.840	1.840 to 5.170	5.170 to 6.280	6.280 to 6.835	6.835 to 7.168	7.168 to 7.390	7.390 to 7.549	7.549 to 7.668	7.668 to 7.760	7.760 to 7.834	7.834 to 13.840	13.840 to 17.170
Price, $/Ton	.158	.079	.053	.040	.032	.026	.023	.020	.018	.016	.158	.079

Precise values of $/ton for other U's: Multiply above by $\frac{0.5}{U}$.

COST SCHEDULE 8

SWITCHING PRICE

(applicable to way train service, not unitized train)

Variable parameters controlling: Q and frequency distribution of daily utilization factor, the latter unknown and approximated here.

Q	$/ton
120	.611
300	.444
510	.366
990	.367
1500	.344
3000	.338
6000	.336

SECTION V

SELECTED EXEMPLARY RESULTS

The computing form and cost schedules have been used to compute a limited number of complete situations at varying capabilities and at two distances, 100 and 50 miles, at a utilization factor of 0.5. The results thereof are shown in Table VI and plotted in Figure 2.

Referring to the figure, it is seen that the unit cost per ton handled decreases with capability. The economic breakpoint between way train and unitized train occurs in the neighborhood of 400 tons/day capability, being a little higher at 100 miles than it is at 50 miles.

The unit cost is definitely sub-proportional to the distance. For example, at 1,000 tons/day capability (500 tons/day average conveyed) the cost of conveying a hundred miles is only 19% more than the cost of conveying 50 miles.

As to the disbursement of the total costs incurred, in most situations the larger share becomes revenue to the railroad, next in order being the community's own expenses for containers and transfer stations, and lowest in order the contractor revenue for the unloading operation at the UDR facility.

The computation method and the basic data of this report may be used for a variety of comparisons. These include the assessment of the sensitivity of costs to various values of the fixed parameters for example labor prices, as well as of the situation parameters, for example utilization factor. Also such computations may be used to fix the locus in distance and capability of the economic breakpoint between way trains and unitized trains. Because this study is preliminary in nature, the opportunity is not given to explore these various relationships here.

However, one exploration will be made because it has been left unresolved from an earlier section. There it was indicated that the cost was insensitive to price of land even to very high land prices of the order of $40,000 per acre, and therefore, the price of land was not an important determinant of the cost of rail hauling. This fact is demonstrated in the last rows of Table VI. For 120 tons/day the land cost is 6.6¢ out of a total cost of over $10,000 land at $20,000 per acre, therefore, contributing 0.65% to the total cost. At the other end of the scale, at 6,000 tons/day land cost is 1¢ out of a total cost of $3.50 to $4.70 per ton, a contribution of 0.29% at the most to the cost of rail haul.

TABLE VI

RESULTS OF EXEMPLARY COST COMPUTATIONS

Q ton/day	120	300	510	990	1500	3000	6000
$/Ton @ U = 0.5, D = 100 miles, V = 30 MPH, P_L = 20,000 $/acre							
Community	4.742	2.874	2.272	1.771	1.590	1.361	1.223
Contractor	1.627	.674	.412	.231	.166	.102	.071
Railroad	4.561	4.394	4.277	3.027	2.777	2.477	2.429
Total	10.930	7.942	6.961	5.029	4.533	3.940*	3.723

$/Ton @ U = 0.5, D = 50 miles, V = 30 MPH, P_L = 20,000 $/acre							
Community	4.742	2.874	2.272	1.771	1.590	1.361	1.223
Contractor	1.627	.674	.412	.231	.166	.102	.040
Railroad	3.811	3.644	2.677	2.227	2.177	2.077	2.256
Total	10.180	7.192	5.361	4.229	3.933	3.540	3.519
Land Cost				0.066		0.010	
Land % of Total				0.65%		0.29%	

*Compare this case in the exemplary computation, Table V @ U = 0.4 where the cost is 4.326 $/ton

CALCULATED COSTS OF CONVEYING
SOLID WASTES BY RAIL

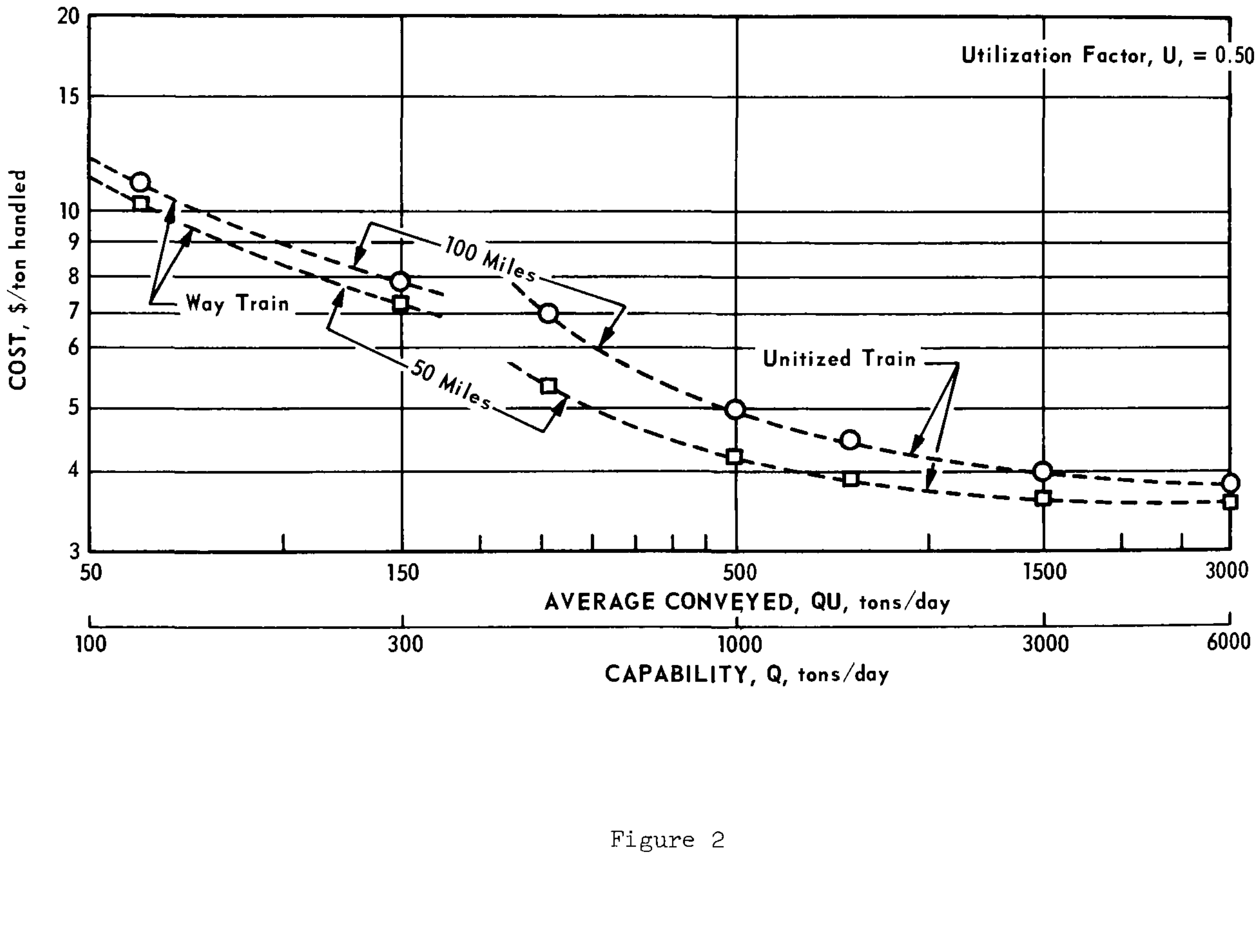


Figure 2

SECTION VI

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PART 9

MUNICIPAL BUYING PRACTICES

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MUNICIPAL BUYING PRACTICES

Improved performance of incinerators and other types of waste reduction equipment is severely limited by the present practices used by municipalities in buying incinerator components instead of total systems. The following material describes the problem in more detail and recommends a possible solution.

The following list of different buying influences indicates the complexity of marketing waste reduction facilities to municipalities:

A. Turnkey

1. Municipality synonymous with regional refuse disposal authority.

   Town Engineer

   Town Mayor or City Manager

   Town Council

2. Consulting Engineer

3. General public (who must accept the concept that the specific waste reduction process is desirable).

B. Integrated Systems (Burning System)

1. Architect - Engineer

2. General Contractor

3. Municipality

4. Consulting Engineer

C. Equipment Components (Stoker, Fans, Furnaces, etc.)

1. Sub-Contractor (incinerator)

2. General Contractor

3. Architect - Engineer

4. Consulting Engineer

D. Service Contract

1. Municipality

   Town Engineer

   Town Mayor

City Manager or Politician

2. Consulting Engineer

The turnkey approach which has been used in the past provides one supplier to perform the role of general contractor, incinerator contractor, equipment supplier, manufacturer of certain proprietary equipment, and guarantor of system performance. This supplier will sub-contract all work he cannot handle.

The integrated system approach provides a standard burning system of tested design with quaranteed performance and quaranteed price with estimated or demonstrated operating costs. This would require more than a straight performance specification because bids on the system would be accepted on an evaluated basis.

Equipment components provide for the sale of proprietary items supplied to detailed specifications.

The present concept of supplying equipment to detailed specifications precludes the very important item of system engineering. Incineration is a process and as such is a series of dependent variables. The performance of one component is affected by the performance of others. Adequate hardware may be selected and integrated into an incompatible system. This results in poorly designed and performing plants. The lack of emphasis or attention to a properly worded performance specification has been apparent in the past and a complete review of this field is required. Trends in procurement legislation and practice will encourage objective performance specifications.

A Federal procurement officer has made this observation:

> "The tightness of a specification must be justifiable, and should be in the form of performance requirements rather than component descriptions . . ."
>
> "The modern concept of specification writing in procurement differs completely from the patent-type specification. The invitation bid must state clearly and concisely what is required. It must provide a basis for rejecting bids on items not meeting the needs of the service. It must provide a necessary 'hammer' to enforce performance under the contract, which includes guarantees, service policies, maintenance facilities. Performance requirements, properly stated, will control this more effectively than penalty clauses or component details." (R. G. Wessells, American City, April 1961)

The performance guarantees, demonstrated costs, and system integration contemplated in a burning system seem ideally suited for the future trends. If system analysis is to be advocated as the means by which we are to solve our solid waste disposal problems, then it is logical to infer that the system approach should also be used when contemplating specific pieces of waste reduction equipment. By firmly fixing the responsibility for design and selection of the system with one group, the probability of meeting performance goals is increased. The performance specification, properly evaluated, which involves a system concept offers municipalities a combination of benefits that are not only needed, but should have a high probability of being widely used.

It is recognized that considerable resistance to standardized burning systems can be initially expected from many engineers. Naturally, options among non-proprietary components must be considered in line with objective requirements of optimum technical performance.

Although refuse incineration technology needs further development, it has reached a state where considerable standardization of burning systems is feasible. Standard burning system modules could be developed now without much risk that they would be quickly obsoleted by a basic new advance.

Standardization is compatible with technological progress. A basic burning system could be designed to accommodate future improvements in stokers, air pollution control systems and equipment, instrumentation and control systems, etc.

Standardization is compatible with adaptability. The particular needs and preferences of most communities can be met through options to the basic burning system modules, for example, needs and preferences with respect to total plant capacity, number of furnaces per plant, degree of air pollution control, degree of automation, type of stack (stub or regular), etc.

Standardization is compatible with future improvement of individual plants. Retrofitting or replacement can be a design consideration in both the basic modules and the advances that are achieved in stokers, air pollution control equipment, etc.

Options can be compatible with profitability serving a major share of the market. The number and character of the options should be kept within limits that will prevent dissipation of the technical and economic benefits -- and the competitive advantage and profitability -- afforded by standardization in design, components, and construction.

Buildings can benefit from standardization of basic layout and sub-systems. Compared with a custom-designed building, a standardized building would offer lower first cost, usually lower maintenance costs, and assure convenience and efficiency of layout, facilities, and sub-systems. A reasonable number of options could adapt the building to the individual requirements of most municipalities.

A standardized plant -- built from options to the municipality's individual requirements -- would offer a decisive combination of advantages over a custom-designed plant. There would include guaranteed burning performance, system integration, and operating characteristics at lower net ultimate cost to the community. Standardization makes it possible to guarantee initial price, burning performance and pollution control, and to reliably demonstrate total annual operating and maintenance costs.

Economic and technical advantages of standardized modular plants will make it unnecessary and wasteful to custom-engineer each of the 100 incinerator plants that will be erected in the next five to seven years.

Present attitudes toward the idea of standardized plants, designed and supplied by manufacturers, are largely negative. It is widely believed that this practice in the past -- from the 1920's to the 1950's -- was mainly responsible for holding back the development of incineration technology. Progress in recent years is attributed to the growing capability of city engineers, and consulting architect engineers, and their initiative in taking responsibility for the basic design of individual incinerator plants.

While there are some negative attitudes toward standardized systems, they have persisted largely because no company with the requisite technical capability, financial resources, and stature has undertaken to serve the municipal market's need for standardization combined with technological progress. Some city engineers and consulting firms have an understandable preference for custom-engineered plants.

The introduction of standardized systems, even by a highly regarded company, would encounter some initial resistance and suspicion -- and a "thousand reasons" why it won't work.

Resistance to standardized modular plants can be overcome if a company earns and gains acceptance of the following four propositions:

1. The company's adaptable standardized plants are decisively advantageous to the municipality compared with custom-designed plants.

2. The company is capable of making substantial contributions to incineration technology, and will undertake a program to do so.

3. The company will incorporate proven technological advances in its standardized modules and, where feasible, contract to incorporate improvements in modules that are already in service.

4. The company's development program will seek not only improvements to its existing standard systems, but also fundamental advances that could require basic redesign of those systems.

The market acknowledges that there has been considerable progress in incineration technology. But it expects that there will be more. The market will not "buy" the idea of standardized systems until it is convinced that standardization will be utilized not to impede progress, but to make progress available in the most economical form.

The four propositions above must be demonstrated to be believed by buying influences. Many will simply state they "haven't seen it yet".

In their role as independent, outside experts -- ostensibly free from biasing relationships with municipalities or equipment manufacturers -- consulting and architect engineers perform functions that are almost universally valued by municipal buying influences. High among these functions is the protective one of providing municipal officials with outside rebuttal of actual criticism, or prevention of potential criticism -- from the public or other officials. An equipment manufacturer can seldom perform this protective function, in the face of presumed economic interest. The independent consultant also helps enlist public support and gain required approvals from state agencies.

The consultants protective role, together with the valuable engineering work done by capable consultants, indicates that they are an extremely active and influential force in this market. The most prevailing attitude is that projects like incinerator plants require a great deal of survey work, detailed engineering, evaluation, and coordination. These have to be done by somebody, and it should be done by qualified consultants who can also lend protective and support-enlisting authority to the project.

Consulting and architect-engineers are essential professional allies of both the municipality and the equipment manufacturers. To regard them otherwise is to attack their profession and the judgment of those who value the functions they perform, including their participation in the specification for bids and awarding of contracts.

Some consultants would be opposed, initially, to the idea of standardized plants. But they could be convinced that it is professionally untenable to oppose such plants, once their advantages to municipalities are demonstrated by actual installations and operating results.

Major engineered systems such as incinerator plants are less subject to questionable buying practices than are products like parking meters and sewer pipe.

Modern incinerator plants have many characteristics of electric generating stations, and are increasingly taking on the character of municipally-owned utilities and, potentially, of regulated investor-owned utilities.

Socio-economic factors such as higher standard of living, urban renewal, higher literacy, etc. will focus attention on the incineration process. Federal and state legislation will force sound system practices.

Finally, leadership itself could be a factor increasing the proportion of sound incinerator business. This would come about not as a separate project, but by conducting the business in the mutual best interests of private business and the communities it would be serving.

In summary, certain legal requirements may restrict purchasing practices, however, cognizant committees should advocate modifications and changes in legislation where they are not compatible with the best technical interest of the public.

In the integrated burning system, the responsibility for the performance of the above factors must ultimately rest with one major guarantor.

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