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Waste Automotive Lubricating Oil As A Municipal Incinerator Fuel

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WASTE AUTOMOTIVE LUBRICATING OIL AS A MUNICIPAL INCINERATOR FUEL

By

Steven Chansky
Billy McCoy
Norman Surprenant

Contract No. 68-01-0186
Project 15080 HBO

Project Officer

Richard Keppler
Environmental Protection Agency
John F. Kennedy Federal Building
Boston, Massachusetts 02203

Prepared for

OFFICE OF RESEARCH AND MONITORING
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ABSTRACT

The technical, economic and environmental impact of utilizing waste automotive lubricating oils to improve the municipal incineration combustion process was examined. Utilization of the heating value of waste oil in a municipal incinerator can help to alleviate the high level of combustible air pollutants and poor residue quality resulting from the firing of wet and/or low BTU-value refuse. Laboratory analyses of selected physical properties of waste oil and a waste oil burner testing program were conducted to complement an information search program. The information search consisted of a review of published literature and contacts with waste oil reprocessors and burner manufacturers.

The physical and chemical properties of waste oil were reviewed in relation to its suitability as a fuel oil. The auxiliary fuel heat flux requirements to offset the adverse effects of wet refuse were estimated utilizing a combustion model of a refuse bed. Various methods were evaluated for transferring this required heat flux to the refuse bed. Suggested designs for monitoring and control; and waste oil storage and feed systems were presented.

The impact on air quality from the combustion of waste oil in a municipal incinerator was estimated. Three-month average ground level concentrations for lead were calculated and presented as concentration isopleths.

Capital Investment and Operating costs were developed for auxiliary waste oil systems in conjunction with municipal incinerators.

This report was submitted in fulfillment of Contract No. 68-01-0186 under the sponsorship of the Office of Research and Monitoring, Environmental Protection Agency.

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SECTION I

CONCLUSIONS

1. The physical and combustion properties of automotive waste oils as described in Section IV make such oils extremely suitable as an auxiliary fuel in a municipal incinerator.

2. The estimated theoretical energy requirement for alleviation of the adverse affects of wet refuse (40% moisture) in municipal incinerator is:

   550 - 625 BTU per pound of normal refuse
   (28% moisture, 23% inerts)

3. Mixing waste oil directly into the wet refuse to supply this additional energy requirement has in the past resulted in smoke.

4. Preheating underfire air cannot supply the necessary quantity of additional energy to wet refuse because of the following con - straints:

   - Significant increases in underfire air rates will result in air channeling through the refuse bed and increase particulate emissions.
   - Temperatures in excess of 400°F may cause structural damage to grates and duct systems.
   - Heat transfer rate between appraised underfire air and refuse is limited.

5. Auxiliary burners with the following design and operating criteria are estimated to be capable of providing a significant quantity of the required energy to the refuse bed:

   - Burners should be located above the drying zone and as close to refuse bed surface as possible.
   - High flame temperatures >> 2000°f
   - Highly luminous flame to enhance radiative heat transfer mechanism.

- Long flame lengths so that the entire width of the refuse bed can be covered by two burners (one at each end).

- High burner gas velocities so that hot burner gases can penetrate the bed and enhance convective and radiative heat transfer mechanisms.

- Minimal plugging and maintenance.

- High degree of safety.

6. Based on inputs from burner manufacturers and the results of a 5 day burner testing program, air atomizing burner systems meet the above criteria very effectively.

7. Utilization of automotive waste oil as an auxiliary fuel in a municipal incinerator can significantly reduce air pollution emissions.

   - Combustible gaseous and particulate emissions will be significantly reduced during the firing of wet and/or low BTU value refuse and during cold startups.

   - Waste oil has a sulfur content equivalent to a low sulfur fuel, and will therefore not significantly contribute to SO_2 emissions.

   - Maximum 3-month average ground-level lead concentration from a waste oil auxiliary fuel system in conjunction with a 400 ton per day municipal incinerator are estimated at $0.05 \mu g/m^3$.

8. The capital investment cost for a waste oil auxiliary fuel system in conjunction with a 400 TPD municipal incinerator is estimated at $106,400.

9. The annual operating cost associated with a waste oil auxiliary fuel system in conjunction with a 400 TPD municipal incinerator is estimated at $27,800.

10. The capital investment and annual operating costs associated with waste oil auxiliary fuel systems of various capacities can be estimated from the data presented in Figure 9 of this report.

SECTION II

RECOMMENDATIONS

1. Based on the projected technical and economic feasibility of utilizing waste oil as an auxiliary fuel in conjunction with municipal incineration, we recommend that Phase II of this study be implemented. The following outlines the scope of such a program as currently envisioned:

   - <u>Demonstrate the effectiveness of burning waste automotive crankcase oil in a municipal incinerator</u>.

     The effectiveness of burning waste oil should be evaluated for the alternative designs, locations, and numbers of waste oil burners recommended in the Phase I program. Flexibility in the burner installation is therefore essential to effectively evaluate the alternative burner systems proposed in Phase I.

     The criteria for judging effectiveness will include:

     - Stack emissions levels;
     - Residue quality; and
     - Burner and incineration maintenance problems.

     Based on these criteria, an important aspect of the test program is the monitoring of both stack effluents and organics and putrescibles in the incinerator residue.

   - <u>Quantify the waste oil needed in relation to refuse composition and moisture level.</u>

     In demonstrating the effectiveness of waste oil in alleviating the air pollution and residue quality problems stemming from low BTU and high moisture refuse, the data generated will verify the quantities of waste oil needed. In this manner more accurate estimates of annual incinerator waste oil consumption can be made.

- Demonstration and evaluation of monitoring and control systems for firing waste oil burners.

  The system recommended in Phase I should be demonstrated and evaluated. Again the evaluation criteria will be their effectiveness in minimizing stack emissions and poor residue quality during the firing of "wet" and low BTU value refuse.

- Demonstration and evaluation of the waste oil storage and feed system recommended in the Phase I study.

  Based on the performance of the storage, pretreatment and feed systems utilized in the demonstration phase, modifications in the design should be made where necessary and evaluated in order to optimize the design for future installations.

- Verification of economic studies

  Data on the investment and operating costs associated with the demonstration of this concept should be collected and correlated to verify and update past economic estimates. Included in this program should be the generation of cost data associated with the collection and delivery of waste oil to the incinerator site by waste oil collectors.

2. In addition to the application of waste oil in conjunction with municipal incineration, we recommend that other fuel oil applications for waste oils be investigated. These investigations should include the influence of various levels and types of waste oil pretreatment on such considerations as:

   - The physical and combustion properties of waste oil

- Markets for waste oil and associated demand
- Waste oil selling price and cost of goods sold
- Impact of waste oil impurities on the environment and on combustion and associated equipment.

SECTION III

INTRODUCTION

This report addresses two problems of increasing concern to many municipalities throughout the country:

- the recovery of growing quantities of waste automotive lubricating oils economically and without contributing to environmental insult;
- the significant levels of air contaminants and organic and putrescible residue materials generated from municipal incinerators as a result of poor combustion.

GCA Technology Division has investigated the feasibility of alleviating these two problems by utilizing the available waste oil in a community to reduce the variability of the refuse heat release rate in a municipal incinerator which is a primary reason for poor combustion. The utilization of virgin fuel oil in a municipal incinerator is not a new concept. Auxiliary fuel has been used in the past to start up and stabilize ignition as well as with afterburners to achieve more complete burnout of combustible emissions. In this study, however, the feasibility of recovering the heating value of spent automotive waste oil to improve combustion in a municipal incinerator is examined.

Background

The Waste Oil Problem

It is currently estimated that as much as 500 million gallons of waste automotive lubricating oils are generated annually in the United States. In this report, waste oil is defined as:

- Automotive and other vehicular waste crankcase oils from service stations, garages, car dealers, fleet operators, agricultural and marine applications and individuals changing their own oil.

Although a portion of this oil is currently being collected, profit incentives appear marginal at best. Reprocessing of this oil back to a lube oil, once the primary use for the collected oils, is becoming less competitive and economically viable due to such factors as:[43]

- more rigid specifications for oils used during longer drain intervals,

- increased complexity of reprocessing newer oils with higher additive content,
- disadvantageous tax situations in many localities as compared with virgin oils,
- labeling requirements to indicate that the oil was "previously used".

As a result of such factors, total capacity of reprocessing plants in the United States has declined by an estimated 50 percent during the past 7 years. In 1970 capacity was at about 100,000,000 - 125,000,000 gallons per year.(1)

With waste oil reprocessing to a lube oil on the decline in the U.S., and the demand for other uses such as a road oil and for agricultural purposes also on the decline, many concerned organizations are considering its potential as a fuel oil. Preprocessing to a fuel oil, however, also is faced with economic constraints. To illustrate, GCA estimates that current costs of collection, distribution and reprocessing to a No. 4 heating fuel are approximately 10 cents/gallon (3.0 cents collection, 4.0 cents treatment, and 3.0 cents distribution). In comparison, low sulfur No. 4 virgin fuel oil is currently selling for about 12 cents/gallon to apartment houses and commercial establishments in New England. No. 5 fuel oil is selling for about half that price. Consequently, significant financial incentives to use waste oil as a fuel oil are limited if not nonexistent in some areas.

In addition costs for reprocessing to a fuel oil are expected to increase due to new additives. Insufficient separation of these suspended impurities results in ash deposits on boiler tubes during combustion. The increased maintenance costs, relative to virgin oils, in removing such makes as the economics of reprocessing to a fuel oil even more marginal.

It seems clear, then, that unless new approaches and incentives are developed, waste oil generation may become an increasingly serious problem to our environment.

<u>The Incineration Problem</u>

Unlike the burning of relatively homogeneous fuels such as natural gas, oil and coal, variability in the chemical and physical properties of refuse can cause significant fluctuations in the rate of heat released during the combustion process. This variation poses a serious problem to the designer of municipal incinerators as the heat release rate is a primary design parameter. The design engineer, out of necessity usually sizes his induced draft, overfire and underfire air fans based on an "average heat release rate". Variations from this average value, however, often result in poor incinerator performance as characterized by such symptoms as:

- fluctuating temperatures in the primary chamber resulting in increased refractory maintenance costs
- increased concentrations of combustible gaseous and particulate stack emissions
- increased organics and putrescibles in the residue.

The use of auxiliary fuel in a municipal incinerator is of primary benefit when the actual heating value of refuse drops below the incinerator "design" value such as during the firing of refuse with an abnormally high moisture content. Wet refuse constitutes a significant and widespread problem to incinerator operators, particularly during start-up of a cold furnace. Grass clippings and yard trimmings are especially difficult to handle even when no heavy rain has occurred. In the fall, wet leaves can become almost unmanageable and have been known to extinguish an operating furnace. The difficulty appears to result primarily from low furnace temperatures, and if the furnace temperature can be maintained at a sufficient level, approximately 1400^oF or higher, adequate burnout of wet refuse can be achieved.

When faced with wet or low-BTU value refuse, common incinerator practice is to adjust the percent excess air, overfire to underfire air ratio, and/or grate speed. Unfortunately, altering these variables may often compound existing problems. A reduction in grate speed inherently limits incinerator capacity. Increasing the quantity of underfire air to dry wet refuse also may lower the flame temperature of the bed and increase particulate stack emissions. A reduction in the percent excess (overfire) air may well raise the temperature of the gases in the primary combustion chamber but will decrease the turbulence and mixing characteristics of the flue gases. The study examines the feasibility of alleviating these operating and environmental problems by proper utilization of the heating value of automotive waste oil.

Purpose and Scope

The purpose of this study is to examine the technical and economic feasibility, including impact on air quality, of utilizing waste automotive lubricating oils to improve the municipal incineration combustion process. The ultimate goal is to demonstrate the viability of this concept at a municipal incineration site. This study, however, lays the groundwork for such a demonstration program by supplying the following necessary information:

- The physical and chemical properties of waste oil in relation to its suitability as a fuel oil.
- The estimation of the necessary quantities of waste oil needed in relation to the amount of refuse fired.
- Evaluation of alternative techniques for injection of the waste oil into the incinerator.
- Evaluation of monitoring and control techniques.
- Evaluation of Alternative Waste Oil Storage and Feed Systems.
- The impact of Firing Waste Oil on Air Quality.
- The economic feasibility including capital and operating costs for the proposed system.

The conclusions of this program in conjunction with the recommendations made, will serve as major inputs for specifying the design as well as the testing and evaluation phases of a demonstration system at a municipal incinerator.

SECTION IV

TECHNICAL EVALUATION OF THE PHYSICAL AND COMBUSTION PROPERTIES OF WASTE AUTOMOTIVE LUBRICATING OIL

A detailed information search augmented by a laboratory analytical program was performed to determine the physical and combustion properties of waste oil. Each phase of the information search will be summarized below together with a discussion of the resulting data. A discussion of the chemical properties (inpurities) of waste oil is found later in this section under Impact on Air Quality.

Information Search

Literature Review

An extensive literature review was performed and the list of references obtained and examined are included in the Reference Section (Section XII) of this report. Table 1 summarizes the data obtained from this literature review. Examination of Table 1 indicates that two references supplied most of the published data and these were:

Ref. 1 - Final Report of the API Task Force on Used Oil Disposal, May, 1970.

Ref. 2 - Final Progress Report on Water Pollution Control Demonstration Grant No. WPD-174-01-67 to WPCA by Villanova University, 1968.

Questionnaire Program

The information search also included sending questionnaires to all the known rerefiners of automotive waste lubricating oils in the United States.

Table 2 lists these rerefiners and Appendix A presents a copy of the mailed letter and accompanying questionnaire. Of the 50 questionnaires mailed, 7 were returned for a rather poor response of 14 percent. Of these, 6 contained useful data and the pertinent information on physical and combustion properties from these questionnaires is also summarized in Table 1.

TABLE 1

PHYSICAL AND COMBUSTION PROPERTIES OF WASTE LUBRICATING OILS

Data Source	API Gravity (60°F)	Viscosity-SUS 100°F	Viscosity-SUS 210°F	Flash Point °F	Pour Point (°F)	Heat of Comb. (Btu/#)	Water (Vol %)	Water & Sed. (Vol %)	Ash (Wt.%)	Solids (Wt. %)
Ref. 1	24.6	248	56.4	215 COC*	-	19,000**	4.4	0.6***	--	--
Ref. 1	26.0	268	--	350-400	-	19,132	--	--	--	--
Ref. 1	27.3	148.3	60.1	175	-	19,200**	2.8	3.8	--	--
Ref. 1	25.6	197.1	--	185+	-	19,100**	10.0	14.0	--	--
Ref. 1	24.8	262.6	--	190	-	19,100**	8.2	12.0	--	--
Ref. 1	27.5	137.4	47.2	170	-	19,200**	5.0	8.0	--	--
Ref. 1	25.0	256	--	218	-	19,100**	--	--	1.61	--
Ref. 1	27.9	161	--	265	-	19,200**	--	2.4	1.10	--
Ref. 2	--	--	--	--	-	--	.06	--	--	5.64
Ref. 2	--	--	--	--	-	--	.60	--	--	1.55
Ref. 2	--	--	--	--	-	--	2.2	--	--	7.03
Ref. 2	--	--	--	--	-	--	nil	--	--	6.40
Ref. 2	--	--	--	--	-	--	11.0	--	--	3.30
Ref. 12	--	--	51.0	--	-	--	--	--	--	--
Ref. 12	--	--	49.1	--	-	--	--	--	--	--
GCA Analyses: Sample No.										
1	24.7	--	--	--	-35	--	5.9	1.8***	--	--
2	23.9	--	--	--	-35	--	0.30	1.6	--	--
3	23.1	--	--	--	-35	--	0.10	5.2	--	--
4	26.1	--	--	--	-40	--	0.08	1.7	--	--
5	24.2	--	--	--	below -40	--	0.09	1.8	--	--
6	22.0	--	--	--	-30	--	4.8	7.2	--	--
7	23.6	--	--	--	-30	--	0.17	3.2	--	--
8	30.8	--	--	--	below -40	--	0.15	0.15***	--	--
9	25.4	--	--	--	--	--	10.0	5.2***	--	--
Quest.1	27.2	130	--	170	--	19,200**	4.0	7.1	--	--
Quest.3	28.5	210	--	200 COC*	--	19,300**	5-10	5-15	.025	--
Quest.5	29-30	--	50-33	180-230	--	19,300**	4.0	6	.75	--
Quest.6	24.8	--	58.0	330 COC*	--	19,100**	4.0	18.0	2.16	--
	22.0-30.8	130-268	33-60.1	170-400	≤ -30	19,000-19,300	0-11%	0.6-18%	0.025-2.16	1.55-7.03

*Cleveland Open Cup: others are Pensky-Martens Closed Cup.

**Estimate utilizing standard procedures for hydrocarbon fuels.

***Poor separation observed.

TABLE 2

LIST OF COMMERCIAL RE-REFINERS IN THE UNITED STATES[1]

ARIZONA

Gerdon Jackson
1019 West Prince Road
Tucson, Arizona 85704

Aldous V. Steen
Kaibab Industries, Inc.
2600 South 20th Avenue
Phoenix, Arizona 85009

ARKANSAS

Henley Oil Company
Norfleet, Ark.

CALIFORNIA

A. Ray Banks
Palmer Odegard
Bayside Oil Corp.
977 Bransten Road
San Carlos, Cal. 94070

George Leach
Leach Oil Co. Inc.
625 E. Compton Blvd.
Compton, Cal. 90220

H. B. Millard
Motor Guard Lubricants Co.
4334 E. Washington Blvd.
Los Angeles, Cal. 90023

Charles R. Nelson
Pacific Petroleum Co.
Michael D. Marcus
Economy Refining & Service Co.
7929 San Leandro St.
Oakland, Cal. 94621

A. W. & Roy Talley
Talley Bros. Inc.
2007 Laura Ave.
Huntington Pk., Cal. 90255

Otis F. Humphrey
Nelco Oil Refining Co.
1211 McKinley Ave.
National City, Cal. 92050

COLORADO

Lloyd Cunningham
Williams Refining Co.
5901 N. Federal
Denver, Colorado 80221

FLORIDA

George Davis
Davis Oil Company
Box 1303
Tallhassee, Fla. 32302

Sol Blase
Petroleum Products Co.
Box 336
Hallendale, Fla.

John Schroter
Peak Oil Company
Rt. 3, Box 24
Tampa, Fla. 33619

GEORGIA

Jack & Bernard Blase
Seaboard Chemical Co., Inc.
Box 333
Doraville, Ga. 30040

ILLINOIS

R. E. Poindexter
Motor Oils Refining Co.
7601 W. 47th Street
Lyons, Illinois 60534

TABLE 2 (Cont.)

Jim L. Pierce
Sorco Oil & Refining Co.
Div. of Westville Oil & Mfg. Inc.
1925 E. Madison
Springfield, Illinois 62702

INDIANA

Charles Bates
Bates Oil & Refining Co.
Box 267
Chandler, Ind. 47610

Andrew Carson
Westville Oil & Mfg., Inc.
Box 104
Westville, Ind. 46391

John W. Swain Jr.
Alvord Oil Company
1509 S. Senate Ave.
Indianapolis, Ind. 46225

IOWA

Norman R. Schlott
U. S. Oil Works
116 - 29th Avenue
Council Bluffs, Iowa
Mail: 727 So. 13 St.
Omaha, Nebr. 68102

KANSAS

Robert O'Blasny
Coral Refining Company
765 Pawnee Avenue
Kansas City, Kansas 66105

M. C. McDonald
McDonald Oil Company
1603 S. Walnut
Coffeyville, Kansas

Ava Johns
Super-Refined Oil Co.
915 East 21st St.
Wichita, Kansas 67214

MICHIGAN

Jack W. Epstein
Dearborn Refining Co.
3901 Wyoming Avenue
Dearborn, Michigan 48120

MINNESOTA

C. H. Romness
Gopher State Oil Co.
2500 Delaware SE
Minneapolis, Minn. 55414

A. L. Warden
Warden Oil Company
187 Humboldt Ave. N.
Minneapolis, Minn. 55405

MISSISSIPPI

H. K. Robertson
Jackson Oil Products Co.
Box 5686
Jackson, Miss. 39208

MISSOURI

F. A. Gettinger
Glen Gettinger
Midwest Oil Refining Co.
1900 Walton Road
St. Louis, Mo. 63114

NEBRASKA

Marvin Walenz
Monarch Oil Co.
Box 1257
E. Omaha, Nebr.

NEW JERSEY

C. Kenneth Johnes
Mohawk Refining Corp.
472 Frelinghuysen Avenue
Newark, N. J. 07114

Martin Morrison
Diamond Head Oil Refining Co.
1427 Harrison Tpke.
Kearney, N. J.

TABLE 2 (Cont.)

Solfred Maizus
National Oil Recovery Corporation
Box 338
Bayonne, N. J.

NEW YORK

Geo. T. Booth & Son Inc.
76 Robinson St.
No. Tonawanda, N. Y. 14120

R. W. Mahler
327 Edwards Drive
Fayetteville, New York

William Krause
Triplex Oil Co.
37-80 Review Avenue
Long Island City, N. Y. 11101

NORTH CAROLINA

Jerry Blair
South Oil Company
Box 106
Greensboro, N. C. 27402

OHIO

Jac Fallenberg
Alan Gressel
Research Oil Refining Co.
3680 Valley Road
Cleveland 9, Ohio

S. R. Passell
Keenan Oil Company
No. 1 Parkway Drive
Cincinnati, Ohio 45212

OKLAHOMA

Frank A. Kerran
Cameron L. Kerran
Double Eagle Refining Co.
Box 11257
Oklahoma City, Okla. 73111

Edward Kitchen
Kitchen Oil Co.
Stroud, Okla.

OREGON

A. L. Geary
Nu-Way Oil Company
7039 NE 46th Avenue
Portland, Oregon 97218

T. M. Davis
Harold W. Ager, Jr.
Ager & Davis Refining Co.
9901 NE 33rd St.
Portland, Oregon

PENNSYLVANIA

R. H. Schurr
Berks Associates, Inc.
Box 617
Pottstown, Pa. 19464

TENNESSEE

William M. Gurley
Gurley Oil Company
Box 2326
Memphis, Tenn. 38102

TEXAS

R. A. Swasey
S & R Oil Company
Box 35516
Houston, Texas 77035

UTAH

J. R. Mastelotto
Also Refining Co.
133 No. First West
Salt Lake City, Utah 84113

VIRGINIA

V. T. Worthington
A C Oil Company, Inc.
1500 North Quincy St.
Arlington, Virginia
(Also D. C. & Maryland)

WASHINGTON

Virginia & Gunnar Forsmo
Superior Refineries, Inc.
Box 68
Woodinville, Wash. 98072

Time Oil Company
Tacoma, Washington

WISCONSIN

M. A. Warden
Warden Refining Co.
1910 S. 73rd
W. Allis, Wisconsin 53214

Laboratory Studies

During the information search, it became evident that more waste oil physical data were needed in some areas. Consequently, the following tests were performed at GCA's laboratories:

- Pour Point by ASTM D-97
- Water Content by ASTM D-95
- API Gravity by ASTM D-287
- Water and Sediment by ASTM D-1796
- Viscosities using a Brookfield viscometer

Saybolt viscosity tests were also planned using ASTM-88, but problems in equipment delivery prevented the tests from being performed.

Waste Oil Samples

Samples of waste automotive oil were collected from nine sources including two large waste oil collection companies, several service stations and an individual automobile. The origin of each sample is shown in Table 3. Samples 1 and 9 are believed to be excellent composite samples because they were taken from large filled tanks of about 100,000 gallons at the collection companies.

Analytical Results

The test data are included in Table 1, and brief summaries of these results follow:

Water content - Because all but one of the samples from individual service stations and automobiles showed only trace amounts of water, it appears that the high water content generally found in waste oil from collectors may result from handling after the oil leaves the service stations. The presence of water influences combustion efficiency and proper selection of burners is essential for successful combustion of oil containing high percentages of water.

Pour point - This test defines the lowest temperature at which an oil can be stored and still be capable of flowing under low forces. In conjunction with viscosity data, pour point data enables one to make a judgment as to the need for heating waste oil prior to handling and/or the need for preheating of the oil before firing. The measured pour points were very low in all cases, the highest value being -30°F. In comparison, No. 4 fuel oil, which does not normally require either heated storage or preheating, has an ASTM maximum pour point specification of 20°F.

TABLE 3

ORIGINS OF WASTE OIL SAMPLES

Sample No.	Source
1	Pierce Bros. Oil Co., Waltham, Ma.
2	Bedford Amoco Sta., Bedford, Ma.
3	Burlington Sunoco Sta., Burlington, Ma.
4	Rte. 62 Mobil Sta., Burlington, Ma.
5	Rte. 62 Texaco Sta., Burlington, Ma.
6	Burlington Shell Serv., Burlington, Ma.
7	Parson's Shell Sta., Bedford, Ma.
8	Crankcase of High Specific Output Foreign Automobile (Alfa-Romeo)
9	State Oil Service, Norwalk, Conn.

API gravity (60°F) - The gravity determinations agreed well with the literature values reported in Table 1 with the exception of sample No.8. The latter sample was known to be a light lubricating oil diluted with gasoline by cold weather operation.

Sediment and Water - Fair-to-good separation of the sediment and water from the oil was observed for all samples except numbers 1, 8 and 9. In samples 1 and 9 the water formed an emulsion, while sample 8 had very little water, making separation more difficult.

Viscosity

A Brookfield viscometer was utilized to determine the effect of temperature on the viscosity of waste oil and the resulting data are presented in Table 4. Figure 1 is a plot of this data which compares the viscosity of waste oil to No.'s 4 and 5 fuel oils.

Discussion of Physical and Combustion Properties of Waste

Physical Properties

From the data presented in Table 1, it appears that the API Gravity of waste oil is relatively constant compared to the variability in the other parameters. The API gravity is important to this program as it will influence the design of the storage and feed system. In addition, when used in conjunction with other properties, it is of value in determining weight-volume relationships and in estimating the heating value of oil.

The requirement for preheating the waste oil will be influenced primarily by its viscosity and pour point. The pour point is a primary indication of the lowest temperature at which it can be stored and still be capable of flowing under very low forces. The viscosity also is an indication of the relative ease of flow but in addition, indicates the ease of atomization. Therefore, viscosity will also be a significant burner nozzle design parameter. The data collected thus far as shown in Figure 1, indicates that the viscosity of waste oil is similar to that of a light No.5 fuel oil. Consequently, preheating may be required depending on climate and the type of burner and feed equipment utilized.

Although the viscosity of waste oil may correspond most closely with a light No. 5 heating oil, itspour point may be more representative of a lighter heating oil. For example, the pour point of No.'s 2 and 4 heating oil (requiring no pre-heating) is about 19° F (7°C). The data in Table 1 shows pour points $<30^{o}$F.

The flash point of a fuel oil is an indication of the maximum temperature at which it can be stored and handled without serious fire hazard. The range reported in Table 1 is 170-400°F, whereas the ASTM specification shows 130°F (55°C) as the minimum allowable value for No.'s 4 and 5 fuel oils. Consequently the flash point of waste oils fall well above the minimum specified ASTM values.

TABLE 4

VISCOSITY OF WASTE OIL AT VARIOUS TEMPERATURES

Temperature °F	Viscosity CP	Viscosity SSU*
30°F	420	2150
	730	3750
	810	4200
	570	2900
	680	3500
	450	2300
	620	3200
40°F	175	900
	360	1845
	470	2400
	350	1800
	445	2300
	380	1950
	435	2200
73°F	95	490
	145	735
	175	900
	120	620
	155	800
	130	660
	140	720

*Calculated from viscosity measurements in CP (SSU = CP x $4.62/\rho$; where $\rho = 0.9$ gm/cs).

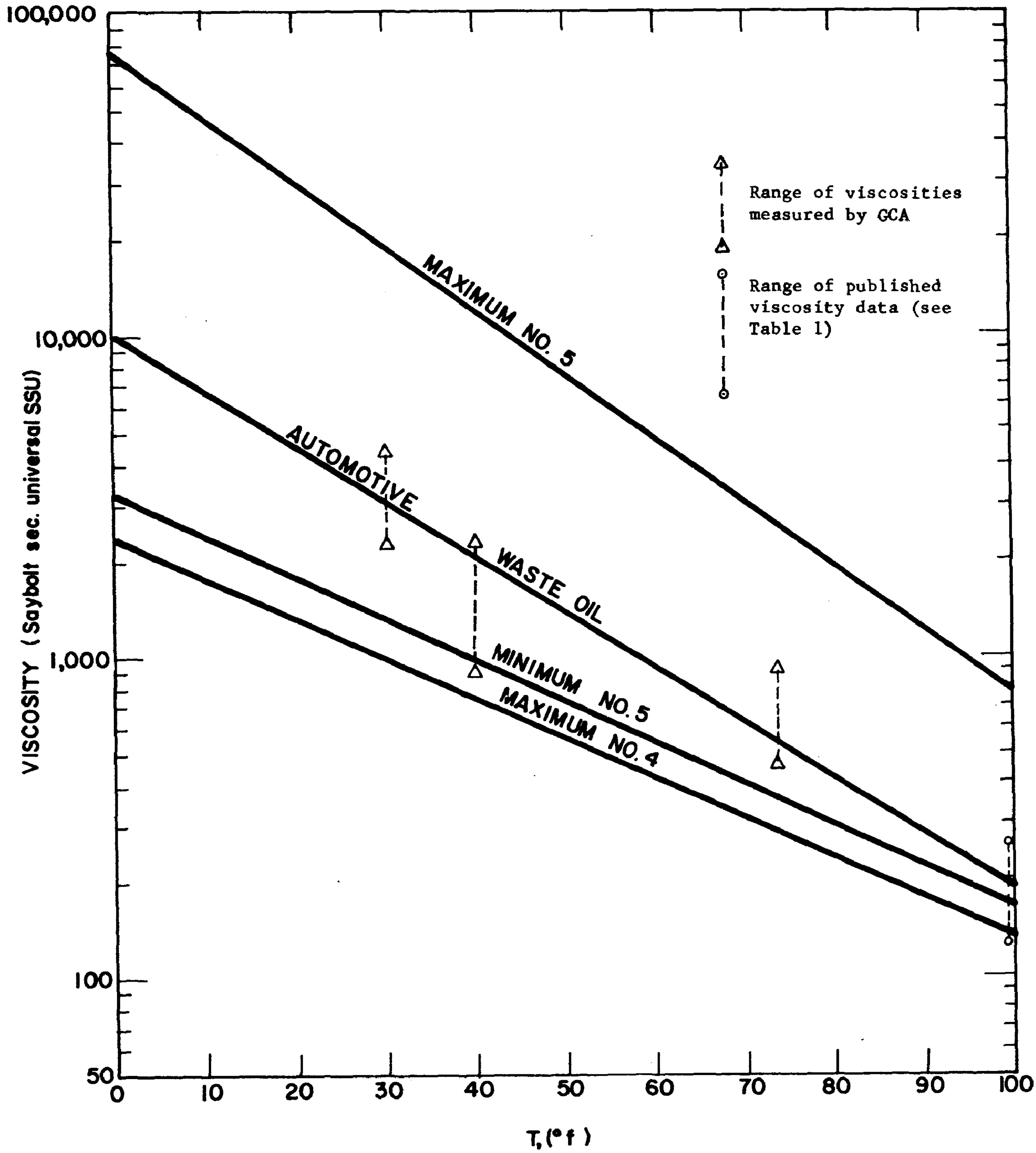

Figure 1. Viscosity of Automotive Waste Oil and Virgin Fuel Oils vs. Temperature.

The quantity of ash is indicative of the level of noncombustible material in a fuel oil. Table 1 shows a range of from 0.025% to 2.16% ash in waste oil whereas the ASTM specifications for No.'s 4 and 5 fuel oil is 0.1%. Excessively high ash contents may suggest the presence of materials which cause high wear on burner pumps and valves and plugging of burner nozzles. These considerations, therefore, should be accounted for in the design of the burner and feed systems.

The presence of water and sediment in a fuel oil can cause fouling of burner nozzles and feed systems if not properly designed. In addition, materials of construction for storage and handling equipment should be selected to alleviate corrosion from the water present. The ranges of water and sediment (by volume) shown in Table 1 are 0.6 - 18%.

Heating Value of Waste Oil

The heating value or heat of combustion of waste oil is of importance because it directly affects the amount of oil required to evaporate the excess moisture from wet refuse. However, in spite of the importance of this variable, only one value for the heat of combustion was obtained from the literature. This value, 19,132 BTU per lb (about 143,300 BTU per gal.) was obtained from the API Study (Ref. 1).

Fortunately, standard methods are available for deriving reasonable estimates of the heating value of liquid hydrocarbon fuels from the API gravity. (For a more detailed description of the method, see such standard references as Hougen, O. A., et al., Chemical Process Principles and Mobil's Technical Bulletin, fuel oil Properties Determined from Inspection Tests). This technique was utilized to obtain most of the heat of combustion data tabulated in Table 1. These data indicate that waste oil has a heating value equivalent to that of a conventional No. 2 fuel oil.

SECTION V

HEATING REQUIREMENTS OF WASTE OIL

Discussion of Phenomena Occurring in a Refuse Bed

When the heating value of municipal refuse drops below the incinerator's "design" value, several combustion phenomena occur within the refuse bed which result in poor residue quality and an increase in combustible pollutant emissions into the atmosphere. Although these phenomena are difficult to describe quantitatively, a recently developed combustion model of a refuse bed(29) was utilized for the purposes of this study. Figure 2 presents a schematic diagram describing the various zones in a municipal incineration refuse bed as defined by this model. Although this is certainly a simplified view, it highlights the major zones and their interrelationships.

The raw refuse is first dried in the drying zone after which it ignites and burns either with excess oxygen present (region of active burning) or under reducing conditions (pyrolysis). The angle of the plane separating the drying zone and region of active burning is very much influenced by the extent of moisture in the refuse bed as seen schematically in Figure 3. With increasing quantities of moisture present in refuse, the drying zone becomes larger, essentially because it takes more time to dry the refuse. This shifts the ignition plane to the right, delaying refuse ignition. The additional energy now required to vaporize and heat this increased quantity of moisture results in lower temperature both within and above the refuse bed. Lower temperatures above the bed also serve to lower the drying rate, resulting in an expansion of the drying zone. In addition, the increased moisture and lower temperatures will have a pronounced effect on the kinetics and equilibria of the reactions in the bed. The end results associated with these phenomena are a higher percent of both unburned refuse in the residue and increased gaseous and particulate combustible emissions being generated.

Utilization of Mathematical Model to Calculate Heat Flux Needed to Dry Wet Refuse (40 Percent Moisture)

Although the term "wet refuse" covers a wide variety of moisture contents, we will consider for this discussion wet refuse as refuse with a moisture content of 40 percent (0.2 lb of additional moisture per lb of normal refuse containing 28% moisture). We will be representing the organic component of refuse as: cellulose, $\left[C_6(H_2O)_5\right]_n$. Therefore, the organic content plus any moisture present can be expressed as:

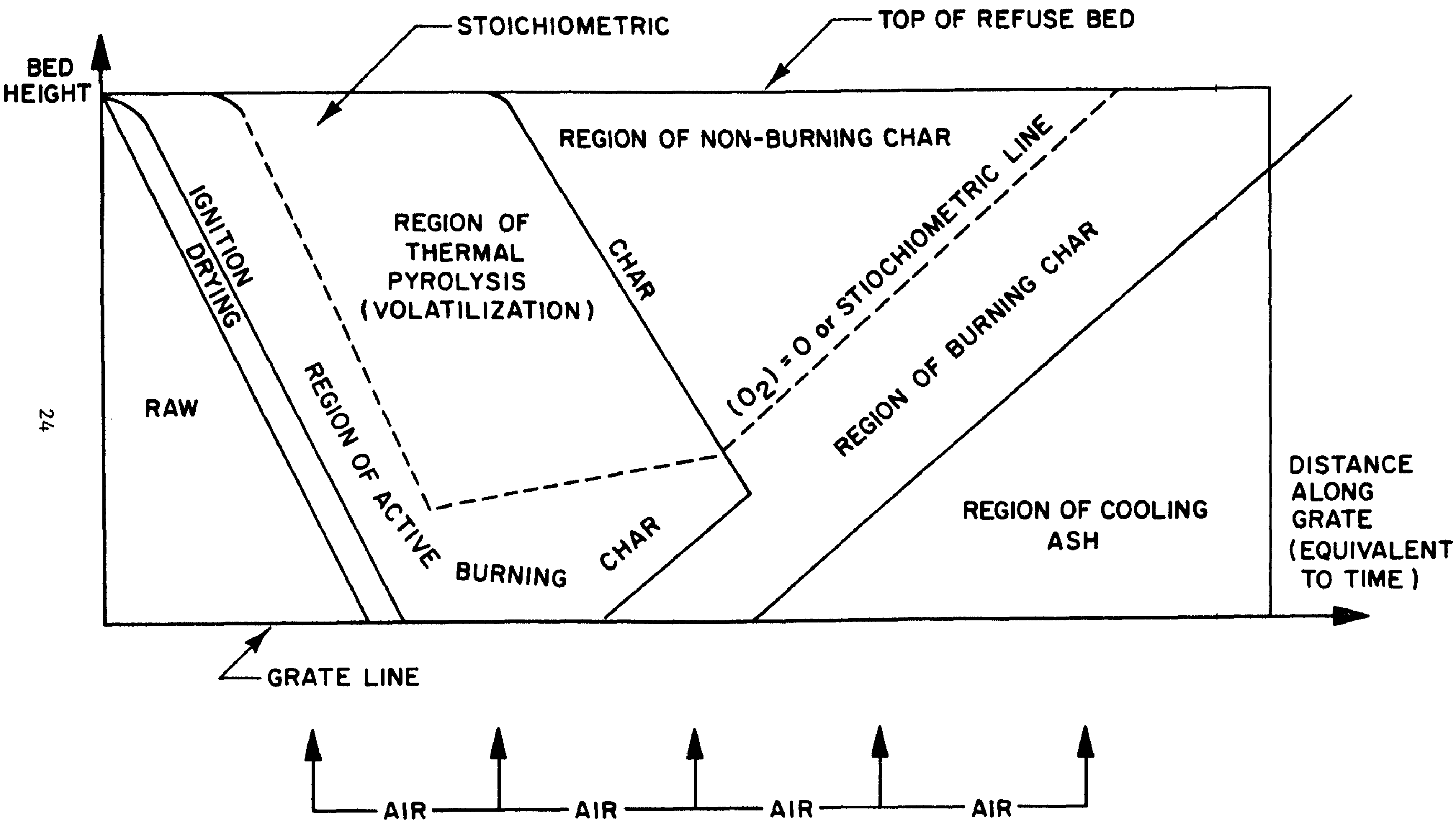

Figure 2.[29] Schematic of Cross-Feed Bed Burning Process (Assuming Combustion Process Raw→Dry→Volatilize→Char→Ash).

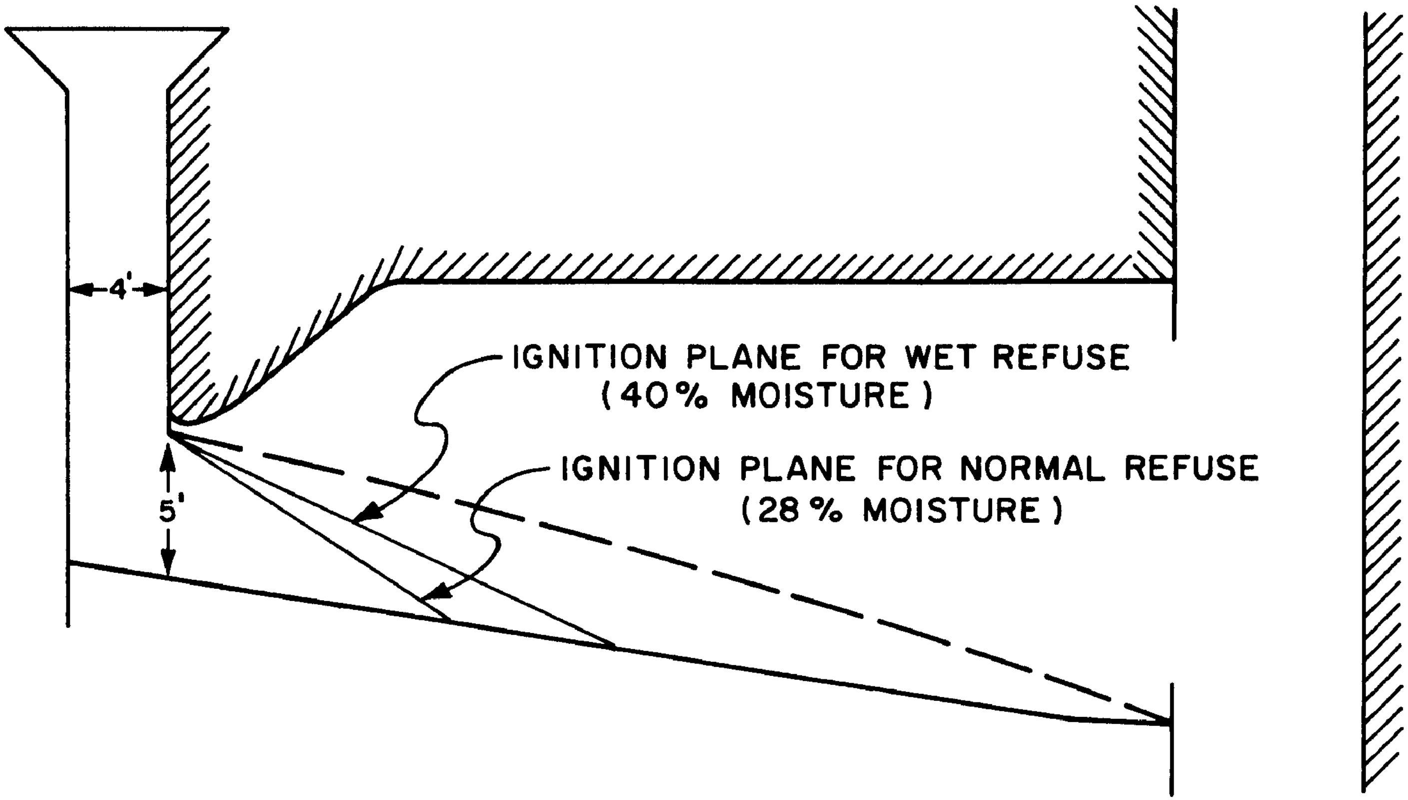

Figure 3. Schematic of a Municipal Incinerator Showing Ignition Plane when Firing Wet Refuse and Normal Refuse.

$$C(H_2O)_n = C(H_2O)_{\frac{5}{6}} + H_2O_{(n-\frac{5}{6})}$$

dry organic — moisture

Typical municipal refuse has an inert content ranging from 20-25%. For this model we are assuming an inert content of 23%. Based on these assumptions, the "n" values for dry refuse (0% moisture), 28% (normal refuse) moisture and 40% (wet refuse) moisture are presented below.

Percent Moisture	Calculation	"n" value
0	$0 = \frac{18n-15}{12+18n} \times 0.77$	5/6
28	$0.28 = \frac{18n-15}{12+18n} \times 0.77$	1.69
40	$0.40 = \frac{18n-15}{12+18n} \times 0.77$	2.46

The mathematical model we have utilized[29] is based on the following equations:

Generalized equation for refuse combustion:

$$O_2 + jC(H_2O)_n + 3.76N_2 \rightarrow aCO + pCO_2 + iH_2 + dH_2O + eC + 3.76N_2 \qquad (1)$$

Water gas shift reaction:

$$H_2O + CO \rightarrow CO_2 + H_2 \qquad (2)$$

Energy Balance around refuse bed:

$$Q_R = Q_P + Q_L \qquad (3)$$

Q_R = The quantity of energy release within refuse bed

Q_P = The quantity of energy convected out of refuse bed by gasification products

Q_L = Heat loss out of refuse bed

Energy Released above the refuse bed:

$$Q_E = \left[H_{r_{CO \rightarrow CO_2}} \right] x \ a + \left[H_{r_{H_2 \rightarrow H_2O}} \right] x \ i \quad (4)$$

From equation (1), material balances can be generated for carbon, hydrogen and oxygen as presented below:

Carbon balance:

$$a + p + e = j \quad (5)$$

Hydrogen balance:

$$i + d = nj \quad (6)$$

Oxygen balance:

$$p + \frac{(a+d)}{2} = 1 + \frac{nj}{2} \quad (7)$$

Data from the Oceanside Incinerator recently generated by Elmer Kaiser[29] indicate that the water gas shift reaction is in equilibrium directly above the refuse bed at a temperature of 2000°F. Consequently, the equilibrium equation for the water gas shift reaction can be used.

$$pi/da = k_{eq} \quad (8)$$

This model represented by the above equations was used by GCA to estimate the auxiliary energy Qg(g=gain) needed to "counteract" the "adverse effects" of the 12% excess moisture (40% - 28% = 12% excess moisture) in the refuse. One of the most pronounced adverse affects that the model clearly shows is the decrease in the amount of energy released above the refuse bed, Q_E, with increasing levels of moisture in refuse. This energy level is calculated using equation (4) presented above and is a result of the exothermic combustion reactions of hydrogen and carbon monoxide above the refuse bed. GCA after examining the assumptions and limitations of the model, chose to use this parameter, Q_E, as the primary criteria for estimating the energy gain Qg needed to compensate for the adverse affects of wet refuse. We can therefore restate the criteria as follows:

> The quantity of waste oil required to compensate for the adverse effects of wet refuse is estimated as that quantity which provides the auxiliary heat input, Qg, needed to obtain the same level of energy released above the refuse bed (Q_E) while firing 40% refuse as is achieved without auxiliary heat while burning normal refuse (containing 28% moisture).

A detailed presentation of the assumptions and limitations of this mathematical model is presented in a report by Arthur D. Little, Inc. to EPA's Office of Air Programs, dated February 1972, entitled <u>Incinerator Overfire Mixing Study</u> - Contract No. EHSD 71-6.[29] The reader is referred to this reference for further information related to this model.

Results of Application of Mathematical Model

Table 5 presents the results of the mathematical model presented above used to calculate the theoretical heat flux needed to dry wet refuse. As seen from this table, six cases were examined. In the first two, a moisture content of 28%, the average moisture content of "normal" refuse, was assumed. Cases 3 and 4 represent wet refuse (40% moisture) with no auxiliary fuel being fired. Two values, 0.5 and 1.0, were chosen for the fraction of carbon gasified. The lower value is representative of an intermediate underfire air flow rate which results in a char residue (e moles of C - see equation 1). At higher flow rates, essentially all the carbon is gasified and the char residue is eliminated. The bed was assumed to be adiabatic so heat losses were considered to be zero. A flue gas temperature directly above the bed of 2000°F was assumed based on Kaiser's work at Oceanside.[29] The corresponding equilibrium constant for the water-gas shift reaction is 0.4 at 2000°F.[44]

Comparison of case 1 with case 3 and case 2 with case 4 in Table 5 shows the effects of increased moistures in refuse. Note that while the moles of CO_2 remain relatively constant, the moles of CO and H_2. significantly decrease with increasing moisture content of refuse. Also it is interesting to note that while the energy released from the bed via convection, Q_P, remains relatively constant,* the energy released above the bed, Q_E, decreases sharply as a result of the increased refuse moisture content.

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*This model assumes a refuse bed temperature of 2000°F. In actuality the temperature within and above the refuse bed will be affected by refuse moisture content. This in turn, will affect the quantity of sensible heat transferred from the bed via convection.

TABLE 5

RESULTS OF MATHEMATICAL MODEL USED TO CALCULATE THE THEORETICAL HEAT FLUX Qg NEEDED TO DRY WET REFUSE CONTAINING 40% MOISTURE

	Case No.					
	1	2	3	4	5	6
Assumed Conditions (Basis: 1 mole of O_2)						
n	1.69 (28% mois.)	1.69	2.46 (40% mois.)	2.46	2.46	2.46
Fraction of Carbon gasified (1-e/j)	0.5	1.0	0.5	1.0	0.5	1.0
Heat loss, Q_L (BTU)	0	0	0	0	0	0
Temp. of gases above refuse bed (^oF)	2000	2000	2000	2000	2000	2000
Equil. constant for water gas shift reaction (keq)	0.4	0.4	0.4	0.4	0.4	0.4
Energy released above refuse bed, Q_E (BTU)	-	-	-	-	99,712	169,776
Calculated Values (Bases: 1 mole of O_2)						
a - moles CO	0.349	0.779	~ 0	0.271	0.279	0.667
p - moles CO_2	1.100	0.970	0.970	1.017	1.175	1.091
i - moles H_2	0.549	0.719	~ 0	0.305	0.629	0.849
d - moles H_2O	4.349	2.237	4.830	2.863	6.525	3.476
j - moles refuse $C(H_2O)_n$	2.898	1.749	1.940	1.288	2.908	1.758
Gas Composition						
% CO	3.4	9.2	~ 0	3.3	2.3	6.8
% CO_2	10.9	11.5	10.1	12.4	9.5	11.1
% H_2	5.4	8.5	~ 0	3.7	5.1	8.6
% H_2O	43.1	26.4	50.6	34.8	52.7	35.3
% N_2	37.2	44.4	39.3	45.8	30.4	38.2
Energy released above refuse bed, Q_E (BTU)	99,712	169,776	~ 0	64,782	-	-
Q_P = energy released from bed via convection	242,150	184,622	247,718	196,116	332,678	239,883
Required heat gain, Qg(BTU) ($Q_g = -Q_L$)	-	-	-	-	99,564	53,395

Based on the results obtained from cases 1 through 4, the energy levels released above the refuse bed, Q_E, in cases 5 and 6 were fixed to correspond with the levels experienced when firing normal refuse. The heat gain Qg, required to accomplish this was then calculated and the results as shown in Table 5 are summarized here:

Case	Qg BTU/mole O_2	Qg BTU/lb of normal refuse (28% moisture 23% inert)	Theoretical Waste Oil Requirements in gal/hr per ton/day of Incinerator Capacity
5	99,564	625	0.37
6	53,395	550	0.32

Consequently, the theoretical heat flux needed to offset the adverse effects of wet refuse (40% moisture is estimated to be between 550 and 625 BTU per pound of normal refuse (28% moisture - 23% inerts as fired). The following discussion indicates, however, that the amount of waste oil needed to supply this heat flux may be significantly greater than the theoretical quantities of waste oil presented above.

SECTION VI

METHODS OF TRANSFERRING REQUIRED HEAT FLUX INTO REFUSE BED UTILIZING WASTE OIL

GCA examined three techniques which were felt to have potential for transferring the required energy from waste oil combustion into the refuse bed:

- Mixing waste oil directly into the refuse
- Preheating underfire air with waste oil
- Utilizing auxiliary burners above the refuse bed

Each of these techniques is discussed below.

Mixing Waste Oil Directly into Refuse

This technique although simple in concept, could prove to be a problem because of the possibility that the oil will "burn with a smoky flame". Theoretically, about 0.37 gallons of waste oil would be required per hour for each ton per day (TPD) of incinerator capacity based on the results of the model. This oil could be distributed onto the refuse either prior to feeding or else via nozzles located directly above the drying zone of the refuse bed. Previous experience using waste oils mixed with refuse has resulted in smoke,[38] but in such cases the oil was applied just by pouring the oil onto the refuse. By utilizing nozzles to spread droplets of waste oil uniformly onto the refuse bed, such smoking could possibly be avoided. During the Phase II demonstration program, we will determine the effectiveness of such a technique.

Preheating Underfire Air

The technique of preheating underfire air has been recommended[38] as a means of alleviating the detrimental affects of wet refuse. Calculations by GCA support this conclusion but show that this technique alone may not be completely satisfactory. Consider a continuous 200 ton per day incinerator chamber unit. Based on the information from the model, an estimated additional 10,400,000 BTU/hr. would be required when firing wet refuse (40% moisture). Assuming that underfire air is being provided at 60°F and at stochiometric conditions (3.21 lbs. air/lb. refuse). The air preheat temperature would have to be about 830°F to provide the necessary heat input. The calculations are presented below:

$$g = n \cdot c_p \cdot (T_p - 60)$$

$$10{,}400{,}000 \frac{BTU}{hr.} = 53{,}500 \frac{lb.\ air}{hr.} \times 0.25 \frac{BTU}{lb.^{o}F} \times (T_o - 60)^{o}F$$

$$\Delta T = (T_o - 60) = 770^{o}F$$

$$T_o = 830^{o}F$$

The maximum safe preheat temperature which will avoid structural damage to grates is estimated at below 400°F. Consequently, the preheated underfire air rate would have to be increased by more than a factor of two in order to provide the estimated BTU's to the refuse bed. This does not consider the possibility of air channeling or the degree of heat transfer obtainable from the preheated air to the refuse. Assuming however, that the normal underfire air rate is increased about 1.5 times (higher underfire air rates would likely cause significant channeling and "stir up bed" so as to increase the quantity of particulate emissions),(42) we estimate that preheated underfire air could provide up to 2/3 the necessary heat input to the refuse bed.

$$q = 1.5 \times 53{,}500 \frac{(lb.\ air)}{hr.} \times 0.25 \frac{BTU}{lb.^{o}F} \times (400-60)^{o}F$$

$$q = 6{,}830{,}000 \text{ BTU/hr.}$$

$$\text{Percent of heat input supplied} = \frac{q}{10{,}400{,}000} = \frac{6{,}800{,}000}{10{,}400{,}000} \cong 66\%$$

In reality however, only a portion of this heat input would be "absorbed" by the refuse due to heat transfer limitations and channeling effects. Consequently, if preheating underfire air was utilized, it would best be applied in conjunction with one of the other specified techniques.

Utilizing Auxiliary Burners Above Refuse Bed

Burner Location

In order to provide the necessary heat flux into the refuse bed via auxiliary burners so as to satisfactorily compensate for wet refuse, the location of these burners is critical. Their function is primarily to dry the refuse and so the burners should be located up above the drying section which generally comprises about the first 10 feet or so of the bed on a continuous grate system. In addition, the flame should cover the entire width of the refuse bed. If the burners are positioned too far from the bed so that conduction becomes the primary mechanism for heat transfer within the bed, only a small percentage of the required theoretical heat flux is obtainable. Consequently, the burners should be located as close to the bed as possible so that the hot burner gases actually penetrate the refuse bed. Typical velocities of gases leaving the burner jet are estimated at approximately 1000 feet per second which is almost 200 times the estimated 6 feet per second velocity of gases emanating from the refuse bed. This would enhance the convective and radiative heat transfer mechanisms within the bed which is necessary to achieve the required heat flux.

Figure 4 presents two schematics of a continuous incinerator chamber, one viewing the chamber from the end of the grate where the ash is "dropped off" and the second viewed from the side wall. Notice that by locating the auxiliary burners in the side walls directly above the drying zone of the bed, the burner flame will have less difficulty covering the width of the bed than if it were firing directly into the bed flame where a great deal of turbulence exists. We are suggesting placement of burners in the side walls because in most incineration systems this location is where the burners can be closest to the refuse bed surface. With each specific incinerator design, however, the optimum burner location must be selected on an individual basis.

Burner Design

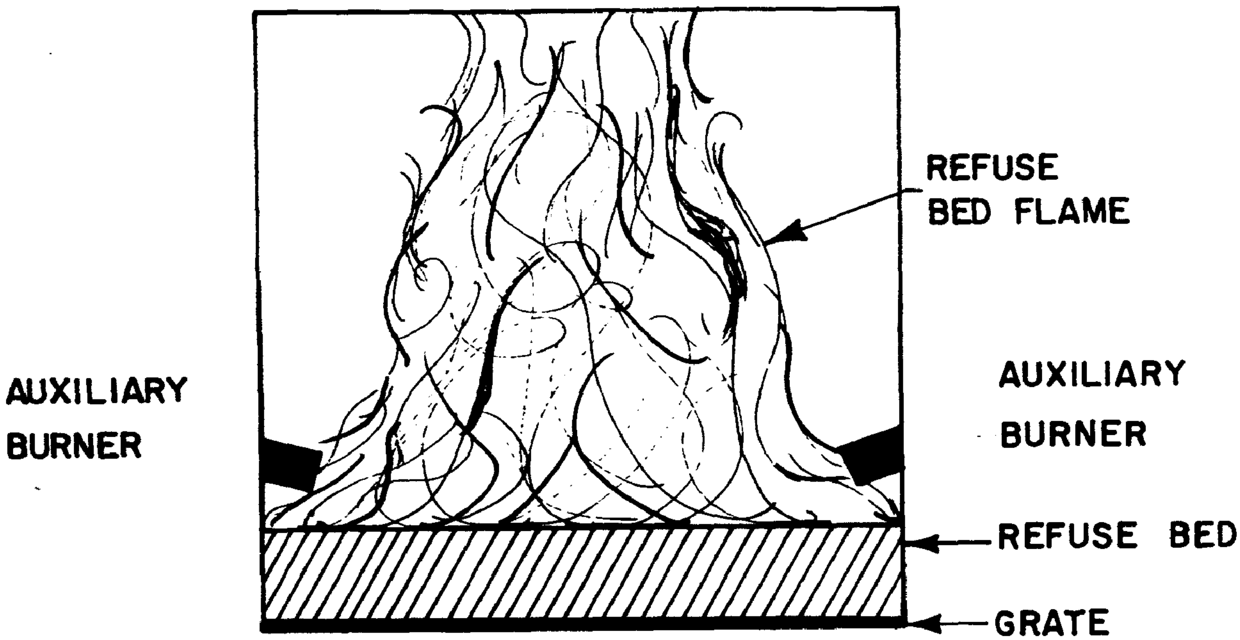
GCA in the conduct of this study mailed letters to over 40 oil burner manufacturers requesting information on oil burners and components which can burn waste oil in an incineration environment with minimal plugging and maintenance. Twelve responses were received and of these, ten indicated that one or more of their burner systems were satisfactory. The types of burners recommended and the number of responses associated with each are presented below:

Burner Type	No. of Responses
Atomizing (air or steam)	8
Vortex	3
Rotary	1

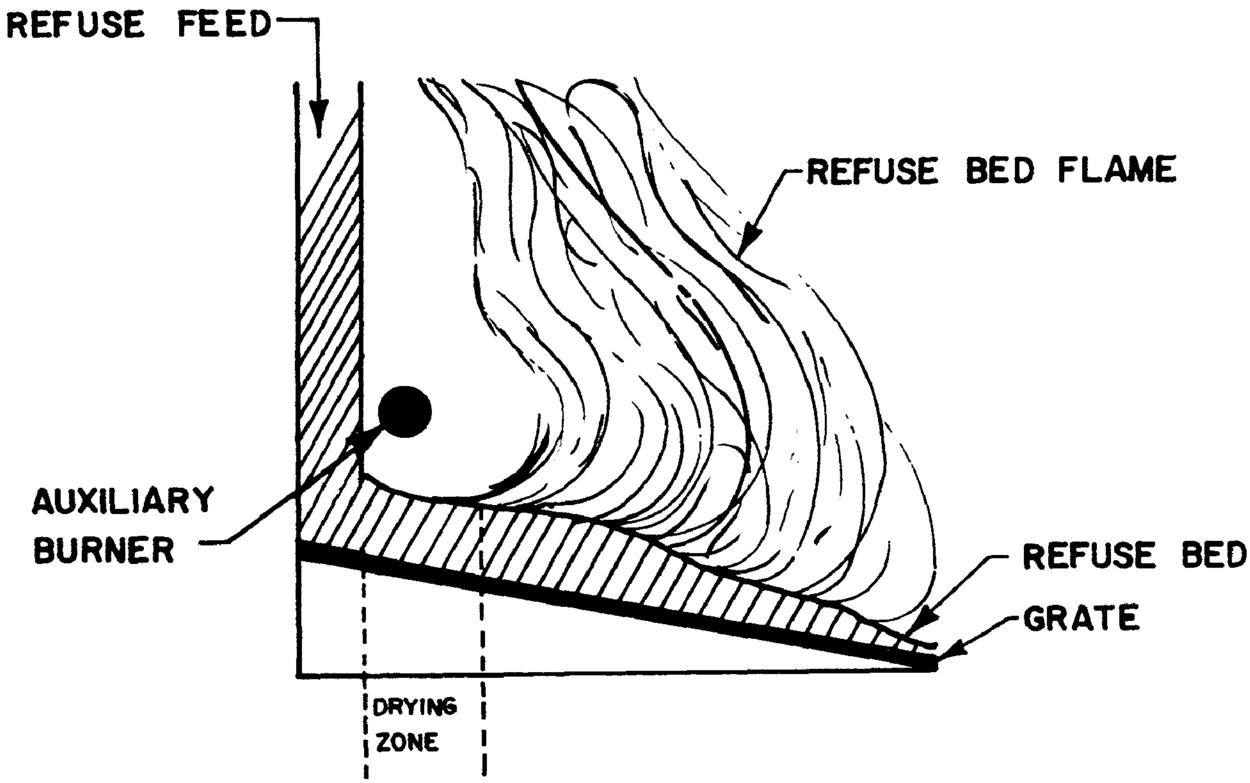
These burners were next evaluated in relation to the six basic burner operating criteria selected by the GCA staff.

- High degree of safety
- Minimal plugging and maintenance
- High flame temperatures ($\gg 2000^{\circ}F$)
- Highly luminous flame

SCHEMATIC OF A CONTINUOUS INCINERATOR PRIMARY CHAMBER



VIEW FROM END OF GRATE



SIDE VIEW OF INCINERATOR PRIMARY CHAMBER

Figure 4

- Long flame length ($\geq$ 5 feet)
- High burner gas velocity

Of the three burner types listed above, only the atomizing burners met all of these operating criteria. The use of rotary burners for waste oils is not recommended by Underwriters Laboratories so that this burner type did not meet the safety criteria. The Vortex burners examined, although highly efficient, produced only a short stubby flame which was not long enough to cover 5 feet or about half the width of a typical incinerator continuous grate. The atomizing burner, however, produces a highly luminous flame with flame lengths adjustable to well over 5 feet and with high gas velocities. The high degree of luminosity is desirable so as to increase the degree radiative heat transfer from the flame to and within the refuse bed. High velocities are desirable so that the hot burner gases can penetrate the refuse bed and therefore enhance the convective and radiative heat transfer mechanisms.

GCA feels that a significant portion of the required theoretical heat flux can be transferred to the refuse bed with the use of atomizing burners in conjunction with the recommended operating methods and burner locations mentioned above. The question that currently remains unanswered is what waste oil firing rate is needed to achieve this theoretical heat flux? The required firing rate can be minimized by operating the burners so as to maximize the penetration of the hot luminous gases into the refuse bed, thus enhancing the radiative and convective heat transfer mechanisms. The complex nature of the geometry and the tremendous variation in refuse bed characteristics, however, prohibited within the scope of this program, the development of a heat transfer model with which to estimate the required waste oil firing rate. However, based on heat transfer calculations performed by the GCA staff as well as on work done by others,[45,46] we are estimating the required firing rate as twice that needed to supply theoretical heat flux requirements. This is equivalent to approximately 0.74 gallons per hour of waste oil per ton/day of incinerator capacity. It is only through actual testing of this concept, however, that a more accurate determination can be made. Consequently, in the Phase II demonstration program, we recommend that waste oil burners be utilized over a wide range of firing rates and that the demonstration facility have the necessary design flexibility to accomplish this.

Waste Oil Burner Testing Program

In order to further determine the viability of atomizing burners for the combustion of automotive waste oil, a five day waste oil burner testing program was conducted. The testing was performed at the facilities of Combustion Equipment Associates in Stamford, Connecticut during the period from September 18 - September 27, 1972. Approximately 800 gallons of untreated waste oil were burned over five 8-hour periods at flow rates ranging from 9 to 25 gallons per hour. A Power Flame Gas-Oil Air Atmoizing Burner #PGA02-B4 was utilized to fire the waste oil. The combustion chamber consisted of a refractory-lined cylindrical chamber about 1.5 feet in inside diameter and 5 feet in length. Figure 5 presents some photographs of the test apparatus.

The testing program was witnessed by GCA, CEA and EPA personnel and all agreed that from visual inspection the fuel appeared to burn extremely clean. In fact it was felt that it burned significantly "cleaner" than comparable residual fuel oils. No particulate analyses were performed on the resulting flue gases. All estimates of trace metal concentrations were based on the waste oil impurity data in Table 6 presented in Section VIII and by assuming that 100 percent of all these impurities enter the combustion chamber with the flue gases.

During the test program, flame temperatures were estimated using an optical pyrometer. Temperatures up to 2,650°F were observed. In order to determine the relationship between flue gas temperature and burner operating parameters, orsat analysis was used to estimate the percent excess air (by measuring the percent CO_2 in the flue gases). Figure 6 is a plot of this data showing the relationship between percent excess air and flame temperature. This figure indicates that for a chamber geometry similar to that utilized during the test program, the percent excess air should be kept below 20 percent in order to achieve flame temperatures above 2500°F.

Flame luminosity and flame length were also continuously observed. The flame luminosity could best be described as a bright yellow which remained so under varying conditions of waste oil flow rate and percent excess air. Flame lengths of 5 feet or longer were obtained at oil firing rates in excess of 12 gallons per hour and at excess air levels less than 50 percent.

In regard to burner plugging, there was no problem observed during the 40 hours of operation. After each 8 hours of operation, the burner nozzle together with the suction (1/32" perforations) and discharge (1/16" perforations) strainers were dismantled and examined. Very little buildup occurred in the strainers (<1/2 ml of sludge per strainer) and the nozzles were clean except for occasional small pieces of metal filings that were collected. These did not hamper burner performance and can be prevented from reaching the nozzle by specifying a slightly smaller perforation diameter for the strainers. GCA and CEA personnel estimated that the burners could operate for at least two weeks (10, 8-hour shifts) without any maintenance and by utilizing self-cleaning strainers, even longer periods between maintenance checks could be achieved.

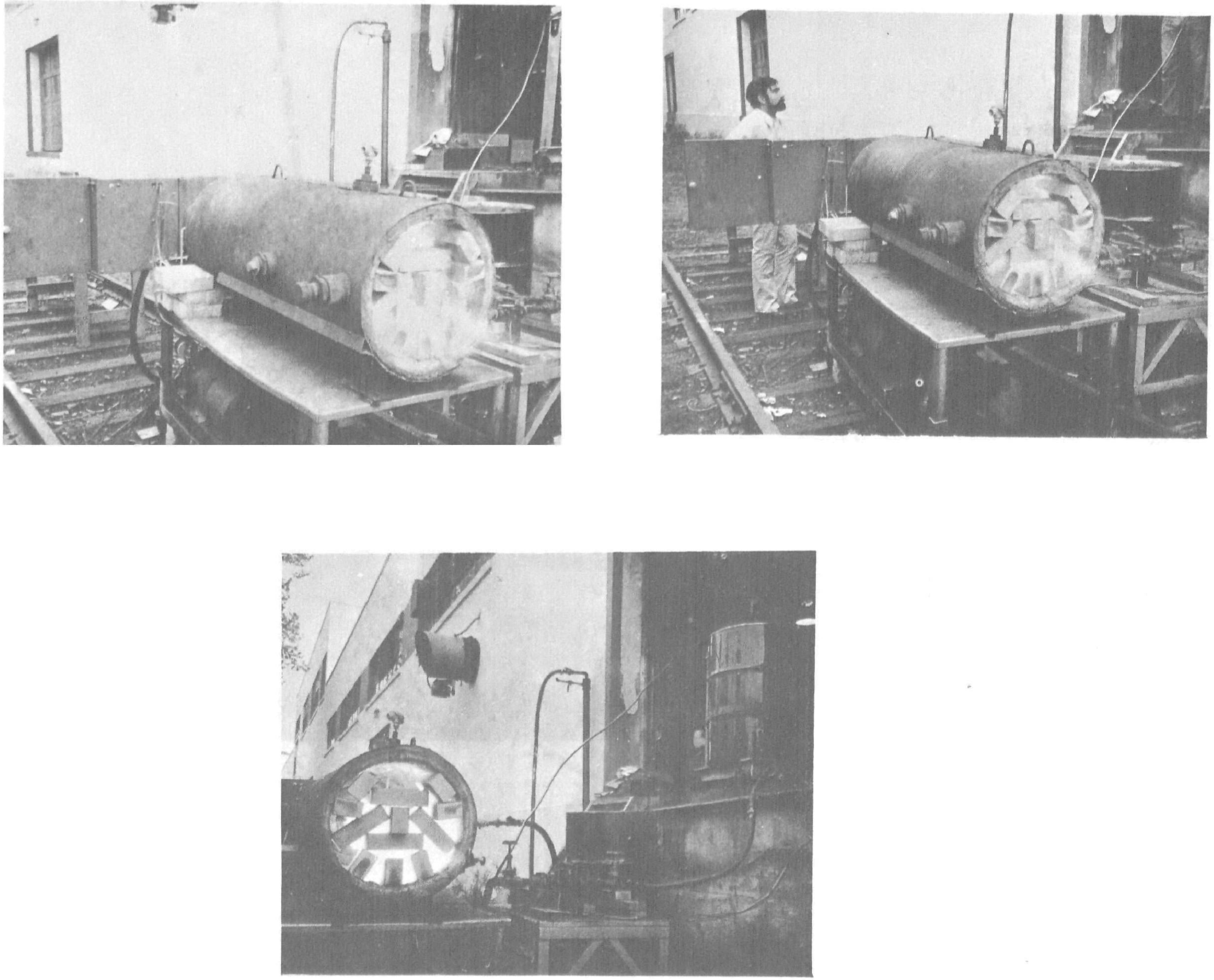
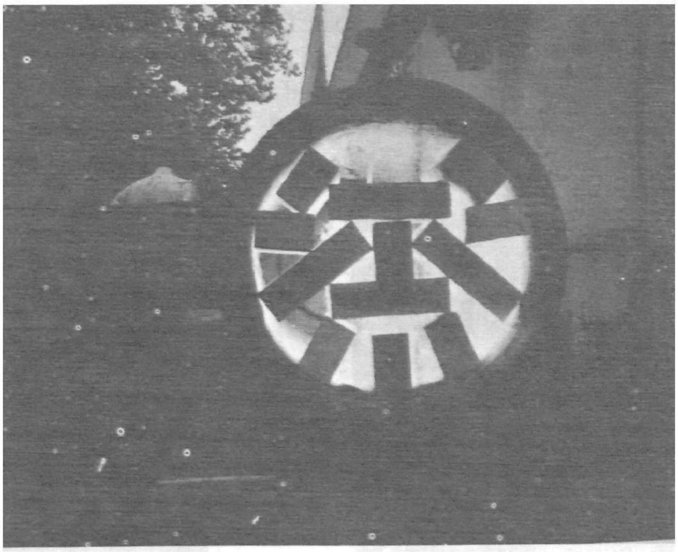


Figure 5. Photographs of the Waste Oil Burner Test Apparatus.



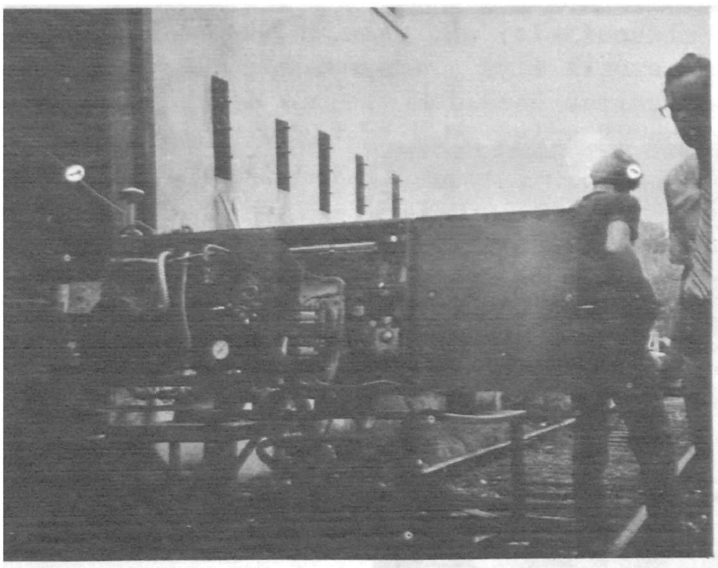


Figure 5 (continued)

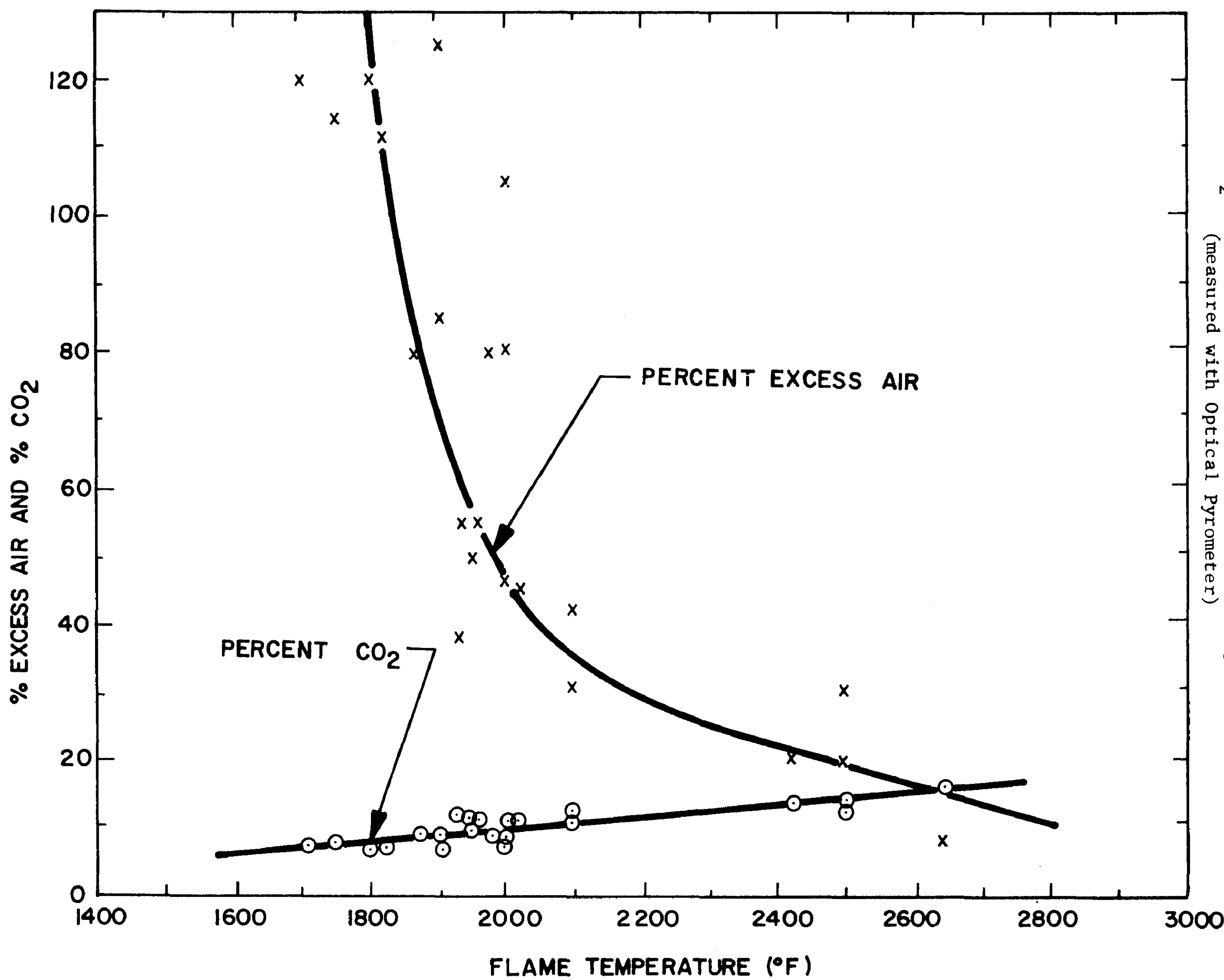


Figure 6. % CO_2 and % Excess Air vs. Observed Flame Temperature (measured with Optical Pyrometer)

SECTION VII

MONITORING AND CONTROL

To derive maximum benefit from the proposed Phase II demonstration installation, accurate measurements and good control of those factors affecting the overall combustion process are necessary. Such measurements as the important refuse characteristics, incinerator operating conditions and performance, and the parameters affecting auxiliary fuel burning are needed to provide the means of evaluating the effectiveness of the proposed system. Good control of the combustion system is required to reduce the possibility of spurious responses and to provide the experimental flexibility necessary for a demonstration facility.

In the following sub-sections the monitoring, control and safety equipment considered essential for the successful accomplishment of the Phase II program will be discussed. The equipment includes devices for measurement of temperature and pressure; mass flow rates of air, fuel oil, flue gases, refuse, and residue; for measurement of particulate emissions; and for analyzing the flue gases. In general, most incinerators will not be instrumented to this extent, and supplementary instrumentation may have to be provided to support the experimental program.

The design, selection, and installation of the monitoring, control and safety equipment associated with this system will be carried out in conformance with recognized standards for such equipment. To the extent possible, all gauges, control switches, warning lights, etc., will be mounted on an integral control panel for easy visibility and access.

Incinerator Monitoring and Control

Refuse Characteristics

Basic to our evaluation of the auxiliary fuel burning system is an understanding of pertinent refuse characteristics. Important refuse parameters include the refuse feed rate, heating value, and moisture content. While the average feed rate is normally obtainable from incinerator operating data, other information is not generally available due to difficulties in obtaining representative samples. Consequently, during the Phase II program, indirect measurements associated with incinerator performance such as flue gas temperature and composition, and residue quality should be monitored as indicators of refuse characteristics and auxiliary burner enhancement of the combustion process.

Temperature

The performance of an incinerator is strongly dependent on temperature, and accurate monitoring of flue gas temperature is of utmost importance. Flue gas temperature is a major indicator of such performance factors as the extent of combustion, combustible particulate emission levels, and residue quality. Thermocouples are normally used as the measurement devices because of their low cost, rapid response, and ease of signal processing. It is anticipated that adequate monitoring of flue gas temperature (and temperature at other incinerator locations) will exist as an integral part of any operating incinerator and additional monitoring of temperature should not be required.

Pressure

As with temperature, instrumentation should exist within the incinerator facility for measurement of pressures at various locations. No further instrumentation should be required.

Combustion Products

The products of combustion will include flue gases, particulate matter in the flue gases, and the residue. All of these factors should be monitored to determine the extent and quality of combustion and to provide information relating to the character of the refuse fed to the incinerator.

A flue gas analysis should include techniques for measurement of oxygen, carbon monoxide, carbon dioxide, water, and combustibles. From this data, and measurements of temperature, pressure, and stack velocity (pitot tube), gas flow rates can be calculated. Reasonably accurate estimates of factors such as excess air flow and refuse moisture content can also be obtained.

The amount of particulate matter in the flue gases should also be monitored since a reduction in solids emission is a major benefit to be derived from improvements in the combustion process. Residue quality will also provide information concerning the combustion process and the effectiveness of auxiliary fuel burning.

Auxiliary Fuel Monitoring and Control

The auxiliary fuel system will be equipped with devices for measurement of fuel and air pressure, and flow at various locations throughout the system. Power requirements of the various components can also be determined. These measurements are necessary to evaluate overall burner system performance and cost of operation.

Measurement techniques will be straightforward and standard. Thermocouples will be used for temperature determinations of flue gases in the incinerator primary chamber and will serve as an indicator of auxiliary fuel needs. Fuel and air pressure will be measured by diaphragm gauges and draft gauges. An orifice type flow meter will be used for air flow measurements and oil flow will be determined by a positive displacement device such as a rotating vane (velocity) meter.

Because of the highly experimental nature of the Phase II program, automatic control of burner operation to maintain constant furnace temperature is not being recommended. Such a control system may be desirable in future installations and could be installed for under $5,000.

Burner combustion rates can be normally controlled within certain limits which depend to some extent on the types of burner used. Reduced combustion rates will be obtained by a lowering of the combustion air flow. Fuel flow will be proportionately and automatically reduced by an oil-air ratio regulator.

A number of safety control mechanisms will be provided. As an integral part of the recommended burner system MH Flame Safeguard controls with an HV UV detector and appropriate safety switches will be used with a shutoff valve to stop the flow of oil in cases of ignition failure. This safety shutoff valve will be sensitive to any possible failure in the burner and its control system.

In addition, the pumping set will be equipped with relief valves which act as short circuits around the pumps if values in excess of a preset pressure are obtained. Provision for stopping flow in the event of a leak will also be provided.

Other elements of the feed system, particulary the oil preheaters, must be equipped with control and safety devices. In the case of the oil heaters, thermostatic controls should be provided to prevent excessive heating. Relief valves and associated piping will also be provided to prevent damage to the units due to overpressure.

SECTION VIII

STORAGE AND FEED SYSTEMS

The storage tank selected for the proposed installation is an above ground, carbon steel tank mounted on a reinforced concrete foundation. Sizing will be based on projected waste oil feed rates in conjunction with the selected municipal incinerator. Storage capacity should be sufficient for at least an estimated four days operation. For example, a 10,000 gallon tank can provide four days of continuous operation for an auxiliary fuel oil system in conjunction with a 400 ton per day municipal incinerator. With regard to such tank safety considerations as location, construction, venting, and fire prevention, recognized standards will be followed - e.g., National Fire Prevention Association (NFPA) Standards No. 30 and 31. The tank will be provided with adequate corrosion protection, gaging, and means for removal of sediment.

Although a significant amount of sediment is not anticipated, any potential plugging of fill and suction lines will be avoided by locating them at least six inches from the tank bottom. Periodic removal of sediment by a tank cleaning company can be accomplished by a portable pump which will draw oil and sediment through a pipe extending to within one inch of the bottom of the tank. An access manhole also will be provided to permit entrance for manual cleaning if required.

At the present time we are not recommending the installation of an oil heater within the tank since the pour point of waste oil (-35^{o}F) is well below typical minimum temperatures in the U.S. Tank oil heaters, however, can be added if needed.

The design and installation of the oil feed system will be performed in accordance with recognized safety standards such as the aforementioned NFPA Standard No. 31. In general, the piping circuit will contain strainers, valves, relief valves, flow paths, instruments, and controls consistent with good operating practice. The selection of pipe size, since it is dependent upon the equivalent length of the fuel line, cannot be made until an incinerator site is chosen. However, the actual pipe size will be selected on the basis of a flow twice that of the anticipated burner flow for an oil with a viscosity of 10,000 SSU. This viscosity was estimated to be that of the average waste oil at 0^{o}F based on the viscosity data presented in Figure 1.

A schematic of the proposed oil handling system including storage tank is shown in Figure 7. Oil will flow from the storage tank through a shutoff valve, check valve (if needed), and strainer to heavy duty positive displacement pumps. These pumps can operate under a wide range of temperature viscosity conditions such as:

Temperature: $-40^{\circ}F \rightarrow 225^{\circ}F$
Viscosity: 0.1 cp → 10,000 SSU

Preheating of the oil for purposes of pumping, therefore, will not be necessary. The oil flows from the pump through a second strainer and then divides into two streams, one going to the burners, the other returning to the tank. At the present time it is planned to install electric heaters in the lines leading to the burners to insure good atomization of the waste oil. These 40 kw heaters are each capable of heating 300 gph of waste oil through a $100^{\circ}F$ temperature rise and should provide good burner atomization for all anticipated flow and temperature conditions. They are low watt density units designed to minimize carbonization and cracking of the oil. Appropriate flow paths, controls, contactors, insulation, and strainers will be provided for these units.

This storage and feed system has been designed to provide the reliability, control, and flexibility necessary for an experimental installation. Subsequent installations, resulting from a study of this type, will be simpler and less costly.

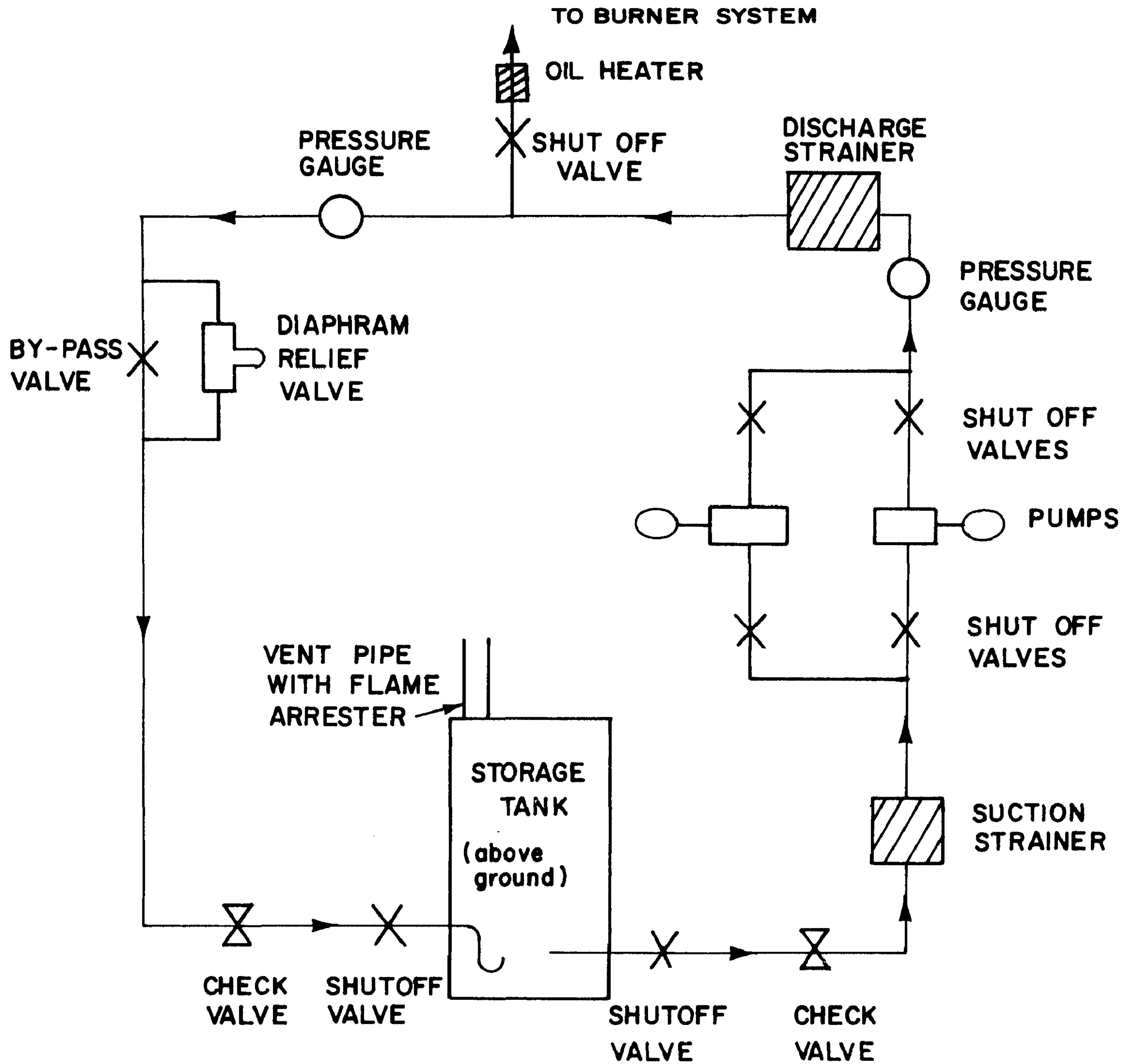


Figure 7. Schematic of Waste Oil Storage and Feed System.

SECTION IX

IMPACT ON AIR QUALITY

Before waste oils can be utilized in municipal incinerators for improvement of the incineration process and the alleviation of waste oil as a potential water pollutant, assurance must be provided that the waste oil combustion does not have any adverse effects on ambient air quality. The waste oil firing is intended to increase the temperature in the incinerator and reduce smoke and particulate emissions while firing wet or low-BTU value refuse. However, the presence of impurities in the emissions such as lead may themselves contribute to unacceptable ground level concentrations of air pollutant. The following presents a theoretical estimation of ground level lead concentrations which should be verified during the Phase II Program.

The levels of the principal pollutants present in waste oil expressed as a weight percent are tabulated in Table 6. These data indicate that the most significant impurities, from an emissions stand point, are lead and sulfur. The sulfur content, however, corresponds to that of a low sulfur fuel oil. Lead, on the other hand, is considered as a hazardous material by EPA and consequently warrants further investigation.

Although national ambient air quality standards for lead have not yet been set, EPA has indicated[52] that a 3-month average concentration of 2 $\mu g/m^3$ is associated with a sufficient risk of adverse physiologic effects to constitute endangerment of public health. Accordingly, GCA has made preliminary estimates of average ground-level concentrations in the vicinity of a municipal incinerator using waste oil as an auxiliary fuel over a 3-month period.

The input data for these calculations are shown in Table 7 and are based on a waste oil auxiliary fuel burner system in conjunction with a 400 ton per day municipal incinerator. Exhaust gas temperatures are typically about 500°F. Actual volumetric flow rates were estimated to be 166,000 ACFM based on a typical incinerator excess air level of 200 percent. Using the estimated quantities of waste oil needed per ton of refuse fired (0.74 gallons/hour per ton/day of incinerator capacity) as discussed earlier in this report, an estimated 2,250 lbs per hour of waste oil would be fired. Based on the fact that precipitation occurs on approximately 35 to 40 percent of the days in the Northeast, we are assuming that waste oil firing would occur during approximately one-third of the operating time of the incinerator. Table 6 shows that the lead content of measured waste oil samples vary from approximately 0.1 to 1 percent. The larger value of 1 percent was utilized for GCA's

TABLE 6

IMPURITIES IN WASTE OIL (Wt.% OF ELEMENT OR MATERIAL AS LISTED)

Data Source	Lead	Sulfur	Sulfated Ash	Aluminum	Barium	Boron	Calcium	Chromium	Copper	Iron	Magnesium	Nickel	Phosphorus	Silicon	Tin	Vanadium	Zinc
Ref. 1	1.11	0.34	1.81	--	.06	--	.17	--	--	.036	--	--	.09	--	--	Trace	.08
Ref. 1	0.90	--	1.80	--	.10	--	.10	--	--	.020	--	--	.11	--	--	--	.07
Ref. 1	0.72	0.29	1.02	--	.01	--	.15	--	--	.010	--	--	.06	--	--	--	.035
Ref. 1	0.68	0.32	1.43	--	.02	--	.09	--	--	.013	--	--	.08	--	--	--	--
Ref. 1	0.75	0.31	1.60	--	.01	--	.11	--	--	.013	--	--	.07	--	--	--	--
Ref. 1	0.67	0.30	1.13	--	.03	--	.07	--	--	.005	--	--	.06	--	--	--	.042
Ref. 1	1.12	0.21	2.41	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Ref. 1	0.08	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Ref. 30	0.82	--	--	.003	.05	.002	.13	.002	.001	.04	.02	.0002	.13	.02	.0007	--	.04
Ref. 30	0.82	--	--	.004	.03	.002	.21	.003	.001	.03	.01	.0003	.13	.01	.0007	--	.05
Ref. 30	0.50	--	--	.002	.07	.001	.16	.004	.002	.02	.02	.0003	.15	.01	.0007	--	.06
Ref. 30	0.71	--	--	.004	.02	.002	.13	.001	.001	.03	.03	.0030	.12	.02	.0010	--	.04
Ref. 30	0.60	--	--	.003	.04	.002	.21	.004	.002	.03	.02	.0005	.10	.02	.0010	--	.06
Ref. 30	0.90	--	--	.003	.01	.002	.14	.002	.002	.04	.03	.0006	.16	.02	.0010	--	.05
Ref. 30	0.82	--	--	.003	.04	.002	.12	.002	.001	.03	.02	.0003	.11	.04	.0010	--	.03
Ref. 30	0.71	--	--	.003	.05	.002	.16	.003	.002	.03	.05	.0010	.11	.01	.0020	--	.03
Ref. 30	0.82	--	--	.005	.05	.002	.16	.001	.002	.04	.02	.0007	.10	.02	.0010	--	.05
Quest.1	0.63	0.3	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Quest.3	0.14	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Quest.5	0.30	0.4	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Quest.6	0.79	0.32	--	--	Trace	--	.12	--	--	Trace	--	--	Trace	--	--	--	Trace
Range	.08-1.1	.21-.34	1.0-2.4	.002-.005	.01-.07	.001-.002	.07-.21	.001-.004	.001-.002	.005-.04	.01-.05	.0002-.003	.06-.16	.01-.04	.0007-.002	Trace	.03-.08

assessment of air quality impact. A lead collection efficiency of 50 percent was utilized based on data presented on waste oil burning studies by Mobil Oil Corporation.[1] A stack height of 100 feet was assumed although stack heights on many facilities greatly exceed this value.

The ground level concentration calculations are based on the usual Gaussian diffusion model for an elevated source, and plume expansion rates specified in Turner's Workbook of Atmospheric Dispersion Estimates.[53] Wind data for the model calculations were taken from climatological records obtained over an 18-year period at Falmouth, Massachusetts. The 3-month period used for the calculations was comprised of the three winter months of December, January, and February. The wind data were restricted to the daytime period from 0900-1700 EST, conforming approximately to the daytime period of incineration. For the model calculations, the wind data were expressed as frequency of occurrence of 16 wind direction and 5 wind speed categories. Daytime stability classes from A to D were assigned on the basis of the observed wind speed categories and estimated solar radiation categories. For simplicity, only two effective plume heights were used. The first assumed a plume rise from heat and momentum forces of 75 meters, and was used when the surface wind was equal to or less than 6.5 knots. The second assumed a plume rise of 35 meters and was used when the surface wind speed was greater than 6.5 knots. These values were selected as conservative estimates on the basis of trial calculations, using Briggs plume rise formula.[54]

The results of the calculations of 3-month average lead ground-level concentrations in $\mu g/m^3$ are presented as concentration isopleths in Figure 8. The calculations assume that waste oil is burned continuously for 8 hours a day, 7 days a week. For shorter operating periods, the ground-level concentrations should be reduced proportionately. For example, the concentrations should be multiplied by 0.7 for a five-day week. An additional multiplier of 0.33 should be utilized to account for the ratio of waste oil on-time and incinerator on-time as presented in Table 7. Consequently, for an incinerator operating at:

- 1 8-hour shift per day
- 5 days/week
- ratio of waste oil burner on-time and incinerator on-time = 33%

the values of the concentration isopleths presented in Figure 8 should be multiplied by 0.23.

Figure 8 shows that the estimated maximum, 3-month average, ground-level concentration attributable to an incinerator when operating as described above is approximately 0.05 $\mu g/m^3$, and occurs about

TABLE 7

INCINERATOR INPUT DATA

Incinerator Capacity	400 Tons/day
Exhaust Gas Temperature	500^{o}F
Gas Flow Rate at 500^{o}F	166,000 ACFM
Waste Oil Burning Rate	2250 lbs/hr.
Ratio of Waste Oil on Time to Incinerator on time	33%
Lead Content	1% by weight
Lead Collection Efficiency	50%
Stack Height	100 feet.

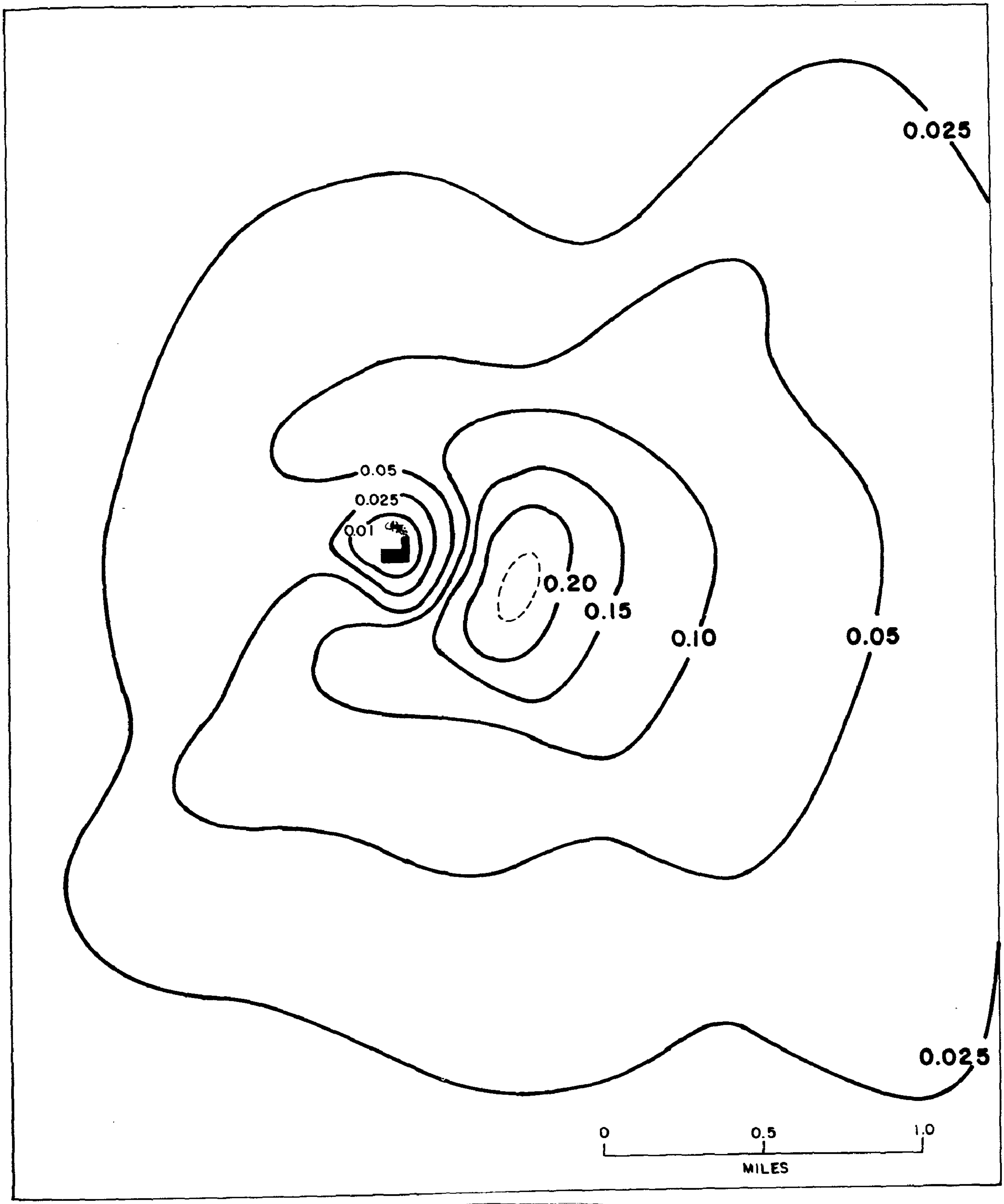


Figure 8. Isopleths of average ground-level concentration of Pb for winter season. Units are $\mu g/m^3$.

one-half mile from the incinerator. This is approximately one-fourtieth of the level suggested by EPA as injurious to public health.

SECTION X

ECONOMIC FEASIBILITY

Sections IV through IX illustrate that from a technical viewpoint, automotive waste oil appears to be extremely suitable as an auxiliary fuel to improve the municipal incineration combustion process. The costs associated with installing and operating such a typical system are presented in this section. The installation and operating costs of the Phase II demonstration facility, however, would be somewhat higher than those presented here since the demonstration unit would be expected to have more operational flexibility and instrumentation to facilitate the experimental program.

Economics of a 'Typical' Waste Oil Auxiliary Fuel System

The capital investment and operating costs presented below will be based on an auxiliary waste oil system in conjunction with a 400 ton per day (TPD) continuous municipal incinerator facility. Such a facility is comprised of 2- 200 TPD units each operated 8 hours/day, 6 days per week. Waste oil will be fired through four air-atomizing burners located in the walls of the primary combustion chamber (2 burners per unit). The firing rate will be set at twice the estimated theoretical heat requirements or 300 gallons per hour. The burner on-time is estimated at approximately one-third of the incinerator operating time (100 days/year; 8 hours/day) which is equivalent to 240,000 gallons/year. These assumptions are summarized below:

Incinerator Capacity:	400 Tons/day; 2-200 TPD units
Waste Oil Burner Capacity:	4 units; 90 gph each
Waste Oil Firing Rate:	300 gph; 75 gph each
Waste Oil Annual Consumption:	240,000 gallons/yr

Capital Investment

The capital investment costs for a "typical" facility are summarized in Table 8. These costs were compiled during December 1972 for the location of Boston, Massachusetts. The Engineering New Record Construction Cost Index can be utilized to obtain complete costs for other locations.

Waste Oil Burner and Feed System

Table 8 indicates that the estimated installed cost of a Waste Oil Burner system comprised of 4-90 gph units and including all Safety and Control systems is $73,600. This cost is based on a detailed

TABLE 8

CAPITAL COST ESTIMATE OF A WASTE OIL AUXILIARY FUEL SYSTEM FOR A MUNICIPAL INCINERATOR

Incinerator Location:	Boston, Mass., December 1972
Incinerator Capacity:	400 Tons/day; 2-200 TPD units
Waste Oil Burner Capacity:	4 units; 90 gph each
Waste Oil Firing Rate:	300 gph; 75 gph each
Waste Oil Annual Consumption:	240,000 gallons/yr

Installed Equipment Costs

Waste Liquid Burner System	$73,600.00
4 - PAO_6 - DB Burners including: . atomizing air compressor . oil piping train . forced draft combustion air fan . MH flame safeguard controls . air piping train . safety switches, controls & control panel	
2 - Viking HL 195 pumps 1 - Kraissl 3" duplex section strainer 1 - Kraissl 3/4" duplex discharge strainer 1 - Cash 123 1" pressure regulating valve 2 - pressure relief valves	
Piping and mechanical work as required	
Electrical work as required	
Furnace front plate modifications and burner attachment	
Furnace refractory work	
Waste Oil Storage System	$12,000.00
1 - 10,000 gallon carbon steel tank Reinforced concrete foundation	
Oil Preheaters	$4,000.00
2 - in-line electric resistance heaters (40 KW each)	
Total Installed Equipment Cost	$89,600.00
Engineering Services, Installation and start-up	16,800.00
TOTAL INVESTMENT	$106,400.00

quotation obtained from Combustion Equipment Associates[47] and is in reasonable agreement with the costs of a similar system installed in the Hartford, Connecticut area about one and one-half years ago.[48]

To determine the cost of a similar burner system of a different capacity, the normal procedure is to apply a scale factor of the form

$$\frac{\text{Cost of New Unit}}{\text{Cost of Old Unit}} = \left(\frac{\text{Size of New Unit}}{\text{Size of Old Unit}}\right)^{\text{S.F.}}$$

The choice of scale factor is an empirical one and wide variations may occur. A study of the literature and discussions with burner manufacturers indicate that for installations of this type a scale factor of 0.6 may be applied.

Fuel Storage Tank

A 10,000 gallon carbon steel tank, costing $12,000 including piping, installed outside the incinerator on a reinforced concrete foundation has been recommended for this system. This is sufficient for four days of continuous operation. Again, any scaling of tank size may be accomplished, if required, by applying the six-tenths factors. This factor is recommended based on data for vertical tanks given in "Modern Cost Engineering Techniques".[49]

Oil Preheaters

Fuel oils with the exception of No.'s 1 and 2 are preheated in varying degrees to provide good atomization and clean, efficient combustion. The viscosity of the waste oil is similar to that of a number 5 fuel oil and it is anticipated that some degree of preheat will be required.

For the proposed system, we are recommending the use of two in-line, electric resistance heaters with appropriate controls and safety interlocks. Under extreme environmental conditions, the heat requirement will be significant. In the Boston area, it is not inconcievable that a temperature increase of $100^{o}F$ would be required to lower the viscosity of the waste oil to the desired range of 100-250 SSU. The preheat kilowatt requirement for our proposed installation would then be:

$$\frac{600 \text{ gallons/hr.} \times 4 \text{ BTU/Gallon} \times 100^{o}\text{F}}{3414 \text{ BTU/KW hr}} = 70 \text{ KW}$$

This calculation assumes that an oil recycle rate equal to the firing rate is utilized. To achieve this kind of input, we are recommending that two 40 kw units, such as Chromalox NWHO-840F1, be used in the lines between the fuel burners and tanks. The cost per unit including controls will be approximately $2,000.

Because of the low pour point (-35^{o}F) of the waste oil, no provision has been made for storage tank heating. If necessary, this could be provided for an additional cost of about $1,000.

Engineering Services

The cost of $16,800 for engineering services associated with the design, installation and start up of such a facility have been estimated based on GCA cost files as well as discussions with engineering consultants experienced in such activities. This cost is consistent with the 15 percent figure generally utilized as the median value for such services. A scale factor of 0.6 should be applied to determine the cost of engineering services for installations different in size from the proposed system.

Annual Operating Costs

The annual operating costs for the waste oil facility described above are presented in Table 9 and are discussed below.

Fixed Costs

(1) Amortization of Capital Investment - The capital investment for this system has been amortized over a period of 20 years. The expected lifetime of 20 years is based on GCA staff experience with equipment of this type and on discussions with burner manufacturers and consulting engineers.

A straight-line method, which distributes the capital investment cost uniformly over the 20-year period, was used for this cost estimate. Size scaling of this and all other fixed cost items should be proportional to the scale factor used for determining capital investment costs. In this case the factor is 0.6.

(2) Interest or Loan - The interest of 3.1 percent of the total capital investment was selected on the basis of discussions with banks in the local area who offer financial aid to municipalities.[50] The interest is to be paid after one year, but is capitalized uniformly over the estimated 20-year lifetime of the equipment.

(3) Insurance - The cost of insurance was estimated to be 0.5 percent of the equipment cost. This figure is suggested by Perry[51] as a maximum for similar facilities.

TABLE 9

ESTIMATED OPERATING COST OF A WASTE OIL AUXILIARY FUEL SYSTEM FOR A MUNICIPAL INCINERATOR

Incinerator Location:	Boston, Mass., December 1972
Incinerator Capacity:	400 Tons/day; 2-200 TPD units
Waste Oil Burner Capacity:	4 units; 90 gphr each
Waste Oil Firing Rate:	300 gallons/hr; 75 gal/hr each
Waste Oil Load Factor:	100 days/year; 8 hours/day
Waste Oil Annual Consumption	240,000 gallons/year
Capital Investment:	$106,400.00
Fixed Costs	ANNUAL COST
Amortization at 5% of CI annually	$5,320
Interest on loan (3.1% of CI)*	165
Insurance (0.5% of equipment cost)	450
TOTAL Fixed Cost per Year	$5,935
Variable and Semi-Variable Costs	
Waste Oil (5 cents/gallon)	$12,000
Power (2.75 cents/KW hr)	1,450
Labor (200 hours - $10.50/hour)	2,100
Maintenance (7% of equipment cost)	6,300
TOTAL Operating Cost per year	$21,850
TOTAL ANNUAL COST	$27,785

*Paid in one year; amortized over a 20-year period.

Variable and Semi-Variable Costs

(1) Waste Oil - An average cost of 5 cents per gallon was assigned to the waste oil following discussions with a number of waste oil dealers in the New England area. This price includes delivery to the incinerator. The cost of 5 cents per gallon represents the higher end of the cost spectrum but even at this level is significantly cheaper than conventional fuels. Our best estimate of the cost of competitive virgin fuel in the Boston area for the volume required are as shown below.

Fuel	Cost/10^6 BTU
Natural Gas	$1.70
Oil	
#2	0.94-1.48
#6	0.76-1.08
Waste Oil	0.34

Since the cost of waste oil is roughly 55 percent of the total annual non-fixed costs, its use represents a significant savings relative to other potential fuels.

The cost of waste oil for systems of different size will vary directly with the size (scale factor equals 1.0) provided the storage tank volume is adequate to accept the waste oil delivered.

(2) Power - The electrical requirements of this system are based on stated requirements for the total burner system plus the oil preheat requirements. For purposes of estimating, a temperature differential of 50°F was assumed to be the average daily preheat requirement. At this level of preheat, approximately 26,400 kilowatt hours are required annually, which is equal to the power required to operate the burner system. The cost of electricity as supplied by Boston Edison should be about 2.75 cents/kw hr for this load and demand.

Size scaling is difficult because of the complexity of the rate schedule. For purposes of this study, we have assumed that the cost per kw is independent of the amount of electricity used. The cost of power will then be directly proportional to the size of the installation.

(3) Labor Costs - The annual labor cost associated with the operation of the waste oil system was obtained by assuming that a total of two hours per operating day would be required at an hourly rate of $10.50. This is probably a conservative estimate. As the new system becomes more familiar to the operating personnel, the time requirement should decrease. Automatic operation, if instituted, would also decrease labor costs.

For purposes of this study, a scale factor of 0.25 has been used for determining labor costs as a function of size. This factor is taken from an article by F.P. O'Connell in "Modern Cost-Engineering Techniques"(49) and is based on data gathered for 52 chemical processes.

(4) Maintenance Costs - An annual maintenance cost of 7 percent of the capital equipment cost was selected for this analysis. This is a high figure, representative of that normally found for corrosive processes or those associated with extensive instrumentation. However, in view of the fact that waste oil combustion is not a well-established operation, the choice of a higher than normal maintenance cost appears justifiable for estimation purposes.

Since maintenance costs have been estimated as a percentage of the initial cost, the same 0.6 scale factor should be applied to determine the cost of other installations.

Affect of Capacity of Waste Oil Auxiliary Fuel System On Economics

Figure 9 provides a means of estimating the capital investment and operating costs of a waste oil auxiliary fuel system for those systems associated with incinerator capacities other than 400 TPD. These curves are based on the scale factors associated with each of the costs as discussed above. For example, the costs associated with a waste oil system to be utilized in conjunction with a 600 TPD incineration system are:

Capital Investment (1.27 x $106,400)	$136,000
Operating Costs	
Fixed Costs (1.27 x $5,935)	7,580
Operating Costs	
Fuel & Power (1.5 x $13,450)	20,200
Labor (1.11 x $2,100)	2,330
Maintenance (1.27 x $6,300)	8,030
Total Operating Costs	$ 38,140

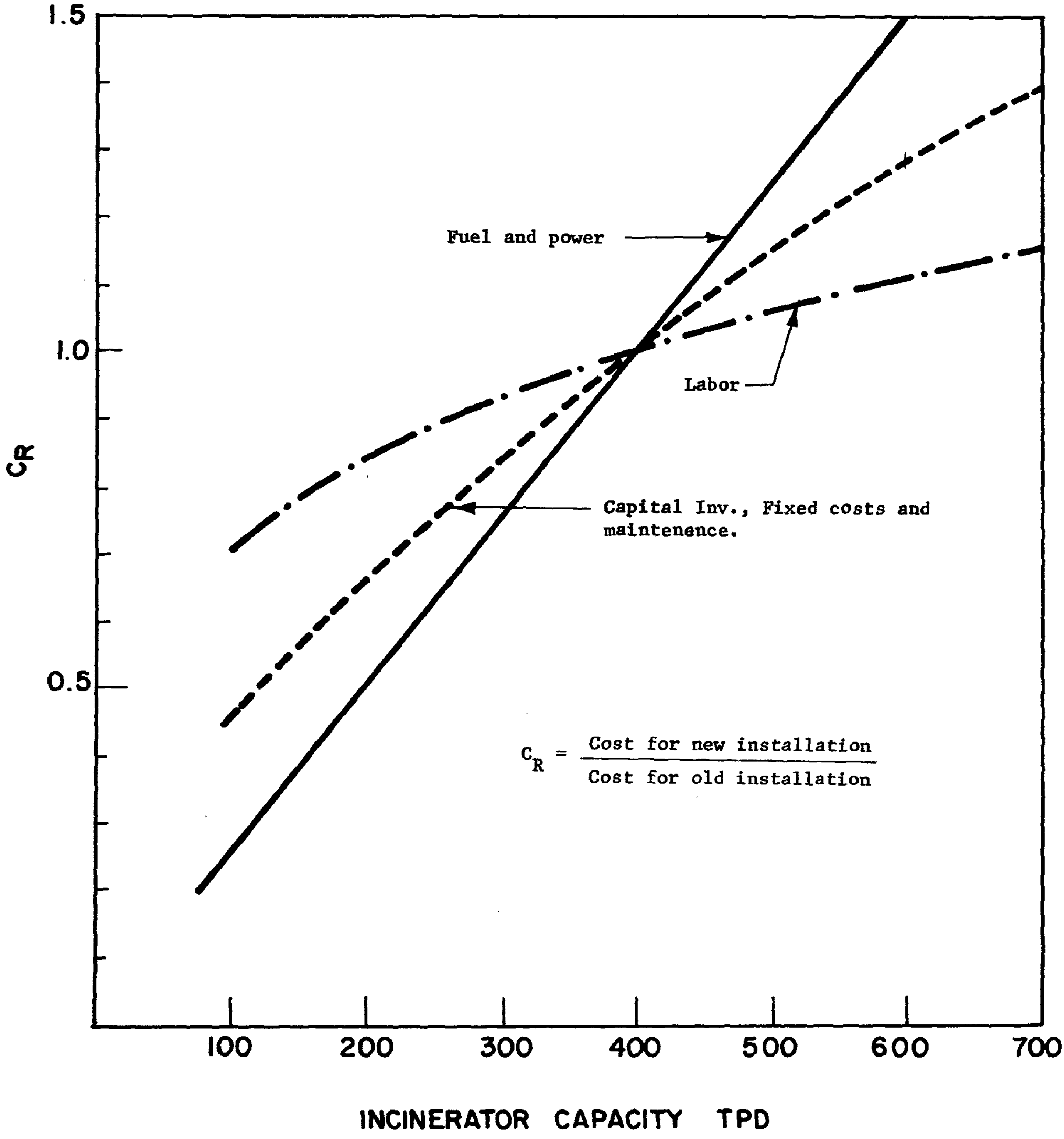


Figure 9. Investment and operating costs of waste oil auxiliary fuel system as a function of incineration plant capacity.

SECTION XI

ACKNOWLEDGEMENTS

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SECTION XII

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SECTION XIII

APPENDICES

APPENDIX A - LETTER AND QUESTIONNAIRE TO WASTE OIL REFINERIES

APPENDIX A - LETTER AND QUESTIONNAIRE SENT TO REREFINERS

GCA TECHNOLOGY DIVISION

A Division of GCA Corporation

Bedford, Massachusetts 01730 Telephone: 617-275-9000

Gentlemen:

GCA Technology Division is performing work for the Environmental Protection Agency (EPA) which could expand the current market for recovered waste lubricating oils. Part of this program requires the collection of data which define typical properties of these oils prior to re-refining. Both physical parameters, such as specific gravity and viscosity, and chemical characteristics, such as percent sulfur and percent lead, are needed to complete the work. The attached questionnaire lists the data which will be useful to this program.

GCA requests your help in securing the needed data by providing the information listed on the questionnaire for the waste oil as you receive it. It is realized that some of the characteristics listed might not be available in all instances; in other cases, you may feel that a range of values for a specific characteristic is most representative. In either case, please fill in whatever information is at your disposal. A stamped pre-addressed envelope is enclosed for your convenience. Your cooperation in this task is greatly appreciated.

Sincerely,

Steven Chansky

Steven H. Chansky
Project Manager

SHC/lhr

QUESTIONNAIRE FOR
WASTE OIL CHARACTERIZATION

Return to: Steven H. Chansky/Project Manager
GCA Technology Division
Bedford, Massachusetts 01730

I. GENERAL INFORMATION

A. Company Name____

Company Address______________________________________

City__________________State_____________Zip Code_____

B. Person Filling Out Form______________________________

Position (Title)______________________Tel. No ________

II. WASTE OIL CHARACTERISTICS

A. General Information

Principal Source(s) of Oil (Service Stations, etc.)_______

____

Do you collect the waste oil yourself? Yes_______ No______

If not, from whom do you receive the oil?________________

____

What are your chief products?

Lubricating Oils_________________

Fuel Oils_______________________

Other Products (specify)_________________________

____

B. Waste Oil Characteristics

Specific Gravity:______________ ^{o}API at___________ ^{o}F (degrees Fahrenheit)

Viscosity:________________SUS (Saybolt Universal Seconds) at _____________________ ^{o}F.

Flash Point (Closed cup or Open Cup, Specify):_____________ _____ ^{o}F.

Corrosiveness: Equivalent to ASTM No.___________Corrosion Standard.

Water:_________% by volume.

Sediment and Water:___________% by volume

Ash Content:_______________% by weight.

Sulfur Content:________________% by weight.

Lead Content________________% by weight.

C. Additional Comments:____________________________________

____

____

SELECTED WATER RESOURCES ABSTRACTS

INPUT TRANSACTION FORM

1. *Report No.*

2.

3. *Accession No.*

W

4. *Title*

Waste Automotive Lubricating Oil As A Municipal Incinerator Fuel

5. *Report Date*

6.

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13. *Type of Report and Period Covered*

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15. *Supplementary Notes*

Environmental Protection Agency report number, EPA-R2-73-293, September 1973.

16. *Abstract*

The technical, economic and environmental impact of utilizing waste automotive lubricating oils to improve the municipal incineration combustion process was examined. Laboratory analyses of selected physical properties of waste oil and a waste oil burner testing program were conducted to complement an information search program.

The physical and chemical properties of waste oil were reviewed in relation to its suitability as a fuel oil. The auxiliary fuel heat flux requirements to offset the adverse effects of wet refuse were estimated utilizing a combustion model of a refuse bed. Various methods were evaluated for transferring this required heat flux to the refuse bed. Suggested designs for monitoring and control; and waste oil storage and feed systems were presented.

The impact on air quality from the combustion of waste oil in a municipal incinerator was estimated. Three-month average ground level concentrations for lead were calculated and presented as concentration isopleths.

Capital Investment and operating costs were developed for auxiliary waste oil systems in conjunction with municipal incinerators.

17a. *Descriptors*

Automotive Waste Oil Combustion, Municipal Incineration, Refuse Combustion, Incinerator Air Pollutants

17b. *Identifiers*

waste oil, incineration, waste oil combustion, refuse combustion, incineration air pollutants

17c. *COWRR Field & Group*

18. *Availability*

19. *Security Class. (Report)*

20. *Security Class. (Page)*

21. *No. of Pages*

22. *Price*

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Abstractor Steven Chansky *Institution* GCA/Technology Division