Solid Waste Demonstration Projects

Proceedings of a Symposium

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FOREWORD

THE SOLID WASTE DISPOSAL ACT of 1965 (Title II, P. L. 89-272) and the broader mandate of the 1970 amendment (Resource Recovery Act, P. L. 91-512) provided the means and authority to promote the demonstration, construction, and application of improved solid waste management and resource recovery systems.

Under the legislation, public and nonprofit agencies can procure Federal aid to study or test promising approaches that may provide actual operating examples of effective solid waste *management*. This involves: controlling the quantity and characteristics of wastes; efficiently collecting those that must be removed; recycling those that can be reused; properly disposing of those that have no further use.

A vital sequel of the demonstration grant program is to motivate productive interchange between the grantees and communities facing similar solid waste problems and to encourage widespread application of new and improved techniques. We hope that mechanisms such as the symposium and these proceedings will further a primary program objective--disseminating the results of demonstration projects to those active in the solid waste field.

--SAMUEL HALE, JR.
Deputy Assistant Administrator
for Solid Waste Management

PREFACE

IN MAY 1971, 5 years after the solid waste demonstration grant program was initiated, the Office of Solid Waste Management Programs convened a meeting in Cincinnati to provide a forum for status reports and discussions on projects considered to offer the best potential for the future transfer of improved technology. For the 3-day technical symposium, 13 projects were selected focusing on the subjects of management systems, collection and transport, processing, resource recovery, and ultimate disposal.

This volume contains the proceedings of that symposium. The intent is to afford readers a better understanding of the work that has been carried out with the support of solid waste demonstration grant funds and insight into the possible applicability of the work to the solution of their own solid waste management problems. The projects and studies discussed range from descriptions of a mechanized collection vehicle that uses a telescoping arm to empty refuse containers to descriptions of full facilities for converting waste to useful products, as reclaimed materials or power.

The Office of Solid Waste Management Programs is indebted to the speakers--the project directors and the project consultants--for their participation in this symposium. Special acknowledgment is due Frank Bowerman, Director, Environmental Engineering Programs, University of Southern California, who monitored the entire symposium and provided the summation; to Harold Gershowitz, Executive Director, National Solid Waste Management Association, and Stuart Eurman, formerly Executive Director, Metropolitan Planning Commission Kansas City, who along with myself, served as the session moderators; and to Thomas C. Jones, U. S. Environmental Protection Agency, who coordinated the symposium.

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SANITARY LANDFILL OPERATIONS IN ABANDONED STRIP MINES

*Ward Barstow**

IN JULY 1966 the Maryland State Department of Health, through its Division of Solid Wastes, submitted an application for a Federal grant to demonstrate whether or not abandoned strip mines could be efficiently used to dispose of solid waste.

There are approximately 2,300 abandoned strip mines in the two westernmost counties of Maryland. Over the years, mining companies have purchased large tracts of land in Allegany and Garrett Counties, excavated huge trenches to reach a coal seam, and removed several feet of coal. The trenches were left open and the spoil, or the dirt removed from above the coal seam, was left piled around the open ditches.

DEFINING THE PROBLEM

Abandoned strip mines have long been a blight on the otherwise picturesque western Maryland countryside. Their very presence seems to typify the poor socioeconomic plight of persons residing in this area. In addition, water that drains into these huge gullies finds its way to nearby surface streams and is a major contributor to acid water pollution.

The Maryland State Department of Health felt that the use of abandoned strip mines for the disposal of solid waste could help in the elimination of three major problems:

1. The stripped out areas could be filled in with refuse and the spoil material used as cover to result in a landscape that blends in with, rather than detracts from, the surrounding area.
2. Drainage of acid mine water could be reduced or eliminated. The accepted sanitary landfill procedure of cutting diversion ditches around the operation and compacting and covering the refuse with compacted earth on a slope to allow rainfall runoff

* Maryland State Department of Health and Mental Hygiene, Division of Solid Wastes.

should eliminate acid mine water drainage originating from runoff from surrounding areas. There is also the possibility that water draining from drift mines, shaft mines, and other strip mines could be channeled through the buried organic matter, which could then act as an oxygen scavenger and acid buffer to immediately retard acid formation from these sources.

3. The strip mines could provide sites for the ultimate disposal of solid waste. Strip mines in fact have certain inherent advantages. They normally are remote and outside the range of neighborhood objection. They are within easy access to haul routes, since it was originally necessary to construct access facilities so that the coal could be economically hauled from the areas. Cover material, the spoil from the strip mine operation, is immediately available. And lease or purchase is economical, since no other use exists for the defunct mines.

OBJECTIVES OF THE PROJECT

The original objectives of this project were: (1) to determine the correct procedures, equipment, and operating techniques for efficient year-round use of abandoned strip mines for solid waste disposal; (2) to determine any special precautions needed to prevent ground or surface water pollution caused by water leaching through the fill; (3) to determine the effect of sanitary landfill operations on acid formation; (4) to determine unit costs for disposal of solid waste under desirable conditions; (5) to determine the unit capacity of strip mine landfills when used for disposal of solid waste; (6) to locate the abandoned strip mines in Maryland that are suitable for waste disposal and to estimate their capacity for solid waste disposal.

The following objectives were included after the first project year: (1) to determine if persons from the Work Experience Program can be employed at sanitary landfills; (2) to determine if a State regulatory agency can actually operate a facility within the limits it sets for those it regulates; (3) to determine if it is possible for several solid waste producing areas (town, county, State or interstate areas) to proportionately share the capital costs of such a facility if the operating costs are borne by a central authority; (4) to determine if it is feasible to institute an area-wide cleanup and dump-elimination program in conjunction with a solid waste disposal facility open to the public during normal working hours; (5) to determine the type of data that should be collected at all central disposal facilities; (6) to determine if it is feasible to provide intermediate disposal facilities for those who cannot visit the established landfill during normal working hours.

PRELIMINARY NEGOTIATIONS

The Maryland State Department of Health received notification on November 3, 1966, that a grant for the project fiscal year of November 1, 1966, through October 31, 1967, had been approved. At that time it became necessary to secure agreements from local supporting agencies (the town of Frostburg and Allegany County) to contribute approximately one-third of the operating cost of the initial sanitary landfill.

Objections to the installation of the solid waste disposal facility were voiced by local organizations, service groups, and news media. Representatives of the Division of Solid Wastes of the Maryland State Department of Health attended numerous meetings to convince community leaders that the proposed facility was not to be just another dump. While most groups adopted a wait-and-see attitude, the Frostburg City Council and the Allegany County Commissioners agreed to appropriate $13,200 to the Maryland State Health Department towards its share of the demonstration project. In return, the State Health Department agreed to accept solid waste generated within the boundaries of the city of Frostburg and from surrounding areas of Allegany County. It took several months to convince the local citizens' organizations and the councils of Frostburg and Allegany County that this facility would be an advantage rather than a detriment to the community. Finally, an agreement was negotiated and signed by Frostburg, Allegany County, and the Maryland State Department of Health specifying the responsibilities and privileges of each participant.

The next step was to approach one of the local mineral landowners to negotiate a deal for the use of his stripped out property for the project. Again, much resistance was met; but probably because of the groundwork that had been laid, the company's representatives were convinced that this use of the stripped out areas would benefit all concerned. After the approval of the State Department of Water Resources and the State Bureau of Mines was secured, an agreement was made to use a stripped out area southeast of Frostburg as a sanitary landfill. Incidentally, both the State Department of Water Resources and the State

Department of Mines gave their wholehearted approval to this project.

Once agreements had been signed and a suitable site selected, the site had to be prepared for an acceptable solid waste disposal facility. The selected strip mine is located approximately 1-1/2 miles southeast of Frostburg and adjacent to the Maplehurst Golf Course. The abandoned mine is 1,900 ft long, 50 ft wide at the bottom, 110 ft wide at the top, and from 35 to 50 ft deep.

The first truckloads of refuse were deposited in the strip mine on April 1, 1967. There were several reasons for the delay between the date of award of the Federal grant and date of initiating operation of the landfill. A public relations program to sell local citizens on the project had to be completed. A legal instrument designating the privileges and responsibilities of Frostburg, Allegany County, and the State of Maryland had to be drawn up and approved by all three government agencies. The original budget had to be completely reworked to reflect necessary changes in receipts and expenditures when it became apparent that the original budget statement was inaccurate in many respects. And finally, the changes had to be approved by the Public Health Service even though the total amount of the grant was not affected. From the outset a sampling program was instituted to determine what effect, if any, the landfill would have on the bacteriological, mineral, and chemical content of underground streams. Nearby wells were first sampled before any refuse was deposited. Samples are now being taken on a regular basis and will continue even after the project is completed. An experienced bulldozer operator had to be found, hired, and trained in landfill operation. Specifications had to be prepared, and bid proposals accepted for equipment needed at the site. Work also had to be completed on preparing the site for acceptance of the solid waste.

SITE PREPARATION

When the site was investigated during the summer of 1966, the pit was dry. After runoff from melting winter snows and early spring rains found its way into the pit, however, there was about 5 ft of standing water in the strip mine.

Since the 24-in. layer of coal removed from this strip mine rested on solid rock, it was necessary to use dynamite to construct a 300-ft drainage ditch. After most of the water had been drained the resulting condition of the pit dictated that additional work be done to stabilize the base of the mine and to slope it so that any new water would drain to the drainage ditch. All standing water in the strip mine resulted from either direct precipitation or runoff from surrounding areas. A simple diversion ditch constructed along the top edge of the strip mine eliminated the runoff problem, and proper operation, particularly in compacting and sloping the cover material of the landfill, has permitted access to the fill during all types of weather for the entire period the fill has been in operation. Since it was anticipated that snow would probably become a major factor during the winter months, the fill operation was started at the highest end of the strip pit so that the length and degree of the slope of the access ramp could be kept to a minimum and facilitate the runoff of surface water.

Not until late April was the base of the strip mine prepared for acceptance of solid waste. According to the terms of the agreements with Allegany County and the City of Frostburg, however, refuse was to be accepted from these two sources by April 1. Adjacent to the main pit there was a smaller pit 100 ft long, 75 ft wide, and 12 ft deep that was used as a sanitary landfill to dispose of refuse during the 3-week period when the main pit was still being prepared. This landfill was completed by the end of April, covered with 2 ft of compacted earth, and seeded. The blending of this completed landfill with the surrounding landscape has aided tremendously in our area-wide public relations campaign. Visitors to the site have been able to observe the excellent operation of the facility and at the same time to get an idea of how the area will look when the landfill is completed.

OPENING OF THE FACILITY

By March, operation had begun at the original site. Refuse from about 16,000 inhabitants of the city of Frostburg and the surrounding Allegany County area was accepted when brought in during normal working hours. Refuse received at the site was compacted and covered at the end of each day's operation, according to accepted procedures of sanitary landfill operation.

When the landfill was opened to receive refuse on April 1, the only assets we had were a D-4 bulldozer, a tractor operator with no previous experience in landfill operation, a person assigned from the Work Experience Program of Allegany County, and the realization by the State Health Department's Division of Solid Wastes that the landfill operation was necessarily the best operated refuse disposal facility in Maryland. During the first 2 months of operation, considerable time was spent picking up paper and debris and using picks and shovels to keep the area neat. Such action was felt necessary to set the pace for the operation of a model sanitary landfill. During April and May 1967, extremely heavy winds at the site coupled with the inexperience of the operators of the facility could very well have caused the proposed landfill to become just another open, blowing dump.

Each day during the first 2 months, at least one representative (and usually more) from the groups opposing the landfill visited the site--obviously to prove to themselves that they were correct in opposing it. Within a few months, however, the original opponents came to realize what a properly operated sanitary landfill is. As a direct result of the early efforts of our personnel, the individuals and organizations who most objected to the establishment of this facility have now become its greatest admirers. They speak in an amazed tone when they say such things as, "I drove in unannounced and didn't even see so much as a gum wrapper."

Meanwhile, the Allegany County Health Department opened a campaign to remove all haphazard and illegal dumps in the surrounding areas. A truck with three laborers financed by the county visited all of the 87 roadside dumping areas within 6 miles of the sanitary landfill. Refuse that had accumulated at these sites over many years was shoveled onto the dump trucks and hauled to the Frostburg disposal site. Dirt was placed over the abandoned dumps and signs were posted informing persons that dumping was no longer permitted at these sites. During this entire period, a concentrated newspaper, radio, and television campaign was waged to inform the public that the laws against haphazard dumping would be enforced and that a sanitary landfill had been established in the area. So far, 24 of the 87 dumps have been eliminated.

Although weighing facilities were not yet present at the site, we attempted to estimate the amount of refuse that was being received at the site during the first 5 months of operation. The County Roads Department and the County Health Department have confirmed that haphazard dumping in the area has decreased during these same months.

DEVELOPMENT OF ADMINISTRATIVE FACILITIES

During the first 2 months of operation most efforts were directed toward establishing a true sanitary landfill operation. During this same period, however, specifications were being drawn for bid submissions on the water system, sewerage system, platform scales, and administration building. When bids on the administration building came in almost 50 percent higher than expected, and when representatives of the Maryland State Department of Water Resources advised us that the first available water strata lay below an underground shaft mine, our thinking had to be reevaluated.

Investigations revealed that an office trailer could probably be purchased for somewhat less than what was originally estimated for an administration building and almost half of what a new building would cost under the terms of the lowest bid received. A trailer also has the advantage of being easily moved from one site to another. Bid specifications were drawn up and a bid was accepted on an office trailer measuring 10 ft by 36 ft. The trailer includes two desks and chairs, electrical wiring and lighting, refrigerator, shower, toilet, wash basin, drafting table, two heat pumps, and a storage locker. The total cost for this facility is $3,820.

A half-acre farm pond located within 400 ft of the site of the office trailer contains about 8 ft of water. Analyses of water samples indicated that, with treatment, this pond could be our source of water. Bids were let for equipment to pump, pipe, and treat this water. The equipment included a 1/3-hp. centrifugal pump, a positive displacement hypochlorinator, and a pressure anthracite filter. The water supply system, was constructed under permit from the Allegany County Health Department, using as labor personnel of the department and employees at the sanitary landfill. Although so far all samples collected in the trailer have tested negative for organisms of the coliform group, this water system has not yet been certified as a potable water source because of the turbidity that still remains.

Bids were also prepared and the low bid accepted for construction of an underground sewage disposal system. A permit has been issued by the Allegany County Health Department.

Meanwhile, the various types of truck scales available were discussed with several scale companies, and it was concluded that a Thurman portable truck scale would be best suited to our needs. The scale selected has an 80,000-lb capacity and its platform measures 10 ft by 25 ft. The platform was installed, ramps were constructed for access and egress by the vehicles, and the area under the scale platform was boxed in using old railroad ties. A time and date stamping device was also installed so that weights and quantities of refuse received at the site could be correlated with the time it was brought in.

To fulfill the objectives of the first phase of this demonstration project, it was necessary to collect additional data on which to base conclusions. In determining what data should be collected for future analysis, the need for uniform data collection throughout the State was considered. In other words, though the data collected at the Frostburg landfill has a direct bearing on the conclusions reached about the operation of this particular facility, the aim is to develop a system that can be used at all major refuse treatment, transfer, and disposal facilities in Maryland. After a thorough study of the type of data that is particularly required for this site, for those developing a comprehensive statewide plan, and for those planning or operating major refuse facilities, it was determined that in addition to the weight, time, and date, the following information should be collected: vehicle number, vehicle type, type of refuse, source of refuse (the general area from which the refuse is received), and weather conditions (including both temperature ranges and precipitation).

While the type of data was being determined, various methods for collecting this information were also being considered. After investigating many methods of data collection, it was concluded that the most efficient would be to code the information so that it could be printed directly on data processing cards. The cards could be processed through a keypunch machine with a keypunch operator reading the material from the card and punching the data into the same card. It was also concluded that the best way to print this information on the card was through the use of a designating key module. This piece of equipment consists of a keyboard (somewhat resembling the keyboard of a calculator) of 10 columns each of which contains digits 0 through 9. This machine is attached in a vertical position directly beside the dial face of the scale. Numbers punched on its keyboard will print out on paper inserted under its stamping device.

The operation of the designating key module was correlated with the design of data processing cards and the administration of the facility so that the following routine of data collection is practiced:

1. The loaded collection vehicle drives onto the scale platform.
2. The weighmaster observes the number of the vehicle and sets the scale fulcrum for the empty weight of the vehicle. Where the empty weight is not known the weighmaster records the gross weight as the vehicle passes over the scale, and the tare weight when it returns from the landfill. The tare weight is then subtracted from the gross weight to give the net weight of the refuse received at the site, and the tare weight of the vehicle is recorded on a separate sheet for

future reference. Variances in the number and weight of the occupants of the vehicle and variances caused by modifications in the vehicle will probably even out in the long run. Random samples of tare weights of vehicles will, however, continually be checked throughout the project period to determine if variances in the tare weights of the vehicles fall within reasonable confidence limits.

3. Keys on the designating key module are then depressed by the weighmaster to reflect the information to be recorded by that device.
4. The data processing card is inserted into the guide area.
5. The button on the scale is depressed, activating the machinery that prints out the weight and coded factors in the appropriate spaces on the data processing card, and the vehicle is waved off the scales.
6. The card is inserted into the time and date machine so that this information is printed in the appropriate spaces on the card.
7. The cards are stored for later punching by the keypunch operators for ultimate data retrieval.

Although a computer program for data retrieval has not yet been developed, it was evident that if this data collection and retrieval system were to blend in with information collected at other major refuse facilities throughout the State, it would be necessary to establish a statewide solid waste facility permit system, with the permit numbers designating such things as year of issue, county and election district in which the facility is located, site number within the county, and type of facility. The purchase and installation of this data collection system costs \$6,758 (\$6,271 for the portable platform scales, \$262 for the designating key module, \$75 for the time and date recorder, and \$150 for 100,000 data processing cards).

COSTS

By using the scale, it was possible to keep records in relation to cost per ton. During the first year and a half or so of this project, cost figures could not be calculated as accurately as desired because both site Nos. 1 and 2 were placed in operation before the scales were installed. Every effort was made, however, to keep as accurate records as possible. It is interesting to note that during the project's 5-year life, the population presently being served by this facility has increased from 16,000 to more than 50,000, and that the tonnage has increased from 30 to 40 tons a day to as much as 300 to 500 tons a day, (approximately 30 or 40 percent is industrial).

During 1970, the project operation cost was $1.45 per ton, which includes amortization and interest on capital expenditures, and direct operating costs. Some items that are acceptable at a demonstration project of relatively short life cannot, however, be considered for a new model facility. The $250 surplus dump truck, for example, would be replaced by a new truck costing $13,000 to $15,000. A more substantial equipment service building, separate sanitary facilities for landfill operating personnel, and sanitary facilities for delivery truck drivers are additions to the site development that can be expected at a sanitary landfill that is not established as a demonstration project. Conversely, the amortization period for the site development costs would be extended for a longer fill life, which would help to offset these additional costs.

ACID MINE DRAINAGE STUDIES

In compliance with the requirements of the grant for the Allegany County project, the first of six filter beds were constructed at site No. 2 in Westernport. The first filter bed test pit was filled on January 18, 1969 (Figure 1). The purpose of these pits was to determine what effect acid mine drainage would have on different types of solid waste.

A total of 362,380 lb of general refuse was compacted in this bed with a compaction rate of nearly 1,000 lb per cu yd. This bed was then sealed with a plastic cover and no water was pumped into it until June 16. At this time, 7,500 gal were pumped into the pit. On June 23, 2,250 gal were again pumped. Starting on July 9, 500 gal were pumped each day until July 18. Again on July 21 and 22, 500 gal were pumped.

Initially very little effluent passed into the septic tanks and sand filter on the downstream side. The pH of the acid mine water was raised from an average of 3.7 to about 5.9 (Table 1).

In passing through the test pit, most of the yellow color and slime growth that was due to the iron and sulfur was removed from the water. Chemical samples have been collected for analysis, but at this writing, the results have not been released by the laboratory. Extreme organic interference was noted in some of the initial tests. Considerable odor was also noted.

Preliminary observations indicate an initial enhancement of the pH with an accompanying removal of iron. There is also a degradation of the water through formation of the organic acid

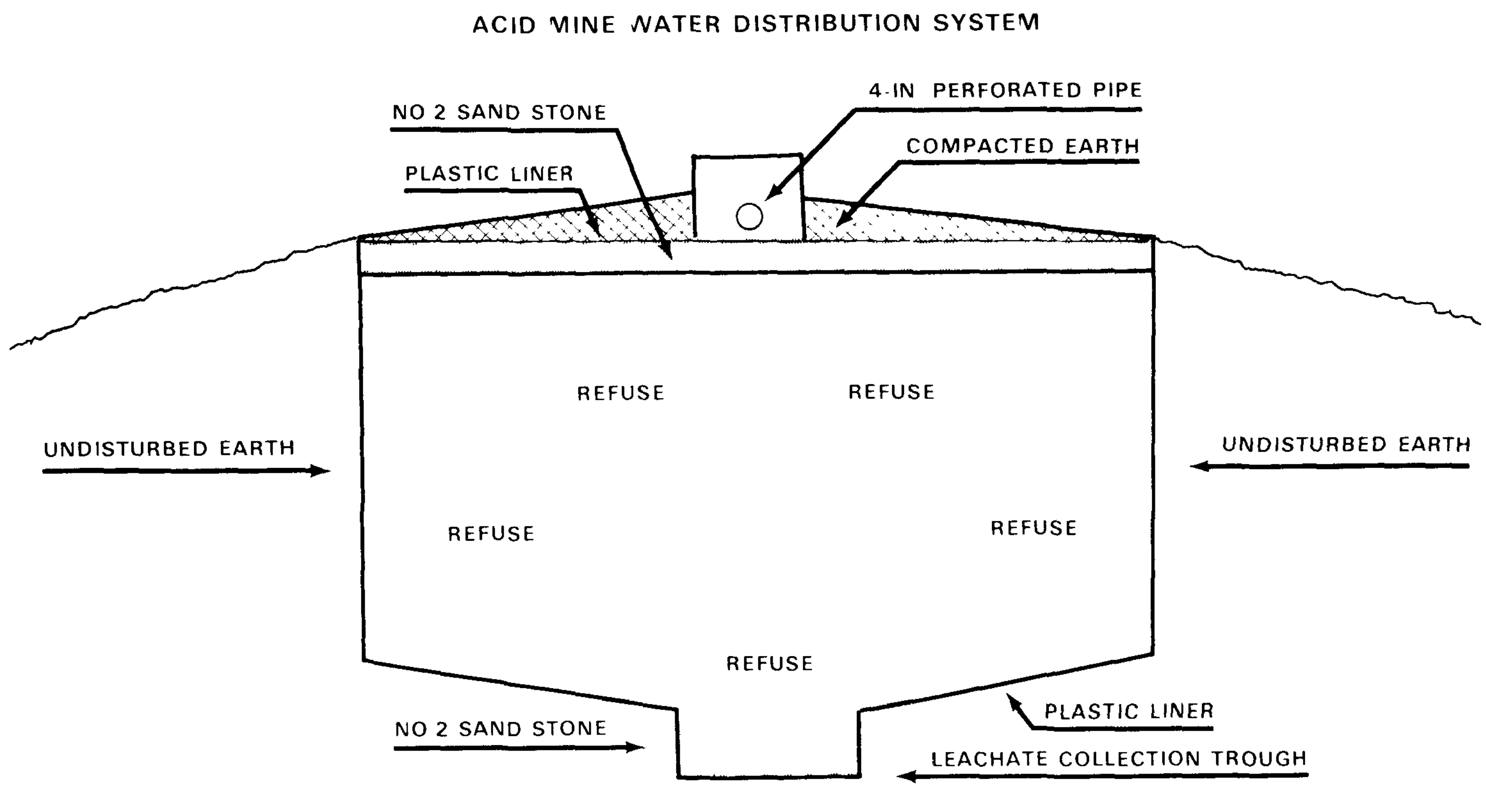

Figure 1. End elevation of experimental filter bed at site No. 2, Westernport. Pit is 100 ft long, 6 ft deep, and 15 ft wide. Leachate is conveyed to a collection box consisting of a sand filter and Cl_2 contact chamber.

TABLE 1

CHEMICAL RESULTS AND SUPPLEMENTAL DATA FOR FILTER BED STUDIES, JULY 1968

Item	Source					
	Stream		Tank No. 1 before sand filtration		Tank No. 2 after sand filtration	
Day	1	16	1	16	1	16
Color	25	37	60	500	45	55
Turbidity, (units)	20	37	320	180	90	120
pH	3.7	3.6	5.6	5.6	6.0	5.9
Chloride, ppm	42	18	937	834	497	699
Nitrate, ppm	0.04	0.60				
Total solids, ppm	3,274	3,304	46,792	21,842	9,770	13,142
M.O. alkalinity, ppm	-44	-163	4,881	3,596	23,392	2,494
Hardness as $CaCO_3$, ppm	386	883	673	---	---	117
Iron as Fe, ppm	75	85	1,200	650	600	600
Sodium, ppm	23	17	975	1,075	625	775

and other soluable putrescible material, however. On a larger scale, it is felt that this could be controlled economically with chlorine.

Before being discharged, the effluent is run through a sand filter, after which it is retained in a chlorine contact chamber before being pumped into a nearby stream.

Plans are being made to continue these studies during the summer and fall months as long as the weather permits.

RESEARCH STUDIES

During the last 2 years of the project, research efforts have been expanded. Thirteen wells were installed at site No. 1 in an effort to learn more about the possibility of contaminated substances moving through the soil. Three of these wells, designated as landfill observation wells A, B, and C (Figure 2) were installed in the center of the landfill itself. Also, 10 additional ground water observation wells were installed adjacent to the landfill on the north side.

Samples collected from the ground water wells on the north side of the landfill contained lead and cadmium. The presence of these metals does not confirm that they originated in the

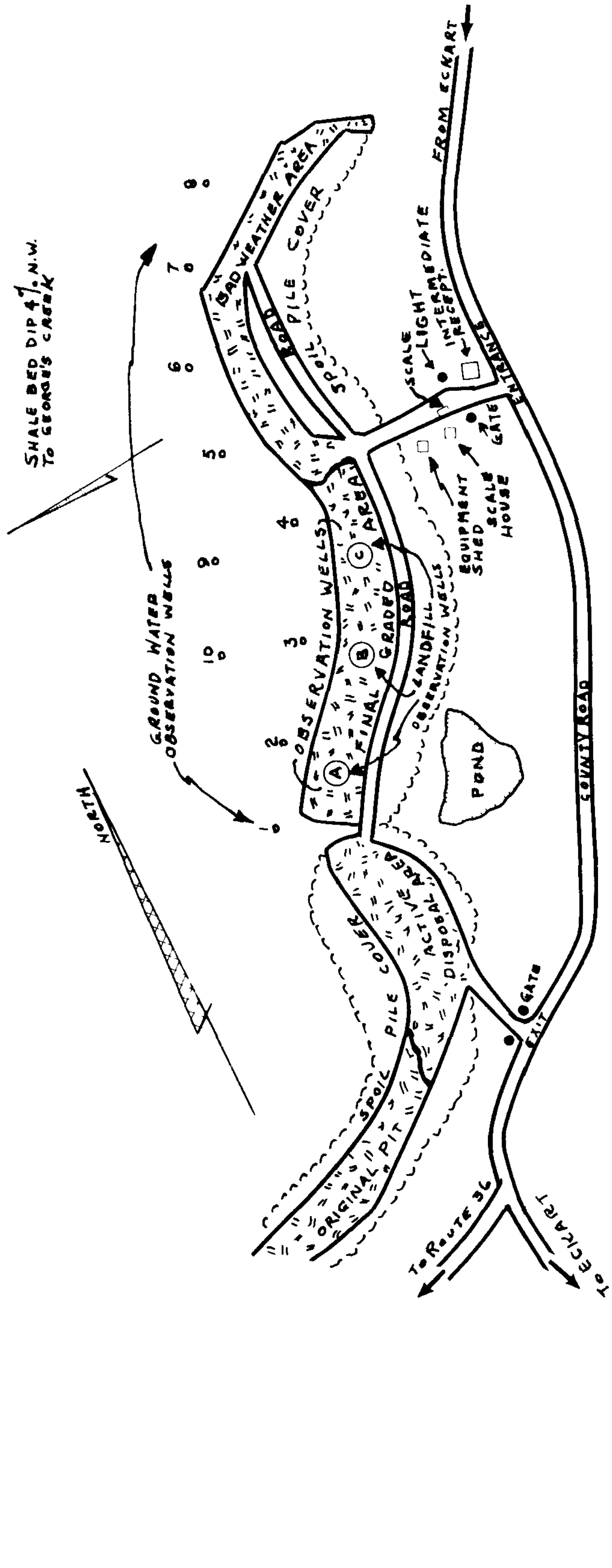

Figure 2. Plan for Hoffman Sanitary Landfill, Allegany County, September 1970.

landfill, since they occur naturally in coal deposits in Maryland, West Virginia, and Pennsylvania.

Neither lead nor cadmium was found in the samples of leachates collected from the landfill wells A, B, and C. Boron tracers seeded in the landfill wells were not found in samples of water collected from the ground water wells. As a result of these studies, it can be concluded that so far there has not been any movement of leachate from the landfill to the ground water observation wells. Samples from these wells will continue to be taken in an effort to note any changes.

Chemical analysis of samples of leachates from landfill wells A, B, and C revealed high levels of phenol, oils, and grease, as well as heavy metals, all of which inhibit the growth of most types of microorganisms. Metabolic inhibitors might very well be present as organic solvents, detergents, strong acids and bases, and organic enzymes.

Interestingly enough, aerobic spore formers were found in this anaerobic environment. It is suspected that these may be faculative anaerobes functioning as aerobes because of the presence of some oxygen.

Limited studies conducted on the effects of percolating acid mine water through accumulations of solid waste on the filter beds at site No. 2 revealed that the resulting filtrate exhibited: (1) a greatly increased iron content, (2) an increase in pH, (3) increased BOD, (4) increase in color by iron and sulphur compounds, and (5) objectionable odors.

CONCLUSION

In conclusion, it should be mentioned that over the past 5 years, this project has set standards for the establishment of sanitary landfills throughout the State of Maryland. As a regulatory agency, the Division of Solid Wastes of the Maryland State Department of Health has benefited tremendously, because the demonstration project provided the opportunity to function as an operating agency and thereby enabled the Division to better understand the many facets of solid waste disposal through sanitary landfilling. As a result of this 5-year experience, we have been placed in a better position to advise and serve the people of Maryland.

This project has been supported by demonstration grant No. G06-EC-00048 from the Environmental Protection Agency, pursuant to the Solid Waste Disposal Act as amended.

RURAL COLLECTION AND DISPOSAL OPERATIONS IN CHILTON COUNTY, ALABAMA

Robert Alexander, Jr., and James V. Walters†*

UNTIL RECENTLY, county engineers in rural areas were seldom concerned with the storage, collection, and disposal of solid wastes. Now those engineers find that like so many other aggravating environmental problems, solid waste management is claiming an increasing amount of their professional time and energy. Few of the rural areas served by public highways have any system for the collection and disposal of solid waste generated by local residents and businesses. Despite the conscientious effort of the vast majority of the rural population to come up with satisfactory methods of waste disposal for individual households, much of this material comes to rest within the rights-of-way of our public highways. Increases in population densities and in the amount of waste generated by each person have combined to cause dramatic increases in the quantity of waste being deposited along our rights-of-way in recent years. Particularly because of the difficulty and cost of removing such materials, county administrators have become much more interested in initiating and operating collection and disposal programs that would prevent such despoilage of our highways.

Project CLEAN AND GREEN is an example of the efforts of one county to solve its solid waste problems on a unified basis. The project represents a partnership of the Chilton County government with the governments of the county's four municipalities, Clanton, Jemison, Maplesville, and Thorsby.

Chilton County lies in the geographic center of Alabama and is traversed by Interstate Highway 65. The Coosa River is its major eastern boundary. Nearly a tenth of its 699-sq mile area lies within the Talladega National Forest. Timber and other agricultural efforts dominate its land use, but the prime economic resources of the county are the many industrial enterprises that have grown up there. The 1960 population of Chilton County

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was approximately 26,000. The approximate population in the incorporated municipalities were: Clanton 5,700, Jemison 1,000, Maplesville 700, and Thorsby 1,000.

ENVIRONMENTAL CONDITIONS BEFORE PROJECT CLEAN AND GREEN

Before Project CLEAN AND GREEN began, the environmental conditions relatable to solid waste disposal in Chilton County were similar to those found in most rural counties of Alabama today. Solid waste in municipalities was being collected house-to-house and disposed of by dumping and burning. Waste generated by rural families was disposed of by the individual householder wherever he could most conveniently throw it, and waste generated by transients was rather thoroughly distributed along the county's highways.

Each of four municipalities operated a dump and burned wastes there to reduce their volume. The odor and smoke from these operations were objectionable, and in each case, the capacity of the site was nearing completion.

In the rural areas, householders had created and used approximately 40 major unauthorized dumps, and many more small dumps were observed along the roads of the county. In an effort to reduce the hazards and undesirable conditions resulting from this large number of unauthorized dumps, the county had previously attempted to encourage the use of dumps in four specific locations where the landowners were agreeable to such use of their property. County equipment was sent periodically to cover the accumulation of waste with soil. With only four dumping areas in the entire county, however, the haul distance discouraged the householders, who mostly ignored the county's efforts and continued to dispose of their wastes at the unauthorized dumps.

The amount of waste generated at the boat landings on the river had prompted the county to locate 55-gal steel drums near the landings and in the adjacent picnic areas. The containers were well received by the public. For several years sportsmen had cooperated by placing wastes in the containers, which were periodically emptied by county personnel. Ultimate disposal was at one of the existing dumps. Another costly service the county was forced to provide was the cleanup of the right-of-way along its highways.

The situation finally caused the governing bodies of the county and its municipalites to come together for serious consideration of their solid waste disposal problem. The factors that compelled them to adopt an improved program of waste disposal were the unacceptable conditions resulting from the unauthorized county dumps and from the municipal dumps, the cost involved in cleaning up solid waste strewn over large areas along the highways, and the relative scarcity of land for future dumps.

COUNTYWIDE SOLID WASTE DISPOSAL SYSTEM

The unsatisfactory conditions caused by dumping and burning, the scarcity of land for future dumps, and the extremely high cost of operating individual sanitary landfills for each municipality led the governing bodies to consider the use of one centrally located sanitary landfill. Because the county also had solid waste disposal problems and because the selection of a central disposal site would necessarily be outside the boundaries of at least three of the municipalities, it was reasonable that the county be chosen for major responsibility in implementing a central landfill project. The responsibility for administration of the operation was placed in the county engineer's office in order that the personnel and equipment of that office might be made available for the construction and other nonroutine activities proposed for the project.

Since the municipalities already owned and operated municipal collection equipment, it was decided that they should continue to be responsible for the door-to-door waste collection within their corporate limits. The cost of door-to-door collection in the rural portion of the county prohibited its consideration. But because the rural householder was already carrying his waste some distance to one of the unauthorized dumps, it was felt that he might be expected to deposit it in a suitable container located at no greater distance than he was accustomed to. Later, the waste could be collected and taken to the central landfill.

The countywide system chosen for implementation includes continued door-to-door collection by the municipalities of waste generated within their corporate limits, collection by the county of rural waste from approximately 60 approved container sites, and satisfactory disposition of all solid waste generated in Chilton County by placement in a central sanitary landfill. Operation of the rural collection system and rehabilitation of all the existing dumping areas was made the responsibility of the county engineer.

Central Sanitary Landfill

The county was fortunate to already own a parcel of land that appeared to be a satisfactory site for the landfill operation. Evaluation of that site was initiated by a survey and topographic mapping of the property. Alabama's State geologist was helpful in evaluating the geology of the plot. To verify his inferences, a subsurface investigation was performed by personnel of the county engineer's office. Soil borings at the site were advanced below elevations to which landfill operations are expected to occur. Soil samples from these borings were analyzed to evaluate their water carrying characteristics and their suitability for use as landfill cover material. The sand-clay soil sampled by the borings performs very well as a landfill cover. The boreholes opened during soil sampling were used for observations of the ground water table. Water table observations allowed planning for all waste to be placed above the existing water table elevations over the proposed fill areas at the site. When full evaluation of the site confirmed its desirability, it was possible to begin site preparation and construction of operating facilities. All other operations of the new system were dependent on the initiation of the central landfill.

For documentation of the landfill operations, it was necessary to install scales to weigh all waste deposited there. The scalehouse was planned to provide shelter and sanitary facilities for landfill personnel and to allow office space for the landfill manager. An all-weather road was constructed to provide access from the nearest paved county road. The access road subsequently has been paved. Fencing was erected to prevent uncontrolled entry to the site and undirected deposition of waste before and after the normal hours of operation. Waste receptacles were installed just outside the gate to allow deposition of waste at those times. The utilities required by the scalehouse were electricity, water, and telephone. The need for gas and sewer services was avoided by the use of electric heaters and a septic tank. The major item of equipment necessary for the landfill operation was the tractor, which was purchased to place, compact, and cover deposited wastes. In addition to the landfill bulldozer, several pieces of county equipment were used for site clearing and road building operations.

The 33-acre landfill site is relatively hilly and is contiguous with both highway I-65 and the county airport at Clanton. Utilization of the site has been planned so that waste will be placed at the lower elevations on the property, and cover material will be excavated from the tops of the hills. The full effect of the plan will be to improve the surface shape of the ground by making it more uniformly sloped, and to uncover two large areas of undisturbed, preconsolidated soil suitable for the support of buildings. The areas that will be filled can be used to store commodities that are not undesirably affected by subsidence of the surface that supports them or for such purposes as playgrounds or parking lots. The improved surface shape and the 3/4-mile proximity to the nearest I-65 interchange should make the undisturbed areas of the site very desirable for the construction of an industrial or institutional facility.

Personnel required to operate the central landfill have been the manager, the operator, and the utility maintenance operator. Under supervision of the county engineer, the manager directs operation of the facility, weighs all wastes deposited, and maintains records of the activity. The operator drives the bulldozer to compact and cover the wastes. The utility operator directs individual trucks to the proper spot for waste discharge, helps maintain the cleanliness of the site, can relieve either of the workers in the event of illness, and performs other duties to be mentioned below in the rural collection operation.

Full operation of the central landfill was begun during September 1968. As soon as the site became available for waste disposal, efforts were turned to closing the existing dumps.

Dump Rehabilitation

From the outset it was apparent that implementing a rural collection system would be pointless unless disposal at the unauthorized dumping areas was terminated. To mark the termination of unauthorized dumping and to remove the hazards that past dumping had created, rehabilitation of the old dump areas was planned. A most important facet of dump rehabilitation was rodent eradication.

Chilton County's sanitarian, Mr. C. C. Gay, Jr., planned this rehabilitation function in conjunction with personnel from the Alabama State Department of Health and from the U. S. Environmental Protection Agency. Their eradication plan called for initial poisoning with red squill in a bait composed of sardines and rolled oats. Secondary poisoning was with Warfarin in coarse corn meal. Evaluation of the effectiveness of the poisoning was to be based on rodent population surveys before and after the poisoning.

When surveys indicated that satisfactory eradication had been accomplished, a bulldozer was brought to the site to bury all waste. The area was then dressed and seeded in a manner that emphasized the posted notice that the area was no longer to be used for the disposal of solid waste.

A D-7 bulldozer was the only equipment required to rehabilitate all but the Clanton dump. There, three bulldozers, two 15-cu yd scrapers, and one motor grader were used to excavate a hole in the middle of the area, move the waste material into the hole, and finally cover the entire area with a graded, compacted soil surface. To date, approximately 50 dumps have been rehabilitated at a cost slightly in excess of $12,500. This cost, including equipment costs, based on national average rental rates averaged about $390 per acre for the 32 acres of dumps rehabilitated.

The rehabilitation of the rural dumps had to wait, of course, until the countywide system of rural collection was in effect and able to provide an acceptable alternative to the old dumps.

Rural Collection System

Several criteria were used in selecting probable container sites. Containers should be located near existing unauthorized dumps to take advantage of the householders' old habits, but they should be far enough away to spacially separate the two concepts of disposal. They should be located within the county road right-of-way and in a position that would pose no hazard either to persons depositing waste or to the driving public. During initial planning for the project, it was not certain whether the State Highway Department and the Bureau of Public Roads would allow the use of their rights-of-way for container sites. Since then, however, an evaluative trial of three such sites has been negotiated. A third criterion was to place a container within 10 min of driving time of the vast majority of the rural homes in Chilton County. The final criterion was that container sites had to be located along a route that could be served by a single piece of collection equipment, since the purchase of two packer trucks would be beyond the financial resources of the county. The distances involved in the tentative collection routes required the use of the largest easily maneuverable loader-packer body available on a standard truck frame. A 30-cu-yd E-Z Pack packer body was chosen for mounting on an International cab-over-engine truck frame. The packer body, truck frame, and sixty 4-cu-yd containers were the equipment originally purchased for use in the rural collection system. By November 1969, 43 container sites had been implemented. The 43 sites accommodated 57 containers and were located in such a manner that 50 percent of the rural households were nearer than 1.6 miles to the closest site, 90 percent were nearer than 3.7 miles, and 95 percent were closer than 4.8 miles. Additional sites have been implemented since then, making a total of 79 containers now in use at 60 sites. A dozen other containers owned by the county board of education are located at schools for their specific use, but the waste is collected by the project's collection truck. To improve the all-weather utility of the rural collection system for the public, all container sites located on county road rights-of-way have been paved.

The essence of the rural collection system is graphically presented in Figure 1. For clarity, only major arteries and roads used as a part of the collection routes are shown.

As it exists presently, the countywide solid waste collection system comprises two collection routes. There are 23 container sites along the northern route, which is approximately 90 miles long. The southern route is approximately 125 miles long and passes 37 such sites. The two routes are serviced on alternate days, thus providing collection from each container three times a week. The personnel assigned to the collection activity and routine maintenance of the packer truck are the packer-truck driver and the utility operator mentioned above who also serves as a relief driver.

It was thought desirable to have a half-ton pickup truck dedicated to the waste disposal operation of the county in order to use it for cleanup around the rural waste-collection receptacles. All personnel of the county engineering department are responsible for observing conditions at the various receptacle sites as they go about their normal duties. Use of a two-way radio system allows immediate reporting of any undesirable conditions and makes possible quick correction of the conditions by the cleanup crew. One or more operating personnel from the landfill perform such cleanup services.

With the beginning of rural collections in January 1969, the entire countywide solid waste disposal system became operational. Experience reported here covers approximately 2 years of landfill operation and about 18 months of rural waste collection.

During the first 20 months of sanitary landfill operation, 5.2 acres of the site received 12,100 tons of waste, which occupies a volume of 19,100 cu yd. The average density of the waste as compacted is approximately 1,270 lb per cu yd. About 28,300 cu yd of soil were used to cover the deposited wastes. Though such a volume

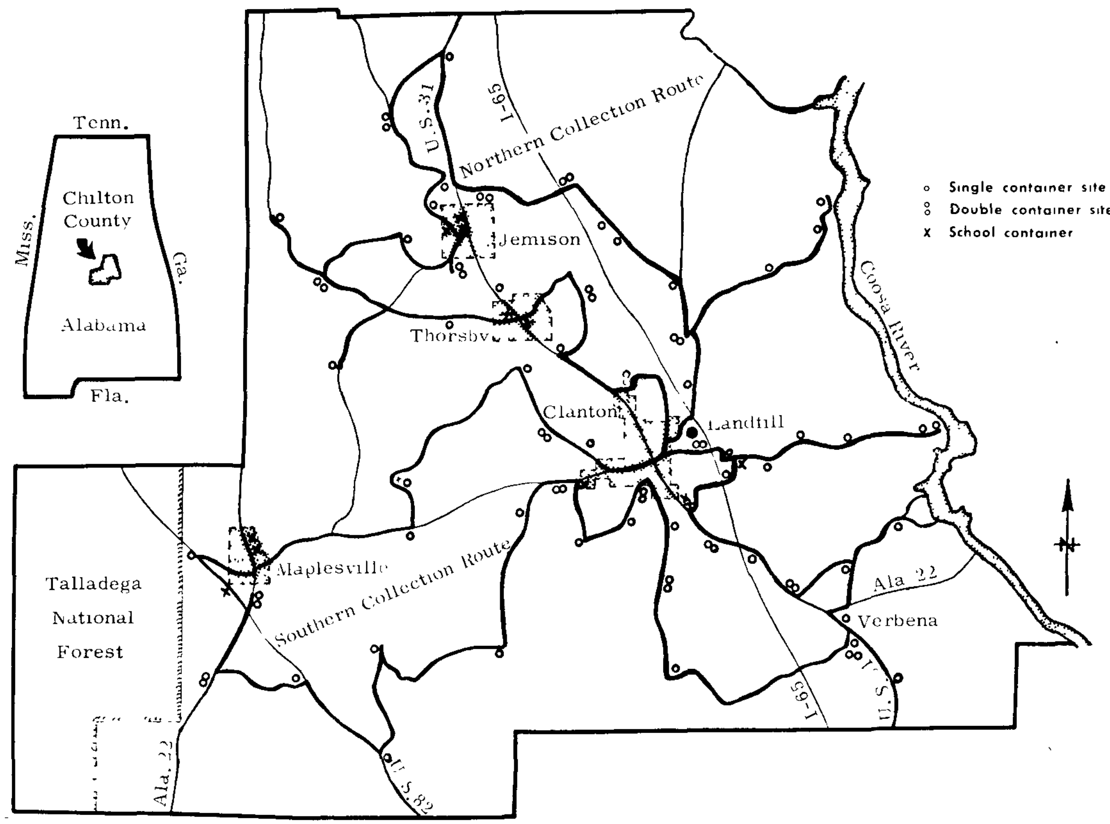

Figure 1. Rural collection system, Chilton County, Alabama.

of cover material may seem high, about 6,000 cu yd of this soil were used to construct a barrier between the exterior of the first (and lowest) landfill cell and the creek. The average thickness of the barrier wall is about 15 ft. Even allowing for that construction, the volume of cover material used is excessive. But for this particular site, the only cost of fill is the cost of tractor fuel, and selected excavation of the higher elevations on the site does result in ultimate site improvements.

The cost for a typical month of operation is about $6.75 per ton for the rural collection system (Table 1) and about $2.06 per ton for the central sanitary landfill (Table 2).

The trend since the beginning of the countywide system has been for the amount of rural waste collected to increase from month to month. Since, however, the major cost items are relatively independent of the amount of material handled, it is anticipated that unit costs for rural collection will be somewhat reduced before the system reaches its capacity. (Increased demand for service is one result of initiating such a system.) The effect of increased utilization of the system on the unit cost is dramatically shown by comparing the unit cost for the month shown in Table 1 ($6.75 per ton, 184 tons of waste collected) with the unit cost for the same month during the previous year ($10.17 per ton, 116 tons of waste collected). One portion of the cost that is not known with certainty is depreciation. For instance, the estimated life for the rural packer truck was set at 6 years. If this estimate proves to be inaccurate, depreciation cost would vary from those presented.

Other results of the rural waste collection system are less technical and much more readily recognizable. Anyone riding through Chilton County before and after the beginning of Project CLEAN AND GREEN could surely see the difference in a countryside now free of dumps. Anyone familiar with the former open burning municipal dumps would readily notice the cleaner air. Crews responsible for mowing highway right-of-ways have given unprompted reports of the dramatic decrease in cans, bottles, and parcels of waste they encounter daily. The most important overall result of Project CLEAN AND GREEN is that it demonstrates the availability of a practical countywide solid waste disposal system that almost any rural county can afford to adopt.

TABLE 1

COST OF RURAL WASTE COLLECTION FOR A REPRESENTATIVE MONTH*

Item	Amount
Labor	$ 454.12
Fuel and supplies	198.59
Repair and maintenance	171.00
Equipment depreciation	373.82
Supervisory costs	45.00
Other	0
Total cost	1,242.53
Total unit cost per month	6.75 per ton

*Based on a total of 184 tons of collected waste.

TABLE 2

COST OF CENTRAL SANITARY LANDFILL OPERATION FOR A REPRESENTATIVE MONTH*

Item	Amount
Labor	$ 649.12
Fuel and supplies	47.17
Utilities	77.14
Equipment repairs	6.71
Equipment depreciation	521.85
Supervisory costs	350.00
Total cost	1,651.99
Total unit cost per month	2.06 per ton

*Based on a total of 803 tons of deposited waste.

This project has been supported by demonstration grant No. G06-EC-00178 from the Environmental Protection Agency, pursuant to the Solid Waste Disposal Act as amended.

FIBER RECOVERY THROUGH HYDROPULPING

*Bernard Eichholz**

THIS IS THE STORY of the solid waste disposal and reclamation facility being built by the city of Franklin, Ohio, with the assistance of the Federal Office of Solid Waste Management Programs. Located in southwestern Ohio in the valley of the Great Miami River, Franklin is a small city of 10,000. About 4 years ago, it became apparent that Franklin was rapidly exhausting its solid waste landfill. Concerned city officials, and in particular, councilman Joe Baxter, Jr., decided to investigate the possibility of pulping solid waste using paper mill equipment, removing the metal and glass centrifugally, and dewatering and burning the remaining material in a fluid bed reactor. Mr. Baxter is an engineer with the Black Clawson Company, a company engaged in the manufacture of papermaking machinery in Middletown, Ohio, 5 miles from Franklin.

The Great Miami River Valley is dotted with paper manufacturers who located in the valley to avail themselves of the plentiful underground water. This abundant supply of underground water provides not only the huge volumes of pure water necessary for the paper manufacturers, it is also the source of water supply for some 1.5 million persons living in the valley. Under these circumstances, landfilling of solid waste could be a potential health hazard to the millions of persons whose water supply might be polluted by the decaying garbage.

ESTABLISHING AND DESIGNING THE SYSTEM

The idea of pulping solid waste was presented to the Federal Office of Solid Waste Management Programs, and as a result, Franklin received a grant to design and construct this innovative facility. The Black Clawson Company set up an operational pilot plant in their Middletown plant as an aid to the design and eventual operation of the Franklin facility. The city retained A. M. Kinney, Inc., consulting engineers, Cincinnati, Ohio, to design the plant and

*City manager, Franklin, Ohio.

oversee its construction, since this firm had been instrumental in the development of the Hydrasposal process.

Suprisingly, the scope of the project began to expand. The Black Clawson engineers wondered if paper fibers from the waste could be reclaimed, since 50 percent of municipal solid waste is paper. A. M. Kinney, Inc., was therefore retained to design a fiber reclamation system to be integrated with the Hydrasposal system. The fiber reclamation system will extract reusable fiber along with metals and glass. The possibility of extracting glass attracted the attention of the Glass Container Manufacturers Institute. Now the City and the Glass Container Manufacturers Institute, with financial assistance from the Office of Solid Waste Management Programs, are adding a glass sorter that separates the aluminum from and then sorts the glass into three colors: clear, amber, and green.

The Franklin Environmental Control Complex

During the preliminary studies it was discovered that sewage sludge--raw, digested or activated--could be mixed with the organic waste from the solid waste operation, dewatered without coagulants, and disposed of with the organic waste.

Armed with this knowledge, Franklin began planning for a new sewage treatment plant that would save the construction and operating costs of sludge digestion facilities. The Miami Conservancy District, Dayton, Ohio, a public authority responsible for water resource management in the Miami Valley, proposed that the District design, build, own, and operate a regional waste-water treatment plant alongside and in conjunction with the new solid waste plant. Necessary authorizations were obtained, and the Franklin Environmental Control Complex was born.

Approximately 230 acres of land on the outskirts of Franklin, very close to the existing inadequate sewage treatment plant, were made available to the Conservancy District. The District acquired the property and then leased to Franklin a couple of acres upon which to construct the solid waste plant.

The two plants will in fact be right next to each other. From a process standpoint, the liquid and solid waste plants are mutually dependent upon each other.

- Process and scrubber water for the solid waste plant will be effluent from the secondary clarifiers.
- Waste process water, about 50 gpm, from the solid waste will be treated in the water treatment plant.

- Primary and secondary sludge from the water treatment plant will be mixed with organic waste of the solid waste plant and burned in the fluid bed reactor.
- Ash containing scrubber water will be mixed with the industrial waste water and used as a settling agent in the industrial clarifier.
- The two plants will share certain common services--potable water, fire service, access road, etc.

There obviously will be some clean, washed, inorganic residue remaining from all this processing--perhaps about 5 percent of the original volume--and this can be safely and sanitarily landfilled in an area adjacent to the solid waste plant.

Still another very vital function for the combined facility will be the disposal of residues consisting of crank-case oil, spray booth offals, and other nonaqueous liquid wastes. They are normally dumped and cause serious ground and water pollution problems. It is believed that the fluid bed reactor installed in connection with the solid waste disposal facility is also capable of disposing of these liquid industrial residues, and a program for testing this feature of the facility is included in the design.

The fluid bed reactor is a type of furnace uniquely suited to burning the unsalvageable portion of municipal and industrial waste. In our case it is a vessel approximately 24 ft in diameter and 30 ft high. There is a perforated plate in the bottom covered with about 4 ft of sand.

During operation, air is blown through the perforated plate and up through the sand to keep the sand in suspension. At first the fluidized sand is preheated to 1,200 F by oil burners. Then the refuse is introduced into this hot fluidized bed. As the minute grains of sand come into contact with the finely chopped waste material, the result is complete incineration. Combustion of the waste maintains the temperature, and no further addition of heat is required. The products of combustion are discharged from the reactor at 1,500 F, which is sufficient to eliminate all odors. These gases are then cooled and washed with water in a scrubber to remove the ash.

Because of the publicity received by this facility, inquiries have come from persons and businesses all over the world who are seeking a place to dispose of their waste--truly a growing problem, soon to reach crisis proportions. These inquiries reveal the glaring fact that most of the inquirers have been dumping their waste in hollows, creek beds, etc. Now, at long last, the spotlight is revealing their actions and nature is rebelling.

ESTIMATED COSTS

Estimated construction cost for the Hydrasposal plant is $2 million. The glass sorter alone will cost $225,000. These estimates do not include the adjacent regional sewage treatment facility being constructed by the Miami Conservancy District.

The plan is to start operations in June 1971, with a disposal charge of $6 per ton. The economics of the plant are such that if Franklin were a larger city, this unit cost could be reduced to as low as $3 per ton. In fact it is possible that even Franklin might receive a great enough volume of solid waste to result in a rate of $3 per ton. Obviously, if the volume justifies a second 8-hr shift, the economics change radically, since the fixed charges, such as amortization, insurance, demand electrical charges, etc., can be spread over two shifts.

PLANT OPERATIONS

The Franklin solid waste plant will very nearly duplicate the pilot plant (Figure 1). Essentially unsorted municipal refuse is loaded onto a conveyor and fed into a specially modified Hydrapulper. Pulpable and friable materials are reduced in size until they will pass through the 3/4-in. diameter openings in the extraction plate beneath the rotor. They are then pumped away as a slurry of 3 to 3.5 percent consistency.

Nonpulpable materials, mostly tin cans and other ferrous objects, are ejected from the side of the Hydrapulper into a continuous junk remover. The tin cans are balled up, and wire and other small objects cut into small pieces. This material is washed and the ferrous metals removed magnetically.

The slurry from the pulper is then subjected to a number of rather typical papermaking operations. The first step is to remove larger inorganic particles in a Liquid Cyclone. The inorganic rejects from the Cyclone contain about 80 percent glass and 20 percent aluminum, other metals and just plain dirt. The glass concentrate will be cleaned and sorted for recycling as described later in the paper.

The next operation is to defiber small pieces of paper and to screen out nondefiberable organics such as plastic, leather, textiles, twigs, etc. This is accomplished in a V R Classifiner, which has a high-speed rotor operating against a screen with 1/8-in. diameter perforations.

Figure 1. Partial view of pilot plant showing Hydrapulper in background.

The material that passes through the 1/8-in. perforations is diluted to a .5 percent consistency, then passed through a conventional paper mill screen with 1/16-in. openings. The balance of the stringy, nonpapermaking fibers are removed in this operation.

Very fine sand and shives are next removed in centrifugal cleaners, and the cleaned slurry is passed over a surface screen to remove fine fibers, etc.

The rejected material from the three screens and the centri-cleaners, mostly nonrecoverable organics, is combined with sludge from the sewage treatment plant, dewatered to about 40 percent solids in a press, and burned in a fluid bed reactor.

The accepted stock from the last screen is dewatered, cooked in mild caustic, washed, dewatered and baled for shipment.

Figure 2 shows the completed Franklin plant.

The plant is designed for a nominal capacity of 150 tons of municipal refuse per 24-hr day. Current plans are to operate only 8 hrs per day. It is anticipated that the following materials will be recycled per 8-hr day:

Paper fiber	8 - 10 tons per day
Ferrous metals	4 - 5 long tons
Glass cullet	2 - 3 tons (future)
Aluminum	400 - 500 lb (future)

Liquid Waste Processing

The Miami Conservancy District, under the leadership of Wesley A. Flower, Chemical Engineer, designed the wastewater treatment plant to incorporate the newest technologies and to take advantage of the adjoining solid waste plant. The basic flow sheet is shown in the upper portion of Figure 3.

Municipal waste water will be introduced from the existing collection system and pass first into a conventional gravity clarifier with flocculation chamber. Detention time is 3 hr. Via a junction chamber, the clarified overflow then will be passed through three aeration basins in series for secondary treatment. Each basin has a capacity of 9 million gal. Basin No. 1 has two 75-horsepower fixed aerators, Nos. 2 and 3 have two 50-horsepower fixed aerators each. The basins are of earthen construction with clay seal, and aerator agitation is designed to prevent settling. Retention time is 6 days.

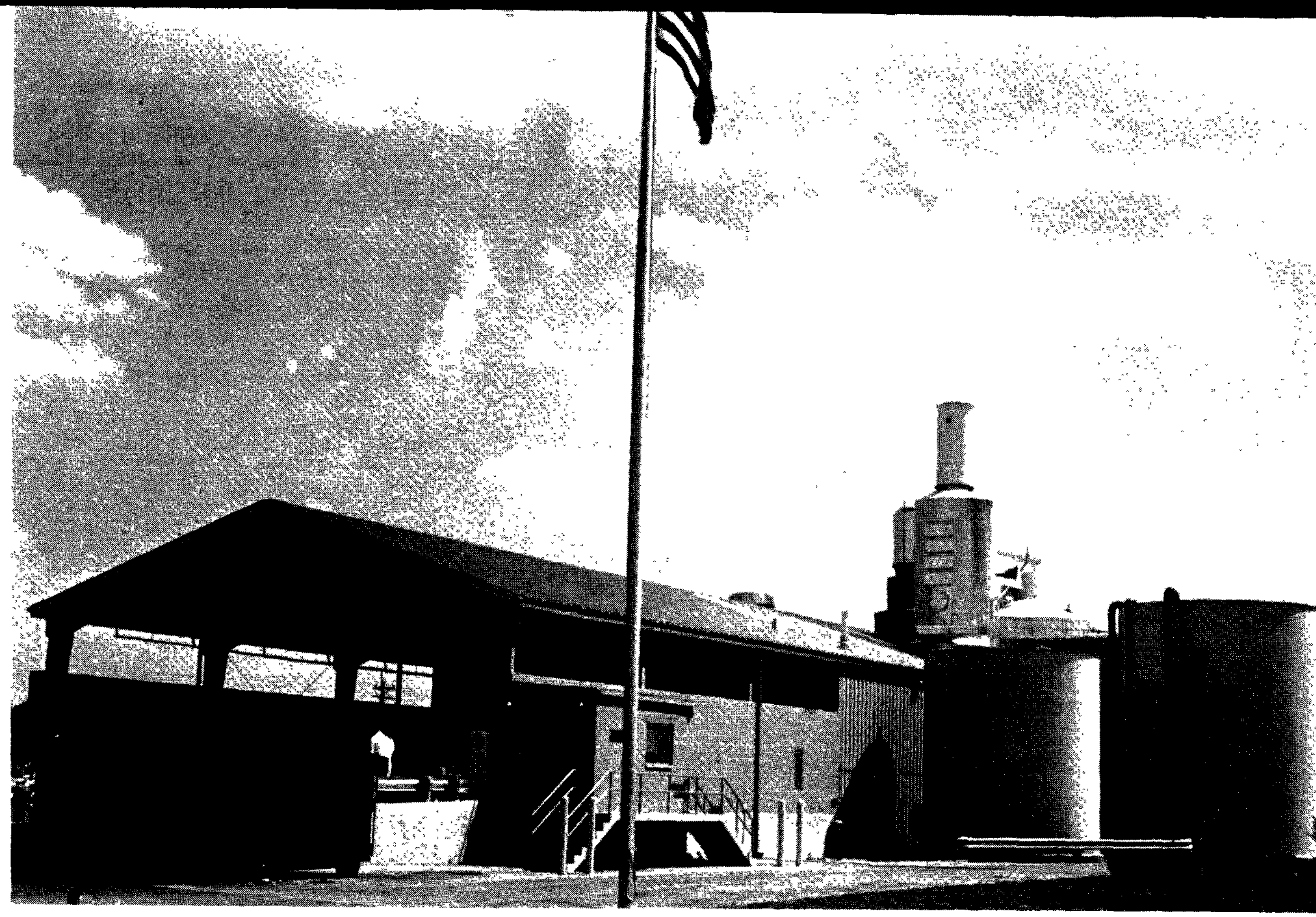

Figure 2. Completed Franklin Solid Waste Plant.

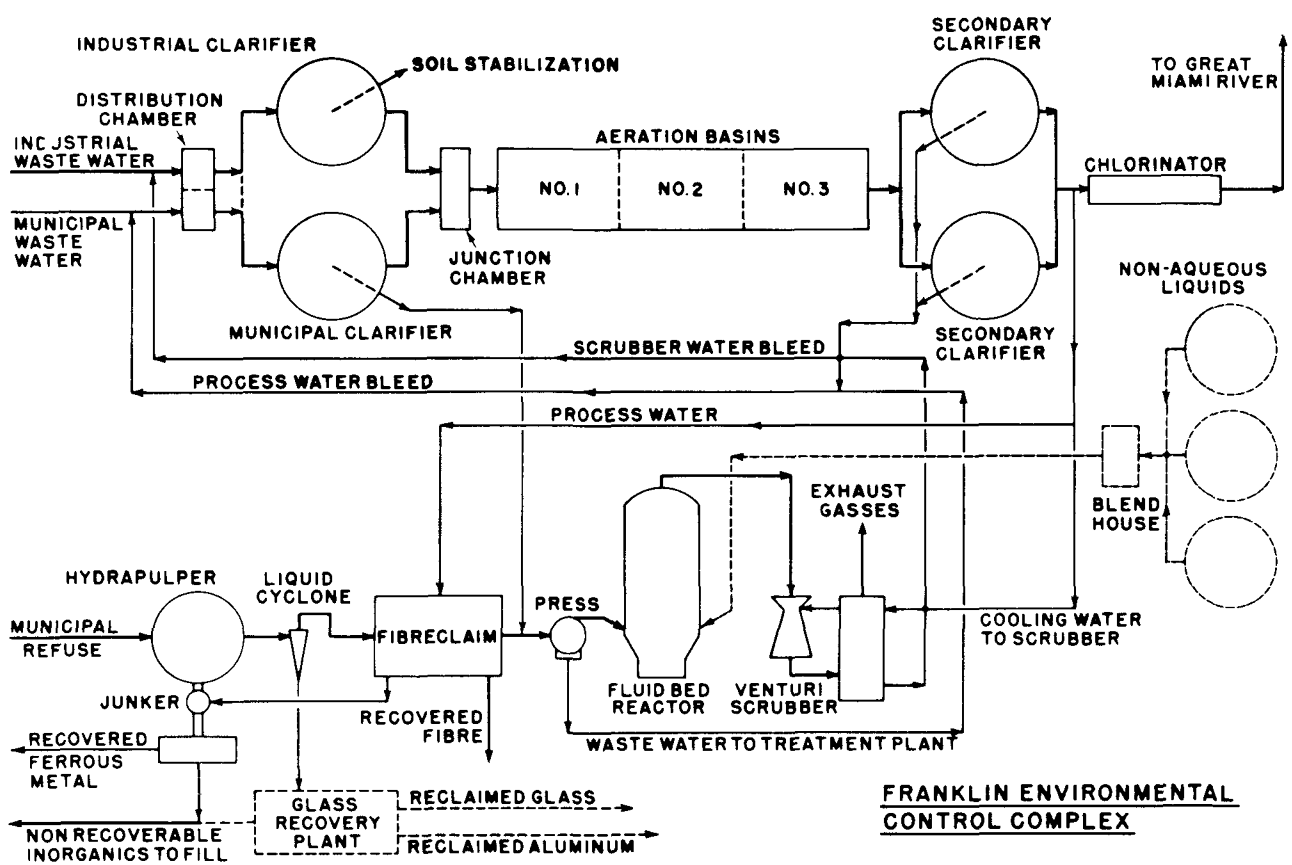

Figure 3. Basic flow sheet for combined solid waste and sewage treatment plants.

Two secondary clarifiers are provided, arranged for parallel operation. Retention time is 3 hours. The clarified effluent will be chlorinated before returning to the Miami River. Expected BOD of the effluent is 20 to 40 ppm.

The sludge from the secondary clarifiers, a biological ash that is essentially inert, will normally go to the industrial primary clarifier, though a portion may be diverted into the municipal clarifier.

The industrial waste water will be collected in a separate sewer system and introduced into a separate primary clarifier. Tests have shown that the effluent from four paper mills--a cotton fiber mill, a white paper mill, a cylinder board mill, and a roofing felt mill--contains mostly inorganics and that the sludge can be landfilled with no further treatment. The overflow from the industrial clarifier will be combined with the clarified municipal water and treated as described above.

Design parameters are given in Table 1.

TABLE 1

DESIGN PARAMETERS FRANKLIN SOLID WASTE PLANT

Design data	
Capacity, as received	150 tons/24 hr
Building area	11,000 sq ft
Connected horsepower	1600 hp
Operating data	
Scheduled operation	8 hr/day 5 days/week
Tons waste to be processed	40 - 50 tons/day
Tons sludge to be processed	7 tons/day
Number employees	4
Process water	50 gpm
Scrubber water	112 gpm
Auxiliary fuel	0
Fuel required for cold start	2500 gal

THE FUTURE

Two additional operations are in advanced engineering stages for the Franklin complex.

The Glass Container Manufacturers Institute (GCMI) has sponsored research work on recovering glass cullet from solid waste, and especially from the glass concentrate rejected from the Liquid Cyclone. The concentrate is dried, screened, magnetically cleaned, and then air-classified to obtain a relatively pure mixed glass cullet, with particle sizes ranging from 1/4 in. to 3/4 in. This glass is then color sorted by a Sortex optical separator. This machine discriminates between different shades, and will sort the glass particles into clear (flint), amber, and green--the color sorting required for glass container manufacture. One of the byproducts of the air separator is an aluminum concentrate, which is currently being evaluated by the aluminum companies.

The Miami Conservancy District has studied the problem of handling nonaqueous commercial and industrial liquid wastes in the Miami Valley. They have determined that each week some 75,000 gal are generated for which no disposal facility is presently available. In composite, these waste liquids have a calorific value of about 4,500 Btu per lb., almost adequate for autogenous combustion. The fluid bed reactor has been used successfully in many applications of waste oil and oily sludge burning.

The solid waste plant is scheduled to operate only 8 hr per day; the fluid bed reactor can handle residual combustibles from the operation in about 6 hr. Oily liquid wastes could be incinerated during the remainder of the day.

The Miami Conservancy District is engineering a tank farm and blending station to be installed beside the solid waste plant. The waste liquids will be delivered by private contractors, stored, blended, and burned during the off-hours of the solid waste plant. Work is also underway to recover the copper and lead values and the rare metals, and to convert the nonrecoverable organics into energy.

CONCLUSION

It is believed that when the glass sorting and nonaqueous waste facilities are completed, this plant will be the first in the world to treat municipal sewage, industrial waste water, nonaqueous liquid wastes, and municipal refuse on the same site; to recover paper, iron, aluminum and glass in recyclable condition; and to accomplish this with no pollution of the air or the land.

This is the Franklin story, originating in a small community of 10,000, which feels gratified and proud to play a part in offering a solution to one of our Nation's most vital and pressing problems. Perhaps it can best be expressed in the words of the plaque to be erected on the facility: "Dedicated to the Citizens of this small Community who had the foresight and the courage to save the purity of the land entrusted to them by God."

This project has been supported by demonstration grant No. G06-EC-00194 from the Environmental Protection Agency, pursuant to the Solid Waste Disposal Act as amended.

REFUSE MILLING FOR LANDFILL DISPOSAL

Robert K. Ham, Warren K. Porter,† and John J. Reinhardt††*

IN EARLY 1966, the Heil Company approached the city of Madison with a proposal to utilize the services of the University of Wisconsin and jointly investigate the European concept of milling refuse and placing it in a landfill without daily cover. The Europeans claimed that in milling the refuse, its characteristics are changed in such a manner that rodent and insect vectors are not a problem, blowing paper is nil, vehicles can travel across it in wet weather, and accidental fires are easily controlled. In other words, many of the operational problems of the sanitary landfill are minimized and the reasons for daily cover are eliminated.

The city of Madison investigated the proposal and agreed to the concept if funding under the Solid Waste Act of 1965 could be obtained. After submitting the applications, the city of Madison was awarded a grant in June 1966 to pay up to two-thirds of the costs; one-third of the costs were required to be paid by others.

Arrangements for the project were as follows:

1. The Heil Company furnished and installed the equipment and provided the technical assistance necessary to adapt the equipment to American refuse. They also provided the matching funds in the amount of $116,000 for the equipment and the project evaluation by the University of Wisconsin. Under terms of a purchase option contract, the equipment could be bought by the city of Madison at the end of the project if it proved successful. (The city of Madison purchased the equipment in 1969).
2. The city of Madison provided the site, site improvements, operating personnel, and the combined refuse as needed, and the matching funds ($69,000) for this portion of the project.
3. The University of Wisconsin was retained to gather the data and evaluate the project as an impartial third party.

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* Professor, University of Wisconsin.

† Program director, University of Wisconsin Extension.

†† Principal civil engineer, city of Madison, Wisconsin.

The general objectives of the original project were threefold:

1. To evaluate economics and operating problems of (a) the French-manufactured Gondard ballistic rejection mill and feed conveyors, (b) the final disposal system for the milled refuse (which consisted of a Barber Green rubber belt conveyor and Heil Load-Lugger containers with a hoist truck), and (c) the management of such a plant.
2. To investigate the milled refuse itself and compare it to unmilled refuse.
3. To investigate the procedures and European claims for using the milled refuse in landfill without daily cover.

The original project was to a large extent a developmental project. In late 1968, experience indicated that milling refuse was a promising enough approach to Madison's sanitary landfill problems to warrant an enlargement of the project. At the same time, the Heil Company became interested in evaluating the English-manufactured Tollemache hammermill, which has a vertical shaft and a ballistic rejection feature. They were also interested in cooperating with the city of Madison and using the experience gained during the project to revise the existing facility to solve the problems of feeding the refuse to a mill and taking it to the landfill. The new project consisted of additional tests on milled refuse and installing and/or evaluating the following items: (1) the Tollemache mill; (2) a feed system for the Tollemache mill consisting of a short, direct-feed bin conveyor with metal flights; (3) a stationary packer with self-unloading, 75-cu-yd transfer trailers; (4) building expansion to allow operating two shifts; (5) the Tollemache mill and Gondard mill operating at the same time to mill about 280 tons per day in a two-shift operation.

A two-year renewal grant was received from the U. S. Environmental Protection Agency to cover part of the plant operating expenses and finance the conveyor modifications, stationary packer, transfer trailers, and additional evaluation work by the University of Wisconsin.

DESCRIPTION OF THE ORIGINAL SYSTEM

The original Gondard milling system consisted of a scale, a building, a storage hopper, conveyors to transport the refuse to the mill, a French-manufactured Gondard mill, a conveyor to transport milled refuse from the mill to the haul-away vehicle, and a truck to haul the milled refuse to the landfill (Figure 1).

The original milling system is centered about the Gondard hammermill and consists of the necessary material handling equipment in addition to the pulverizer. The refuse fed to the Gondard mill is either ground finely enough to pass through a grate or is sent ballistically by the impact of hammers up a chimney and out of the mill. The ballistic rejection feature enables the mill to operate nearly continuously, with little or no hand sorting or monitoring of the feed going into the machine. The French-manufactured Gondard mill and conveying equipment were used in the plant because of Gondard's considerable developmental work with this type of equipment at the time of the original project.

The refuse is first weighed at the scale and then emptied inside the building into a storage hopper or onto the floor when the hopper is full. A front-end loader pushes refuse from the floor into the storage hopper as needed. The bottom of the storage bin is a metal-slated conveyor that carries refuse through an opening at one end of the storage bin, where two rubber belt conveyors carry it to the Gondard mill. Refuse was stored in both the bin conveyor and on the floor to eliminate the need for an overhead crane and operator and to minimize the need for materials handling. The bin conveyor is driven by a 15-hp. motor connected by a hydraulic coupling to a variable-speed drive. The variable-speed drive allows the flow of refuse to be controlled by increasing or decreasing the speed of the conveyor belt.

Two rubber belt conveyors are used to lift the refuse to the mill, where it is dropped onto the hammers through the side of the chimney. The conveyors provided the change in direction so that the size of the building could be kept as small as possible. The hammermill is of a standard design except for the ballistic rejection tower over the mill. The mill consists of a 6-in. main shaft around which is mounted four subshafts. Each subshaft contains 12 hammers weighing 15 lb each and measuring 1 1/4 in. by 4 in. by 11 in. The hammers (Figure 2) have a shaft through one end so that they can stand out by centrifugal force and pulverize the refuse. The mill is operated at approximately 1,200 rpm by a 150-hp. motor. The unique feature of the mill is the chimney placed over the top to allow rejection of items that would clog the machine.

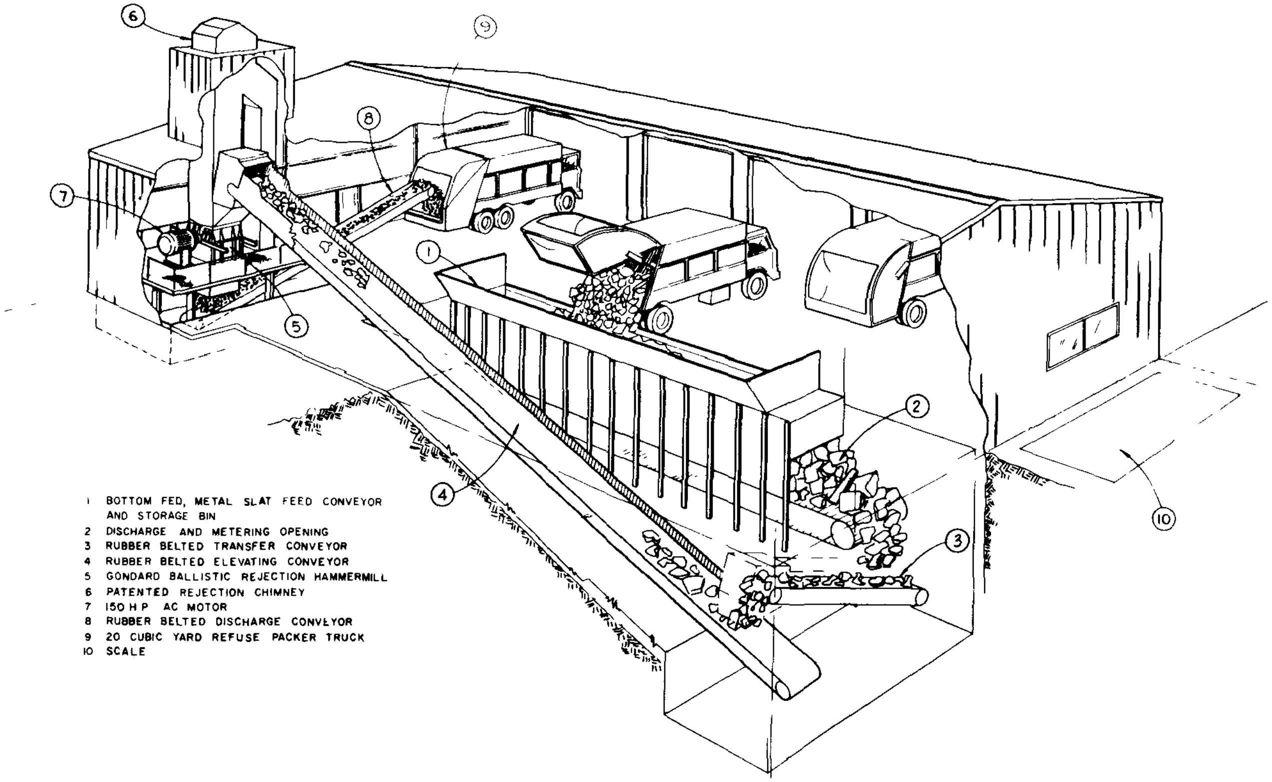

Figure 1. Major components of the Gondard refuse milling system components, Madison, Wisconsin.

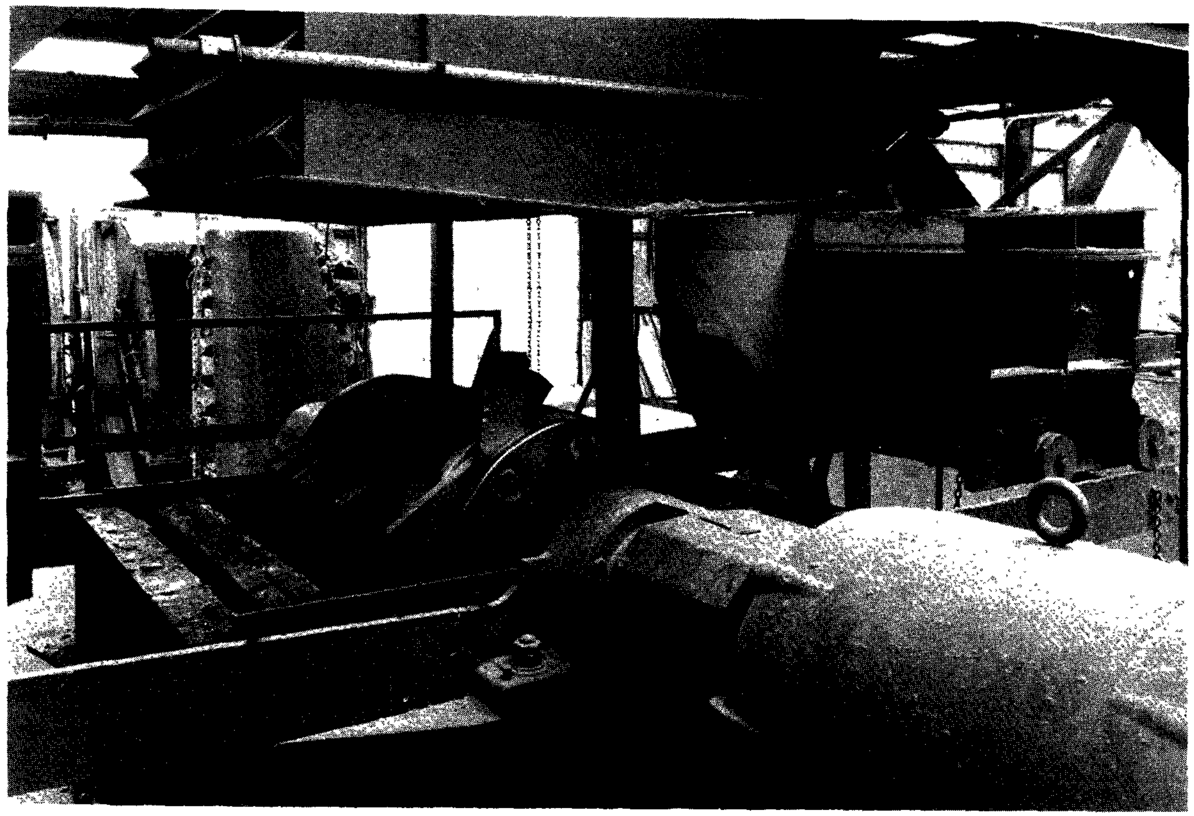

Figure 2. Rotor and hammers of the Gondard ballistic rejection mill.

Originally, both the pulverized refuse and the ballistically rejected items were discharged onto a conveyor that emptied into a conventional refuse collection truck that took the refuse from the plant to the landfill. At first, 10-cu-yd bins with a load-lugger truck were used to carry the milled refuse from the mill building to the landfill. The system was chosen on the basis of European milled refuse densities in an uncompacted state. The densities of uncompacted milled refuse at Madison, however, were considerably lower, and the 10-cu-yd bins were too small to handle the volume of milled refuse efficiently. A 25-cu-yd refuse packer truck with a continuously cycling compaction blade was tried next. The unit proved successful for the 8-ton-per-hour production rate of the Gondard mill, but it was inadequate for the 15-ton-per-hour production rate of the Tollemache mill.

THE TOLLEMACHE INSTALLATION AND PLANT EXPANSION

In early 1969, the Heil Co. of Milwaukee requested permission from the city of Madison to install and test an English-manufactured Tollemache vertical shaft hammermill in the existing refuse milling plant. Permission was granted in the summer of 1969. The Tollemache mill was installed next to the Gondard mill in such a manner that it could discharge milled and rejected material onto the discharge conveyor of the Gondard mill. A new feed system design was based on 2 years of experience with the original Gondard system that indicated that mill production was mainly a function of the rate that refuse could be fed into the mill and carried to the landfill after processing. The Tollemache feed conveyor consists of a 45-in. wide metal flight conveyor that fits into one end of the Gondard bin conveyor. The Tollemache feed conveyor operates in the opposite direction of the Gondard bin feed conveyor and feeds directly into the Tollemache mill without changing the feed direction to the mill.

The Tollemache mill has a funnel shape (Figure 3) that can be combined with three different diameter rotors to allow different types of grinding to take place. The rotors and shafts are mounted in a vertical plane and the hammers swing in a horizontal plane--an arrangement that is the opposite of the Gondard mill. The funnel-shaped top section and top hammers act as a prebreakdown section that reduces loading on the mill motor by allowing hard-to-grind items to be chewed to pieces before they reach the next set of hammers. The funnel section also serves as a ballistic rejection mechanism. Items that are

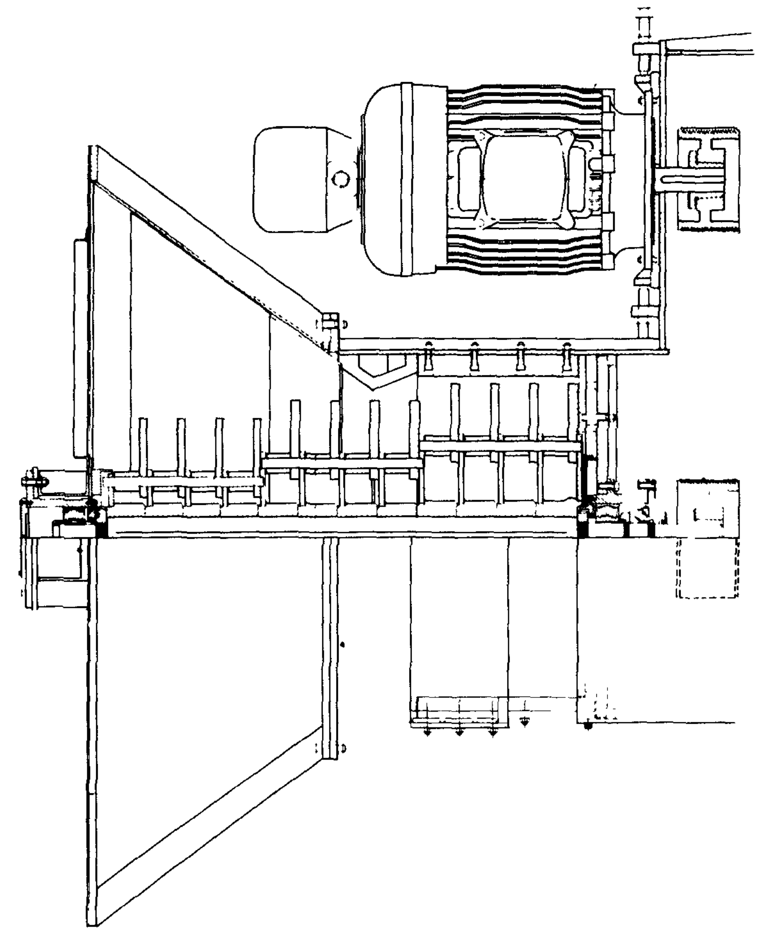

Figure 3. Cross-sectional view of the Tollemache mill.

hard and are not ground finely enough to pass through the 41-in. neck section of the mill are spun around the funnel and out a reject chute by the ballistic force of the hammers. The 41-in. neck acts as the grates do in the Gondard mill. The particle size is also partly controlled by the hammer pattern and hammer length at this point. The three rotors are mounted on the central shaft, which turns on bearings located at the bottom and the top of the shaft. Each rotor has six subshafts on which the hammers are mounted. The hammers are 10 in. by 4 in. by 1-3/16 in. and weigh 15 lb. The original hammer pattern contained 54 hammers, but early experience with the mill showed that this number of hammers produced a grind that was much finer than needed for landfill purposes. Various hammer patterns have been tried, and the first evaluation of the mill was done with a 32-hammer pattern. Presently, a 34-hammer pattern is being used. The hammer tip diameter in the top rotor is 33 in., the middle set is 38 in., and the bottom set is 43 in. The mill is driven by a 200-hp., 440-volt, squirrel-cage, high-torque motor at 1,300 rpm.

The unmilled refuse enters the mill at the top on one side of the funnel where the hammers in the prebreakdown section reduce large items. Smaller-sized particles fall down into the throat of the mill where they are ground as they fall through the hammer set. The material then falls down to a set of hammers that grinds the material and throws it out the side of the machine onto a conveyor belt. This set of hammers does most of the work.

Other Plant Modifications

Early in the project it was recognized that economics were largely a function of the scale of operation and that the original installation was only a pilot plant if one considered the total amount of millable refuse in the city of Madison. Studies of ways to expand the pilot plant into a larger scale facility indicated that a reasonable approach would be through a number of steps that would allow the city to capitalize on experience gained in the early years of the project. In 1968, a plan was developed that consisted of the following major parts: (1) addition of a second mill to allow a two-shift operation based on a plant production rate of 280 tons per day; (2) expansion of floor storage to allow a second shift operation; (3) revision of the materials-handling system for the milled refuse to reduce the labor required with the load-lugger bin system and the refuse packer truck system that had been used to that time; (4) operation of a second shift to reduce the depreciation cost per ton.

The first step taken after the installation of the Tollemache mill with the new feed conveyor was the installation of a materials-handling system to handle the milled refuse from the mill to the landfill. The modifications (Figure 4) consisted of: (1) the installation of a 4-ft-wide Barber Green rubber belt conveyor to carry the material from both the Gondard and the Tollemache mill to a small, 36-in.-wide rubber belt conveyor that transferred milled refuse to a stationary packer in a building addition adjacent to the mill; (2) the installation of a stationary packer unit that loads a 75-cu-yd transfer trailer; (3) the use of a 75-cu-ft transfer trailer that has its own motor and ejection plate to unload the trailer at the fill site.

PLANT OPERATIONS

Much information is available on pulverizing refuse in the Gondard machine. For the Tollemache pulverizer, cost and production information is limited since it is based on an evaluation of the 3 months since installation and completion of a break-in period. The data on the Tollemache machine was obtained from Mr. Gerald Sevick, project specialist for the University of Wisconsin.

The tonnage processed per hour is not a direct reflection of the machine capacity because the feed conveyors, mill, and haul-away system operate in series. Thus, the whole system is only as strong as its weakest link. The Gondard mill was the strongest link in the original processing system. Until February 1969, the mill was never fed at an average rate of more than 60 percent of theoretical power consumption, despite improvements in the feeding apparatus. The feed is still irregular (perhaps because of the heterogeneous nature of refuse) and is a definite limitation on the plant capacity.

The Tollemache mill was installed in late 1969 and underwent a break-in period until May 1970. An evaluation of milling combined, residential refuse was conducted during a 14-week period from July through early October 1970. At the same time, the stationary compactor and transfer trailer were installed to handle the combined output of the two mills.

Over the period of the project, many improvements have been made in the plant operation. These improvements include, for example, placing vertical sides and rubber cleats on conveyors to assist in material flow, and providing quicker access to the

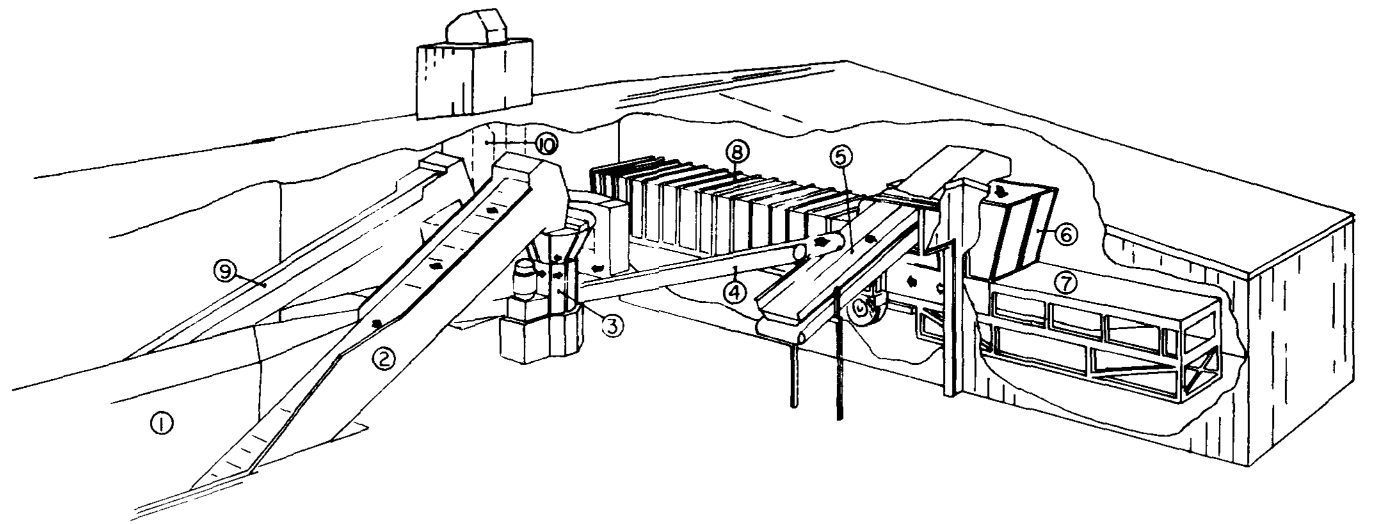

Figure 4. Tollemache mill installation with transfer packer station.

hammermill. Actual downtime due to clogging of conveyors and jams in either mill are no more than 15 min. per day. However, the results achieved in the operation of the plant are based on operation of the pulverizers for 5.3 hr per 8-hr day. In addition to the downtime attributable only to the milling operation (jams of feed conveyors and the mill), there were considerable periods of nonproductive work. In an attempt to quantify these nonproductive work times, the daily records when only the Gondard was in use, from April 1 through November 29, 1968, were examined. The average number of minutes per day of nonproductive work are itemized as follows:

	Minutes
Elapsed time between arrival of first load of refuse and start of milling	33
Conveyor and mill jams	13
Nonproductive time during milling:	
Out of refuse	15
Truck breakdown	12
Lunch	19
Other	4

During the same period, there were 37 recorded cases of hammer maintenance and 24 cases of general maintenance, all of which account for some of the nonproductive work time listed above. Two things should be noted: (1) many of the shutdowns could be eliminated through proper initial design (this is something that is gained only by experience and is the purpose of such a demonstration project), and (2) other shutdowns could be reduced or eliminated by rearranging work schedules.

More recent experience with the Tollemache indicates that the daily average downtime that is due to jamming of the mill is less than 5 min. Because of the higher capacity of the Tollemache, the plant has been out of refuse for an average of 1/2 hr at least once each working day. The consequences of this situation are threefold: (1) continuous operation of the mill is interrupted; (2) overtime hours are required to complete daily operations; (3) all refuse entering the plant could not be ground because of overtime restrictions.

To increase the productivity of the plant, working hours are being revised to start the first shift at 11 a.m. Incorporation of additional storage space, which is now completed, should permit continuous operation at a high production rate.

Operating Data for the Gondard Hammermill

The Gondard machine is constructed with a screen in the bottom through which refuse must pass after being pulverized. During the year of experimental trials, the grate at the bottom of the mill was changed systematically to determine the optimum grate size or clear space between the bars of the grate. Considerations included machine capacity, operating costs, landfill space usage, and particle size--all of which vary with grate size and season. Thus, three grate sizes were used each season. Initially, 2-in., 4-in., and 6-in. grates were used. However, use of the 2-in. grate was discontinued after the first trial, since it pulverized the refuse finer than required for landfill, slowed production, and thereby raised costs. The 4-in., 5-in., and 6-in. grates were therefore used throughout the remainder of the experimental phase of this project.

Production Aspects. The overall production rate of the Gondard machine (Table 1) is the tonnage processed during mill operating time plus downtime charged against the milling (conveyor and mill jams, for example). Not included in the overall rate is time lost because of exhausting the supply of refuse, truck breakdowns, lunch, and time lapse between arrival of the first load of refuse and the start of milling operations. These items were not included in the overall production rate because they are not directly caused by machinery limitations. Instead, these are personnel and supervisory matters. The lost time cannot merely be set aside: it does in fact exist and will continue to exist with even the best of supervision. The question is, how much can the downtime be reduced?

TABLE 1
THE GONDARD HAMMERMILL:
RELATION OF OVERALL PRODUCTION RATE TO GRATE SIZE

Item	Tons per hr*		
	3½-in. grate	5-in. grate	6¼-in. grate
Average rate for last full year	8.3	7.4	7.7
Projected average rate†	8.4	9.0	9.4

*Includes both operating and shutdown time.
†Based on installation of cleats to improve feed to mill.

From September 1967 through January 1968, the rejectable items were separated into a bin and weighed. During this time it was found that 1 to 7 percent of the total refuse could be ballistically separated when the reject chute extended vertically 27 ft above the mill.

As indicated before, the mill was not operated at theoretical capacity. Theoretical capacity will probably never be reached because of material-handling problems associated with the heterogeneous nature of refuse. A load factor, or the ratio of power consumed to theoretical power consumption, was computed as a rough indicator of how hard the machine worked compared to its theoretical capacity. The average load factor ranged from 0.6 to 0.7, depending on the grate size used.

Cost Data. Cost data are presented for the third and final year of this demonstration project, from June 1968 through May 1969. Although it is proper to report the costs incurred at the existing plant, one must be cautioned about adapting these costs to other installations. This project is a pilot plant demonstration whose operation is probably more expensive than that of future plants. The regional variations in labor, power costs, heating costs, and depreciation methods must also be taken into account. The section on cost projections gives a more accurate indication of what future plants might cost. These projections indicate costs per ton ranging from $3 for one mill operating one shift, to $1.30 for four mills operating two shifts.

Furthermore, the unit costs (Table 2) are higher for the pilot plant than they would be for a larger plant of different design. Some of the reasons for the higher unit costs are as follows: (1) refuse is not conveyed to the mill as fast as the mill can grind; (2) a similar plant without extra conveyors and the extensive foundations necessary for the site's soil conditions would be less costly; (3) a plant using one mill and having proper haul-away equipment might be operated by two men, thereby reducing labor cost; (4) the plant is not milling refuse for 7 hr daily for reasons indicated previously.

Hauling costs are not included in this section. Land costs are excluded because they are commonly omitted from other studies, and because this plant was built on an existing city site purchased many years ago. Administrative costs are also commonly omitted since they vary with the organization.

The costs per ton (Table 2) are calculated on an annual cost basis in which the annual cost is divided by the projected annual tonnage. The annual tonnage is calculated by using the overall production rate, the average number of operating hours per day, and the number of operating weeks per year.

TABLE 2
THE GONDARD HAMMERMILL: RELATION OF COST PER TON TO GRATE SIZE

		Cost per ton		
Item	Annual cost	3½-in. grate, 10,750 tons/yr	5-in. grate, 11,500 tons/yr	6¼-in. grate, 12,050 tons/yr
Labor	$39,800	$3.70	$3.46	$3.30
Amortization	32,200	2.99	2.80	2.67
Power	Variable	.34	.30	.30
Lighting	2,300	.21	.20	.19
Water	200	.02	.02	.02
Gas heat	1,200	.11	.10	.10
Hammer wear	1,660-1,710	.16	.15	.14
Mill maintenance	850-950	.08	.08	.08
Small equipment	800	.07	.07	.07
General supplies	1,100	.10	.10	.09
Front-end loader operation	500	.05	.04	.04
Other	1,700	.16	.15	.14
Total cost /ton		7.99	7.47	7.14

Refuse Composition and Characteristics of Milled Refuse

An important qualification of any refuse processing system is the composition of the wastes being processed. Samples of combined refuse have been analyzed physically and chemically. Personnel from the Office of Solid Waste Management Programs made physical analyses of the waste in November 1968 (Table 3).

A physical analysis was also made of the milled refuse to quantify the particle size. This analysis was made to relate particle size to possible problems of blowing litter in the landfill. Samples of milled refuse pulverized through different sizes of grates were shaken through a sieve commonly used for aggregate analysis in road construction. This method is tenuous but to our knowledge is the best method available for making such a quantification. The range of particle size was determined for 3 sizes of grates (Table 4).

The most noticeable features of the milled refuse are that it is homogeneous and that its individual components, such as newspaper and plastic bottles, are not recognizable. Milled refuse has an appearance of oversized confetti or torn newsprint.

TABLE 3

RANGE OF COMPOSITIONS OF SOLID WASTES, WET BASIS*

Item	Percent of total		
	Minimum	Maximum	Average
Food waste	4.4	28.9	15.3
Garden waste	0.0	31.1	13.8
Paper products	35.1	53.2	42.4
Plastics, rubber, leather	0.3	3.7	1.8
Textiles	0.1	7.8	1.6
Wood	0.0	2.6	1.1
Metals	5.0	14.5	6.7
Glass and ceramics	4.4	17.6	10.1
Rocks, dirt, ashes, etc.	0.6	17.6	7.2

*Moisture content varied from 30 to 48 percent, with an average of 37 percent.

TABLE 4

SIZES OF PARTICLES PROCESSED IN THE GONDARD HAMMERMILL*

Grate size	Percent of particles finer than			
	3 in.	2 in.	1 in.	0.5 in.
3½-in.	99	97	74	46
5-in.	93	87	67	42
6¼-in.	91	83	59	38

*Excludes ballistically rejected items and cans.

Many of the tin cans are crumpled. The glass is disintegrated and appears as small chips approximately 1/8 in. by 1/8 in.

The milled refuse appears to be bulkier after it comes out of the mill than before it went in. The bulking, which is thought to be due to the pulverizing of paper and paper products, is the reason that the original detachable-containers system proved to be undersized and was soon replaced with mechanical compaction-type collector trucks as a means of hauling the milled refuse to the landfill. When using mechanical compactors in good operating condition, we have achieved densities of 650 to 700 lb per cu yd in the haul-away truck, compared to less than 350 lb per cu yd in the incoming collection trucks used in 1967.

Tollemache Hammermill Operation

Production Aspects. Based on the 14-week evaluation, data is provided on production capability and costs. Extensive experimentation was done during the break-in period to determine the hammer pattern needed in the Tollemache. Unlike the Gondard mill, the Tollemache has no screen through which pulverized refuse passes. The hammer pattern is thus the prime determinant in the fineness of the grind and in the production capacity of the machine.

Overall production rates (Table 5) include downtime attributable to the milling equipment and conveyors. The mill was operated an average of 5.3 hr per day. The plant production per day should be increased by the revisions in plant operating hours and more efficient utilization of personnel.

TABLE 5

OPERATING AND OVERALL PRODUCTION RATES
FOR THE TOLLEMACHE HAMMERMILL

Period	Tons Milled	Time (hours)		Production rate (tons/hr)	
		Operational	Overall	Operational	Overall
July 6-31	1,480	100.4	104.0	14.72	14.22
August	1,573	104.9	107.7	15.01	14.62
September	1,701	122.5	125.3	13.89	13.58
October 1-9	564	38.0	38.3	14.82	14.72
July 6-October 9	5,318	365.8	375.3	14.53	14.18

Cost Data. Costs encountered during the 14-week evaluation are tabulated in Table 6. In areas such as depreciation, where an expense occurs over a longer time than that covered in the evaluation period, expenses were proportioned to the evaluation period.

During the 14-week evaluation period, 5,320 tons of refuse were milled. The resulting cost is $26,200 per 5,320 tons or $4.92 per ton. Again, this figure is based on operating the mill only 5.3 hr per day. As in the case of the Gondard mill, the unit cost could be lower if the plant did not require excessively costly foundations because of soil conditions onsite, and if the plant were operated for 7 hr per day. Continued development, revisions of operating hours, and provision of more storage to permit two-shift operation should enable reduction of these unit costs.

TABLE 6

COST OF 14 WEEKS OF OPERATION OF THE TOLLEMACHE MILL

Item	Cost
Labor	$13,378
Depreciation*	9,760
Hammers	657
Power	1,390
Hammer shafts	72
Welding rods	177
Plant supplies	153
Tractor maintenance	112
Front-end loader maintenance	171
Transfer trailer maintenance	30
Water	-------
Heat	-------
Lighting	278
Total	26,178

*Depreciation would be lower if a common building were erected. Since this building is constructed on poor soil, a very expensive foundation had to be provided.

COST PROJECTIONS FOR FUTURE PULVERIZING FACILITIES

One of the purposes of a demonstration project is to determine information that will have wide application. This part of the presentation lists some basic engineering design information on the milling process for use by others planning similar installations. Factors, such as machine capacity to be used in making cost projections are listed first. Cost projections are made in the last section bv using the basic data and other estimates.

The following list and Table 7 contain recommended figures to be used in making cost projections. The list itemizes factors that apply to both the Gondard and Tollemache mills:

Production aspects:

Operating hours and days............ Maximum of 7 hr per 8-hr work shift; 245 days per year (49 weeks).

Labor requirements.................... A minimum of 2 men for a one mill in a building located at the landfill.

Fringe benefits...........................30 percent (exclusive of overtime).

Depreciable life of equipment	"Butler" type steel building -- 20 years. Weight scale -- 20 years. Front-end loader -- 8 years. Grinders and conveyors -- 15 years.
Interest rates (Nov. 1969) for municipality	5.8 percent on municipal bonds. 7.0 percent on general fund.
Wearable parts in Gondard mill	Grates and wear plates -- 8,000 tons. Welding rods -- 80 per set of hammers, at cost of $.50 per rod.
Transportation:	
Capacity of truck	6 tons on a 25-cu yd packer.
Depreciation life of truck	10 years.
Landfill:	
Density of milled, combined refuse	870 to 1,090 lb per cu yd for refuse characterized in Table 5.
Apparent density of raw refuse with intermediate cover	570 lb per cu yd (including *volume* of cover dirt).
Actual average depth of cover dirt	6 in. on milled refuse, 15 in. on raw refuse.

TABLE 7

COST PROJECTION FACTORS: PRODUCTION ASPECTS

Item	Amount			
	3½-in. grate	5-in. grate	6¼-in. grate	no grate
Gondard mill:				
Machine capacity (tons/hr)	8.4	9.0	9.4	---
Power consumption (kw-hr/ton)	14.5	11.9	10.3	---
Hammer life (tons)	1,200	1,300	1,450	---
Tollemache mill:				
Machine capacity (tons/hr)	---	---	---	15.0
Power consumption (kw-hr/ton)	---	---	---	7.0
Approximate hammer life (tons)	---	---	---	1,500

These factors and other approximations have been used to make the cost projections below. The projections are made for new plants, based on the experience gained at the city of Madison pilot plant with the Tollemache Mill. The major assumptions are:

1. The plant is located at the landfill site.
2. One man can monitor two mills.
3. Generally, transfer trailers will be used to haul milled refuse to the fill site, but packer trucks will be used for a one-mill installation.
4. Refuse will be accepted from all sources. Thus a separate landfill compaction machine will be provided in addition to the front-end loader used in the plant.
5. Each Tollemache mill has a capacity of 15 tons per hr.
6. The mills will be operated 7 hr per shift, 245 days per year.
7. The milled refuse will be covered with dirt only when the landfill is filled to the final elevation.
8. Land costs are excluded.

The projected unit costs for new facilities range from $3.02 per ton for one mill operated on a one-shift basis to $1.31 per ton for four mills operated for two work shifts (Table 8).

LANDFILL CONSTRUCTION USING MILLED REFUSE WITHOUT COVER

In recent years, there has been a major emphasis on the elimination of open dumping (often associated with open burning) in favor of the sanitary landfill. This trend recognizes that the level of operation achieved in a true sanitary landfill is sufficient to protect natural resources and avoid insult to citizens and the environment.

The essential ingredients of any sanitary landfill are that (a) the entire system is engineered with respect to site selection, operation, and final use; (b) refuse placed in the site is compacted to reduce its volume and to enhance utilization of the completed landfill; and (c) a layer of compacted earth is used to cover the accumulation of refuse at least once a day. Since

TABLE 8

ANNUAL COST AND PRODUCTION OF FACILITIES, BY NUMBER OF SHIFTS AND MILLS

Item	Number of mills			
	1	2	3	4
One-shift operation:				
Tons milled per day	105	210	315	420
Plant operating cost	$40,500	$59,500	$72,200	$91,900
Depreciation	21,600	38,000	50,900	64,200
Total operating cost	62,100	97,500	123,100	156,100
Landfill operating cost	13,200	15,900	15,900	15,900
Depreciation	2,300	4,300	4,300	4,300
Total annual operating cost	77,600	117,700	143,300	176,300
Tons milled per year	25,700	51,400	77,100	102,800
Cost per ton	3.02	2.29	1.86	1.71
Two-shift operation:				
Tons milled per day	210	420	630	840
Plant operating cost	76,000	114,700	139,200	178,100
Depreciation	24,300	41,300	55,900	70,400
Total operating cost	100,300	156,000	195,100	248,500
Landfill operating cost	15,200	14,500	15,300	16,100
Depreciation	3,500	4,300	4,300	4,300
Total annual operating cost	119,000	174.800	214,700	268,900
Tons milled per year	51,400	102,800	154,200	205,600
Cost per ton	2.31	1.70	1.39	1.31

omitting the daily cover would depart significantly from the established method, it was considered necessary to examine the factors that make a sanitary landfill acceptable and to consider use of uncovered, milled refuse with respect to each of these factors.

The requirement that a sanitary landfill be engineered with respect to site selection and utilization will not be given further attention here, for skilled engineering design is necessary whether the landfill is a traditional sanitary landfill or one constructed with milled refuse. Some of the design considerations may change according to factors outlined below; however, excellence of design is a prerequisite to either type of operation.

First of all, compaction is required in a sanitary landfill to reduce voids that may harbor rodents or abet fires, and to provide the most efficient use of space. Compaction also improves the usefulness of the completed landfill by providing more uniform settling and a reduced change in volume from that first observed after site completion to that reached after degradation is complete. Even though compaction of milled refuse would be practiced, the departure from the usual sanitary landfill to a milled refuse landfill without cover was examined carefully with respect to in-place refuse densities and settlement.

Evaluation Procedures

The acceptability of not providing daily cover for milled refuse was evaluated with respect to each of the reasons cited for the use of daily cover as well as to general operating characteristics of such a landfill. Field evaluations were done at the city of Madison's Olin Avenue Landfill, adjacent to the milling facilities. This area is about 60 acres in size and is actually an old open dump that filled a marsh. The area was leveled, covered with some 2 ft of soil, and deactivated as an open dump in the early 1960's. The water table is typically 1 to 2 ft beneath the surface.

To provide a direct comparison between the milled refuse without cover and the sanitary landfill technique, refuse was placed in piles called cells. The cells were 5 to 6 ft in height and were level. Lengths and widths varied, but the smallest cell was at least 40 ft in its shortest dimension. Cell construction was scheduled so that both covered, unmilled cells and milled, uncovered cells were constructed simultaneously, allowing for ready comparison. Cells were typified by the season of the year during which they were constructed, their age, and, in the case of milled cells, the grate size used in the mill. Both cell types were compacted with a D-7 caterpillar tractor, and in the case of covered cells, the cover soil was a sandy-silt obtained from a site 5 miles away. Six in. of soil were used for all covered cells.

It should be noted at this point that, strictly speaking, those cells constructed with unmilled refuse and covered were not sanitary landfills. Insufficient refuse was available to construct an entire cell, or even a major portion of a cell, in a single day. A choice had to be made, therefore, between covering the small amount of refuse placed daily, covering all exposed refuse daily except for the working face, or covering each cell upon its completion. It was felt necessary to avoid the atypical situation of having cells consisting of small pockets of refuse bounded by soil and the attendant difficulties in understanding and tracing moisture and gas movement in such a situation. Furthermore, it would be poor practice to leave an entire cell uncovered until its completion. The decision was, therefore, to leave only the working face exposed at the close of each day's operation. The difference between a cell covered in this fashion and a true sanitary landfill (which is covered daily) is felt to be insignificant with respect to the results of this study.

In addition to the landfill observations, some special tests were run at other locations. These tests will be described later in the presentation.

Specific Test Procedures, Results, and Discussion

Each of the many aspects of the landfill evaluation program will be considered on a point-by-point basis, with a presentation of the test procedures and a discussion of the results for each one. All of those areas of concern mentioned previously will be considered, as well as general operational characteristics of milled, uncovered daily landfills.

Esthetics. Milled refuse was found to look like shredded paper to the nearby viewer. As one moves away from the refuse, it rapidly begins to look nondescript. Perhaps the most valid basis for this statement is that of all the thousands of people who have viewed the landfill, no one has objected to the sight of milled refuse that was not covered. A typical first reaction is one of surprise that refuse can look so unobnoxious.

Odors. The Olin Avenue Landfill is within the city of Madison, bounded by a playfield on one side, residential areas on two sides, and the Dane County Coliseum and County Fairgrounds on the other. The Coliseum is a new 10,000-seat facility for sporting events, concerts, and other performances playing to large audiences. There was some apprehension when the project was first formulated that the location of the test landfill would invite complaints if the slightest odors were produced.

No odor problems have developed, however. Experience has indicated that visitors are surprised at this and usually ask why there is essentially no odor. Project personnel believe that the unusually free access of air to the refuse cells and the rapid drying out of the surface of the cells provides an aerobic buffer zone that removes or reacts with potential odor-forming substances formed within the cells. In support of this theory, it was noted that by digging 3 to 6 in. into a cell, one begins to detect an odor typical of decaying refuse. On digging a foot or more, a most disagreeable odor is produced.

Some relatively minor odor problems were detected during unusually wet periods when, because of improper drainage of the depressions between the test cells, ponds of water were formed. These problems were readily overcome by filling in such areas or by providing drainage.

Blowing Paper. Blowing paper is one of the problems most frequently cited by sanitary landfill operators or administrators. The city of Madison is no exception. In spite of 6-ft fences around its Mineral Point and Truax Field Sanitary Landfills and the use of 15-ft movable fences placed downwind from the working face, blowing paper continues to be a problem. In 1969, some $22,000 was spent for manpower to pick up this blowing paper in a sincere attempt to reduce complaints.

The city is so pleased with the lack of blowing, milled refuse that the director of public works has stated that he would be willing to use the milled refuse system for this reason alone. There have been essentially no blowing problems with milled refuse, even though operations have been continued at winds up to 60 mph on a flat landfill.

There are two reasons for the lack of blowing. First, milled refuse particles tend to become intertwined so that they are discharged as a group rather than as individual particles that can be blown away. Second, if one drops a page from a newspaper and a 2-by 2-in. piece of newspaper simultaneously in a strong wind, the small piece will blow a few feet and come to rest, but the full page will blow long distances. As milled refuse is ejected from the transfer vehicle it is observed to blow a few feet in a strong wind, but that is all.

Fires. In August 1969, the city of Madison fire department carried out an evaluation of any fire hazard arising from the lack of cover on milled refuse. Tests were run both on refuse that had been placed within a month of the test date and on refuse placed at least 1 year before the test. The temperatures during the test period were generally in the low 70's, relative humidity near 70 percent, and wind velocities were 2 to 6 mph. The moisture levels of the refuse cells would be expected to be less than average, arising from less than average rainfall for the preceding month.

The fire department undertook tests in which milled refuse cells without cover were ignited by several methods chosen to simulate potential fire sources in actual landfill situations.

In summary, it was observed that the aged, milled refuse would not support a flame, nor would it propagate combustion in the sense that the area of combustion would continually expand with time. The refuse would smolder on the surface and was readily extinguished with water. Freshly milled refuse will also burn at the exposed surface but will only smolder and not produce a flame. A major difference between aged and freshly milled refuse was that the area of combustion in the latter case would grow, eventually encompassing the entire cell surface. Again, however, the rate of propagation was slow, and combustion was limited to the cell surface, where it could be extinguished with water.

Vectors. A rather extensive description of all the vector studies has been published in the January-February 1971 issue of *Compost Science*, and earlier articles in *Public Works* (July, 1969 and June, 1970) presented in more detail certain portions of the vector studies. Only a summary of the vector studies is presented here.

The portion of the vector work dealing with rats is divided into three parts: first, to determine whether rats are more likely to be found near milled refuse without cover or covered refuse that was unmilled; second, to determine if milled refuse without cover will draw a rat population; and third, to determine if rats can survive on milled refuse.

The first portion of the rat studies involved placing bait stations at many locations within the Olin Avenue Landfill and observing the rate of bait consumption. This evidence, plus observations of burrows, the apparent activity of the burrows, and actual rat sightings were used as an indication of where the rats were located at the landfill, and whether they preferred milled, covered refuse cells, or covered, unmilled refuse cells.

The conclusions of this portion of the study were, first, that the rats had a definite preference for locations near the periphery of the landfill, especially the border closest to a nearby creek. This preference overshadowed any preference for either the milled or unmilled cells. Second, most of the burrows were found on covered cells containing refuse that was unmilled. Although there was much test drilling on milled refuse cells, few burrows were developed, probably because of the lack of food materials of sufficient size and the difficulty in making a stable burrow in the milled refuse. In this regard, it was noted that most burrow development occurred when there was a surface irregularity on a cell, such as an erosion gully or the protrusion of a large object. Both of these situations were less likely to occur with the milled refuse cells.

In two instances, milled, uncovered refuse was placed in remote locations to determine whether rat activity would be drawn to it. In the first case, the refuse was placed in an open space within a residential area where no rats were positively known to exist. In the second case, refuse was placed in a remote, unused spot in the Olin Avenue Landfill where rats were known to exist at the time. When no evidence of rat activity could be found on either test pile after several months, the test was terminated.

The final portion of the rat studies involved feeding milled refuse to rats to determine whether they can survive on refuse and water. This portion of the work was contracted to Purdue University, where a large colony of wild Norway rats is kept for test purposes. On four occasions, groups of 10 rats were placed in cages containing only water, refuse and nesting facilities. Sufficient milled refuse from Madison was placed in the cages to insure that at least two to four times the amount of food matter required by rats was present at all times. In two tests, freshly milled refuse was used; in two other tests, refuse milled two years before was dug from an Olin Avenue Landfill cell. The conclusions were that the rats could not survive on either aged or freshly milled refuse, for after 6 to 12 days, they resorted to cannibalism to survive.

The fly studies were also divided into several parts. The first part was to indicate whether milled, uncovered refuse was more or less preferable to flies than unmilled, covered refuse. The second part of the study was to compare fly emergence on milled and unmilled refuse. The third section was to determine whether flies can survive and complete their life cycle in milled refuse under laboratory conditions, and the fourth was to determine the mortality rate of maggots passed through the milling process with municipally collected refuse.

A Scudder Grille was used to determine fly population densities at the Olin Avenue Landfill. The grille looks much like a miniature wooden fence, consisted of 1/4-in. by 3/4-in. slats arranged in such a fashion that flies would be drawn to it because of the many edges. The grille was placed on each test spot, and the flies present after 30 seconds were counted. If this procedure is done under specified, uniform weather conditions, it is a standard means of evaluating fly populations in the immediate vicinity of a test area.

The Scudder Grille was used to evaluate the relative numbers of flies on the several types of test refuse cells at the Olin Avenue site. In particular, the densities of the fly populations on the milled, uncovered cells were to be related to the densities on the unmilled, covered cells. The conclusion was that there was little difference between the two cell types with respect to fly populations to be found on them. The results suggest that slightly fewer flies were found on the milled cells, but that the differences as well as the fly populations in each case were small.

The second portion of the fly studies dealt with the likelihood of flies emerging from milled and unmilled piles of refuse. Approximately 2 tons of refuse were placed in each of three screened enclosures measuring 10 by 10 by 6 ft high. Milled refuse was placed in two of the enclosures, and unmilled refuse that had been compacted with a D-7 tractor was placed in the third. No cover was used in any case. Periodically during a 1-month period in midsummer, the number of flies in each cage was estimated. The results indicated that considerably fewer flies emerged from milled refuse. In addition, of the 3,200 adult flies and maggots introduced to the one milled refuse cage, the flies were able to survive but the maggots could not complete their life cycle.

The final two portions of the fly studies were directed to the question of why so few flies were observed on milled refuse. Freshly milled and 6-month-old milled refuse samples were subjected to the optimum temperature, humidity, and light conditions commonly used to promote fly populations in laboratories to determine if flies could ever complete their life cycle using milled refuse as a substrate. Cardboard cartons filled with milled refuse of the desired moisture content were covered with cheesecloth. To one carton of each refuse type, approximately 1,000 fly eggs were added; no eggs were added to the other two cartons. In the carton of freshly milled refuse to which no eggs were added, no flies were observed; in the carton to which 1,000 eggs were added, approximately an equal number of flies developed at the end of the 3-week life cycle. This test result indicates that under the closely controlled laboratory conditions, freshly milled refuse can support flies throughout the growth cycle. This ability was evidently lost within the first 6 months of aging, however, for no houseflies were observed in either carton containing the aged, milled refuse.

The final portion of the fly tests examined the survival of maggots in the milling process itself. Two tests were undertaken by adding 6.000 and 12,000 maggots, respectively, to about 100 lb of refuse on the feed conveyor going into the mill. This refuse was then collected in plastic bags after milling and subjected to the laboratory conditions shown previously to promote fly emergence with freshly milled refuse. The results were that no adult flies emerged from the first refuse sample, but 84 did from the second.

The conclusions of the fly studies point to several reasons why there have been no fly problems with milled, uncovered refuse throughout the 4 years of this project. First, the milling process itself kills nearly 100 percent of the maggots that may be present in incoming refuse. Second, the optimum conditions necessary for freshly milled refuse to support the fly reproduction cycle are rarely obtained in a landfill (moisture content is especially important). Third, once the refuse has aged a few months, this ability is destroyed, even under optimum conditions. Fourth, field studies indicate that whether flies emerge from refuse or elsewhere, they will be no more attracted to milled, uncovered refuse than to covered piles of unmilled refuse.

Leachate and Gas Production. Of the 22 refuse cells built at the Olin Avenue Landfill, 14 were provided with a mechanism for leachate collection. This mechanism consisted of a plastic sheet approximately 40 by 40 ft, placed at the base of each cell and contoured in such a manner that water flowing onto the sheet was directed to a reservoir at the center. The reservoirs consisted of vertical sections of pipe at least 6 in. in diameter, sealed at the lower end, and protruding above the top of each cell. Appropriate slots were cut into each pipe so that leachate would flow from the plastic sheets into the reservoir, where it could be pumped out using a vacuum pump.

The leachate accumulated since the previous sampling was pumped out once every 2 to 4 weeks or more, depending on the season of the year and the history of each particular cell. The volume of leachate and its temperature were noted, and samples were taken for laboratory analyses for conductivity (specific conductance), pH, alkalinity, hardness, chemical oxygen demand (COD), chlorides and sometimes nitrogen in its various forms, phosphorus, biochemical oxygen demand (BOD), dissolved oxygen, and iron. Records were also kept of weather station precipitation data for use in interpreting leachate volume results.

Gases were sampled from various locations with 12 of the refuse cells by means of rubber tubes connected to plastic funnels imbedded in the cells at 1-, 3-, and 5-ft depths. The open ends of the funnels were covered with coarse screen to prevent blockage. The sampling process consisted of withdrawing gas through the rubber tubes and into 125-ml gas sampling flasks, using a vacuum pump. The assembly was purged for 30 seconds before the valves on either side of the sampling flasks were closed to isolate the sample. Analyses were performed using a Fisher Gas

Partitioner to determine concentrations of H_2, N_2, O_2, CO_2, and CH_4. It is noted that this device does not measure water content. A special effort to measure NH_3 was unsuccessful because of very low concentrations. Gas sampling normally was done monthly.

The data indicate that the milled cell produced leachate more rapidly and at a higher rate than did the cell with unmilled refuse. It is likely that the flat surface of very absorptive, milled refuse readily soaked up moisture rather than passing it off as runoff, thus accounting for the more rapid leachate production. Once the cell with unmilled refuse had picked up sufficient moisture to reach field capacity, however, it produced leachate at approximately the same rate as did the milled cell.

As refuse reaches field capacity and begins to produce leachate regularly, complex reactions take place as it undergoes the process of decomposition. Biological activity becomes increasingly important as moisture levels above a threshold level are reached; and as a result of biological action, previously solid organic matter is rinsed out by water flowing through the refuse. This leached organic matter is measured by the COD test in terms of the oxygen equivalent required to chemically oxidize it in a strongly oxidizing solution.

The milled cell rapidly produced leachate with a peak COD value, and the peak occurred soon after leachate was produced regularly. This fact is in keeping with the observation that the milled cell accepted moisture more rapidly, produced leachate more quickly, and therefore reached moisture levels more suitable for decomposition sooner than did the unmilled, covered cell. The COD value began a steady decline after this peak and exhibited minor rises during subsequent summers as summer weather warmed the cells and promoted slight COD increases.

The cells of covered, unmilled refuse exhibited much different COD curves. COD values of these cells increased to an initial peak value after a longer waiting period than with the milled cell. The peak is relatively low at 20,000 ppm. This initial COD peak represents removal of only a fraction of the total COD to be produced, however, and it is left for continued activity during subsequent warm summer months to remove the remaining COD. It is not possible to conclude from these results which type of degradation curve is better for the environment. Whether one curve is more desirable than the other is a matter of judgment. But for a landfill in use over a period of several years, approximately the same amount of COD will be produced regardless of which curve is applicable.

Conductivity is similar to COD in that both are gross indicators of the amount of certain classes of material in leachate. COD is primarily a measure of organic content. Conductivity is mainly a measure of the ionic content, which is in turn a measure of the dissolved inorganic matter in the leachate. The solubility of inorganic matter is a function of several factors that are related to the level of biological activity, including temperature, pH, and direct biological action. It is not surprising, therefore, that the conductivity curves are somewhat similar to the respective COD curves. As with the COD values, a peak conductivity value was produced more quickly with the milled refuse cells. The conductivity of the leachate from the milled refuse cell also dropped off to a continued but lower value rather quickly after the peak value was reached; with the unmilled, covered cell, conductivity values have continued at higher levels through the later years of study.

It is beyond the scope of this article to consider the results of the other leachate analyses, including alkalinity, hardness, chloride, iron, nitrogen, and phosphorus. The results of these analyses are useful in attempting to understand the decomposition process in more detail, and they do provide some insight into the pollution potential of landfill practices. It is simply noted here that the curves of these parameters fit in well with the COD and conductivity results and the discussion of these results given previously. Typical concentrations of these parameters are provided in Table 9.

The gas composition results were not nearly as informative as those on leachate in describing the decomposition and the environmental effects of the two cell types. The data for different cells of the same type, which would normally be expected to correlate, varied so widely that it was difficult to describe typical curves to determine the real differences between milled, uncovered and unmilled, covered cells. Part of this variability is evidently inherent in gas sampling, since even the results for one specific cell often fluctuated widely from one sampling period to the next.

There are several reasons for the variability in the gas results. First, gas samples represent the gas composition at the point and time of sampling, whereas leachate samples represent averages over large portions of the cells and from the previous sampling date. Second, a given sampling location may be highly unrepresentative of the entire cell, for refuse composition or moisture routing through the cell may be atypical at that point. Third, cracks or other ready access to the cell surface

TABLE 9. TYPICAL VALUES OF VARIOUS LEACHATE PARAMETERS

Item	Maximum value		Minimum value		Average value	
	Cell 2*	Cell 14†	Cell 2*	Cell 14†	Cell 2*	Cell 14†
Total hardness (mg/l as $CaCO_3$)	9,140	6,660	1,030	680	2,490	3,650
Calcium hardness (mg/l as $CaCO_3$)	3,420	4,620	240	860	940	2,580
Alkalinity (mg/l)	8,200	10,100	770	1,310	2,880	3,880
Chloride (mg/l as Cl)	970	2,120	120	300	530	1,160
Iron†† (mg/l as Fe)	- - -	- - -	- - -	- - -	73	636
Total soluble phosphate†† (mg/l as PO_4)	- - -	- - -	- - -	- - -	4.2	19.6
Total soluble nitrogen‡ (mg/l as N)	275	625	197	342	232	423

*Cell 2 is milled and uncovered. The typical peak temperature of such cells was about 120°F.

†Cell 14 is unmilled and covered. The typical peak temperature of such cells was about 100°F.

††Recent average values (earlier values are not reported here because of different analytical techniques).

‡Apply to first 2 years or so of decomposition.

may be brought about by the way a cell is constructed and by aging of the cell. Last, the permeability for gas transfer of refuse itself and of any cover used varied from cell to cell. In part, this is a function of the degree of compaction. The desire to compare milled, uncovered and unmilled, covered cell constructions, however, led directly to different permeabilities and, accordingly, to different results than would be expected.

For example, it was noted that during the first year or so of decomposition, when milled, uncovered cells were undergoing more active decomposition as indicated by leachate and cell temperature results, the CH_4 and CO_2 contents of the milled cells were typically less than those for the unmilled, covered cells. This apparent discrepancy may be explained by the relative ease of gas transfer between the interior of the milled cells and the atmosphere. The transfer would improve the rate of loss of the CH_4 and CO_2 produced as well as increase the N_2 and O_2 levels.

To summarize the gas results, it was concluded that the results do not contradict the other indicators of decomposition measured, particularly the leachate analyses. It is beyond the scope of this paper to present sufficient data and discussion to enable the reader to make this conclusion for himself, particularly since the other test results are much more meaningful in this respect.

The above data constitute only a summary of the conclusions arising from the leachate and gas studies. A more thorough technical article dealing with these matters is presently being prepared as an OSWMP interim report on this project.

Use of Cover Dirt. The practice during this project has been to cover the top and sides of the raw refuse cells, but not the daily working face. This practice amounts to providing what is commonly called intermediate cover. The corresponding milled refuse cells were not covered. Not until August 1969 were two milled refuse cells covered to estimate cover dirt requirements in the event that it was needed. It appears that practical depth of cover dirt on raw refuse is 14 in. on top and 18 in. on the sides of the cells. The volume of dirt used to cover the sides of the cells could be diminished, however, if the sides were not as steep and if the sides were better compacted to reduce infiltration into the voids.

Based on the measurements of depth of cover dirt, a practical depth of cover dirt for use on milled cells is 6 in. The cost of cover dirt (purchased or hauled from onsite) appears to be less for milled refuse since these cells require less depth of cover and have reduced area to be covered because of greater density of milled refuse.

Refuse Densities. Piles of milled and raw refuse were constructed at the same time so that comparisons could be made between them. The densities are used as a measure of the amount of landfill space that can be conserved by milling. It is important to note that the milled cells have no cover dirt on them. The raw refuse cells were covered, however, and the volume of cover dirt is included in the volume and density results for these cells. All cells were constructed above grade and hence are simply piles rather than filled trenches or ravines. The cover dirt that was placed on the raw refuse cells was a cap on the top and sides, but no daily cover was applied on the working face. This type of cover dirt operation is what is commonly termed intermediate cover.

Although one may not practically expect to leave milled refuse uncovered as long as it was in this project, it appears that aside from ground water contamination considerations, no daily or intermediate cover is necessary. The question of water pollution seems to be more dependent on local hydrogeological conditions than on differences between raw and milled refuse. In a multilayer landfill, the bottom layers may possibly remain uncovered until the next layer of milled refuse is placed on top of it. This sequence could be followed until the landfill reached final grade at which time the refuse would naturally be covered. Such practice would appear practical only if the area left uncovered were kept within some reasonable limits of space and time -- covering with earth or refuse within 6 months, for example.

Field Volume Tests. The test cells of milled and raw refuse were compacted to a 6-ft depth by a D-7 bulldozer. Thus, both the same equipment, methods, and depth were used in constructing both types of cells. The cells were then surveyed using techniques common to highway work. The initial results are that milled refuse has an average density of 930 lb per cu yd, and raw refuse has an average apparent density of 570 lb per cu yd, including the volume of cover dirt. The average density of unmilled refuse before it was covered with earth was 780 lb per cu yd, or 11 percent lower than the average density of milled refuse without cover. As a practical consideration, however, uncovered, milled refuse can be compared to covered, raw refuse because sanitary landfill implies use of cover dirt and this project is based on using milled refuse without cover. Hence, comparison of the densities of refuse cells constructed in a similar manner (except for cover dirt) is as valid as the comparison of two dissimilar disposal methods (sanitary landfill and milled refuse landfill).

Effect of Milling on Landfill Operations

Milling is only one alternate processing method that can be used in conjunction with landfill. It is not meant as a replacement for sanitary landfill, but its characteristics may enable a higher set of operating standards to be followed. Because of the low cost and satisfactory results attainable with a sanitary landfill, it is natural that this system should be the prime disposal method. But where the desired quality of sanitary landfill operation is difficult to attain because of local conditions, other processing methods such as milling or baling merit consideration for use in conjunction with sanitary landfill.

In the opinion of the author and the city of Madison, for the same effort, milling of refuse for landfill results in a higher quality operation than standard sanitary landfill techniques. Since milled refuse appears to be less esthetically objectionable than raw refuse, compaction, covering, and other landfill operations are more flexible when using milled refuse. The supervisory emphasis must, however, be shifted from the landfill to the milling plant to assure continuous operation at high performance. Both the project director and the director of public works believe that the improved quality of landfill operation may well justify the increased cost of milling. The improved operating quality of milled refuse landfills must be acknowledged when comparing costs.

FUTURE DIRECTION OF THE PROJECT

Steps are presently being taken to start a two-shift operation that will mill 280 tons a day to verify the cost projections for this size operation. On the basis of the results, a decision will be made whether or not to build an additional milling facility to handle all millable refuse in the Madison area.

If new milling facilities are built, more efficient plant operations can be achieved on the basis of experience gained to date. Better plant layout and better feed and take-away systems will be incorporated into any new facility.

Negotiations are presently underway with a community 12 miles south of Madison to acquire an 870-acre landfill site. If negotiations are successful, the proposal will be to build a high-elevation refuse hill with milled refuse on this site beginning in late 1972 or early 1973.

Permission to use approximately 1500 sq ft of floor space in the new plant addition has been given to the Forest Products Laboratory of the U. S. Department of Agriculture. They will carry on bench tests of various material handling concepts to sort wood fiber from the milled refuse stream. If any of these concepts are successful, they will hopefully be incorporated into the existing and future milling facilities if markets can be obtained for the wood fiber.

There is presently a demand in the Wisconsin area for cans for detinning. The feasibility of separating the tin cans from the milled refuse is being considered.

A proposal is planned to try a concept that uses the earth as a "biological incinerator," an idea developed by Sam Hart. The proposal is to apply from 100 to 200 tons of milled refuse to a sandy soil with little or no humus and then irrigate for crop growth. Laboratory tests with the sandy soil have shown that the addition of milled refuse improves the soil's moisture retention capability.

The present site used for the Madison project was the only one available in 1966 that met the criteria for the original project. The site had not previously been engineered, so there are many problems on the site that make good demonstration of the milled refuse concept impossible. Procedures are being evaluated to be used on a new site that will show that the milled refuse concept can be used in an innovative way to shape land and operate a disposal site one generation away from the present sanitary landfill concept.

At the present time, negotiations are underway with the Federal Office of Solid Waste Management Programs for additional testing in regard to milled refuse. Although these tests will add substantially to the present knowledge of milled refuse operations, only successful field experience will in the end prove or disprove the worth of the concept.

CONCLUSIONS

The conclusions reached during the demonstration milling program at Madison are as follows:

1. The capacity of the Gondard hammermill is 9 tons per hr and that of the Tollemache vertical shaft hammermill is 15 tons per hr. These figures were obtained with hammers and grates chosen to grind refuse as coarse as possible without creating blowing litter problems in the landfill (90 percent of the particles pass through a 3-in. screen).
2. Aside from some minor problems with the mills themselves, most of the initial operating problems were associated with conveying refuse to the mills and carrying milled refuse to the landfill. The steeply inclined feed conveyor and the stationary compactor with a 75-cu-yd transfer vehicle used with the Tollemache mill have greatly increased the ability to handle both raw and milled refuse on a production basis.
3. Based on 1970 figures, cost projections indicate that the cost of milling and landfilling 61,800 tons of refuse per year, exclusive of land charges and administration, will be $2.80 per ton with the Gondard mill. Comparable costs for the Tollemache mill handling 61,800 tons per year are $2.12 per ton.
4. Domestic solid waste can be shredded in either type of hammermill without presorting and with negligible downtime due to mill stoppage.
5. Milled refuse has been left in a landfill without cover for up to 4 years without complaints having been received about odors, nuisances, offenses to onlookers, blowing milled material, insects or rodents.
6. Experience with the use of milled refuse without daily cover indicates that the quality of operation at this type of landfill is superior when compared with sanitary landfill operations at Madison with respect to travel over the fill and at the face of the fill, blowing paper and dust, tracking of trucks on highways, appearance during operating hours, and maintaining a uniform, high level of operations during cold and wet weather.
7. Fully loaded trucks exceeding 72,800 lb can drive on the milled refuse in inclement weather, facilitating continuous, high quality landfill operations. Tire problems have not been experienced from traveling on the uncovered, milled refuse.

8. Experience and specific tests have indicated that there is less fire hazard with milled than unmilled refuse. Although freshly milled refuse does support a fire, it spreads slowly and is readily extinguished with water.
9. Density of milled refuse without cover dirt was found to be approximately 10 percent more than the density of unmilled, uncovered refuse. When intermediate cover dirt was placed on the unmilled cells, the apparent density of the milled refuse cells was from 53 to 90 percent greater than the apparent density of the unmilled cells. Translated into space savings, 35 to 48 percent less space may be required for milled, uncovered refuse than for unmilled, covered refuse.
10. Rats and flies are no more likely to be found on milled refuse without cover than on unmilled refuse that is covered as customary in sanitary landfill practice.
11. Rats cannot survive on a diet of milled refuse.
12. Under optimum weather and moisture conditions, flies can breed in freshly milled refuse; however, once the refuse has aged several months, this ability is evidently lost. Cage studies and fly counts on the landfill provided data that complements operating experience at Madison, where no fly nuisance problems have been observed.
13. Tests with the Gondard mill showed that nearly all of fly maggots passing through the mill with refuse were killed.
14. Milled refuse cells that were not covered produced leachate faster and with higher contaminant concentrations than nearby cells containing unmilled, but covered, refuse. Once the period of peak productivity is passed, the milled refuse cells produce leachate of ever decreasing contaminant concentrations. Levels dropped much lower than unmilled refuse cells 6 to 12 months after the peak. Unmilled, covered refuse cells continued to produce leachate at substantial contaminant concentrations throughout the 3-year length of this study.

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EVALUATION OF THE KUKA "SHARK" COLLECTION VEHICLE

*William O. Schumacher**

THE PUBLIC WORKS DEPARTMENT of the city of Savannah has undertaken a study of its solid waste collection system and a special waste collection vehicle commonly referred to as the KUKA "Shark." This vehicle is manufactured by Keller and Knapisch of Augsburg, Germany, and is distributed in the southeast area of the United States by a subsidiary of the St. Regis Paper Company.

CURRENT OPERATING PROCEDURES AND EQUIPMENT

Before describing the project as such, a brief description of our problem and some definition of terms are in order. The city of Savannah is a coastal plain city with a population of approximately 120,000. All solid waste collection services are provided by Savannah within the city limits. The city has a commercial refuse collection operation that uses the dumpmaster type of collection with front-end loaders. Residential refuse in cans is collected twice a week behind the home or in the alley and all other solid waste (yard waste, bulk waste, etc.) is collected from the curbside and alleys of the city on a scheduled but infrequent basis. In addition to the solid waste collection system, the city of Savannah operates a sanitary landfill that serves not only the citizens of the city, but about 35,000 additional people from the county. The private collectors who serve the county areas pay a fee for using the landfill. In 1969, Savannah purchased a landfill compactor (Bros Sani-pactor) that has extended the life of the landfill by about 15 months beyond what had been anticipated.

Savannah's definitions of solid waste may differ from some of the terms used in other communities. The terms below are used in the following contexts:

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Commercial refuse collection. This term refers to any solid waste placed in a dumpmaster container and collected by the front-end loaders.

Residential refuse collection. Collection of only those items placed inside cans or in containers directly adjacent to the cans.

About 60 percent of this collection involves cans that are placed in the alleys and are easily accessible. The other 40 percent of the city involves collection from the rear of the house.

Trash collection. This term includes almost everything not covered by the two categories above. This type of collection ranged all the way from paper pickup to the removal of large appliances. To be collected, all items must be placed either in the alley or on the curbs of the city. The trash removal operation does not involve going onto private property.

Removal of abandoned vehicles. There is no organized program for the removal of abandoned vehicles from the streets, lanes, and private property within the city of Savannah. Vehicles are removed as time permits by both city forces and a private contractor.

The city uses five different methods of collecting solid waste. These are:

Open-pan trucks. The pan trucks are usually manned by a driver and two other men. The two helpers on the truck may either be from a local prison or paid labor. Loading is usually done by hand. The men pitchfork the trash into the open body until the truck is filled; it is then driven to the disposal site. All types of items can be placed in the pan trucks, ranging from leaves to heavy appliances. If a load of leaves is being carried, a tarpaulin is placed over the load to prevent them from blowing out of the truck. Naturally, the disadvantages of this system are the physical effort required to load such a truck and the number of trips to the disposal site that are required each day.

Dump truck with front-end scoop. The city has three of these trucks. Their primary function is to follow the street sweepers and pick up the sweeper dumpings. When street sweepers are not working because of rainy weather or breakdowns, however, these loaders will assist the pan-truck operation by loading both the pan trucks and themselves with trash. Since the actual movement of the refuse from the ground into the truck is quite rapid, the open pan trucks become loaded quickly and must make many trips to the disposal site each day. The loaders are thus idle much of the time.

Packer trucks. In 1969, the city purchased three 20-cu yd packer trucks for use on the trash routes. These packers are efficient to the extent that they can haul a greater total weight per load than the other trucks, thus requiring fewer trips to the disposal site each day. The physical labor required to load one of these packers is much less than the open-pan truck since the distance from the ground to the hopper is only about 30 in. The packers are limited by the type of material that can be placed in them. Large appliances can be handled, but they constitute a hazard to the operating mechanism of the equipment.

Leaf suckers. Savannah has two leaf-falling seasons--the deciduous trees shed their leaves in the fall, and the live oaks and pine trees shed their leaves in the spring. Thus the falling leaf problem affects the city of Savannah from approximately October 1 through November 15 and again from about March 15 through April 30. The trees do not shed their leaves all at once, but gently drop their leaves throughout the two time periods mentioned. The leaf suckers are then employed to remove the leaves from the streets by creating a vacuum and then passing the material through the impeller, where it is ground up and blown into the truck body. On a good day, a three-man team can collect about 18,000 lb of leaves by this method.

Brush chipper. This is a two-man operation using a truck and a brush chipper. The operation is not confined to any definite area but involves a roving truck equipped with a mobile two-way radio. The brush chipper is used to cut green limbs up to about 4 in. in diameter.

STRUCTURE OF THE DEMONSTRATION PROJECT

The five vehicles listed above will provide the baseline for our analysis of the KUKA Shark and for determining whether or not the Shark is a more efficient and effective method of collecting solid waste. The 2-yr project is broken down into three 6-month periods: The first involves dry trash collection, the second has to do with residential refuse collection, and the third will combine trash and residential refuse collection on the same route with the same vehicle.

On completion of this demonstration project, the research undertaken should reveal answers to the following questions regarding the performance of the KUKA Shark versus existing equipment and methods:

1. Does the equipment demonstrated result in a reduction of the man-hours required to collect a given quantity of refuse?

2. Does the equipment demonstrated result in a reduction of the total cost of collecting a given quantity of refuse?
3. Do practical opportunities exist for combining the collection of dry trash and refuse by using the equipment demonstrated?

Because of a delay in the delivery of the Shark, data on this vehicle is not available for this presentation. However, much preparation has already gone into developing forms that will be used to collect data on this equipment. Two types of data will be collected. The first is short-range data collection and the second will cover the entire 18 months of data collection on the project.

The Short-Range Study

Data collection in the short-range study will involve a time and motion study. The plan is to hire nine college students this summer to conduct this part of the operation. This study will analyze the Shark in detail and compare it to our pan truck and packer-truck systems on a direct day-to-day basis. Three teams of three men each are expected to be in the field each day. The three operations must be observed simultaneously otherwise, weather factors would throw off any data collected. These teams will be armed with stop watches, clip boards, and data collection forms (Figures 1-5). They will meet the trucks at the city lot at 7 a. m., and follow one pan truck, one packer, and the Shark throughout the entire day. One of the teams will be selected to monitor the trucks and the drivers with stop watches. Since we assume that all trucks are ready for movement at 7 a. m. each day, the time will begin at that hour. Timing for the day will end when the truck is parked for the evening. One man will be assigned to each of the helpers on the truck and will record all times pertinent to this operation. Figure 1 shows the types of refuse to be collected divided into six categories. The entire operation has been broken down in detail, recording both the number of units and the time needed to accomplish each unit, for appliances, household goods, etc. The number of units is the number of times the worker must go from the ground to the hopper or truck body to clean up a specific pile of trash. Figure 1 has also been partially filled in to show the extent to which this operation was observed.

At the end of each day, the recorder or observer will tally the units and record on Figure 2, all noncollection times, the various times for each category, and the weights of the loads carried to the landfill that day.

Figure 3 will be prepared by the Public Works Department staff from data on Figures 1 and 2. The man-hours will be taken from Figure 1. Costs for each of the operations are the employee's pay rates plus a 19.86 factor for overhead.

Figure 4, a summary of the times each truck is used, will be prepared by the Public Works Department staff.

Figure 5 will be the summary sheet for each truck during the period involved in the time and motion section of the Shark study. This form will also be prepared by the Public Works Department staff.

A procedures manual telling how to complete each space on the forms is in the process of preparation.

To obtain a realistic comparison, the three types of collection systems will be interchanged and observed. Hopefully, exactly the same routing will be used for each system. Thus, over a period of about 4 weeks, the type and amount of trash deposited in a given location within the city should be similar enough to make a very accurate comparison among the three systems. Obtaining a 100 percent accurate picture of the trash collection system may not be possible; phase 2, however, or the residential refuse collection phase of this analysis, will produce conclusive results as to the value of the Shark. When it comes to the combined refuse and trash collection system, methods of collecting data may have to be altered slightly to get the desired results.

A Date__________ B Truck no __________ C Employee name __________

Recorder __________ Type of operation __________ Employee no __________

D Preparation	E Appliances		F Leaves		G Limbs		H Household goods and furniture		I General trash		J Refuse cans or bags		K Remarks
Time	Units	Time	Units	Time	Units	Time	Units	Time	Units	Time	Units	Time	

Figure 1. Form 1: Employee daily record.

A.
Date ____________
Recorder ____________

B.
Truck no. ____________
Type of operation ____________

C.
Time in ____________
Time out ____________
Total time ____________

D.
Mileage in ____________
Mileage out ____________
Total mileage ____________

E.
Weight in ____________ Weight in ____________ Weight in ____________
Weight out ____________ Weight out ____________ Weight out ____________
Total weight ____________ Total weight ____________ Total weight ____________
Daily total weight (all trips) ____________

F.

Activity	Time of day	Mileage
1. Leave yard	______	______
2. Arrive route	______	______
3. Start lunch	______	______
4 Stop lunch	______	______
5 Resume route	______	______
6 Leave route for landfill	______	______
7. Arrive at landfill	______	______
8 Leave landfill for yard	______	______
9 Arrive at yard	______	______
10 Maintenance (gas, etc.)	______	______
11 Wait time	______	______

Figure 2. Form 2: Vehicle daily record.

A.	B.	C.
Date ______	Truck no. ______	1. Name Emp. no. ____
Recorder ______	Type of operation	2. Name Emp. no. ____
Daily ______	______	3. Name Emp. no. ____
Weekly ______		4. Name Emp no. ____
Week of ______		

Manpower Summary	Total Man-hours	Total Cost	Cost/ Man-hour	Emp. no.		Emp. no.		Emp. no.		Emp. no.	
				Range		Range		Range		Range	
				M/H	Cost	M/H	Cost	M/H	Cost	M/H	Cost
Preparation											
Appliances											
Leaves											
Limbs											
Household goods and furniture											
General trash											
Refuse cans or bags											
Total											

Figure 3. Form 3: Work distribution summary.

A.
Week of ________
Completed by ________

C.
Total time M ________
T ________
W ________
Th ________
F ________
Weekly total ________

E.
Total weight
M ________
T ________
W ________
Th ________
F ________
Weekly total ________

B.
Truck no. ________
Type of operation ________

D.
Total mileage M ________
T ________
W ________
Th ________
F ________
Weekly total ________

F. Summary of time and mileage, by purpose

	Time	Mileage
In transit to route	____	____
On route	____	____
In transit to fill	____	____
At fill	____	____
In transit to yard	____	____
Maintenance (gas, etc)	____	____
Wait at yard	____	____

Figure 4. Form 4: Vehicle weekly record.

Vehicle number ________ Month of ________

Date	Miles	Down time	Repair and maintenance	Cost	Gallons of fuel	Personnel cost	Total cost	Total cost/ton	Total cost/ mile
M									
T									
W									
Th									
F									
M									
T									
W									
Th									
F									
M									
T									
W									
Th									
F									
M									
T									
W									
Th									
F									
Total									

Figure 5. Form 5: Monthly performance evaluation.

Driver ____________	Truck number ____________
Helper ____________	Time out ____________
Helper ____________	Time in ____________
Mileage in morning ____________	
Mileage at night ____________	
Loads per day ____________	Weight ____________

Type of trash	Truck trouble	Time down
Light ____________	Tires ____________	
Medium ____________	Won't start ____________	
Heavy ____________	Won't move ____________	

To be completed by DPW staff

Labor costs ____________	Man hours per load ____________
Vehicular costs ____________	Man hours per ton ____________
Supervisory costs ____________	Cost per load ____________
Overhead costs ____________	Cost per ton ____________
Total costs ____________	

Figure 6. Form 6: Daily data to be supplied by the driver of each truck.

The Long-Range Study

The second type of analysis of the Shark is a long-term study and will encompass the three 6-month periods of the project. Instead of selecting one truck for each of the systems used - that is, one packer or one pan truck - the entire trash collection fleet will be divided into its various components, and the total weights, costs, man-hours used, and any other pertinent data will be gathered on the fleet assigned to a particular pickup detail. Last summer a student from Georgia Southern College who was participating in the SPUR program (Student Participation in Urban Revitalization) was assigned the task of analyzing Savannah's current solid waste operation in terms of the cost per ton of trash collected by each of the processes used.

Admittedly, some of the data collected during the summer intern's work was not accurate as to the total cost summary for the operation. Vehicular costs were not divided into the maintenance and operation costs categories. The cost per man-hour did not include supervisory help. The vehicular costs were an accumulation of the cost for the first 6 months of 1970 rather than the actual cost during the time period when the study was being conducted. In addition, the depreciation of the vehicle was on a straight line basis, which involved taking the cost of the equipment, dividing it by the number of years on our depreciation schedule, and then dividing that figure by 2,080 or the assumed number of hours that the equipment will be manned during the year. Mileage was not used. In spite of these slight errors in analyzing the work during the period of June, July, and August 1970, it was discovered that the original premise was not true. The assumption was that the packer trucks would produce a higher ton-per-man-hour ratio or a lower cost per man-hour per ton than the open-pan truck. The daily work sheets show that in spite of the steady trips to the disposal sites by the open-pan trucks, they were able to haul almost as much to the disposal site per day as the larger and more expensive packer trucks. Reasons for this include the use of low-cost prison labor on pan trucks and the ability of pan trucks to handle heavier, denser material such as whitegoods.

The following information describes what data is going to be collected, where will the data be found, and who will collect, compile, and analyze it. From this data it will be possible to answer any or all of the following questions with regards to the Shark and its comparison with other types of trash-collection vehicles:

1. Can the vehicle do the job?

2. Can the city save money by using this vehicle?
3. What type of operators' training program will be required?
4. What will it cost to train the men?
5. Will availability of parts be a problem?
6. Is the diesel operation better than a gas operation?
7. What is the cost per ton?
8. What is the cost per mile?
9. What is the cost per man-hour?
10. What is the cost per residence served?
11. How do the cost figures compare with the other vehicle?
12. What is the downtime on the vehicle?
13. What is the packing capacity or pounds per cubic yard?

The first data collected will be on a daily work sheet of each of the trucks in the system.

At the beginning of this project each driver was given a very complicated form on which he was to record his daily activities in 15-min increments - e. g., collection, breaks, maintenance problems. The form, in effect, impaired the project, principally because the workers had not been assured that it was a study rather than a probe into their work habits. Although most of these men were city employees with long service records, they still had the idea that any study would effect manpower cuts and jeopardize their jobs.

The time and motion portion of this study will be able to provide the percentages of travel time, collection time and other nonproductive time that can be averaged out over the data collecting period. Hopefully, there will not be too much of a variance in the times for each of the processes examined. If there is too much variance on a day-to-day basis, then a closer examination of each individual truck will have to be conducted. The present plan would then be to give the driver of each truck a form such as Figure 6 on which he would record only the pertinent data for his day's operation, such as the mileage, the truck number, the names of employees manning the truck, maintenance problems, and the weight of solid waste collected that day.

From this point on, data will be added and accumulated in the office. We have at our disposal the cost figures for salaries, supervisors, and vehicle maintenance and operation. Our data processing printouts on vehicles give the amount of gas and oil used and break down the type of maintenance performed (transmission, tires, electrical system, and the engine). This vehicular information has been collected since August 1969, thus there is a wealth of information available. Information will also be obtained on density achieved within the Shark and on whether the crushing action of the Shark on bulky wastes affects the landfill operation in terms of ease of handling and possible reduced volume in the fill after compaction.

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MECHANIZED RESIDENTIAL REFUSE COLLECTION

*M. G. Stragier**

THE PROBLEM

METROPOLITAN AREAS are experiencing many demands on municipal income. One of the fastest growing is the demand for improved refuse collection service. As concern about environment grows, burning prohibitions are enforced, and as labor costs soar, municipalities face tougher financial decisions.

The labor force for qualified collectors will continue to increase in cost and shrink in source. It is especially important that we reduce labor cost to improve refuse collection economy and service. As haul length increases, it will become increasingly important to reduce the rising transportation cost. Larger loads must be hauled with less labor. Many cities are receiving criticism of present collection practice in response to public interest in beautification and improved environment.

Collection and haul accounts for about 80 cents out of each refuse disposal dollar. It has a greater potential for savings and justifies early attention.

Considering the relatively primitive conventional methods of laboriously handling special, small, nonuniform, unsightly containers, it seems apparent that mechanization shows promise of providing a solution to many of our collection problems.

DEFINITIONS OF MECHANIZED COLLECTION SYSTEMS

Several grants have been authorized for demonstration of mechanized collection systems. Scottsdale, Arizona, received a grant for demonstration of the Barrel Snatcher, Litter Pig, and Trash Hog. The city of Tolleson, Arizona, received a grant for the demonstration of a nonstop truck collection system. Before discussing the various economic and administrative details, let us first define and describe the various mechanizations that will be considered.

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*Public Works Director, Scottsdale, Arizona.

Castle Keep

Perhaps the simplest mechanization is a modification kit for a rear loader called the Castle Keep. This device has been in use for several years and is marketed by several companies. The device in use in Scottsdale is a pneumatically operated, U-shaped rack into which the container is inserted from the side. The rack is mounted on the rear loader platform and is pivoted by a pneumatic ram to dump containers into the loading hopper. It costs less than $750, has a cycle time of less than 10 seconds, and handles the 80-gal containers fed by hand. The Castle Keep is useful for a small community or one starting a containerization program. The device considerably increases the productivity of the crew, but it provides insufficient savings to offset the cost of containers unless rear yard collection service is eliminated. In comparison with other conventional systems, the Castle Keep produces savings only when the homeowner or subdivider provides containers. The Castle Keep system operating in Scottsdale was furnished by the equipment manufacturer and will be included in our discussion as a basis of comparison and for its general interest.

Godzilla: A Modified Front Loader

The original Godzilla, so dubbed by the city workmen, is a modified front loader (Figure 1). This mechanized piece of equipment was developed by Scottsdale to handle containers during Phase I of its demonstration grant program. It is simply an attachment that enables any front-end loader to lift containers sitting beside the truck. It consists of a fork lift frame turned to extend to the side and an arm that pivots to engage the containers. Hydraulic rams extend the frame sideways and swing the arm in and out. Controls for these operations were added to the normal hydraulic system, which raises, levels, empties and lowers containers. Hydraulic control valves were connected in series to accommodate simultaneous movement. Since the frame extends to the side, the truck does not have to back away to dump the containers. The equipment has a cycle time of about 40 seconds for each container. On the route, it will empty about 50 containers per hour. The modification costs about $2,500 and will handle a wide range of container sizes and designs.

This type of mechanization makes a practical backup system for handling small systems or interim work that is not otherwise economically competitive. If 300-gal containers are used, the system is less expensive than conventional collection. It handles containers only at the side of the truck and will not lift past parked cars or other obstructions.

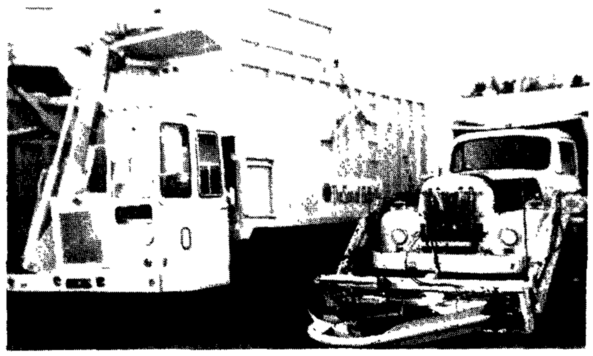

Figure 1. Godzilla – The modified front loader built by Scottsdale to handle containers in Phase I.

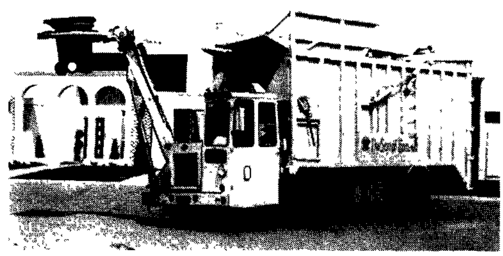

Figure 2. Son of Godzilla – The Barrel Snatcher, or telescoping arm loader, that serves 80-gal containers.

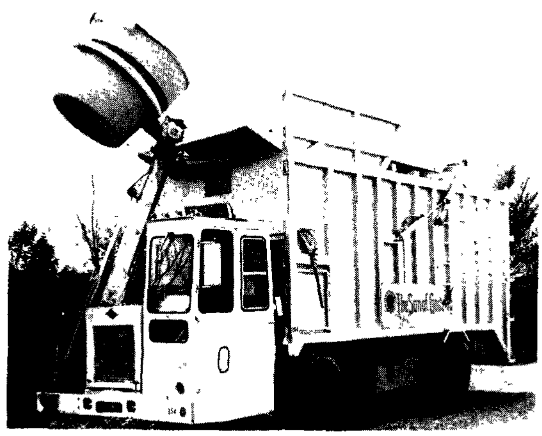

Figure 3. Son of Godzilla – The Barrel Snatcher that serves 300-gal containers.

Son of Godzilla: The Barrel Snatcher

The Barrel Snatcher (Figures 2, 3) is the work horse of the mechanization family. It provides the most economically attractive collection system, is fast, flexible, and has high capacity. It was the objective of Scottsdale's demonstration grant program and is in current operation there. When the old front-end loader, Godzilla, was replaced, the new truck became known as the "Son of Godzilla." It has an 8-ft arm that will telescope to grasp containers 12 ft from the side of the truck. It is operated by a one-hand control, designed so that the container follows the operator's hand. Controls are electrical and operate the hydraulic system through solenoid valves. The Barrel Snatcher is mounted on a special left-hand, cab-forward chassis with a 35-cu yd body capable of a 7-ton payload. The truck has a short wheelbase, 2-axle design that makes it maneuverable enough to operate easily in Scottsdale's 16 ft wide alley system, in spite of competing utility poles. Since the Barrel Snatcher grasps containers from 90° out on the right side to 50° on the left, it can thus grasp containers past parked cars or on either side of the alley. The cycle time for each container is less than 15 seconds. It was manufactured specifically to empty the 300-gal containers, but can be adapted to handle 80-gal containers. The Son of Godzilla has a collection rate of up to 130 curbside containers per hour and has collected regularly in Scottsdale at a sustained rate of over 200 homes per man-hour, including haul, breakdown, and personal time in the alleys.

Litter Pig: The Articulated Arm Loader

The Litter Pig (Figure 4) is another member of the mechanized family. This vehicle is a side loader modified with an articulated backhoe-style arm. The first unit is expected to be delivered in Scottsdale on the 1st of June. The truck will have right hand drive to accommodate manual loading and good visibility. Operated by a simple one-hand control, the Litter Pig will handle the 80-gal containers. It will have an expected cycle time of less than 10 seconds from truck stop to truck start and is designed so that the operator may drive the truck up to a container and away from it without clearing the mechanism from the container. The mechanism rotates the container 180° so the truck may be driven up and then driven away. A reciprocating arm clears the hopper continuously. The operator should empty 80-gal containers at the rate of about 180 per hour.

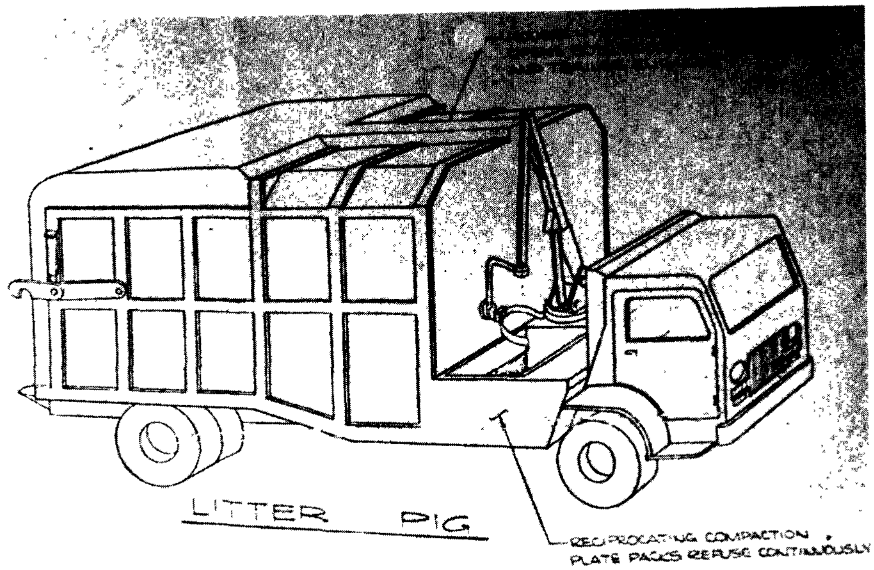

Figure 4. Litter Pig – The articulated arm loader will handle 80-gal containers at the curb.

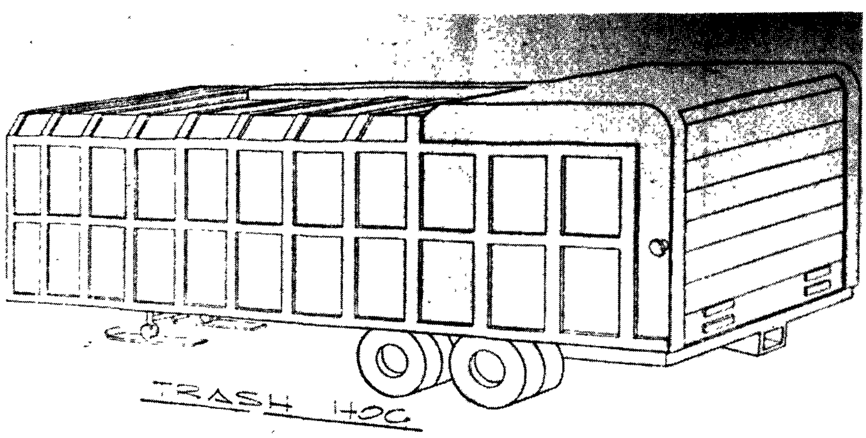

Figure 5. Trash Hog – The portable transfer station accepts refuse directly from the collection vehicle near the collection site.

Nonstop Truck

The nonstop truck is a special design that inverts containers that have been fixed to a stand and placed in the alley. It moves along the alley at a rate of 6 to 8 miles per hour without stopping. The truck bumps each container with a soft tire attached to its front, inverts the container about a horizontal axis, receives dumped material in a hopper along the side of the truck, and then bumps the container back to normal position with a soft tire attached to the rear of the truck. It has been in operation in the city of Tolleson, Arizona, for several weeks. This system will provide collection for up to 480 families per hour. For containers, Tolleson is using 55-gal drums with special lids.

The Trash Hog: A Portable Transfer Station

As haul distances increase and as mechanization reduces collection time, it becomes more and more important to increase the size of loads that may be hauled to the disposal site. The Trash Hog (Figure 5) is a large transfer trailer that will be delivered about the 1st of June as part of Scottsdale's demonstration program. It will have a capacity of over 100 cu yd and will accommodate 3 loads from the 35-yd Barrel Snatcher or 4 loads from the 25-yd Litter Pig. Trucks must be modified to work with the trailers. They require special tailgates and beefed-up ejection systems. Trucks back up to the trailers, tailgate to tailgate, and a guide aligns the two units so that they mate properly. A hydraulic latching mechanism fastens the two units together. Both tailgates are built like segmented garage doors and may be raised by pulling them over the upper rear corner and along the top of the body. With the tailgates interlocked, it is only necessary to raise the truck tailgate to raise both tailgates. The operator may thus accomplish the transfer without leaving the cab of his truck. The trailer will be set up and left unmanned with no need for power. With the tailgates raised, the material is ejected into the rear of the trailer. The truck ejection system must provide sufficient force to push new material into the trailer and to push material already in the trailer up to the front. The truck must therefore push more than 100 cu yd of material at the end of its stroke. Each new load pushes the last one forward in the trailer until it is loaded. With the load transferred, the ejection plate stops at the rear of the truck in a position where its sloped working face can be cleaned off by the tailgates as they are lowered back into place. The ejection plate is slid back as the tailgate is lowered and then retracted to its normal working position. The Trash Hog will haul refuse generated by 1,200 households with twice-a-week collection. Transferring should not keep collection vehicles away from their routes for longer than about 15 min. Several trailers can be serviced by one tractor equipped with the hydraulic and electrical equipment. Trailers can be handled and set up by one man who must leave the cab only to make the electrical and hydraulic connections.

The system should be much more economical than conventional transfer stations. Setups may be made in temporary, convenient locations. Scottsdale intends to use parks, church parking lots, streets adjacent to vacant lots, vacant lots themselves, and other similar locations.

CONTAINER SIZE DETERMINATION

To decide what size containers would be needed, a field survey was made of the quantity of material normally placed for collection. The data, collected on a random sampling basis, closely resembled a normal distribution curve, and therefore a statistical analysis was used to draw conclusions from it. Monthly collection records were also studied to determine that the seasonal variation was small enough to be neglected in the analysis. Experience to date, for the most part, supports the conclusions that have been drawn from the data.

Thirty-six homes were sampled for four collections each. The generation was measured in gallons of capacity needed to take care of the collection. On the first day of the week, the mean generation was 50 gal, with a standard deviation of 22. On the second day, the mean generation was 31 gal with a standard deviation of 22. The 2-week average gave a mean generation of 43 with a standard deviation of 12.

On the basis of these data, 80-gal containers were selected for single families and 300-gal containers for family groupings. The 80-gal container would provide adequate capacity 91 percent of the time on the first day of the week and 99 percent of the time on the second day of the week. The probability of getting four homes together to generate an average of 75 gal apiece is less than the probability of one family generating 80 gal because of the effect of multiplying small probabilities. The 300-gal container should therefore be adequate for four families 98 percent of the time.

Experience indicated, however, that when using municipally furnished containers, generators are more likely to place larger quantities for collection on the first day of the week than when they used their own containers. As a result, containers are more frequently overloaded on the first collection day than had been expected. It was also discovered that during the first several months after municipal containers were furnished, generation rates usually exceeded the average as people cleaned up stored materials. Once the new service habits had been formed and the normal generation rate achieved, the containers provided a very desirable level of service. Several manufacturers helped to design and improve the containers used in the grant. Containers were furnished with lids hinged and fastened to the container (Figure 6). Containers are molded polyethylene, specially shaped to permit mechanical handling and reinforced to permit the grasping and lifting motion. Lids are opened by gravity as the containers are dumped.

The 80-gal containers must be maneuvered by householders and placed at the curb. The first containers were placed on casters so they could be rolled along sidewalks and driveways. When these proved unsatisfactory, two large wheels were furnished. The containers may be tilted back over these wheels like a hand truck and conveniently rolled across lawns, dirt, or gravel, as well as paved areas.

Containers may be furnished in a wide range of colors. Scottsdale chose a light green pastel shade that blends into the background in most locations. The material does not burn readily, but it will melt. Fire has not been a major problem. In Scottsdale, with about 800 containers in use for the last 6 months, we have lost only one container to fire.

Considerable study was given to the advantages of venting containers. The final conclusion was that containers located in the alley and shared by several generators should be vented to prevent build-up of unpleasant odor and to dissipate heat and moisture. The 80-gal containers, which are often stored indoors, are unvented.

GRANT EXPERIENCE

Scottsdale's grant is divided into two phases. Phase I was intended to determine whether homeowners would use containers properly. Phase II, actual demonstration of the various mechanized systems that were approved, is underway in Scottsdale, along with a nonstop collection demonstration in Tolleson. Results of the work are expected to be reported for Scottsdale in 1971 and for Tolleson the following year.

In Tolleson, eight 55-gal containers have been placed on the stands and a preliminary version of the collection vehicle has been operated for several weeks to provide collection service. The prototype equipment that is expected to be placed in operation next summer is now being fabricated. After a period of experimental use and improvement of the equipment, the data gathering will begin next fall.

In Scottsdale, the work of Phase I, has been completed and it has been determined that generators strongly prefer the mechanized system to conventional collection previously provided (Figure 7).

In Phase I, five separate areas of the city were chosen as representative of the city as a whole. In each of these five areas of about 100 homes each, a level of containerized service was provided for 6 months using 80-, 160-, and 300-gal containers and once- or twice-a-week service. Thus, in one area, 80-gal containers were served twice a week. In the next area, 160-gal containers were served once a week. In yet another area, 160-gal containers shared by two families were served twice a week. And in the final area, 300-gal containers were served once a week if shared by two families and twice a week if shared by four families (Figure 8). After serving these families for 6 months with the modified front loader, Godzilla, a careful and thorough attitude survey was conducted and the level of acceptance achieved with each kind of containerized service was determined.

While the containers were being placed in the field, each resident was visited to explain the purpose of the experiment and the use of his container. A number of questions were asked that would be combined with a post-test questionnaire to determine the level of acceptance of the container system. Those unwilling to accept containers were kept on the regular collection system until the experiment was underway, when most of them agreed to participate. Many were hesitant about trying the new system, and many were unwilling to share a municipally-owned container. A careful log was kept of each call from a participating generator and solutions were attempted for the problems encountered. As homeowners became accustomed to the new system, there were fewer and fewer objections. Results were so encouraging, in fact, that permission was given to order the special collection vehicle for Phase II ahead of schedule.

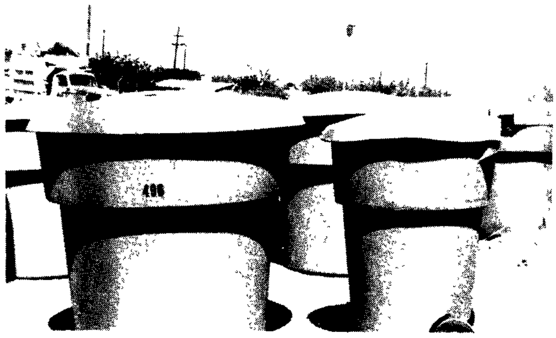

Figure 6. Containers equipped with hinged lids manufactured from polyethylene plastic, reinforced to accommodate grasping and loading. (Note wheels on 80-gal container to accommodate handling by generators.)

Figure 7. A typical alley receiving conventional collection.

Figure 8. A typical alley receiving mechanized service to 300-gal containers serving four families twice a week.

Since the frequency of collection was being reduced from twice a week to once a week in two of the sample areas, the county health department was asked to supervise the experiment and to eliminate once-a-week service if they found that sanitation problems were created. The health department designed a spray program and did fly counts to evaluate the extent of the sanitation problem. Since the lids were fixed to the containers and were normally kept closed, their preliminary conclusions were that the reduction of service did not create a sanitation problem. Furthermore, periodic spraying of lids and interior surfaces with a diluted adulticide substantially reduced the fly population in the experimental areas. The findings showed that no changes in the program were required and that from a sanitation point of view, the new system was generally superior to the old one.

After generators had used one of the new levels of containerized service for 6 months or more, they were interviewed and asked to complete a detailed questionnaire. The questionnaire was designed by a professional in the political science department at Arizona State University. Results of the interview were then accumulated on data processing equipment and conclusions were drawn. Every level of service provided was preferred by users to the conventional system. Attitudes toward the city and the collection service considerably improved during the experiment. Apprehensions were allayed, and users heartily endorsed containerization after experience with it. The report points out that whereas 60 percent of the users agreed that the city was doing an excellent job of refuse collection before the experiment, 94 percent of the participants agreed afterward. Users felt that containers should be made more durable, and 8 percent felt they should be enlarged. Users indicated that the features they liked most were: adequate container capacity (32 percent); cleaner alleys (21 percent); and containers that stay covered and upright (12 percent). Willingness to share a container with a neighbor increased from 55 percent to 78 percent after the experiment. Those who had shared containers were more likely to agree than those who had not. We used a simple rating system to summarize some of the data regarding attitudes in order to create a crude index of favorability for the various levels of service. The following index was derived by using 1.000 as the score for a perfect service that every user would consider satisfactory. The scores are arranged in descending order.

Level of service:	*Score*
160-gal container, one family, once-a-week collection	0.932
80-gal container, one family, twice-a-week collection	.919
300-gal container, two families, once-a-week collection	.904
300-gal container, four families, twice-a-week collection	.868
160-gal container, two families, twice-a-week collection	.860
Conventional service, twice a week	.651

The data above reflects the improved service that results in many of the containerized areas: conventional service in Scottsdale received only 65 percent favorability, but the 300-gal containers serving four families a week received 87 percent, and 80-gal containers serving one family twice a week achieved 92 percent. Based on the work accomplished in Phase I of the Scottsdale demonstration, the following significant conclusions may be drawn:

1. It is economically feasible to provide large containers for single family residences and to serve the containers mechanically.
2. Users prefer containerized service to conventional service.
3. Containerized service creates fewer sanitation problems than conventional refuse collection.
4. Residential generators are willing to containerize their refuse.
5. Residential generators are willing to use containers jointly with their neighbors, and their willingness improves with experience.
6. Generators will effectively position containers at the curb for collection.
7. Periodic spraying to keep flies at tolerable levels may not be necessary.
8. Vented containers are preferred slightly more by generators, but they also create slightly more of a sanitation problem by generating more flies.
9. All levels of service provided in the demonstration were accepted by the users.

ECONOMICS

Economic data has been accumulated and projected for the various mechanized systems discussed (Tables 1 and 2). An attempt has been made to present and arrange the data so that cost projections for local situations can be made.

TABLE 1

PROJECTED COSTS FOR MECHANIZED RESIDENTIAL REFUSE COLLECTION SYSTEMS*

Item	Conventional rear-end loader	Modified rear-end loader†	Modified front loader‡	Litter Pig	Barrel Snatcher	Nonstop truck§
Purchase costs:						
Purchase price	$18,000	$19,000	$30,000	$30,000	$35,000	$18,000
Financing (3-yr, @ 10%)	2,700	2,850	4,500	4,500	5,250	2,700
Total	20,700	21,850	34,500	34,500	40,250	20,700
Monthly operating costs:						
Salary	1,600	1,100	700	700	700	700
Administration and overhead ¶	480	330	210	210	210	210
Operating and maintenance	1,000	1,200	1,100	1,250	1,250	800
Amortization of purchase price #	250	260	410	410	480	250
Total operating cost per month	3,330	2,890	2,420	2,570	2,640	1,960
Monthly cost per residence: **						
Cost of service as a function of t ††						
Curb	1.64+.54t	1.43+.48t	2.06+.34t	0.70+.42t	1.00+.33t	-----
Alley	1.10+.55t	-----	.75+.34t	-----	.37+.34t	0.29+.70t
Cost of service assuming a 1-hr round trip to disposal						
Curb	2.18	1.91	2.40	1.12	1.33	-----
Alley	1.65	-----	1.09	-----	.71	.99

TABLE 1

PROJECTED COSTS FOR MECHANIZED RESIDENTIAL REFUSE COLLECTION SYSTEMS* (continued)

Item	Conventional rear-end loader	Modified rear-end loader†	Modified front loader‡	Litter Pig	Barrel Snatcher	Non-stop truck §
Container cost ♯						
Curb	0	.75	.75	.75	.75	-----
Alley	0	-----	.40	-----	.40	.50
Total monthly cost per residence §§						
Curb	2.18	2.66	3.15	1.87	2.08	-----
Alley	1.65	-----	1.49	-----	1.11	1.49

*Includes cost of collection and haul but excludes cost of supervision, backup equipment and disposal.

†Rear-end loader is modified with lift devices to handle 80-gal containers.

‡Godzilla is used as the base.

§Nonstop truck serves 55-gal containers three times a week.

¶Cost of administration and overhead is 30 percent of salary.

#Amortization is based on 7 years, ignoring resale value.

**Based on 42 hr per week of available collection time, with twice-a-week service except for the nonstop truck.

††t is the average time for round trip to disposal, in hours. Cost is given in dollars.

♯Based on 5-yr amortization.

§§Includes collection only; administrative, disposal, and back-up costs are not included.

TABLE 2

COMPARISON OF CAPACITIES OF MECHANIZED RESIDENTIAL REFUSE COLLECTION SYSTEMS

Item	Conventional rear-end loader	Modified rear-end loader *	Modified front loader †	Litter Pig	Barrel Snatcher	Nonstop truck ‡
Number of residences served per load	300	300	350	300	400	200
Number of residences served per hour:						
Curb	100	100	58	180	130	---
Alley	150	---	160	---	350	480

*Rear-end loader is modified with lift devices to handle 80-gal containers.

†Godzilla is used as the base.

‡Nonstop truck serves 55-gal containers three times a week.

The formula used for calculating the cost of operations per home per month, assuming a 182-hr work month, is as follows:

$$\frac{(\text{No. pickups/mo})(\text{operating costs mo})\,[\text{capacity/load}+(\text{rate/hr})(\text{haul time})]}{(\text{work hr/mo})\quad(\text{capacity/load})\quad(\text{rate/hr})}$$

The following figures are for a Barrel Snatcher serving an alley:

$$\frac{(9)\,(2640)\,[400+(350)\,(t \text{ or } 1 \text{ hr})]}{182\,(400)\,(350)} = \frac{9{,}504{,}000}{25{,}480{,}000} + \frac{8{,}316{,}000t}{25{,}480{,}000} = .37+.34t$$

The most economical service is provided by the Barrel Snatcher with 300-gal containers and service for four families twice a week. The next most economical service was furnished by the modified front-end loader serving the same containers, which ranks equal for this haul time to the nonstop truck serving 55-gal containers on their stands in the alley. The nonstop truck would be more economical for shorter haul times. It is somewhat encumbered by the small load capacity, but hopefully the nonstop truck's performance can be improved as we learn to use it more effectively.

Mechanization will cut normal costs to about half if the homeowner or subdivider provides the containers. To that end, the city council of Scottsdale is now requiring new developments to provide their own containers, so that the city provides only service.

The Trash Hog's effectiveness in reducing costs for longer hauls can be measured in a manner similar to the residential collection vehicles (Table 3).

The economics can be projected on the basis that the Trash Hog will accept transfer from the collection vehicle at an average of 15 min or less and that its subsequent haul time to and from the disposal site will be about the same as it would have been for the collection vehicle.

Provided that the number of trailers are adequate to keep the tractor busy on a full-time basis, and assuming that the tractor will operate for 7 hr a day, 6 days a week, then the maximum number of houses that it will serve turns out to be 24,266 per month divided by the time required for the round trip to the landfill. On the basis of a three-trailer operation (Table 3), the cost per residence per month for the Trash Hog will be \$3,262 divided by 24,266 times h, or \$0.13 h, where h is haul time in hours. The cost of collection for the mechanized collection vehicle in combination with the Trash Hog can be computed by using this formula and the formula used for the collection truck in Table 1. For example, we found that the cost (in dollars) per residence for curb service by the Barrel Snatcher was 1.00 + .33t where t is the haul time to disposal in hours. If the Barrel Snatcher were to be used in combination with the Trash Hog, and if the collection vehicle's haul time for disposal is 15 min or a quarter of an hour, and the haul time for disposal by the Trash Hog is 4 hr, then 1.00 + .33t + .13h, can be substituted in the formula to come up with 1.00 + .09 + .52, or a total cost of $1.61 per residence per month with the Trash Hog. Had the Barrel Snatcher made the haul trip, the cost would have been 1.00 + .33t, or substituting 4 hr for t, 1.00 + 1.32, for a total of $2.32 for the cost of curbside collection.

TABLE 3

THE TRASH HOG: ESTIMATED OPERATING COSTS

Purchase costs:	
Tractor (equipped)*	$ 19,000
Trailers (3)†	66,000
Collection truck tailgate kits (5@$5,000)‡	25,000
Interest (6% over 6 yr)	23,400
Total	133,400
Operating costs per month:	
6-yr amortization of purchase cost	1,852
Operator's salary and fringe benefits	690
Operation and maintenance	720
Total	3,262

*The tractor hauls one trailer at a time to the landfill.

†Each trailer serves 1,200 homes.

‡Average transfer time for collection truck is 15 min.

The cost figures that have been derived provide some remarkable conclusions. Mechanization provides the advantages of better working conditions, furnished containers, better sanitation, and surprising savings. Economics will be the most attractive asset. The costs tabulated in each case are for collection only, assuming that each route is filled, no backup equipment is provided, and no supervision or disposal costs are included. On the other hand, the cost estimates do include fringe benefits, capitalization, labor, maintenance, and operating costs at their measured level in Scottsdale, and the comparison is valid between systems. If a conventional system is used as a basis of comparison, a productive operation will confine costs for curbside collection to about $2.18 per residence. By comparison, the Litter Pig will provide the container and serve it for $1.87 per residence. If the container is provided, it will offer service for $1.12. The Barrel Snatcher serving 300-gal containers in the alley can provide service with the container for $1.11 per family per month. Comparatively, conventional collection costs $1.65 per family per month. In Scottsdale, an annual savings of over $200,000 a year is expected for our population of 70,000 once we have containerized the city. Where haul times are longer, even greater savings may be made. Thus, where the haul time is 4 hr per round trip, the conventional system costs $3.80 per family per month, but the Barrel Snatcher - Trash Hog combination costs only about $2.84, including the cost of containers.

NEW PROBLEMS

There are several additional areas that deserve discussion. Scottsdale has displaced six employees and has had interesting employee relations experiences. We have modified ordinances to require containers to be furnished by developers and subdividers and to be used where they are furnished. Scottsdale has had some public relations experiences that may be valuable.

Displaced Employees

Scottsdale began planning the disposition of displaced employees well in advance. The city held related jobs in other divisions that were opened by attrition. College students were hired to replace these workmen for the summer, and the jobs were thus left open when they returned to school. When the Barrel Snatcher was placed in operation on a full time basis, there were six men who needed to have new jobs. All of the men have been placed in the organization. Two were placed in the parts room, one in street maintenance, and another in sewer maintenance. Two men filled jobs in the refuse collection division. The success of the program was attested to during a recent employee meeting when a laborer asked, "When are we getting some more 'Sons'?" He was anxious to move to his new job, whatever it might be.

Finding employment for displaced employees during the first round was easy. Since the mechanized systems are about 10 times as productive as the conventional one, a "set" of truck and containers will displace about nine employees. The city is looking for help in reemploying these loyal, hard-working men. Attrition and growth won't be enough to absorb them all. The city is working to find grant funds for a detailed study since it wants to develop all the alternatives and select the best. A GED training program has been started, an agreement has been made with the council to set up an apprenticeship program to put displaced employees to work with skilled craftsmen, and the city is planning to hold jobs open. This area of concern needs more attention and more effort will be concentrated on it during coming months.

Ordinance Provisions

The council recently adopted amendments to the subdivision and refuse collection ordinances. The former now gives the council authority to require developers to furnish refuse containers. Developers have taken advantage of the requirement and advertised the modern refuse collection system as a sales inducement. So far, cooperation has been good. The city extends its bulk price to developers and delivers containers as they are needed. The new refuse ordinance requires generators to use containers wherever they are furnished and makes them responsible for negligent damage, cleaning, and keeping a tidy collection station. Copies of both ordinances will be provided on request.

Public Relations

Generators take an intense personal interest in their refuse collection service. It is one of the most important ways that citizens judge their governing bodies. They are often quick to criticize and must be carefully accommodated. We have therefore been cautious and thorough in our public relations. During the experimental phase, information was regularly publicized through the local press. When the new truck arrived, the mayor and our councilwoman held a tea to introduce it to ladies of the city. The truck was demonstrated at parks and schools for children. Since children are among the greatest beneficiaries (they take out refuse and pick up litter), and since they are more aware and concerned about pollution problems, it has been worth the trouble to demonstrate the new system to them. "Godzilla" and the "Son of Godzilla" became well-known. Before containers are placed in a neighborhood, each home is visited by a representative who explains the new system, emphasizes its advantages and offers to return to work out any problems. A letter containing instructions and information including phone numbers is left, and requests for service or trouble calls are followed up. As a result, there has been a minimum of trouble. Less than 1 percent of the users have complained, and then only during the first week or two. Once the extra waste has been cleaned out of the neighborhood and containers are no longer overloaded, there are few complaints. The biggest problem to date has been a lady with an arthritic shoulder who had trouble lifting the lid.

Financing

Since the system replaces high labor costs with high investment costs, it opens a new area of concern for many cities in refuse-equipment outlay financing. The original costs can be financed through municipal revenue anticipation bonds, conditional sales contracts with the manufacturer, lease purchase, improvement districts, interfund loans, and other methods. Scottsdale paid for its first set of containers and equipment from its general fund and will buy subsequent sets with savings. Since unit costs are so much lower, it is a simple matter to finance the capital costs. The system is good protection against increasing labor costs, since productivity is so high.

SUMMARY

The new mechanized, residential refuse collection systems being demonstrated in Arizona are not only cheaper, but they are cleaner, more sanitary, and offer better working conditions. Mechanical devices do the work. The driver never leaves his cab, but he can serve homes more economically than conventional systems with much less effort. Scottsdale is now operating a Barrel Snatcher on a full time basis that enables one man to serve 4,000 homes. It also operates a modified front loader and a modified rear loader as back up equipment. During August 1971, the city will demonstrate more efficient curb collection and a new 100-cu-yd mobile transfer trailer that will accommodate direct transfer from the collection vehicle at the collection site.

Tolleson, Arizona, has begun the demonstration of a new collection vehicle that collects from fixed containers on a nonstop basis.

Using one man who spends his day in an air-conditioned cab with a tape deck and FM radio, the two cities are now collecting with mechanized systems. Compared with conventional systems in which each man serves a population of about 3,000, the mechanized systems will serve populations up to 16,000 per driver. The Scottsdale demonstration project consists of two phases. Phase I was designed to develop feasible containers and to determine whether generators would use them. This phase was successful and has been reported in detail. Users prefer the municipally-furnished containers to the old conventional system by more than 15 to 1. Phase II will demonstrate economics and feasibility of the mechanized equipment. Based on results so far, the new system will live up to expectations. During Phase I, three container sizes were used: 80-, 160-, and 300-gal. Both once and twice- a-week service was tried. Twice-a-week service was found to be more popular and economical. The city has settled on 80-gal containers for curb service and 300-gal containers for alley service. The 80-gal containers are equipped with wheels and are furnished to each homeowner. The 300-gal containers are placed near the joint lot lines to serve four families (two on each side of the alley). Containers are manufactured from polyethylene plastic and have been guaranteed by the manufacturer for 10 years.

Curbside collection costs about $1.33 per dwelling per month and alley service costs about $0.71 per dwelling per month (for a 1-hr trip to the landfill). These figures include amortization, salary, maintenance, and other associated costs; they exclude disposal and administration costs. Adding container amortization costs, the total cost of service per dwelling per month is about $2.08 for curbside collection and about $1.11 for alley service. The transfer trailer, which will haul refuse from about 1,200 homes per load, will provide substantial savings, particularly for long hauls. Five or six drivers are expected to serve the whole community. No longer will employees be required to handle refuse, to struggle in the oppressive heat, or to perform a distasteful, enervating task.

This project has been supported by demonstration grant No. G06-EC-00202 from the Environmental Protection Agency, pursuant to the Solid Waste Disposal Act as amended.

AN ADVANCED PROCESS FOR THE THERMAL REDUCTION OF SOLID WASTE: THE TORRAX SOLID WASTE CONVERSION SYSTEM

John Stoia and Anil K. Chatterjee†*

THE FOLLOWING PRESENTATION deals with the Torrax Solid Waste Conversion System, and more specifically with the Erie County-Torrax Solid Waste Demonstration Project which is being conducted in Erie County, New York, in the vicinity of Buffalo.

Since the initiation of the project in June 1969, work has progressed steadily. Completion is scheduled for September 30, 1971. Total project costs are estimated at $1,840,000. The grantee is the County of Erie, New York. Other funding participants are the parent companies of Torrax, (The Carborundum Company of Niagara Falls and the A. E. Anderson Construction Corp. of Buffalo), the American Gas Association, and the New York State Department of Environmental Conservation. The facility is designed to process 75 tons of refuse in a 24-hr, 3-shift operation, 5 days a week.

The primary objective of the project is to demonstrate a high temperature slagging-type incinerator system capable of converting mixed combustible and noncombustible municipal refuse into a clean, inert, glassy-type, aggregate residue from a molten slag without any unacceptable secondary pollution from the operation. Other secondary objectives are to obtain economic and technical data to evaluate the practical application of scaled-up units throughout the United States, and to train Erie County personnel to operate the facility on a continuing basis when the project is completed.

The County of Erie, New York, (Buffalo area) is the municipal sponsor working through the Federal Office of Solid Waste Management Programs of the U. S. Environmental Protection Agency (see Figure 1). The Erie County Refuse Agency is a

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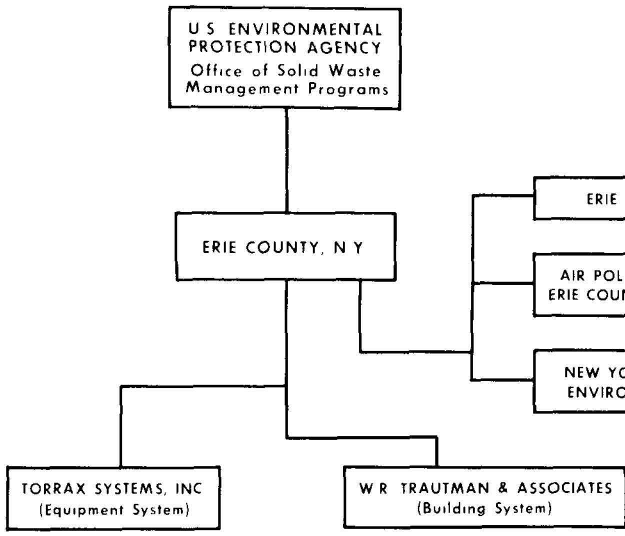

Figure 1. Project organization.

local advisory body made up of public officials, businessmen, and knowledgeable private citizens. The refuse agency was the first to study the merits of the system and its need in Erie County, and to advise the county government to enter into a demonstration project. They subsequently helped the county to prepare the application and guided it through the legislative network. Since then the agency has served in a coordinating capacity with the Department of Sanitation, which directs the project for the county under the Department of Public Works.

The Erie County Air Pollution Control Division of the Erie County Department of Health has assisted in a technical advisory capacity in setting up some of the testing programs, which will be more fully explained later.

The New York State Department of Environmental Conservation, through its Solid Waste Department, is a funding contributor and is coordinating the local program with State planning programs. These organizations coordinate through Erie County's Project Director, Mr. Charles Spencer, P. E., Deputy Commissioner of the Public Works Department.

Implementation of the work was divided into two contracts. One covered the building system, which included the design and construction of the building, utilities, site development, and the overhead crane system. This contract was awarded to W. R. Trautman and Associates, a Buffalo based consulting engineering firm.

The other contract was awarded to Torrax Systems, Inc., of North Tonawanda, N. Y., for the conversion equipment system. This work covers concept engineering, detail design, fabrication, procurement, installation, startup, shakedown, testing programs, training of Erie County personnel to take over the facility, and final reporting.

The project tasks were structured into three major phases (Table 1).

Phase I has now been completed. The primary objective of Phase I was to design, install, and operate those major subsystem components of the entire system necessary to demonstrate that the basic concept is a viable one and that an inert residue could be produced by converting the noncombustible portions of the refuse into a molten slag. These objectives have now been successfully accomplished and will be explained later in more detail.

Phase II involves the installation of remaining equipment for the exhaust-gas pollution control subsystems, startup and integration of the entire equipment system, and Phase II testing. The entire testing program will be explained further on in the presentation.

Phase III will involve the gathering of economic and technical data during sustained 24-hr operations. Erie County personnel will be trained, final reports issued, and the facility turned over to Erie County at the close of the project.

The following description of the concept and how the process works can be better understood by referring to Figure 2, which is a simplified schematic of the system.

The operation does not necessarily require that the equipment be aligned as shown in the schematic. Valves, controls, etc., have been omitted for the sake of simplicity.

The Torrax system is designed to convert mixed municipal refuse--metal, glass and garbage--by completely consuming combustible material and melting noncombustible material at temperatures up to 3,000 F. The refuse is processed without any sorting or pretreatment. The system is designed to operate without producing any unacceptable secondary pollution to the land or air.

TABLE 1

PROJECT TASKS AND TIMING

Phase I (June 1, 1969 – Apr. 30, 1971)	Phase II (May 1, 1971 – Aug. 7, 1971)	Phase III (Aug. 8, 1971 – Sept. 30, 1971)
Design equipment	Procure equipment	Gather data
Design and construct building	Install gas cooler and dust collector	Train Erie County personnel
Install heater, gasifier, and secondary combustion chamber	Startup and shutdown	Conduct sustained 24-hr operations
Startup and shutdown	Integrate system	Make final report
Conduct tests	Conduct tests	

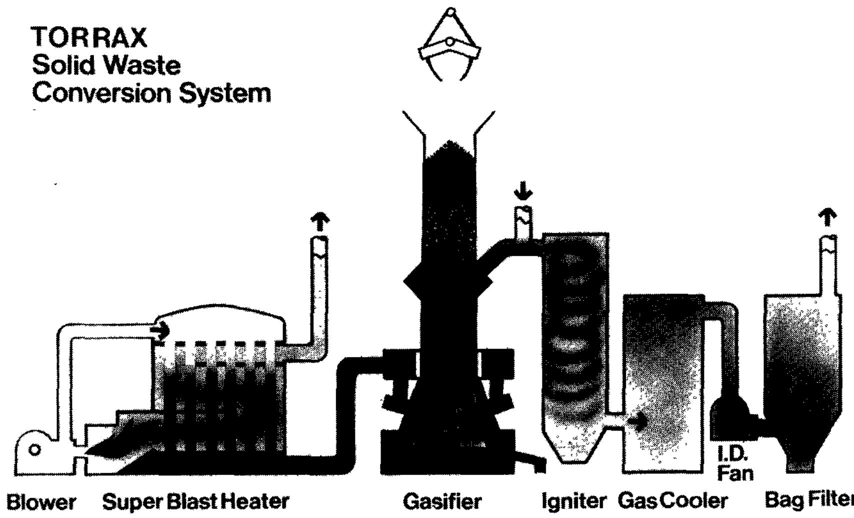

Figure 2. Schematic of the Torrax Solid Waste Conversion System.

There are five major subsystems in the entire process: a super blast heater, a gasifier, and igniter (more commonly called a secondary combustion chamber and so referenced for the Erie County project), a gas cooler (which can be any means conventionally used to cool hot exhaust gases), and an air pollution control device. In the case of the Erie County project, the gas cooler is a waste-heat boiler. Future gas cooling systems could employ either wet or dry subsystems such as wet scrubbers or boilers, respectively. A glass-fabric dust collector is being used in the Erie County project to provide positive assurance against any particulate contamination of the air.

The system uses high temperature, preheated air produced by the super blast heater, which is an all-refractory shell-tube-type heat exchanger. Air up to 1,800 to 2,000 F is generated by incoming air being blown down through the inside of special refractory tubes. This air is heated from the outside of the tubes by hot combustion gases produced from the burning of natural gas or oil. These hot combustion products flow around the tubes and up through the baffle system shown, thereby effecting an efficient transfer of heat to produce the hot blast that is directed into the base of the gasifier. Since the incoming process air is separated from the products of combustion, there is no depletion of its oxygen content. This enables the oxygen in the preheated air to combine with carbon, produced by the pyrolyzation of the refuse, in the base of the gasifier to produce extremely high temperatures sufficient to produce a molten slag.

During operations, refuse will be charged periodically into the top of the gasifier to a level maintained within prescribed nominal limits. The refuse settles slowly down in the gasifier. Hot gases permeating up through the refuse decompose the organic materials. The readily combustible materials are pyrolyzed before they reach the high temperature zone on the bottom. Pyrolyzation occurs because of a controlled deficiency of preheated air furnished to the gasifier. Difficult-to-burn or noncombustible materials that reach the bottom of the system are burned or liquified to form a molten slag, which is tapped and fritted to produce a black, glassy-like, aggregate residue that is inert and clean to handle. Average refuse is expected to undergo a 95-percent reduction in volume in the Torrax system. Eventually this residue may have byproduct value as an aggregate or as a source of raw material for crude metal, glass, and blown fibrous products. The scope of the Erie County project does not include any byproduct studies.

The combustible gases generated from the pyrolyzation of the organic matter are drawn off under negative pressure through an annular header in the upper stack of the gasifier. This negative pressure is induced by the main exhaust fan (shown as the I. D. fan in Figure 2). These evolved gases consist chiefly of carbon monoxide, a variety of hydrocarbons, water vapor, and nitrogen. The refuse column tends to act as a preliminary filter to inhibit the carryover of particulate with these gases into the secondary combustion chamber. The hot gases passing up through the refuse column transfer a large part of their sensible heat into the burden.

The evolved gases are expected to be in a temperature range of 600 to 800 F as they are drawn into the secondary combustion chamber where they are completely combusted. Oxygen analyzers further downstream sense the completeness of combustion and are used to control the right amount of secondary air used in the igniter or secondary combustion stage to assure complete combustion. It is important to note, however, that excess air in this step is kept under 2 percent. This figure compares very favorably with conventional incineration systems, which may use 75 to 100 times as much excess air. This allows for relatively smaller equipment to handle the lower-volume, downstream exhaust gases.

A torrential mixing pattern is induced in the gases as they enter the secondary combustion chamber to promote thorough combustion. Under steady state conditions, the secondary combustion chamber is expected to operate in the range of 2,000 to 2,200 F.

The hot gaseous products of combustion are then drawn from the secondary combustion stage through the rest of the emission control subsystems to be cooled and cleaned before exhausting to the atmosphere. These systems can be either a wet system employing a venturi scrubber, or a dry system utilizing a waste-heat boiler and a glass-fabric dust collector. Other variations of advanced existing technology could also be used, depending on associated economics, possible use of byproduct steam, and other factors that must be weighed for any one location.

A dry system using a waste-heat boiler for the gas-cooler subsystem is being used in the Erie County demonstration project. It is designed to produce about 20,000 lb per hr of process-type, saturated steam at 150 pounds per square inch gauge (psig), which will be condensed and recycled. There will not be any secondary use made of the steam produced in this particular project.

The hot gases from the secondary combustion stage will be cooled to 500 to 525 F before being introduced into the bag house. The bag house will be a pressure type to inhibit any leakage and condensation problems. Incorporated into the system are additional safeguards against any potential condensation problems. Approximately 40,000 actual cubic feet per minute at about 450 F will be exhausted from the bag house. A fabric-type dust collector is one of the most efficient means known to positively assure against particulate pollution to the atmosphere.

In summary, the Torrax system is designed to stress the following key points: (1) very high volume reduction through high temperatures; (2) conversion of resources and energy contained in refuse into other useful forms; (3) production of a clean, inert residue with byproduct possibilities; (4) few mechanical moving parts (there are no grates); (5) elimination of the tell-tale incinerator stack; (6) a relatively smaller-sized plant that can be attractively designed to fit into the community as a satellite plant; (7) overall economics that will be competitive with advanced conventional incinerators of today.

The latter point, economics, has not yet been determined from actual operating data in the Erie County project. This information will be derived from Phase III work, which will take place in late summer of 1971. Our projections to date are based on engineering studies. Actual data may, hopefully, prove to be even better.

The following photographs (Figures 3-7) reveal that the various subsystems shown in the system schematic are not arranged in a straight line fashion. The schematic was so arranged for simple discussion purposes. Any number of arrangements may be necessary, depending on requirements for each particular installation. Before proceeding with a description of the Erie County Torrax plant arrangement, it might be helpful to discuss relative size and orientation.

The plant is painted a bamboo green, and without a tall stack, or any extra architectural treatment, the plant is simple but attractive (Figure 3). There are two large doors in front of the refuse pit where the packer trucks dump their loads. The building is 113 ft long, 43 ft wide, and 60 ft high. Scaled-up plants would be slightly larger, but no higher.

There is a down ramp at the back side of the plant (Figure 4), that serves the primary purpose of providing access into the basement for a front-end loader to remove the residue. At the rear of the plant is stockpile storage space and a paved asphalt drive for trucks.

The plant site proper covers about 1-1/2 acres and is totally enclosed with cyclone fencing. Poplar trees can be seen in the background (Figure 3). The enclosed site is graded and will be seeded with grass. The overall effect is very attractive, clean, and simple.

The gas cooler, I. D. fan, bag house, and water cooling tower are located outside at the rear of the plant (Figure 4). This feature helped reduce the size and capital investment in the building. The cooling tower is part of a closed system to recycle water used primarily to cool the outside of the gasifier shell.

The secondary air line (Figure 4) furnishes the air needed in the secondary combustion stage. This line will serve a dual purpose: by drawing this air in from the back of the refuse pit area through a duct not shown in Figure 4, pit odors will be reduced and at the same time the necessary secondary air will be obtained.

Rather than a mechanical shaker system, reverse air is used to periodically clean the glass bags in the bag house. The main blower furnishes combustion air to the single 10.4-million Btu-per-hr burner to the heater. It also furnishes process air down through the heater (connection not shown in Figure 4) and into the gasifier through the hot blast line. The blower also provides air for a cold-air blend into the hot blast line, which is automatically modulated by heat sensors in the base of the gasifier to account for composition changes in the refuse burden. The

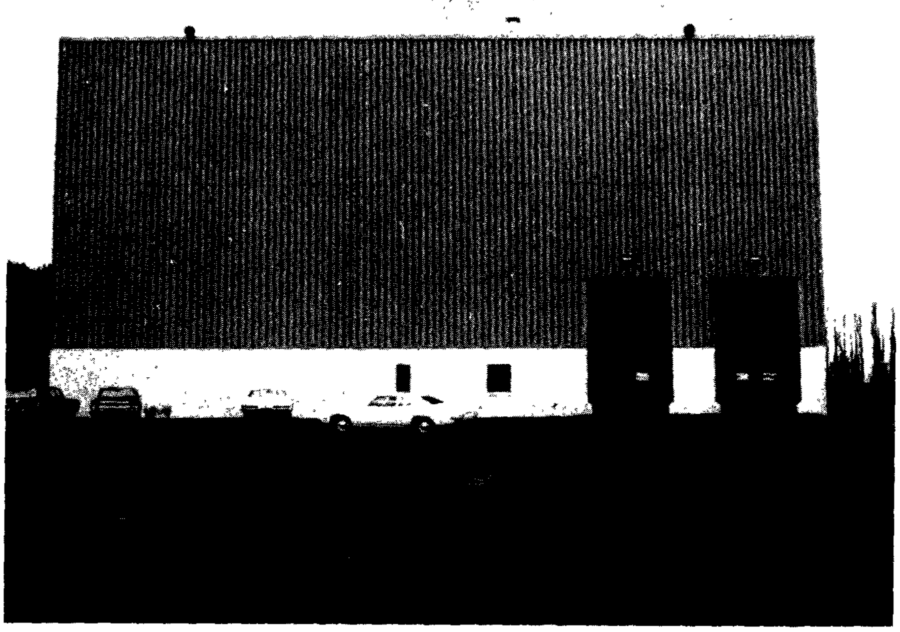

Figure 3. Photograph of plant exterior taken in late April 1971, as asphalt drive and parking area were being installed. Front of plant faces due east.

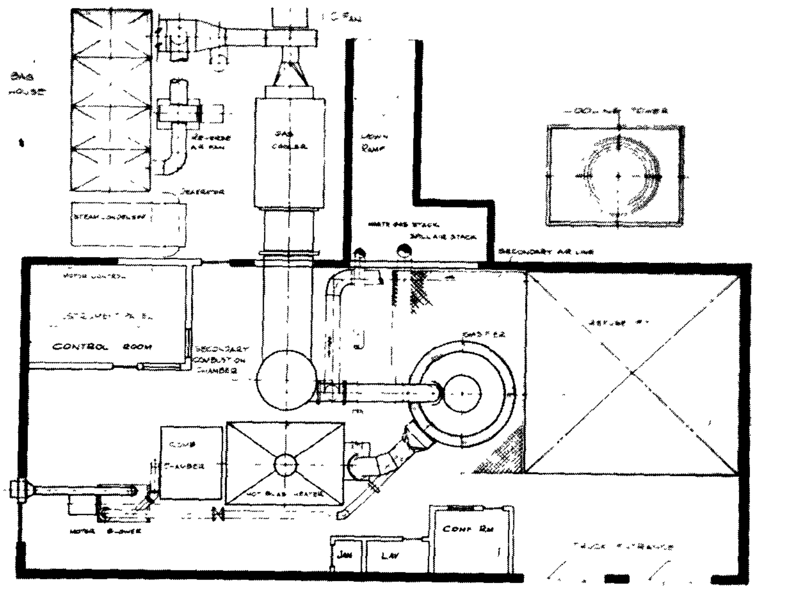

Figure 4. Plant layout and general arrangement of equipment. Truck entrance faces due east, as in Figure 3.

cold-air blend line leads into the hot blast main, which in turn leads into the gusseted circular bussle pipe (Figure 5).

Nearly the entire system is automatically controlled and most of the key controllers are located in the control room (Figure 6). Most of the controllers are also chart recorders in order to have a record of operating data once the entire integrated system is put on sustained operations.

A double bank of automatic alarms on key functions is located in the upper left portion of the panel (Figure 6). Each alarm point is individually identified and produces an audible alarm as well as a flashing light for each station when actuated. The light will remain on until the problem is corrected. Proper safeguards and interlocks have been designed into the control system to cover the entire equipment system. The Torrax system lends itself very well to automatic control, a feature that should minimize the number of operating personnel eventually needed to run such plants.

Refuse is loaded into the gasifier by means of an overhead crane and grapple-type bucket (Figure 7). Average loads to be fed into the gasifier are expected to be in the neighborhood of 500 to 700 lb. An integrating and recording weigh system has been installed in the crane cab to enable an accurate determination of how much refuse is actually processed. This information can then be directly related to capacity and economics. To our knowledge, this is the first time such an approach has been made in a demonstration project. The weigh system utilizes a load-cell type device on the bucket.

Roughly 1-1/2 cu yd of residue were produced from processing approximately 15 tons of mixed refuse (Figure 8). The few larger lumps of material visible on the residue pile (Figure 9) were produced during initial startup and adjustment periods and ordinarily will not occur. Once optimized, the system will produce a finely granulated residue (Figure 10). Most of the residue produced even in the initial trials was of this nature. Some fibrous looking material can be noted on the top of the residue pile in Figure 9. This unusual cotton-candy-like by-product was produced unexpectedly during Phase I trials (Figure 11). It gives rise to speculation that some type of fibrous insulating byproduct might be made from secondary processing of the residue.

The following sections will deal with a description and discussion of test results obtained to date in the Phase I trials. The various tables of data are included at the end of this paper.

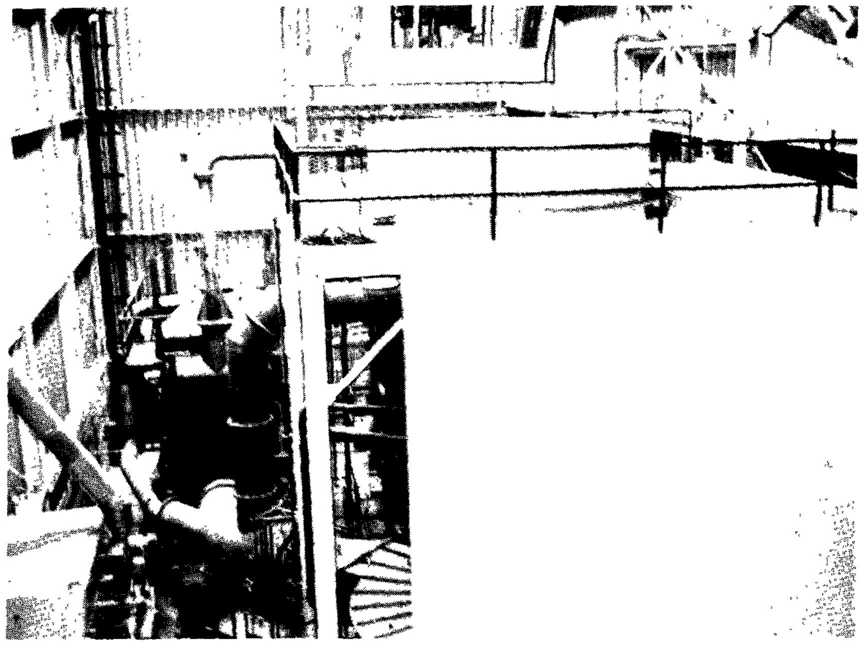

Figure 5. Interior view of the plant taken from north to south end. Note beater on the left, gasifier loading platform with railing at top center, and crane cab directly over the gasifier loading hopper. The refuse pit (not shown) is in front of white spill shield.

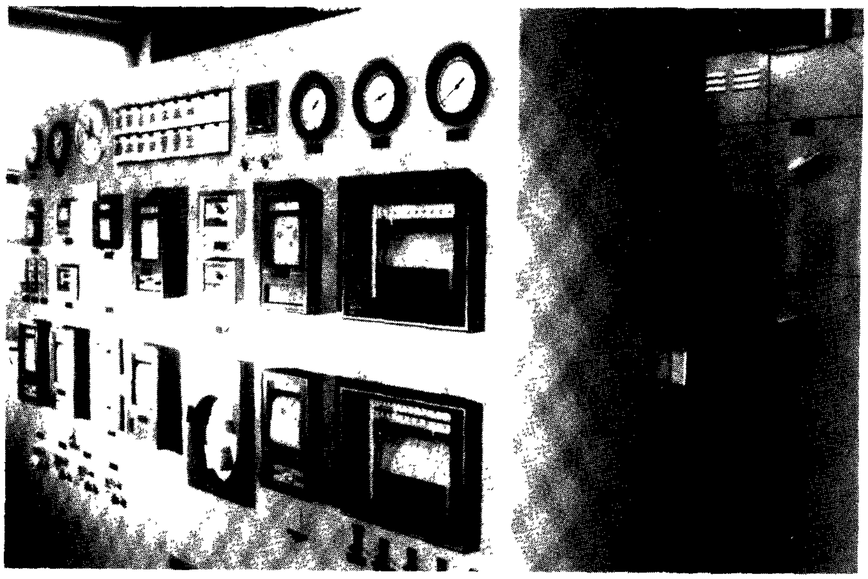

Figure 6. View of instrument control panel (foreground) and motor control center. Photo was taken from the inside northeast corner of the control room.

Figure 7. View of the overhead crane and grapple-type bucket. Photo was taken looking up from the front edge of the refuse pit.

Figure 8. A load of refuse being dumped into the top of the gasifier during Phase I trials.

Figure 9. Residue produced during Phase I trials.

Figure 10. The finely granulated residue that will be the end product of the optimized system.

Figure 11. Cotton-candy-like material produced unexpectedly during Phase I trials. Photo was taken as residue was being removed from the quenching system.

Once again, the primary objectives established for the project are as follows: (1) to convert mixed combustible and noncombustible municipal refuse into an inert aggregate residue from a quenched molten slag; (2) to study system operating parameters; (3) to evaluate the economics related to the systems operation.

We believe results obtained from Phase I operations to date have demonstrated that the system is capable of converting solid waste to a molten slag and a granulated residue.

Based on the physical analysis (Table 2), the high noncombustible content of the refuse processed in Phase I was 22 percent. A volume reduction of more than 95 percent was achieved. Theoretical values of the proximate and ultimate analysis of the refuse have been calculated (Table 3). The slag-producing noncombustible material in the refuse was calculated at more than 27 percent and the calculated Btu content of the refuse on an as-discarded basis is 5,466 Btu per lb.

A close-up view of the aggregate residue (Figure 10) shows that the slag-tap and quenching-system design accomplishes an effective disintegration of the slag. The running molten slag could be clearly seen through high-temperature-type peep holes on the slag box. Some of the spectacular scenes observed inside the hearth section included a tin can or a bottle quickly disintegrating from the intense heat in the hearth section and the molten slag running out.

TABLE 2

PHYSICAL ANALYSIS OF REFUSE*

Component	Percent by weight
Corrugated box	8.15
Newspaper	25.87
Brown paper	15.62
Trade magazines	8.57
Food wastes	2.86
Plastic material	8.65
Rubber products	1.30
Wood	6.80
Metal	8.32
Glass	8.06
Dirt	5.80

*Average bulk density of the refuse is 221.098 lb per sq yd, or 8.19 lb per sq ft. To measure density, a container was filled loosely with average refuse. This method accounts for the relatively lower bulk density value than is usually reported in the literature.

TABLE 3

CALCULATED THEORETICAL VALUES FOR THE PROXIMATE AND ULTIMATE ANALYSES OF REFUSE

Item	Percent by weight
Proximate analysis (as discarded):*	
Moisture (entrained)	8.792
Volatile matter	56.549
Fixed carbon	7.773
Ash	4.694
Metal, glass and dirt	22.192
Ultimate analysis:	
Moisture	8.792
Carbon	35.729
Hydrogen	4.725
Oxygen	28.045
Nitrogen	0.264
Sulfur	0.161
Ash	5.434
Metal, glass, and dirt	22.192

*Btu content of the refuse on an as-discarded basis is 5,466 Btu per lb.

A grab sample of the slag was analyzed in the laboratory. The bulk density of the dried sample was found to be higher than the bulk density of the slag in the as-received condition (Table 4). As the water content of the slag is dried out, the slag aggregate, because of the relatively small particles, packs well in a given volume and thereby produces a greater bulk density without moisture. Converting the bulk density from metric units to English units gives a value for the bulk density, as-received, of 100 lb per cu ft and the bulk density, as dried, of 106 lb per cu ft. The metallic element of the slag is uniformly dispersed throughout the slag medium to make 91 to 96 percent of the residue magnetic. Variations in the melting range of the various factions tested were believed to be primarily due to sample orientation in the test furnace rather than to composition difference.

The high efficiency of disintegration of slag globules in the slag tank is noted from the large percentage of slag falling in the categories of U. S. Standard Screen Size 14, 20, and 30 (Table 5). Only 9 percent of the slag material was over 1/2 in. in size.

Chemical elements present in the slag sample were determined by spectrographic and wet analysis (Table 6). Elements of silicon through sodium were analyzed by a wet method and are shown in Table 6 in their oxide form.

Because of the absence of the final air pollution control equipment and the associated inherent operating limitations in Phase I, gas and particulate analyses were not conducted. This work will be coordinated into Phase II testing. As previously described, Phase II operations will have the gas cooler, the bag filtration equipment, and the induced draft fan added to the Phase I equipment to provide a total equipment facility. Test work on Phase II will involve both component and system performance parameters. Efficiency and operating characteristics will be studied, gas and particulate emission data will be collected, and further analysis of the refuse (analytical) and residue will be made. Construction work is currently underway to install the gas cooler, I. D. fan, and bag house subsystems.

The Phase III test program will involve running tests under sustained operations. In this phase, Erie County personnel will be trained during sustained operation testing. Economic data and other performance parameters will also be obtained at this time.

In summary, as of May 1, 1971, the project is on schedule and should be completed by October 1971, barring any unforeseen delays during Phase II equipment installation. Phase I trials were successful in demonstrating that the Torrax system concept is

TABLE 4

PHYSICAL ANALYSIS OF SLAG GRAB SAMPLE

Item	Amount
Weight of grab sample, as received	835.6 g
Bulk density of sample:	
As received	1.61 g/cc
Dried 18 hr at 225 F	1.71 g/cc
Density:	
Magnetic portion	3.17 g/cc
Non-magnetic portion	2.23 g/cc
Oversize portion (after crushing)	3.35 g/cc
Magnetic separation:*	
Amount magnetic	91.1-95.9 percent
Amount non-magnetic	3.9-4.1 percent
Loss	5.0 percent
Melting range:	1,652-2,147 F
Magnetic portion	1,652-2,462 F
Non-magnetic portion	1,652-2,462 F
Oversize material	1,652-2,300 F

*Sample contained 9.1% oversize material that was not analyzed.

TABLE 5

SIEVE ANALYSIS OF SLAG

Category	Percent on screen
Oversize (½ in.)	9.1
U.S. Standard Screen Size:	
3	4.0
4	1.7
7	6.3
10	9.0
14	20.1
20	17.7
30	15.7
40	9.0
Fines	7.4

TABLE 6

SPECTROGRAPHIC AND WET ANALYSIS OF SLAG BY EMISSION SPECTROSCOPY

Item	Magnetic fraction	Non-magnetic fraction	Oversize fraction	Fibers
		Spectrographic analysis		
Element:				
Si	matrix	matrix	matrix	matrix
Fe	matrix	matrix	matrix	matrix
Al	matrix	matrix	matrix	4.0
Ca	matrix	matrix	matrix	matrix
Na	matrix	matrix	matrix	4.0
K	1.0	1.0	1.0	0.1
Mg	0.4	0.6	0.4	1.0
Ti	0.06	0.06	0.06	0.7
Cu	0.03	0.03	0.03	0.2
Mn	0.04	0.04	0.04	0.2
Sn	0.01	0.01	0.01	0.01
Pb	0.02	0.02	0.02	0.01
Cr	0.01	0.01	0.01	0.03
B	0.01	0.003	0.002	0.004
P	0.5	0.5	0.5	0.2
		Wet analysis		
SiO_2	39.47	38.26	34.64	40.71
Fe_2O_3	39.46	32.72	45.34	34.33
Al_2O_3	7.52	14.68	9.47	6.61
CaO	9.21	9.25	8.89	10.27
Na_2O	4.79	3.85	4.06	5.39
P_2O_5	0.53	0.60	0.57	0.46
K_2O	1.20	1.20	1.20	0.12
MgO	0.67	1.00	0.67	2.12
Others	0.18	0.16	0.16	1.63
Total	103.03	101.72	105.00	101.64
SO_3	1.30	2.37	0.97	---

sound and is capable of producing a molten slag and an inert residue from municipal-type refuse. Remaining work in Phases II and III should demonstrate the economic practicality of applying scaled-up versions of these systems throughout the country as an advanced process to thermally reduce municipal solid wastes. A schedule for public tours through the facility will be announced this summer.

Aside from the technical aspects of this project, we believe it has also demonstrated how effective results can be achieved with a team effort involving sectors of Federal, State, and local governments combined with private industry. We would like to express our sincere appreciation to the funding and technical participants who have so generously contributed to this comprehensive effort.

This project has been supported by demonstration grant No. G06-EC-00239 from the Environmental Protection Agency, pursuant to the Solid Waste Disposal Act as amended.

REFUSE AS SUPPLEMENTARY FUEL FOR POWER PLANTS

G. Wayne Sutterfield and F. E. Wisely†*

THE RECOVERY of waste heat from the combustion of refuse is not new, and there are numerous refuse incinerators in existence that have waste-heat boilers. To date, however, these installations have not been noted for their high efficiency, and the new and more sophisticated installations that have been designed for higher efficiency and greater reliability are becoming extremely costly. Such new installations must also have a market for the steam they produce, and these markets are not always readily available. By comparison, coal-fired utility boilers, though not without their own operating problems, are highly efficient and reliable, have high use factors, and are already integral to power producing systems.

The idea of using refuse as supplementary fuel for power plant boilers was conceived under the basic premises that if refuse were properly prepared, and if it were fired only as a relatively small percent of the total heat requirement of a large, coal-fired boiler, there would be little more, if any, adverse effects on the boiler or its operation than if it had been fueled entirely with coal. The availability of refuse as an essentially constant and inexhaustible source of supplementary fuel makes the concept even more attractive. Also significant is the existence of the many large and efficient boiler installations in or near metropolitan areas. Such boilers are capable of consuming great quantities of refuse, even when it is fired as only a small percentage of their total heat requirement. Further, equipment for processing, handling, and transporting refuse is already commercially available. The process could therefore be implemented quickly and economically, with little further developmental effort.

A study of the concept was originally made for the city of St. Louis, Missouri, with the close cooperation of the Union Electric Company, under a partial grant-in-aid from the Bureau of Solid Waste Management (now the Federal Office of Solid Waste Management Programs). The study culminated in a 1970 report "Study of Refuse as Supplementary Fuel for Power Plants" (Horner & Shifrin, Inc., St. Louis, Mo.) that concluded

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†Horner and Shifrin, Inc., St. Louis, Missouri.

that all the original premises of the study were valid, subject to further confirmation by full-scale tests.

Following completion and acceptance of the report by the city of St. Louis, the Union Electric Company, and the Office of Solid Waste Management Programs, the Union Electric Company offered the use of one of its modern boiler units for a full-scale test. The company also offered to underwrite a substantial portion of the cost of the facilities that would have to be built on their property in order to carry out the test. The city of St. Louis then applied for a demonstration grant to assist in implementing a 3-year design, construction, and operation project with a total estimated cost of $2.6 million. The grant was approved as of July 1, 1970, with both the Office of Solid Waste Management Programs and the Office of Air Pollution Control Programs participating.

To date, the city of St. Louis has purchased some of the more critical pieces of equipment, and bids have been received (April 14, 1971) for the general construction contract covering a processing plant at the site of one of the city's incinerators and a supplementary fuel receiving station at the Meramec Plant of the Union Electric Company. The Union Electric Company has negotiated a contract with Combustion Engineering, Inc., for facilities directly related to firing refuse to the boiler. Unless unforeseen delays develop, initial operation of the facilities will begin in January 1972. It should be noted that not only did Combustion Engineering, Inc., cooperate fully in the original study, but they also relinquished certain patent rights that might be considered applicable in the demonstration project.

COMPARING REFUSE AND COAL AS FUELS

A comparison of some of the most important characteristics of coal and refuse (Table 1) indicates that the major differences are in moisture and carbon content. The heating value for refuse, assumed in this case to be an average of 5,000 Btu per lb, is somewhat less than half that for Illinois bituminous coal. Sulfur content of the refuse was found to be low, as expected. Chlorine content was considerably higher in refuse than in washed coals, but comparable to that in typical coals.

A comparison of ash analyses for refuse and coal (Table 2) showed that in each case the ash was high in silica. Significant differences are indicated in ferric oxide, alumina, lime, and sodium oxide. A comparison of the ash fusion temperatures of refuse and coal (Table 3) shows the remarkable similarity of ash fusion temperatures for the two fuels.

TABLE 1

PROXIMATE AND ULTIMATE ANALYSES FOR REFUSE AND COAL: RANGES OF COMPOSITION [As received]

Item	Refuse* (%)	Coal† (%)
Proximate analyses:		
Moisture	19.69 – 31.33	6.20 – 10.23
Ash	9.43 – 26.83	9.73 – 10.83
Volatile	36.76 – 56.24	34.03 – 40.03
Fixed carbon	0.61 – 14.64	42.03 – 45.14
Btu per lb	4,171 – 5,501	11,258 – 11,931
Ultimate analyses:		
Moisture	19.69 – 31.33	6.20 – 10.23
Carbon	23.45 – 33.47	61.29 – 66.18
Hydrogen	3.38 – 4.72	4.49 – 5.58
Nitrogen	0.19 – 0.37	0.83 – 1.31
Chlorine	0.13 – 0.32	0.03 – 0.05
Sulfur	0.19 – 0.33	3.06 – 3.93
Ash	9.43 – 26.83	9.73 – 10.83
Oxygen	15.37 – 31.90	9.28 – 16.10

*Taken from three samples of St. Louis refuse, with magnetic metals removed.
†Taken from three samples of Union Electric Company coals.

TABLE 2

ASH ANALYSES FOR REFUSE AND COAL: RANGES OF COMPOSITION [As received]

Item	Refuse* (%)	Coal† (%)
Mineral analyses (ignition basis):		
Phosphorus pentoxide	1.02 - 4.69	0.08 - 0.20
Silica	48.93 - 60.07	45.52 - 46.93
Ferric oxide	3.50 - 5.92	15.51 - 25.29
Alumina	5.02 - 13.72	16.54 - 18.53
Titania	0.74 - 1.60	0.81 - 1.01
Lime	7.54 - 18.19	2.13 - 6.31
Magnesia	1.14 - 1.91	0.80 - 0.92
Sulfur trioxide	1.84 - 12.54	1.41 - 6.28
Potassium oxide	1.57 - 2.70	1.70 - 1.78
Sodium oxide	3.62 - 5.95	0.30 - 0.62
Undetermined	0.08 - 0.69	0.39 - 5.25

*Taken from three samples of St. Louis refuse, with magnetic metals removed.
†Taken from three samples of Union Electric Company coals.

TABLE 3

ASH FUSION TEMPERATURE RANGES FOR REFUSE AND COAL

Item	Reducing temperature (F)	Oxidizing temperature (F)
Refuse: *		
Initial deformation	1,890 - 2,070	2,030 - 2,100
Softening (H=W)	2,190 - 2,360	2,260 - 2,420
Softening (H=½W)	2,210 - 2,390	2,290 - 2,450
Fluid	2,400 - 2,560	2,480 - 2,700
Coal: †		
Initial deformation	1,940 - 2,010	2,020 - 2,275
Softening (H=W)	1,980 - 2,200	2,120 - 2,455
Softening (H=½W)	2,180 - 2,220	2,260 - 2,470
Fluid	2,250 - 2,600	2,390 - 2,610

*Taken from three samples of St. Louis refuse, with magnetic metals removed.

†Taken from three samples of Union Electric Company coals.

BOILER DESIGN

The boiler to be used for the test (Figure 1) is small when compared to the newer units in the Union Electric Company system; but it is of modern, reheat design, and the test results from this unit should be applicable to many other similar units in service throughout the country. Built by Combustion Engineering, Inc., with a nominal rating of 125 megawatts, the unit will burn about 56.5 tons of Illinois bituminous coal per hour at rated load. The unit is tangentially fired, with four pulverized coal burners in each corner. It is also fitted to burn natural gas. The furnace is rectangular (about 28 ft by 38 ft in cross section) with a total inside height of about 100 ft.

There is no readily apparent reason why front or side-fired boilers that burn pulverized coal could not be adapted for burning milled refuse as supplementary fuel. The main disadvantage appears to be the possibility of having to modify certain pressure parts of a front- or side-fired unit (at least in some designs) in order to install refuse burning ports. No modifications of pressure parts are necessary for the tangentially-fired test boiler -- a distinct advantage for units of this type.

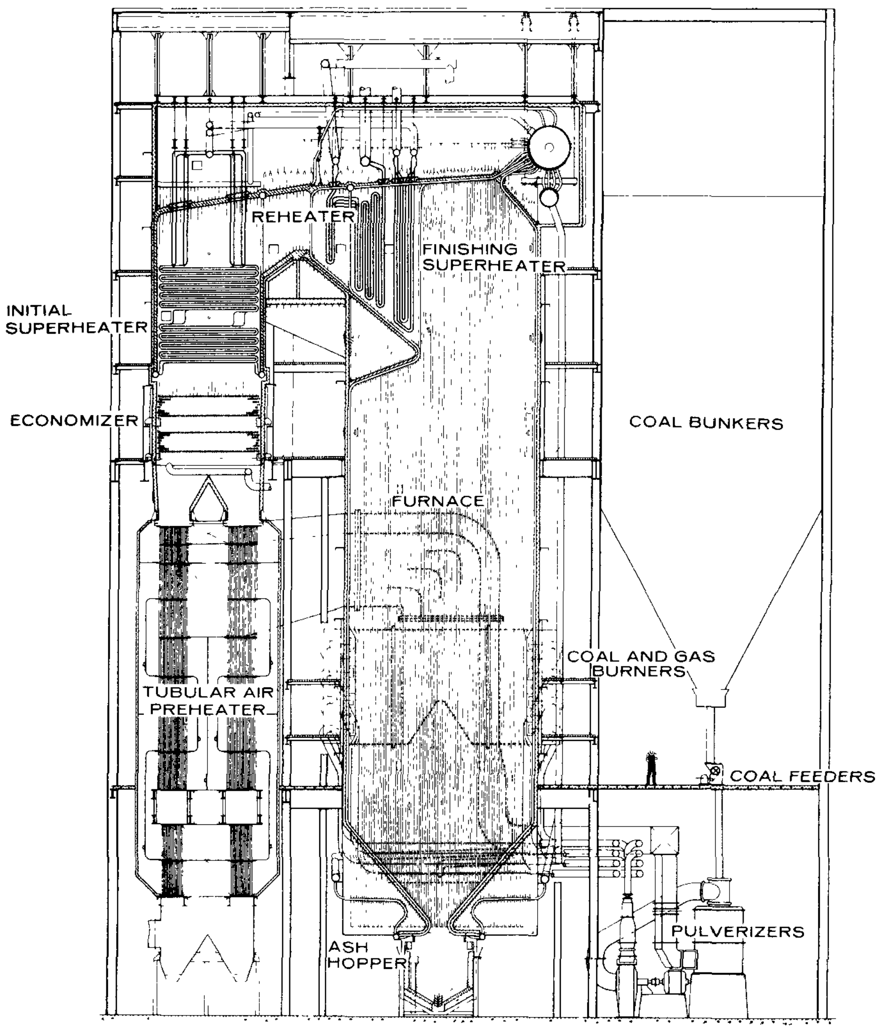

Figure 1. Meramec boiler unit no. 1, Union Electric Company.

The demonstration contemplates firing the prepared refuse at the nominal rate of 10 percent of the heat requirement of the boiler. At full load, the quantity of refuse equivalent to 10 percent of the coal will be 12 to 13 tons of refuse per hour, or about 300 tons per day. Higher rates of firing the refuse, possibly up to 20 percent, will be attempted if no significant problems are experienced at the 10-percent rate. The intention is to fire the refuse 24 hr per day, but only 5 days per week, since city refuse collections are normally scheduled on a 5-day-per-week basis. The interrupted refuse firing schedule is not expected to cause any difficulty in boiler operation.

PREPARING AND PROCESSING RAW REFUSE

Preparation of the refuse will consist of milling the raw material to nominal particle sizes of 1-1/2 in. and less, and removing magnetic materials from the milled refuse. Unless unforseen difficulties occur with this limited degree of preparation, no other removal of noncombustible materials such as glass, ceramics, and nonmagnetic metal, will be performed. It is possible that particle sizes greater than 1-1/2 in. would be satisfactory for the process. Some experimentation with particle size may be carried out during the tests if it appears appropriate.

Collection and Delivery of Raw Refuse

For the initial tests, at least, the raw refuse will be limited to that collected from households by means of packer-type trucks, thereby eliminating extremely bulky objects. The only separation of components before milling will be that required to prevent such items as electric motors, automobile engine blocks, and transmissions from being conveyed to the hammermill.

The milled material is expected to be reasonably homogeneous, with a relatively even distribution of moisture. Its bulk density is expected to vary from 4 lb per cu ft in thin layers, to 10 to 15 lb per cu ft in shallow piles and 20 to 25 lb per cu ft in a storage bin.

Raw refuse usually will be delivered to the processing plant that is to be built during a 6-hr per day period. Since the prepared refuse will be fired continuously 24 hours per day, 5 days per week, provisions must be made for the short term storage of both raw and processed refuse. Special attention is also required to ensure that appropriate processing rates, transport capacity, and firing provisions will provide the necessary continuity of operation at the power plant. The processing facilities will be constructed adjacent to an existing incinerator so that if an emergency arises, an alternate method of disposal will be available for the raw refuse.

The elements of the processing facilities are shown in Figure 2. The raw refuse will be discharged from packer-type trucks to the floor of the raw refuse receiving building. Raw-refuse storage area on the floor of the receiving building is sufficient for two-shift operation. Front-end loaders will be used to push the raw refuse into a shallow pit, the bottom of which is comprised of a vibratory conveyor. The vibratory conveyor will have provisions for varying its stroke up to 1 in. as a means of controlling the rate of feed. From the vibratory receiving conveyor, the raw refuse will be discharged to an inclined belt conveyor, which will be equipped with a belt scale. The belt conveyor will in turn discharge to a vibrating feeder (again with a 1-in. stroke) which will feed the hammermill directly.

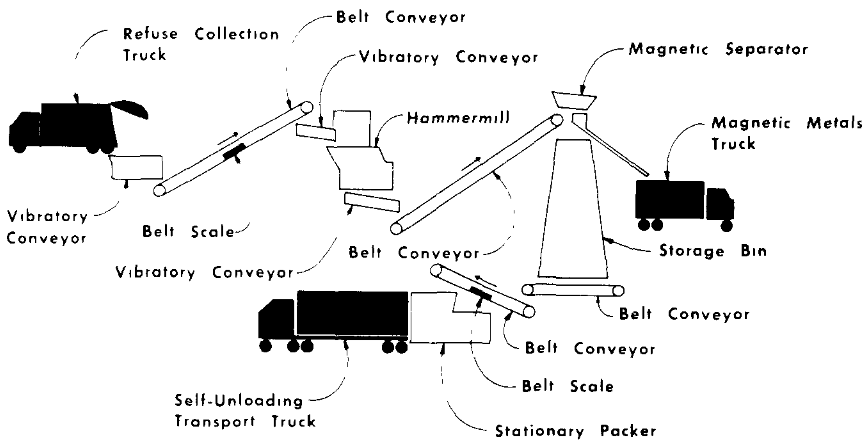

Figure 2. Diagram of the processing facilities for raw refuse.

Feeding the Hammermill

Control over this initial part of the operation will be exercised by an operator stationed with a full view of the receiving conveyor, its transfer point to the belt conveyor, and the belt conveyor leading up to the hammermill. The operator's console (Figure 3) will be equipped with a visual indicator of the rate of feed and the relative load on the hammermill motor. A means of varying the rate of discharge from the vibratory receiving conveyor will also be provided. Since the transfer point of the receiving conveyor to the belt conveyor will be in full view of the operator, he will be able to stop the conveyors to permit the removal of any oversize or undesirable objects that might have accidentally reached this point of the process. The available facilities will hopefully enable the operator, with some experience and reasonable judgment, to control the rate of feed to the hammermill with acceptable accuracy.

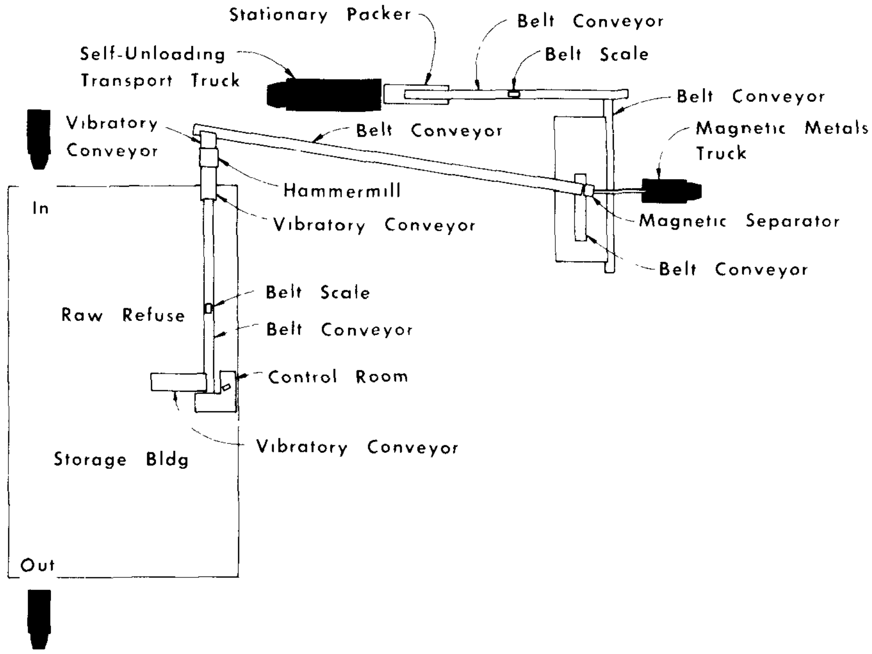

Figure 3. Diagram of plan view of the processing facility for raw refuse showing location of control room.

Housekeeping is expected to be a problem in facilities of this type. Every reasonable effort has been made to control dust and spills by providing seals and enclosures wherever practicable. Combinations of belt and vibrating conveyors were selected instead of pan-type conveyors for the same reason.

The nominal average design rate of feed of the raw refuse with this system is 45 tons per hour, with expected momentary surges of up to 60 tons per hour. An average of about 360 tons is therefore expected to be processed in an 8-hr shift. Provisions have been made to increase the rate of feed, by means of simple modifications, to a maximum of 100 tons per hour, should it become desirable or necessary at some later date.

The Milling Process

For the demonstration project, the intention is to perform the milling operation in one stage by a single pass through a conventional hammermill with a horizontal shaft. The mill will have an interior rotor length of 80 in. and a 60-in. hammer circle. The mill will be driven by a 1,250-hp, 900-rpm electric motor. Short-term tests with an existing city-of-St. Louis mill of similar design but of smaller dimensions have indicated that the required 45-ton-per-hour production rate and the 1-1/2 in. particle size can be achieved with the 80-in. mill. The grate cage of the mill will have openings of about 2 in. by 3 in. The test runs with a mill cage with openings of this size indicated that nearly 100 percent of the milled particles were less than 1-1/2 in., though an occasional piece of paper or plastic film up to 4 or 5 in. in its largest dimension could be seen. The rate of discharge from the mill during the test runs was remarkably uniform, indicating that the mill was serving to even out the unevenness that can be expected in the rate of feed of raw refuse. The mill discharge was also freer of dust than expected, even though the raw refuse used in the test runs did not appear to have an unusually high moisture content.

Nearly all mill manufacturers recommended two-stage milling to achieve the small particle sizes deemed necessary for this process. If two-stage milling were employed, the first stage would accomplish only rough milling to a maximum particle size of 6 to 8 in. Magnetic separation would be performed between the first and second stages. The second stage then would perform the required final sizing. Whether two-stage milling would achieve economy of operation is open to question; but it might alleviate other potential operating problems by decreasing the possibility of damage to the internal parts of the mill by large dense objects such as chunks of solid metal larger than the grate openings.

To control dust from the milling operation, air will be drawn from the top of the feed hopper and discharged through a cyclone separator mounted on top of the feed hopper. The cyclone separator will have a free discharge back into the feed hopper.

To permit adequate time for hammer retipping and routine preventive maintenance, no more than a two-shift operation of the milling process is contemplated. Provisions have been made for opening one side of the mill by means of hydraulic cylinders, thereby allowing free and quick access to the interior of the mill.

Discharge and Storage of Milled Refuse

The hammermill will discharge to another vibrating conveyor, also designed with a 1-in. stroke. This conveyor will discharge to an inclined belt conveyor, which in turn will discharge to the storage bin. Magnetic separation will be performed at the head pulley of this belt conveyor at the top of the bin. Magnetic materials will be discharged through a chute to trucks for disposal. It is anticipated that between 5 and 10 percent by weight of the raw refuse will be magnetic metal. Whether the magnetics will be saleable or not is questionable at this time. If not, it will be necessary to landfill the separated material.

The possibility of pneumatic transfer from the mill discharge to the storage bin was considered at first. But in this case it is believed that the magnetics should be removed before pneumatic conveying to decrease the possibility of metal particles either jamming or causing excessive wear on the pneumatic feeders. A considerably more complex layout of equipment would have resulted if magnetics had been removed from the milled material immediately upon discharge from the mill.

The primary concerns in designing storage facilities were the laminar characteristics of milled refuse, its tendency to compact under its own weight, the potential problems attributable to variations in moisture content, and the possibilities of bridging. All of the facilities provided for the demonstration project were selected and sized to process the raw material as promptly as possible and to make it unnecessary to store the milled material for more than a few hours. The short-term storage bin at the processing plant (Figures 4 and 5) will have a gross volume of about 33,000 cu ft and a gross storage capacity of approximately 300 tons. The bin will be rectangular -- about 19 ft wide at the bottom and 60 ft long. The long sides will have a 5° reverse slope to lessen the tendency for the milled material to bridge.

The unloading mechanism will consist of twin augers that will traverse the entire length of the bin, discharging to a horizontal belt conveyor along one side. This type of bin provides an essentially full, live bottom and has the advantage that the first material conveyed into the bin will be the first material discharged from it. An additional attractive feature is that all moving parts of the discharge mechanism are readily accessible for maintenance. This type of storage facility is in relatively common use for storing bark and wood chips in the paper industry. One disadvantage of a long rectangular bin is the difficulty of loading the bin evenly over its entire length. In this case, a shuttle-belt conveyor has been provided that receives material from the bin-loading conveyor and that will distribute the milled material evenly over the full length of the bin.

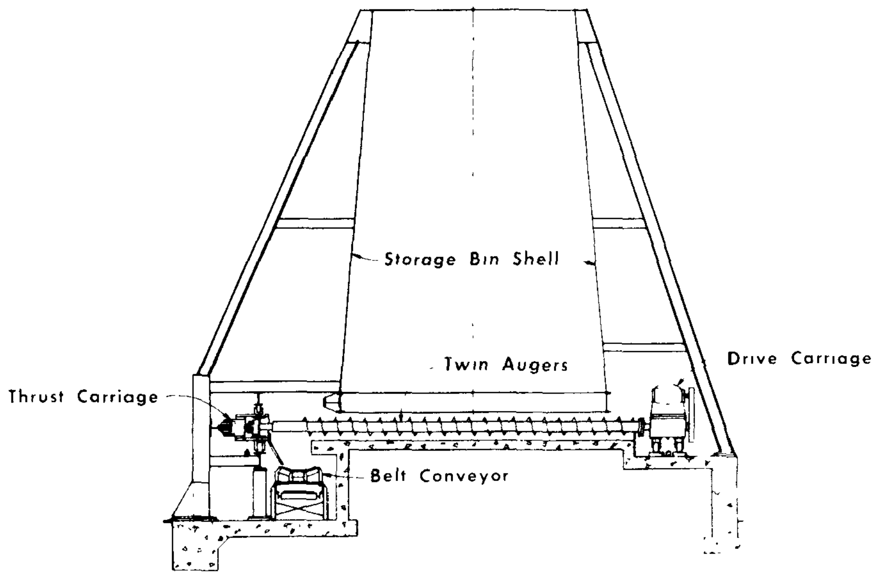

Figure 4. Typical elevation for type H bin and unloader (Miller Hofft, Inc.).

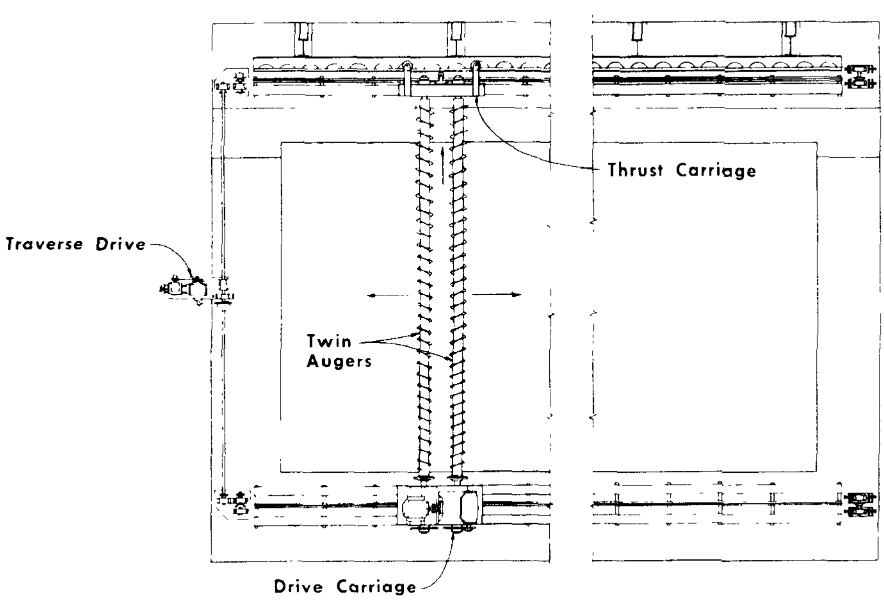

Figure 5. Type H traversing unloader (Miller Hofft, Inc.).

Transporting Processed Refuse to the Power Plant

The milled refuse will be discharged at a 60-ton-per-hour rate from the storage bin to an inclined belt conveyor equipped with a belt scale. The inclined belt conveyor will in turn discharge to the hopper of a stationary packer similar to those in use at conventional raw refuse transfer stations. The stationary packer will be used to load self-unloading trailers that will transport the supplementary fuel 18 miles to the power plant. Pneumatic conveying could be employed for the transfer of material if the processing plant were no more than about a mile from the power plant. Pneumatic transfer, if employed, would mean a considerable savings in transport cost. The intention is to deliver the supplementary fuel to the power plant at the approximate rate it will be consumed by the boilers. Each trailer will be loaded with about 25 tons of material. One truckload every 2 hr or 12 loads per day will be required at 12.5 ton-per-hour firing rate. It should be pointed out that not all localities will permit axle loadings as great as those resulting from a 25-ton payload. A somewhat special statutory condition exists in the St. Louis area which permits axle loadings of greater than normal magnitude in this particular case.

Nearly all of the operations up to this point of the process will be electrically controlled, with alarms and emergency devices to warn of malfunctions and to shut down parts of the plant sequentially in emergencies. The sequential shutdown of conveyors is necessary to prevent pileups of material at the transfer points.

The milling operation sometimes results in the discharge of hot pieces of metal. The possibility of fires starting when the hot metal comes into contact with the more highly combustible components of milled refuse is a matter of some concern. Even when the magnetics are removed before discharge of the milled material into the storage bin, there is still the possibility that fires could occur within the bin. A dry-pipe sprinkler system therefore has been provided in the bin as one means of controlling fires and of protecting the storage bin structure. Manually operated water sprays will be provided in the feed hopper of the mill to assist in controlling fires that might occur within the mill. These sprays will be used only in emergencies.

RECEIVING PLANT AND FIRING FACILITIES

The facilities contemplated at the power plant are shown diagramatically in Figure 6. The self-unloading mechanisms of the transport trailers will push the supplementary fuel into a receiving bin equipped with a twin-auger unloading device similar to that provided for the storage bin at the processing plant. The unloader will discharge to a belt conveyor along one side of the receiving bin. This belt conveyor will in turn discharge to a pneumatic feeder for pneumatic transfer to a surge silo.

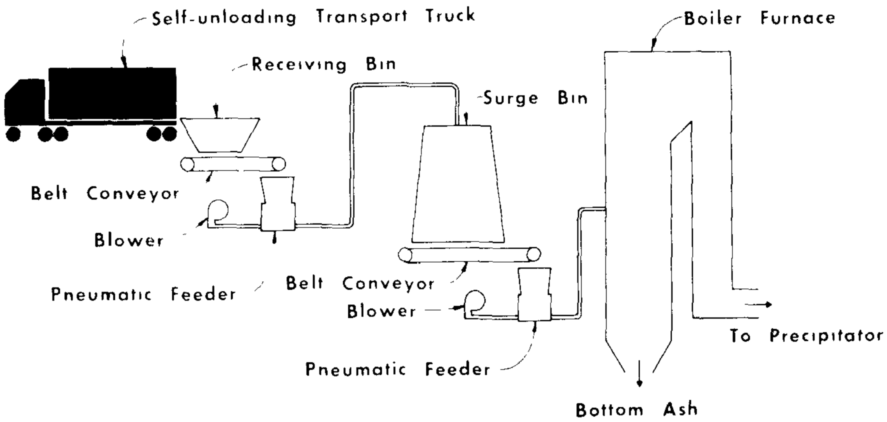

Figure 6. Diagram of facilities contemplated at the receiving plant.

The bin unloader will have a nominal capacity of 40 tons per hour. To insure adequate transfer capacity, the pneumatic feeder will have a nominal capacity of 60 tons per hour. This difference in apparent capacity is considered necessary because of the potential variations in bulk density of the supplementary fuel. The twin auger unloading mechanism is designed on a volumetric basis, whereas the controlling design factor for the pneumatic system is gravimetric. A typical pneumatic blower and feeder is shown in Figure 7.

From the pneumatic transfer system on, the facilities are being furnished and constructed by the Union Electric Company under contract with Combustion Engineering, Inc. The surge silo, into which the pneumatic transfer system discharges, will have a nominal capacity of about 7,500 cu ft, only enough to provide about 6 hr of storage at a boiler feed rate of 12.5 tons per hour. The surge silo will be circular (Figure 8) with a peripheral chain-bucket type discharge mechanism. Four drag-chain conveyors, installed under slots in the silo floor, will convey the supplementary fuel to four pneumatic feeders. The drag-chain conveyors will have variable-speed drives to permit approximate control over the rate of feed of the supplementary fuel. Each of the four pneumatic feeders will convey the fuel to a burner port at the boiler furnace. Four burner ports will be provided, one on each corner of the boiler furnace, located between the two middle pulverized coal burners.

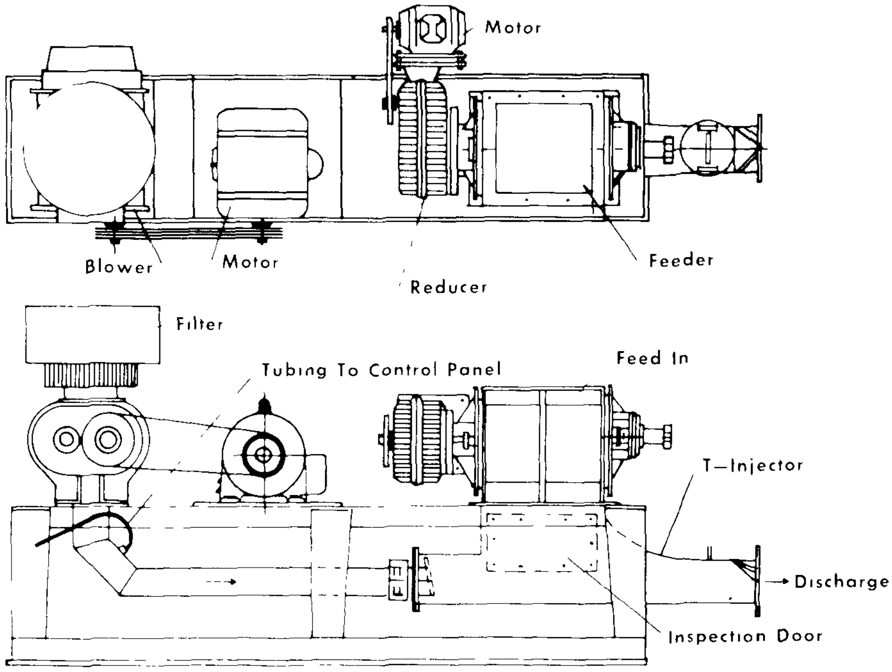

Figure 7. Blower and airlock feeder (Rader Pneumatics).

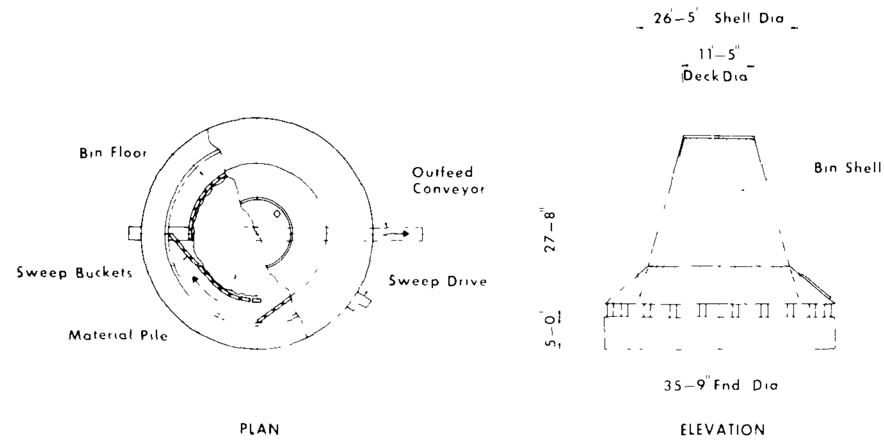

Figure 8. Surge bin (Atlas Systems Corporation).

The installation of the burner ports for the supplementary fuel will not require modification of the pressure parts of the boiler, thereby permitting easy and economical installation. From the operating standpoint, the separate burner ports offer another advantage. In case of malfunction of the supplementary-fuel firing system, all coal-burning ports will still be available to provide the necessary fuel for the boiler. It is anticipated that the refuse will be fired at a constant rate for a given boiler loading, and that the exising boiler combustion controls will modify the rate of firing of the pulverized coal to accommodate any variations in the moisture content or heating value of the supplementary fuel.

POTENTIAL BOILER OPERATING PROBLEMS

One of the potential boiler operating problems considered to be of primary importance relates to the quantity of ash resulting from burning refuse. Coal ash can normally be expected to be in the range of 10 to 12 percent by weight of as-fired coal. The corresponding value for refuse, with magnetics removed, can be considered to be on the order of 25 percent. Based on relative heating values, 1 lb of Illinois bituminous coal would be the approximate equivalent of 2.2 lb of prepared refuse. In a boiler furnace fired with pulverized coal, the bottom ash often will be only 15 to 20 percent of the total ash, with 80 to 85 percent carried out of the furnace with the gases of combustion. Since a relatively higher percentage of the refuse ash is expected to drop to the bottom ash hopper, the bottom ash handling requirement will be increased. Most pulverized coal boilers have some excess bottom ash handling capability, however, so doubling or even tripling the quantity of bottom ash may not prove to be a serious problem.

Some increase in the loading of the dust removal devices is also anticipated. But the degree of increase is only a matter of conjecture at this time, since the relationship between percentages of bottom ash and fly ash for refuse is not known under the conditions that will prevail within the boiler furnace.

Another matter of interest is the effect the low sulfur content of refuse will have on the performance of the electrostatic precipitator. The presence of gaseous sulfur oxides is known to have a synergistic effect on precipitator performance. Whether the small percentage of refuse to be fired will decrease the emission of sulfur oxides to a point that would adversely affect dust removal is not known at this time.

The second major concern in boiler operation relates to the possibility of increased corrosion potential. Coal-fired boilers are subject to both low- and high-temperature corrosion. Extensive research has been performed and is continuing on this subject. The low sulfur content of domestic refuse may have a tendency to decrease corrosion potential. Conversely, the higher chlorine content may have the opposite effect. An evaluation by Combustion Engineering, Inc., concluded that firing a small percentage of prepared refuse with pulverized coal may generally be expected to cause no significant change in corrosion, erosion, slagging, or general operating procedures in the boiler. The test program will, however, include the installation of probes to investigate these potentially adverse conditions.

As for all refuse disposal processes, certain materials will still require disposal by other means. The magnetic metal will have to be disposed of in a landfill if no market can be found for it. The tin content of tinned cans is expected to detract from the market value of the ferrous metal. The total ash generated by burning prepared refuse and coal is expected to be substantially greater than that resulting from coal alone. The Union Electric Company has, however, been able to sell the fly ash it produces to Portland cement manufacturers. Bottom ash also is in demand for construction fill and for highway deicing. The addition of refuse ash is not expected to detract from these established uses for coal ash. Interest has been shown in investigating the possibilities of recovering certain materials from the ash.

COST ANALYSES

An abbreviated summary of estimated capital and operating costs for the 70-ton-per-hour refuse processing, transporting and firing facilities is shown in Table 4. Costs for both single and double production lines are shown. No more than two-shift per day operation is contemplated to provide adequate time for hammer retipping and routine preventive maintenance. The estimated costs are based on facilities providing two-stage milling, a distance of less than 25 miles between processing plant and power plant, and transport of the milled refuse by means of self-unloading trailers. If the transport distance were such that pneumatic conveying could be employed (not much more than a mile), it might be possible to reduce the overall unit cost by $1 to $1.50 per ton.

The tabulated unit costs do not reflect any credit for the value of refuse as supplementary fuel. By 1973, the fuel costs for utilities in the St. Louis area are expected to be approximately 30 cents per million Btu, with the further expectation of a continuing increase. At 30 cents per million Btu, refuse with a heating value of 5,000 Btu per pound would have a theoretical fuel value of $3 per ton. This value may not be completely realistic to a utility, since it presumes an even trade-off of heating value with coal; possibly some additional operating costs attributable to handling the milled refuse might occur. However, even without allowing credit for the value of refuse as fuel, both the overall operating and capital costs of the process should be substantially less than those of conventional refuse incineration.

TABLE 4

ANNUAL CAPITAL AND OPERATING COST SUMMARY

	Number of Processing units	
Item	One	Two
Raw refuse processed *		
Tons per day	980	1,960
Tons per year	305,760	611,520
Estimated capital costs (1973)	$5,211,000	$8,780,000
Estimated operating costs (1973)	$1,075,000	$1,920,000
Amortization costs (annual)	$418,000	$704,000
Equivalent total unit costs		
Per ton of raw refuse	$4.89	$4.29
Per ton of supplementary fuel	$5.29	$4.64

*Two-shift operation, 6 days per week.

Almost all power plant boilers designed to burn pulverized coal should be adaptable to the firing of refuse as supplementary fuel, even if the boilers were subsequently converted to oil or gas firing. The principal obstacle for adaptation of existing boilers could be limitations in bottom-ash and fly-ash handling capability. A few of the existing power plants that could be considered capable of burning refuse as supplementary fuel are listed in Table 5. It is apparent that large quantities of refuse could be disposed of by this means, even when it is fired as only 10 percent of the boiler heat requirement. Corresponding savings of other fuels obviously could be effected. Using the same 10-percent rate of firing, the Union Electric Company will have the potential capability by 1973 of burning over twice as much refuse as is generated in the entire St. Louis metropolitan area, which has a population of about 2.5 million. A single 600-megawatt unit could easily consume about 1,200 tons of supplementary fuel per day, at the 10-percent firing rate.

TABLE 5

TYPICAL STEAM-ELECTRIC PLANTS CAPABLE OF BURNING REFUSE AS SUPPLEMENTARY FUEL

Plant	Utility	Plant capacity* (megawatts)	Metropolitan area	Refuse burning capacity† (tons/year)
Dickerson	Potomac Elec. Power	586	Washington, D. C.	400,000
McDonough	Georgia Power	598	Atlanta, Ga.	410,000
Astoria	Consolidated Edison	1,550	New York, N. Y.	1,060,000
Portsmouth	Virginia Elec. & Power	649	Norfolk, Va.	445,000
S. Oak Creek	Wisconsin Elec. Power	1,170	Milwaukee, Wisc.	800,000
Cromby	Philadelphia Elec.	417	Philadelphia, Pa.	285,000
Mitchell	W. Pennsylvania Power	448	Pittsburgh, Pa.	305,000
Gannon	Tampa Electric	900	Tampa, Fla.	615,000
Russell	Rochester Gas & Elec.	260	Rochester, N. Y.	175,000
Cherokee	Public Service of Col.	375	Denver, Col.	255,000
Cane Run	Louisville Gas & Elec.	700	Louisville, Ky.	480,000
B. L. England	Atlantic City Electric	300	Atlantic City, N. J.	205,000

*From Federal Power Commission Data, 1968.

†Assuming 75% use factor - 365 days/year, using 250 tons of refuse per day per 100 mw of plant capacity.

One of the most intriguing possibilities of the process relates to making it possible for utilities to retain existing boiler units for a longer life as base-load facilities. For example, the power production cost of one Union Electric Company plant is about 10 percent greater than for other larger and newer units. A major component of power production cost is the cost of fuel. Thus, if sufficient economy can be effected by the use of refuse as supplementary fuel, it is possible that the plant could enjoy longer life as a base-load installation, rather than being used only during periods requiring peak power production. This concept, if proven valid, could have a distinct effect upon the capital improvement program of a given utility.

APPLYING THE SYSTEM IN OTHER AREAS

Application of the process requires intimate cooperation between the utility and the governing body or bodies of the metropolitan area it serves. There must obviously be some mutual benefits accruing from it. The principal benefit to a utility must be an economic one, though some utilities may also be motivated by the desire to assist a municipality in solving one of its greatest problems. Municipalities must also give economics proper weight, but other advantages could result as well.

The actual value of the refuse as supplementary fuel to a power plant is subject to negotiation in each given case. In some areas, it might be appropriate for the utility to obtain the fuel at no cost. In others, it might be appropriate for the utility to purchase the fuel. Controlling factors in such negotiations would include the utility's fuel costs, the cost of boiler modifications, ash disposal methods and costs, costs of municipal waste disposal by other means, availability of other means of refuse disposal, and the degree of control of the municipality over the refuse collection system.

The process cannot be considered to be applicable everywhere. If the preliminary appraisals prove correct, however, it may be applicable as an economical primary means of refuse disposal for a number of large metropolitan areas. In addition to the economic benefits, such a system would provide a means of reducing air pollution, conserving natural resources, reducing power production costs, and retaining existing boilers for longer life as base-load units. From every indication to date, these potential benefits can be achieved merely by taking advantage of existing technology and commercially available equipment.

This project has been supported by demonstration grant No. G06-EC-00312 from the Environmental Protection Agency, pursuant to the Solid Waste Disposal Act as amended.

REGIONAL SOLID WASTE MANAGEMENT AUTHORITY: A CASE STUDY

*Robert C. Porter**

THE DES MOINES METROPOLITAN AREA SOLID WASTE AGENCY officially came into being on July 29, 1969, when the Intergovernmental Agreements, signed by the official representatives of 12 cities and towns and two counties, were registered with the Secretary of State of the State of Iowa.

Since that time, the agency has grown from a 14-member board with an office staff of two to the present 16-member board with a 105-man operating staff. The agency now operates enough collection equipment to collect the solid waste from more than 60,000 residential dwelling units and has enough heavy equipment to dispose of the residential, commercial, and industrial solid waste generated in a metropolitan area of 280,000 population.

DELEGATING THE LEGAL AUTHORITY

The legal authority to establish the Des Moines agency rested in Chapter 28E of the Iowa State Code. This chapter is typical of an "intergovernmental cooperation act" that is found in most State codes. It provides in essence that units of Federal, State, or local governments may exercise jointly any powers, privileges, or authority that they are authorized to exercise independently.

The basic framework for the formation of the agency is embodied in a report prepared under demonstration grant G06-EC-00060 for the city of Des Moines and 13 other communities on May 16, 1968, by Henningson, Durham, and Richardson of Omaha, Nebraska, and by Veenstra and Kimm of West Des Moines, Iowa.

Once the report was presented, the responsible officials of the metropolitan area lost no time in disseminating the information and organizing the area communities for action. By September of 1968 they had held their first official meeting with representatives of the 14 political entities that were to make up the nucleus of the agency. There were many things to do, for this was to be a unique organization in the United States.

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*Director, Des Moines Metropolitan Area Solid Waste Agency, Des Moines, Iowa.

Many joint municipal organizations or agencies have been formed under various State intergovernmental cooperation acts, and they are not new. In fact most regional planning commissions and similar organizations have been formed under these acts. The difference between what has been done in the past and what the Des Moines agency is set up to do is that the Des Moines agency is a self-supported field operation requiring manpower, a substantial capital investment in land, facilities, and equipment, and a large operating budget. Most other organizations for joint operations are usually paper- and pencil-oriented with a limited staff supported by assessments levied on the member communities.

The legal council for the Des Moines agency recommended specific legislation to the Iowa legislature to provide for issuing revenue bonds for capital improvements and operating equipment. This legislation (now Chapter 236 of the Iowa Code) together with Chapter 28E of the 1966 Iowa State Code authorized any political subdivisions of the State to join together to perform certain public services and to create a separate legal or administrative entity to render them. The legislation spells out the conditions of such "quasi-municipality," and articles of the Intergovernmental Agreement generated by the Des Moines agency define the areas in which it will function.

To raise the necessary capital funds, the agency elected to issue revenue bonds supported by user fees charged for the collection and disposal of solid waste. The basic intergovernmental cooperation act implied that an agency could do whatever was necessary to accomplish its purpose provided that all member communities had similar authority. It could be construed that such a power included issuing revenue bonds, but prospective bond buyers were reluctant to purchase them without specific legislative authority and a court test of the validity of the legislation.

On December 18, 1969, the Des Moines agency adopted a resolution to issue revenue bonds not in excess of $2-1/4 million for the purpose of purchasing land and equipment. After the resolution had been adopted and the supporting resolutions had been received from each of the 14 municipalities, a taxpayers suit was brought. The suit was instituted on December 30, 1969, in the Polk County District Court in Des Moines, Iowa. It challenged Chapter 28E and Chapter 236 of the law and charged that the agency was not legally empowered to perform the tasks outlined above and did not have the statutory authority to issue revenue bonds to carry out its own purposes.

A decision was rendered by the District Court in favor of the agency on April 16, 1970. This decision was immediately appealed to the Iowa Supreme Court on May 19, 1970. The Supreme Court ruled in favor of the agency on September 2, 1970, upholding the local District Trial Court's decision that the agency was properly created, due authority was properly delegated to it, and the agreement between the members was valid. The agency could issue revenue bonds, fix and collect fees (including interest and principal on bonds) from those using the services. The Supreme Court of Iowa recommended, however, that since the law (Chapter 28E) was unclear as to the status of the County at the inception of the agency, Polk County should resign its membership and rejoin the agency under the new authority outlined in Chapter 1191, Acts of 63rd General Assembly Code of Iowa.

INITIAL ACTIONS OF THE DES MOINES AGENCY

Beginning June 1, 1969, (before official registration of the agency) the agency board received an implementation grant from the U.S. Environmental Protection Agency to implement the recommendations found in the engineer's report. A director and office staff were hired, and the business of setting up the agency, locating sanitary landfill sites, and tending to other legal matters began.

Establishing a Sanitary Landfill

The agency staff has engaged in a concentrated search for the two sanitary landfill disposal sites as recommended in the engineer's report. A total of some 70 different sites, ranging from 40 to 800 acres, were investigated. All but ten were discarded because they did not meet some of the basic criteria as set forth by the staff. The ten that did meet the criteria were then investigated in depth, and five were test bored to determine the underlying soils.

During the search for sanitary landfill sites, numerous other agencies were consulted as to the effect that the sanitary landfill would have on their area or service. Among the agencies that were consulted were the Soil Conservation Service, Agricultural Soils Conservation Service, the Iowa State Health Department, the Central Iowa Regional Planning Commission, the Des Moines Water Company, the Polk County Conservation Board, the local and county planning commissions, and several other special interest groups.

After encountering the usual citizen objections, a 400-acre site was finally selected and given the full treatment, including a thorough engineering and geological study. Split-spoon borings to a depth of 50 ft were made, a full final-use plan was developed, and site development plans were drawn. The Polk County Zoning Board of Adjustment was given a full presentation, and a special use permit was granted to the agency to use the site as a sanitary landfill. Several stipulations, all standard sanitary landfill criteria, were included in the special use permit, which was issued May 21, 1970. On June 15, 1970, several of the aggrieved citizens in the vicinity of the proposed sanitary landfill entered a Writ of Certiorari in the District Court of Polk County, Iowa, alleging that the Polk County Board of Adjustment made an illegal and unconstitutional decision when it granted the Des Moines Metropolitan Area Solid Waste Agency a special use permit to operate a sanitary landfill. The reasons advanced for the action were summarized as follows:

1. The Zoning Board is illegally established since four members are not residents of the area affected.
2. Selection of the board members is in violation of the one-citizen-one-vote rule.
3. The decision is in violation of Chapter 657 of the Code of Iowa.
4. A sanitary landfill will create a nuisance through its attendant pollution.

The District Court did find for the defendants (the Zoning Board of Adjustment and the agency) on November 3, 1970. The Court held that the board was acting within the bounds of its authority and not in a capricious or arbitrary manner when it issued the special use permit for the sanitary landfill.

The District Court's decision was appealed to the Supreme Court of Iowa on November 24, 1970. The case is still pending at the time of this writing so no further comment will be made.

Operating Procedures

The agency's amended and substituted bylaws (registered with the Secretary of State on January 8, 1970) gave it authority to contract with any public entity to collect and dispose of its solid wastes. On that basis, the agency negotiated with the city of Des Moines to collect and dispose of its domestic solid wastes. The contract, which was called a temporary solid waste agreement, was entered into on November 1, 1970, for a period of two years. The agreement was for the agency to collect and dispose of all domestic wastes generated from residences housing up to four families at a rate of $2 per family dwelling unit per month. The agency took over all of the city's current operating equipment, its disposal site, and all its operating personnel on November 1, 1970.

At that time the agency also raised the gate fee enough to acquire the equipment and institute operating procedures necessary to change the disposal site from a dump to a sanitary landfill. A gate fee of 50 cents per cubic yard was established through an engineering cost estimate.

Since the city site was almost exhausted, the city of Des Moines acquired an additional 20 acres of land contiguous to the old site. This additional land would enable the agency to carry out its solid waste disposal commitments to the area while the special use permit granted for the new sanitary landfill site was being challenged in court.

By April 1, 1971, five of the eight disposal sites in the area had closed their gates and the wastes were diverted to the agency's sanitary landfill sites (Metro Park Central). The volume of solid waste received at the sanitary landfill increased from 16,000 cu yd per week in the early months to the present total of 22,000 cu yd per week. This figure includes refuse from the five closed sites and the additional volume generated by the passage of a no-burning ordinance in the city of Des Moines.

The agency provides once-a-week, back yard collection for approximately 60,000 homes within the city of Des Moines. The waste collected includes kitchen garbage, lawn cuttings, leaves, paper products, and all the other materials devised and thrown out by man.

At Metro Park Central all manner of material is being deposited and then buried. All toxic wastes are prohibited, and to the agency's knowledge none has been deposited at the site. Inquiries have been made frequently as to the proper disposal of such items, and recommendations have been made to the parties responsible for generating them.

Among the first lessons learned by the agency personnel is that a maintenance program is vital. Before the agency takeover, the city maintained the collection trucks and landfill equipment as it was needed. The agency continued this policy, but it took only a month to discover that this course of action produced only headaches for those trying to schedule equipment, maintain an operating fleet, and run a sanitary landfill. Waste is generated every day and accumulates rapidly. People demand to be serviced on the appointed day, and the rules require that the waste be compacted and covered every 24 hours. Neither of these things can be done if equipment is not in service.

The agency has felt the sting of criticism from both public and private sources because of its inability to maintain a complete schedule in the dead of winter. The basic problems have been the inability to get equipment through snow and inadequate operating equipment to fill out the assigned routes. The sanitary landfill has suffered equipment breakdowns at critical times and has been unable to operate each and every day as planned.

The Des Moines agency has now instituted a preventive maintenance program. Instead of doing an oil and grease job on our collection packer trucks once every 6 weeks or so, it is now done regularly every 3 weeks. Landfill equipment now gets daily checks and regular servicing by the agency's oiler, and the essential parts are greased every day possible.

The downtime differential is difficult to define, but the agency does know what condition its equipment is in and can at times spot impending troubles. When the new facilities are built, the agency's own preventive maintenance program will hopefully reduce minor breakdowns to a minimum.

Employees have been invited to participate in the maintenance program by calling attention to any problems they encounter while operating their equipment. A number of problems with the trucks have been found and corrected by this procedure. Items reported to the office during the day are attended to during the evening hours, and the trucks are ready to go the next morning.

The working relationship between the agency and its employees seems to be good. Except during the winter when several long weeks were required because of cold weather and snow, agency men have responded to each day's collection with a measure of enthusiasm. Management has frequent contact with its employees and answers their questions with dispatch.

Has the agency succeeded? Public opinion about it varies greatly, but one thing is certain: most area residents know of the agency and its intent, since it has enjoyed considerable publicity, both good and bad. Newspapers, television, and radio have had a field day reporting the happenings at the agency. Some would liken its troubles to the perils of Pauline. The contract and ordinance discussions with the city, the union negotiations that lasted to the 12th hour, the many court fights over a sanitary landfill site, the problems with bad weather and equipment breakdowns, and the new procedures to help clean up the city have all been widely discussed.

The aim has been and continues to be service to the public; and for the most part, the agency has managed to serve them regularly. During the rough winter weather, the agency office logged over 300 complaint calls per day for an extended period. Now that warmer weather has come, complaints dropped to 20-25 per day. This figure is to be measured against the approximately 60,000 homes serviced each week.

Problem Areas

The agency's biggest problem seems to be arriving at a complete understanding with the public. The agency undertook to collect the city's solid wastes for a monthly fee of $2 per family dwelling unit per month. Before the agency takeover, the city had collected household waste only. All expenses were paid out of the general fund, and therefore residents saw collection as a free city service. The full impact of the city's contract with the agency did not hit until the bills for service arrived. Then the full blow was felt by the agency, the city finance department, and the water department (who sent out the bills).

The first series of billings has been completed, and the agency is now in the second set. Residents seem to be using the service far more than was thought, and for the most part they are paying their bills. The solid waste load has doubled and seems to be getting bigger each week. The results of spring cleanup campaigns are being felt by the agency (and the agency is participating in these campaigns). The city is truly being "cleaned up."

Along with the transfer of collection authority, a no-burning ordinance was passed by the city council effective January 1, 1970. The new law made it necessary for people to find some way to store the additional accumulation of waste that previously had been burned.

Plastic bags seemed to be the answer until the dogs of the city found them to be a source of free meals. Plastic bags lost their glamour, and the battle of the dogs vs. plastic bags vs. proper storage practices has not been settled yet. The agency is working on it, however, in conjunction with the city health department.

Occasionally a citizen takes the agency on for its apparent neglect of his solid waste. Both the television and newspapers have shown graphic examples of agency neglect. The real story is not as bad as the one projected, but the offended citizen apparently feels that he will get faster service through the intervention of the news media. He does get service, as do all complaints, but usually no faster than through the regular channels. The agency investigates every complaint and is able to satisfy most.

The unpopular new $2 fee combined with the no-burning ordinance and the worst winter in nearly 30 years has not made the agency's track record look the best. But in spite of their problems, the Des Moines Metropolitan Area Solid Waste Agency is alive and kicking. What lessons have they learned? The following lists some basic advice:

1. Never take over a collection and disposal service at the beginning of the winter season.
2. Arrange for financing, satisfactory equipment, and other operating facilities before beginning actual operations.
3. Start a public relations program during the planning stage.
4. Try not to change the system radically in the beginning.
5. Have a complaint system ready.
6. Employ your own legal and engineering staff for continuity.
7. Remember, an agency like this is a goldfish bowl.
8. Coordinate, cooperate, and coordinate some more.

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THE SYSTEMS APPROACH TO SOLID WASTE MANAGEMENT PLANNING

*Lawrence A. Burch**

THE CALIFORNIA DEPARTMENT OF PUBLIC HEALTH received a grant, in 1966, from the Federal Office of Solid Waste Management Programs to demonstrate the value of a rigorous systems-oriented study on the management of solid waste in an area that faced typical urban-rural expansion problems. The study was to investigate, plan, and design a regional system to handle all of the solid wastes from agricultural, industrial, and community activities on a schedule that would be time-phased for implementation over the next 30 years. The final report of the study, known as the California Integrated Solid Wastes Management Project, was completed in April 1969. This paper represents an abstract of the final report, augmented by a review of progress that has been made in the local waste management system since completion of the study.

A portion of Fresno County located near the geographical center of California was selected for the study. The study area is a region approximately 25 miles by 50 miles, containing 770,000 acres or about 1,200 square miles. This area, which has a population of about 390,000 people, consists of a core city surrounded by 10 incorporated and 16 unincorporated communities. Surrounding and interwoven with the periphery of the core area is a high-density agricultural belt. The principal sources of income are agriculture and agri-business.

The Fresno project was a joint effort by the State Department of Public Health, city and county agencies, and private industry. About half of the total effort was performed, through contract, by the Aerojet-General Corporation assisted by Engineering-Science, Inc. This group possessed the engineering, systems analysis, computer, and related technical capabilities required

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to develop a comprehensive approach to the planning and design aspects of this very complex areal problem. Other responsibilities such as general supervision, agency coordination, environmental criteria, and assistance in public education were performed by the California Department of Public Health.

The "systems approach" for this study was based on the premise that solid waste management involves many complex and interrelated functions, and that a highly sophisticated and systematic approach is needed to achieve a genuine solution. The use of a systems concept provides a new perspective in analyzing the problems of solid waste management. Almost all current methods are concerned with the waste material itself. The systems concept considers waste materials as an "input" to a waste handling system. The components of the system are examined critically to determine their effectiveness versus their costs. Through interaction of scientific, engineering and management technology, the systems approach focuses attention on all the details of the kinds and amounts of wastes, the hardware, and practices for handling them. Also identified are the criteria or standards that control how the wastes should be managed to achieve the health, aesthetic, and projected management goals to provide an optimum environment for urban, agricultural, and industrial activities.

The Fresno project was planned to incorporate five main tasks or efforts.

Task 1. -- The public education program was designed to develop within the people of the Fresno area a readiness to accept the new concepts and recommendations that were expected to be developed by the project.

Task 2. -- The systems-oriented study was expected to: (1) determine, through a comprehensive study, an optimum solution to the Fresno region's solid waste management problems; and (2) develop a technology and methodology for regional solid waste studies that could be applied to solid waste management problems in other urbanizing regions.

Task 3. -- Special entomological studies were devised to conduct special field studies of solid wastes for which sufficient data were unavailable.

Task 4. -- Criteria were developed to guide the proper evaluation of solid waste management systems under the systems analysis study in Task 2. These criteria served as the environmental specifications that the proposed Fresno regional system was required to meet.

Task 5. -- Development of a management program to implement recommendations was and has been a continuing effort of the project since its inception. The likelihood of implementation was one of the most important factors in selecting the Fresno area. This task provided advice and consultation on the new concepts and recommendations developed by the project to public agencies and private concerns in the area.

For the purposes of this program, this discussion will be limited to the systems analysis phase of the project and the resulting management program.

SYSTEMS ANALYSIS

One year before beginning the Fresno project, a prototype study on integrated waste management systems had been completed for the California Department of Public Health by the Aerojet-General Corporation. The logic of systems analysis was applied in that study to the total solid, liquid, and gaseous wastes problem of California. Two major conclusions drawn from that original study were: (1) that it was necessary to consider all waste products within the concepts of a single management program and, (2) that waste management must be provided for on a broad regional basis. That report and other emerging elements conducive to long-range planning were the impetus in developing the concept of the Fresno study.

Specific contractual procedures and supporting information were written and circulated to interested organizations by the California Department of Public Health to assure a thorough and common understanding of the scope and the details of the proposed systems-oriented study. In addition, the procedures covered disclosures that would define the proposer's capacity to perform a complex program of this nature, the role of the California Department of Public Health in the study, the basic terms of the anticipated contract for services, the rates of compensation, anticipated reports and meetings, etc. The State of California, Department of Public Health, awarded a contract to the Aerojet-General Corporation in September 1966 and directed the corporation to proceed with the systems study of solid waste management in the Fresno area. Eight other major proposals were received and evaluated by a selection committee.

The systems-analysis study was performed in two 1-year phases, involving 26 subtasks. Subtask Nos. 1 through 15 and subtask No. 17 were completed during the first phase; these subtasks involved collection of background data, state-of-the-art information, and development of the performance scoring procedure. Subtask No. 16 and Nos. 18 through 26 were completed during the second phase; these involved evaluating the various feasible systems and selecting the best alternative waste management system. A summary description of each of these subtasks is included at the end of this paper.

Examples of Data Generated

A wide range of data was required to comprehensively evaluate alternative waste management systems. The following paragraphs provide brief examples of selected portions of these data.

The population in the region in 1967 was approximately 396,000. Of this number, about 312,000 resided in the region's communities, and 84,000 in areas outside the communities. By the year 2000 the region's population is expected to exceed 1,000,000. The entire regional increase will probably occur in the cities and communities, with the population outside the communities remaining practically static. The distribution of population in the year 2000 is projected to be 973,000 inside communities and 83,000 outside.

Agriculture is by far the largest land use in the region. Of the 770,000 acres in the Fresno study region, 43 percent (329,000 acres) are presently producing high-return crops such as fruits, nuts, field crops, and vegetables. Another 39 percent (300,000 acres) is used for irrigated pasture, alfalfa, hay, or native rangeland. About 52,000 acres are under urban development, and the balance (89,000 acres) are unused. By the year 2000, 585,000 acres are expected to be producing high-yield crops, with 111,000 acres under urban development. The remaining 74,000 acres will be almost totally utilized for alfalfa, hay, and pasture.

Solid wastes in the Fresno region were generated in 1967 at the rate of almost 2.5 million tons per year. This quantity was made up of 432,000 tons of municipal wastes, 256,000 tons of industrial wastes, 1,012,000 tons of animal wastes and manures, and 777,000 tons of crop residues. By the year 2000, the rate of waste production in the region is expected to reach nearly 5.6 million tons per year, with more than 1.5 million tons of municipal wastes, 508,000 tons of industrial wastes, 2.2 million tons of manures, and nearly 1.4 million tons of crop residue wastes.

A review of the policies existing at the time of the study indicated that they had produced a heterogeneous solid waste management system in the Fresno region, with practices varying between county and city, and between cities. There was no standardization of refuse collection equipment or routines, and a great deal of route duplication resulted. Much of the problem of poor equipment and overlapping service in the private sector was considered to be due to the ease with which anyone could get a permit and set up a refuse removal business. The lack of vested property rights interest, such as would be produced by long-term franchise contracts, discouraged the investing of sufficient capital to buy and maintain the better and more efficient equipment.

Scoring Waste Management Systems

To measure the effectiveness of various waste management systems, it was first necessary to identify the problems and the environmental effects that needed to be controlled. In the Fresno region, 82 different solid wastes were identified as occurring in sufficient quantities to create a problem. All these wastes are categorized by origin into three groupings, designated here as municipal, industrial, and agricultural wastes.

To further establish a basis for measuring the environmental effects of solid wastes, it was necessary to determine all states and conditions in which solid wastes presently exist or are likely to exist in the Fresno region for the duration of the study period. The 19 conditions of solid waste were identified as follows:

- Unmanaged
- Spread on ground
- Piled on ground
- Piled on slab
- In open containers
- In closed containers
- In open transport
- In closed transport
- Ground
- Used in pit disposal
- Spray irrigation
- Incinerated
- Burned openly
- Composted
- Lagooned
- Landfilled
- Buried
- In open dumps
- Plowed into ground

After consideration by experts and an extensive review of the literature, it was determined that solid waste had 13 bad environmental effects that needed to be dealt with:

- Flies
- Water pollution
- Air pollution
- Rodents
- Human disease
- Animal disease
- Insects other than flies
- Safety hazards
- Odor
- Plant disease
- Land pollution
- Unsightliness
- Toxicity

Obviously, the evaluation and comparison procedure is complex. Each solid waste management system could include four major waste handling functions (storage, transport, processing, and disposal), each of which has a number of variations. The effect of a system on the environment could be expected to vary according to its location in the region (municipal, industrial, agricultural, or interface areas). Thus over 1,200 separate system combinations were possible. Such an analysis was not practical, of course, and a judgment was required to narrow the number of possible candidate elements of the management systems. For the municipal and industrial wastes, a total of 18 combinations were scored (Table 1). Four combinations were evaluated for agricultural wastes. The mathematical routine used to manipulate these data is simple; but the number of calculations is large, and the presentation of the results is a significant clerical task. A digital computer should therefore be used for more rapid calculation and for feeding the results to a printer to provide a tabulated presentation.

TABLE 1

COMBINATIONS OF HANDLING FUNCTIONS FOR MUNICIPAL AND INDUSTRIAL WASTES

Storage	Collection	Processing	Disposal
Conventional storage		Incineration	
	Vehicular collection and transportation		
Special storage		Composting	On land
	Transport in sewer lines		
No storage		No processing	

To apply systems analysis in this study, methods had to be developed to compare the effectiveness of different handling systems. Two scoring procedures, performance scoring and ancillary-effects scoring, were used to measure the benefits of each system.

Performance Scoring. In the waste management field in general, and particularly in solid waste management, there are few performance standards. The standards that have evolved are the result of emergency pressures and are directed almost entirely toward disease control or the removal of waste from direct sight and contact at the least possible cost.

Underlying this study is the concept that effectiveness of a waste handling system can be expressed in terms of the degree to which it decreases the environmental or bad effects of the waste. If, for example, a unit quantity of waste lying in the open is the constant source of one unit of odor, then a control system such as a tarpaulin cover that cuts the odor in half could be said to have a relative effectiveness of 50 percent, and a tightly sealed container would have one of 100 percent. The procedure developed in this program resulted in a quantitative bad-effects score for a unit quantity of each type of waste when placed in any of the 19 conditions considered above.

The performances of the waste handling systems were evaluated through an eight-step procedure comparing the listed bad effects and waste conditions with an inventory of different wastes produced in the region.

The first step was to have experienced practitioners in the sanitary engineering and environmental health fields provide value judgments as to the relative contribution of a given waste under a given condition to possible bad effects. A rating scale of 0 to 5 was used, with 0 indicating no significant contribution and 5 the highest contribution. For example, using flies as the bad effect and garbage as the waste, ratings for the disposal conditions might be "5" for an open dump and "0" for a sanitary landfill. Each of the 13 bad effects were evaluated in this manner for each condition and each waste.

The second step was to determine a relative condition rating that reflected what happened to the bad effects if a unit of the combined wastes was placed in each of the conditions. Take, as an example, how the condition or manner of waste disposal would be expected to affect fly production. All types of wastes that could be sources for fly breeding are first grouped together (garbage, dead animals, cull vegetables and fruits, manures, etc.). The conditions for disposal of these wastes as a group are rated. This rating was also determined with a 0 to 5 scale; that is, 0 indicates that the condition virtually eliminates the particular bad effect and 5 indicates that the condition is the worst possible way of handling the waste.

Step three involved multiplying the two ratings to get the basic bad-effects scores for a unit quantity of each waste for each of the 13 bad effects under each of the 19 conditions.

The basic bad-effects scores still lacked two features necessary for actual application. First, the scores did not reflect the relative importance of the bad effects in terms of the area or subregion where they occurred--that is, whether the area was predominantly municipal, industrial, agricultural, or an interface area between municipal and agricultural. Second, the values did not consider the relative contribution to the generation of bad effects by solid wastes as compared to other contributors.

The fourth step was to establish a relative importance factor. To rank the bad effects by order of importance, experts compared one bad effect at a time with each of the other bad effects. The more important effect was scored 1 and the less received 0. The scores were then added, and the 13 bad effects were ranked for each subregion. Depending on the order determined above, each bad effect was assigned a numerical value representing its relative importance on a scale of 0 to 100.

Step five involved establishing the relative contribution factor for each subregion. This factor represents a judgment as to what percent of each bad effect is caused by solid waste. For example, solid waste is virtually the only contributor to fly breeding, and therefore this bad effect received a value of 100. On the other hand, solid waste contributes very little to human disease and was scored quite low for all subregions.

The sixth step was to determine the influence coefficient for each bad effect in each subregion. This number is the result of (a) multiplying the specific relative importance factors and the relative contribution factors, (b) adding these numerical values for all the bad effects in a subregion together, and (c) making a ratio of these results for each bad effect to the sum of the multiplied factors for all bad effects in all subregions.

The seventh step was to compute the total weighted bad-effects scores by multiplying the basic bad-effects scores determined in step three by the influence coefficient and adding the resulting scores. This calculation was made for each bad effect, condition, and subregion. The final result is a score representing the total bad effect of a unit of a particular waste in a given condition in a particular subregion. Total weighted bad-effects scores for each subregion were determined for all 82 wastes in each of the 19 conditions.

The eighth and final step was to develop the performance score of the proposed waste management system by multiplying the sum of the total weighted bad-effects scores (for each waste in each condition in each subregion) by the tonnage of each waste unit in the conditions called for by that system.

Several of the conditions are basically transient, that is, the waste remains in the condition for only a short period of time. Compared with disposal conditions, in which the wastes attain a more or less permanent state, the transient scores are relatively low. Combining the two component scores would result in losing the effect of any improvement for transient conditions. Because it was judged that transient and disposal components are of equal importance to society, separate scores were maintained. The final analysis of total system performance includes the combining of these two component scores.

Ancillary-Effects Scoring System. The ancillary-effects scoring procedure was developed as a means of measuring the physical, social, and psychological effects of alternative waste management systems and their components as opposed to performance scoring of the effects of solid wastes. For example, a system that employs trucks to collect solid wastes from households creates noise, traffic interference, exhaust fumes, and is a safety hazard compared to an alternate method such as underground pneumatic tubes. The ancillary-effects scoring procedure becomes important when a number of systems under consideration have similar performance scores and costs. Ancillary effects can then be used to choose the optimum system.

The following are the 12 ancillary effects selected for scoring:

Noise	Air pollution
Traffic interference	Water pollution
Land pollution	Legal problems
Odor	Jurisdictional conflicts
Unsightliness	Employment effects
Safety hazards	Social status

Air, land, and water pollution, odor, unsightliness, and safety hazards were also considered in the performance scoring of solid waste. In this section, however, these effects are considered only with reference to the physical components of waste management systems.

Next, 20 technical and nontechnical individuals provided separate rankings for determining relative importance factors and subsequent weighting factors for each of the identified effects. These two rankings were then multiplied together for each effect. The ancillary-effects score is the summation of the results from the above step for all components of the system.

Limits Imposed in Selecting Solid Waste Management Systems

As described earlier, 18 different systems were considered for managing municipal and industrial wastes, and four methods were examined for agricultural wastes. Minimum improvement goals were established for each proposed system. It was determined that municipal-industrial systems should provide at least a 60 percent improvement over the conditions that would exist if the present system were continued to the year 2000, and that the agricultural waste control methods should result in at least a 50 percent improvement. The existing system was scored and the improvement rate of new systems was measured from this baseline. Another limitation imposed was a ceiling on the total cost of the selected system. The existing system, extrapolated to the year 2000, would cost the region about $33.5 million per year. Of this sum, $25.2 million ($16 per ton) would be required for municipal waste, $1.6 million ($3 per ton) for industrial waste, $5.7 million ($3 per ton) for manures and $1.0 million ($1 per ton) for crop residue management. All costs indicated above are in terms of 1967 value dollars.

Estimates had to be made on the quality of environment that the population would demand and be willing to pay for. An assumption was made, for example, that a 60 percent improvement should be worth doubling the cost of solid waste management. Hence the maximum cost for the municipal system in the year 2000 was set at $50.4 million, or twice the projected cost for the present system. The limit cost of the total solid waste management system in the year 2000 was determined to be $86.7 million. The breakdown is as follows:

Municipal wastes	$50.4 million ($33 per ton)
Industrial wastes	$6.1 million ($12 per ton)
Manures	$26.2 million ($12 per ton)
Crop residues	$4.0 million ($3 per ton)

The cost-benefit analysis (Figure 1) indicated that only municipal-industrial system Nos. 2, 3, and 13 satisfied the imposed technical-economical limitations. But considering the assumptions made in arriving at the limits, it would be unreasonable not to also consider system Nos. 6, 7, and 15.

Any reasonable postulated system for the study region would automatically delete open burning and open dumpings because of their atmospheric and land polluting effects. Recommending a system that used sanitary landfilling exclusively would be

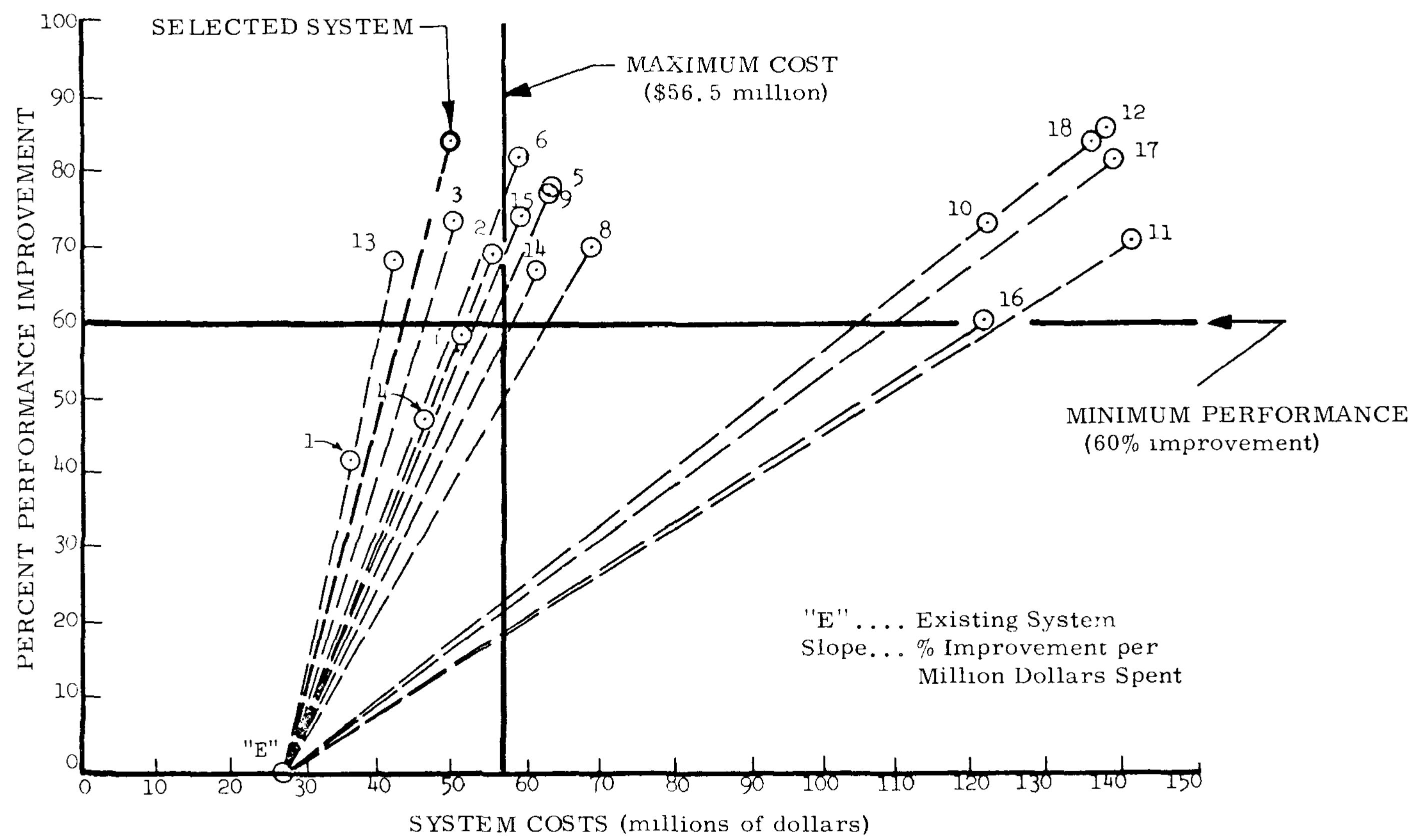

Figure 1. Cost-benefit analysis for municipal-industrial systems in the year 2000.

quite effective but would require even larger sites to accommodate the increased waste production that is projected. Such a solution would pay, in addition, too little attention to the long-range aims of conserving our natural resources. Furthermore, it is highly desirable for any proposed solution to be amenable to waste reclamation operations when they become economically feasible and to recycle as much waste as possible into products that will be useful in the region's economy. Another objective was to build in provisions for an orderly transition from the old system to the new. Additional problems encountered in selecting a system were the region's projected economic capacity and legal, political, sociological, and practical factors.

The Selected System

Three types of solid wastes generated in the Fresno region constituted almost two-thirds of the total amount: organic municipal refuse, organic industrial wastes, and animal manures. The evaluation concentrated on the cost-benefit ratios for the proposed methods of handling both transient and disposal conditions for each of these three categories.

The proposed solid waste management system for the Fresno region in the year 2000 combines features from the best of the 24 original systems. The selected system reserves the most intensive and advanced treatment for the three major types of waste (organic municipal, organic industrial, and animal manures). Between now and the year 2000, these handling methods would gradually be phased into operation, beginning with a sanitary landfill program.

Ultimately, refuse produced in the residential-commercial areas will be stored in containers amenable to automated pickups. The vehicle which serves these areas would be equipped so that it could stop at a collection point, pneumatically evacuate the container, and continue on to the next collection point. Such equipment would permit a significant redistribution of personnel currently required to staff the collection service and would materially reduce the environmental effects of poor storage at the source.

The loaded vehicle would take a large part of the refuse to a well operated sanitary landfill for ultimate disposal. The balance, which would consist of refuse from areas whose solid waste was mainly animal manures, would be transported to a composting plant. Final disposal would then be a soil conditioner and supplier of trace minerals. Materials that are not compostable would be separated and transported from the composting plant to the landfill for ultimate disposal. Organic industrial wastes would also be composted.

The future of the Fresno area appears to include a very large cattle feeding industry; hence, manures from this industry and from dairy farming places a large burden on the environment. The suggested system for the year 2000 provides for combining these manures with refuse high in hydrocarbons. Thus the balance of the carbon-nitrogen ratio would be shifted to make the production of high quality compost feasible. Efficient feedlot cleaning and closed trucking to the compost plant would eliminate most of the present odor and fly problems.

The cost of the proposed system in the year 2000 is outlined below:

Municipal wastes	$42.7 million
Industrial wastes	5.9 million
Manures	26.5 million
Crop Residues	3.5 million
Total	$78.6 million (1967 value dollars)

These figures all fall within the preset expenditure limits.

The effectiveness of the proposed system is indicated by a calculated improvement of 84 percent for environmental effects in the municipal-industrial portion and 70 percent in the agricultural portion.

STATUS OF THE PROGRAM RECOMMENDATIONS

A variety of changes were recommended to provide interim improvement of current solid waste handling processes. Many of these changes were accomplished immediately following the first year of the project. Among the more notable changes were revisions of city ordinances and county regulations to prohibit open burning at disposal sites, the updating of equipment, and the revision of routes and schedules.

One phase of the project that was particularly significant was the investigation into the migration of fly larvae from household refuse containers. This study was the principal basis for adopting an ordinance making twice-weekly refuse collection mandatory in the city of Fresno. The Department has subsequently repeated these investigations in the same area of the city.

Results confirm the effectiveness of increased collection frequency in interrupting the normal fly-breeding cycle.

Nine separate refuse removal operators have merged into an association to unify collection and disposal operations. Such an action would hopefully provide greater efficiency in routing and service to portions of the community not served by municipal agencies. Some problems still remain between the individual operators, and the franchise and rate-control policy of the county is still being resolved.

A cooperative Fresno City-County program has been developed whereby two off-street sewer access points have been constructed for unloading septic tank pumpers into the city's sewerage system. Wash-down facilities are provided at each location. The operation is based on a fee system for the private operators of septic tank pumpers.

Progress has also been made in implementing the longer-term concepts proposed by the project. One of the first measures required to develop the proposed system concept would be to assign some form of regional control. Such an agency (county or special district) would have the power to supplement and complement the activities of local agencies in all aspects of solid waste handling. This type of agency has been approved in principle; the Fresno County Board of Supervisors would act in this capacity, and the County Department of Public Works would serve as the countywide operations-development agency.

One important function of the regional approach would be managing the final disposal of the compost produced by the recommended plan. Composting as recommended in this study differs from composting schemes elsewhere. Here, the composting program is not based solely on the value of the compost for agricultural purposes, as is usually the case; long-term environmental values are considered to be of equal importance. With the responsibility for initiative and management on the regional agency rather than on the agricultural interests, it is believed that a positive program for planned disposal of compost can be successfully achieved in a manner not previously accomplished in this country. In other words, the use of the land for compost disposal should be managed by the regional agency. Agricultural interests would be included but subordinated to the primary function of disposal. An example of this method of operation is disposal/farming activity successfully carried on for the past 20 years in Ontario, California, by the Sunkist Orange Products Inc., for disposal of citrus byproduct wastes.

Following the study, the Fresno County Board of Supervisors directed the Department of Public Works to prepare precise plans on how to put the proposed first phase of the program, a unified sanitary landfill and transfer system, into effect. Eight small disposal sites have now been closed. In December 1970, the first regional sanitary landfill was opened to serve six cities. This month, the second regional landfill is to be opened.

Action on the long-range aspects of the proposed system is still pending. A proposal to demonstrate the composting concept in the Fresno area was developed shortly after the project was completed, but financial support was not available to qualify for Federal solid waste program funds. Recently, there has been a restimulation of interest in the composting project. Other far-reaching concepts of the study, such as constructing and testing the recommended pneumatic collection system, have been approved in principle, but no further action is underway.

APPLICATION TO OTHER REGIONS

Application of the methodologies developed in the Fresno project to other areas would require certain adjustments to the peculiarities of the region to be evaluated.

First it is necessary to establish the conditions under which any proposed system would be required to operate. This step would entail gathering data on regional geology, climate, population, economy and government operation and determining the types and quantities of solid waste to be managed now and in the future.

Next, the scoring procedure developed in the Fresno study would need to be revised to account for the different scale in which certain bad effects may be viewed in a particular region. The basic bad-effects scores without the application of the influence coefficient can be used for all wastes common to those in Fresno. For different wastes, basic bad-effects scores must be developed. The procedures developed in this study could then be used to determine influence coefficients for the region in question that would very likely be different from those developed for Fresno. With the basic bad-effects scores and the new influence coefficients, the weighted bad-effects scores could be calculated and proposed systems scored.

Projected costs for a proposed system must consider the local physical and economic conditions. The cost of local labor, material, construction and land must be evaluated, along with the local topography and availability of suitable sites for proposed system processes.

The ancillary-effects scores of another region will require application of the same techniques used to arrive at the scores in the Fresno region. But more, less, or even different effects may be important in other regions.

With performance scores, costs, and ancillary effects determined, system effectiveness can be compared, and the optimum system selected.

SUMMARY OF INDIVIDUAL SUBTASKS SYSTEMS ANALYSIS STUDY

Subtask 1. -- Developing a direct costing methodology for analyzing alternate solid waste management systems. The task involves developing a standard basis for costing the direct costs of alternate waste management systems so that all costs are comparable. The project requires the identification of major cost elements of the alternate systems and the derivation of cost-estimating relationships that connect the cost element with system characteristics.

Subtask 2. -- Determining problems of solid wastes. The task involves identifying problems in the environment that can be attributed to solid waste in any form. The project requires research of the literature, consultation with experts in the field, and coordination with those groups, agencies, and agency representatives who are adversely affected when no waste management is exercised.

Subtask 3. -- Determining technical state-of-the-art and advanced concepts. The task involves identifying all current and projected processes and techniques for solid waste management that may have applicability in the Fresno region. Identification is to be made in terms of performance characteristics and costs so that a "building block" basis for their consideration in complete systems is established. The project requires research of the literature, consultation with experts in the field, and collation of existing in-house data.

Subtask 4. -- Determining existing solid waste management systems in Fresno. The task involves identifying and evaluating all existing solid waste management systems, procedures, budgeting, and costs in the Fresno region. The project requires field survey, assisted by the various local and regional government agencies.

Subtask 5. -- Determining existing waste loading. The task involves developing basic data relative to the current production of solid waste in the Fresno region, including agricultural, domestic, and industrial sources. The project requires survey of local county, municipal, industrial, and commercial sources and records, and of State agency sources and reports.

Subtask 6. -- Compiling demographic projections. The task involves compiling, interpreting, and projecting data relative to population growth in the Fresno region in terms of size, density, distribution and socioeconomic division. The project requires the employment of standard population projection techniques in conjunction with available local county, city, and private demographic data.

Subtask 7. -- Forecasting land utilization. The task involves collating data relative to current and projected residential, commercial, recreational, industrial, and agricultural land use in the Fresno region. The project requires analysis of existing local county and city planning data, supplemented by data available from other public and private sources.

Subtask 8. -- Compiling regional economic projections. The task involves compiling existing public or private data relative to Fresno region economics as a basis for (a) projecting commercial, industrial, and agricultural solid waste production by type, source, and distribution and (b) determining the capability of the region to assume increased costs for solid waste management. The project requires analysis of existing local county and city planning and tax data, supplemented by data available from other public and private sources.

Subtask 9. -- Collating the region's physical and environmental data. The task involves collating data relative to topographical, geological, hydrological, and meteorological conditions in the Fresno region that are pertinent to the consideration of solid waste management systems. The project requires survey of data available from Federal, State, county and local government sources, supplemented by data from local utility companies.

Subtask 10. -- Identifying related laws and ordinances. The task involves identifying all laws and ordinances that relate to solid waste management in the Fresno region. Complementary laws and ordinances between adjacent jurisdictional areas must also be identified. The project requires study of existing laws and statutes in conjunction with local county and city attorneys and collation of pertinent input data from the California Department of Public Health.

Subtask 11. -- Determining government relationships. The task involves determining the relationships, interrelationships, and lines of authority and communication that exist between Federal, State, county and other local government agencies that may be concerned with solid waste management in the Fresno region. The project requires consultation with Federal, State and local authorities, and with quasi-legal organizations.

Subtask 12. -- Developing a performance scoring procedure. The task involves developing a procedure for measuring the effectiveness of any proposed waste management system in reducing the undesirable effects of solid wastes. The project requires research of the literature, consultation with experts in the field, and coordination with those groups, agencies, and agency representatives who are adversely affected by the undesirable effects of solid waste.

Subtask 13. -- Establishing low-performance and high-cost boundaries. The task involves establishing limits of system cost and performance outside of which it would be impractical to consider candidate solid waste management systems for the Fresno region. The project requires review of system cost and performance goals in conjunction with customer representatives.

Subtask 14. -- Compiling candidate waste-management concepts. The task involves identifying all feasible concepts to the total or partial management of solid wastes in the Fresno region. The project requires selecting previously assembled data on the state-of-the-art and advanced concepts.

Subtask 15. -- Projecting waste loading requirements. The task involves projecting the production of solid wastes in the Fresno region by type (agricultural, domestic, and industrial) source, and quantity. The project requires information derived from previously generated data on waste loading, demography, land use, and the regional economy.

Subtask 16. -- Finalizing performance scoring procedure. The task involves refining and more accurately quantifying the preliminary performance scoring procedure developed in Subtask 12. The project requires continued work, as noted in Subtask 12.

Subtask 17. -- Establishing a truncated list of candidate concepts. The task involves identifying an ordered list of candidate concepts that meet preliminary tests for reasonable cost and performance. The project requires analysis of the previously established list of candidate concepts in conjunction with the preliminary performance scoring procedure and the low performance--high cost boundaries. The practicality of each candidate approach will have to be judged by sanitary engineers.

Subtask 18. -- Defining operating conditions for waste management. The task involves delineating all factors over and above the performance scoring procedure and cost that must be considered in the application and evaluation of any candidate waste management system in the Fresno region. The project requires analysis, extraction, and delineation of all previously assembled data on technical processes, waste loading, existing systems, economy, land use, and legal and jurisdictional information that affects the application or use of any system for the management of solid wastes in the Fresno region.

Subtask 19. -- Designing waste management systems. The task involves synthesizing several alternate systems for the management of solid waste in the entire Fresno region. The project requires defining systems from the truncated list of concepts. They must be consistent with the defined operating conditions and detailed enough to compare them on the basis of cost, performance and application factors ("A" score). The existing system, projected into the future on the basis of presently employed technology, is to be considered as an alternate system approach.

Subtask 20. -- Determining financial resources available for implementing a waste management system. The task involves projecting the financial resources that would be available to implement a solid waste management system in the Fresno region. It requires analysis and interpretation of previously assembled data on regional economic projections, demography, existing waste management systems, and legal government information. Consultation with Federal, State, and local agencies is also required.

Subtask 21. -- Determining practices resulting from existing statutes, ordinances, and recommendations. The task involves determining present practices in solid waste management in the Fresno region that have resulted from existing statutes, ordinances, and recommendations of the various advisory agencies. The project requires consultation with various State and local agencies and analysis of previously established legal and government data in conjunction with established data on existing practices in the Fresno region.

Subtask 22. -- Estimating cost, performance, and "A" scores for system concepts. The task involves determining the overall cost, performance score, and "A" score for each alternate system approach at an "optimum" performance level and at a cost that is reasonable for the Fresno region. The project requires analysis of each alternate system approach in conjunction with the established cost methodology, performance scoring procedure and application factors ("A" score).

Subtask 23. -- Making information applicable to other regions. The task involves defining the methods and limitations of applying the findings and developments for the Fresno region to other similar regions. The project requires analysis and interpretation of all generated data, especially scoring, costing and alternative system data, for applicability to other similar regions.

Subtask 24. -- Ranking of system concepts. The task involves evaluating all alternate system approaches in terms of their cost, performance, and "A" scores, and determining an order of preference for application to the Fresno region. The project requires comparison of the systems on the basis of their relative cost, performance and "A" scores, and interpretation of relative worth of various ratings in conjunction with customer representatives.

Subtask 25. -- Defining the selected system concept. The task involves (a) defining the best alternate waste management system for a long-term solution to the Fresno region solid waste management problem and (b) providing detailed data that will enable immediate improvement of the existing system consistent with the long-term solution. The project requires detailed consideration of the top-rated system from among the candidate system approaches and evaluation of existing system data in conjunction with long-term goals.

Subtask 26. -- Making a final report. The task involves collating all data generated in the preceding tasks into a final report that contains all items delineated in this proposal. In addition to the final report, bimonthly reports and detailed interim reports will be submitted; meetings will be conducted as required.

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SYSTEMS ANALYSIS STUDY OF THE CONTAINER-TRAIN METHOD OF SOLID WASTE COLLECTION AND DISPOSAL

Jeff Chancey and Charles Pinnell†*

THE INITIAL OBJECTIVES of this solid waste collection demonstration project in Wichita Falls, Texas, initiated February 1, 1968, are:

1. to establish procedures and programs for continuous data collection on the various parameters of solid waste collection and disposal.
2. to develop planning techniques through the correlation of solid waste generation rates and land use to project future requirements of solid waste collection and disposal.
3. to analyze the container-train method of solid waste collection so that techniques for optimizing the overall collection operation may be thoroughly evaluated and developed.
4. to develop a comprehensive simulation model of the total collection operation that can be used as a management and planning tool.

Objectives 1 and 2 were met by developing a management information system for solid waste operations. Objective 3 was met by developing computerized procedures for collection route selection and evaluation. Objective 4 was met by developing a comprehensive simulation model of the total solid waste collection operation. In the following sections of this paper, the development procedures for each of the above areas are discussed.

MANAGEMENT INFORMATION SYSTEM

In the container-train method of waste disposal, solid waste is collected by the trains as they move along the streets and alleys. When a train is loaded to capacity, the solid waste it has collected is dumped into a mother truck and transported to the disposal site.

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It was determined that an effective information system could be developed by collecting data on each dump of the trains into a mother truck. The data to be collected is as follows: (1) weight of the solid waste collected by the train; (2) amount of time for the dumping; (3) location of the dumping; (4) I. D. numbers of the train containers and the mother truck; (5) land-use information on the parcels served by the train collection.

A coding system (Figure 1) was used to describe the route and to relate the weight of the solid waste that was collected to the land use. Each link of the collection route is defined by two nodes (A-node and B-node). For each collection link, the following land use data has been collected: (1) number of residential units; (2) total floor area of the residential units; (3) total parcel area; (4) total number of parcels.

When a train dump is made, data on location (node number), weight, train number, and mother truck number is radioed to sanitation headquarters where it is recorded on a data form. In this manner, data on the solid waste collection are recorded throughout the day.

The Weighing Device

Several experiments were conducted by the city of Wichita Falls in an effort to develop a means of weighing refuse at the source of generation. Professor A. M. Gaddis of Texas A & M University was employed to develop a weight monitoring system using strain gages attached to the lifting arms of the mother truck. The original installation of strain gages on the mother truck made use of a 28-in. section of the two upper arms of the truck-loading mechanism (Figure 2). The arms support the load and appear to be uniform in cross-sectioned areas. It was assumed that this portion of the beam was in uniform bending and that the "moment at A" minus the "moment at B" would be equal to the load. $M_A - M_B$ = Shear (Load). A full bridge on each arm was arranged in such a way that this relationship was accomplished in the bridge network.

The two identical bridges (right and left arms) were then placed parallel to each other to complete the overall transducer. The transducer was connected to the balancing network, amplifier, and transmitter (Figure 3). Theoretically, the transducer would take care of any unequal loading that might occur. Calibration of microstrain vs. load revealed a slight change in slope at 1,500 lb that was caused by the "assumed beam" changing shape under load. This condition became continually worse with time. The

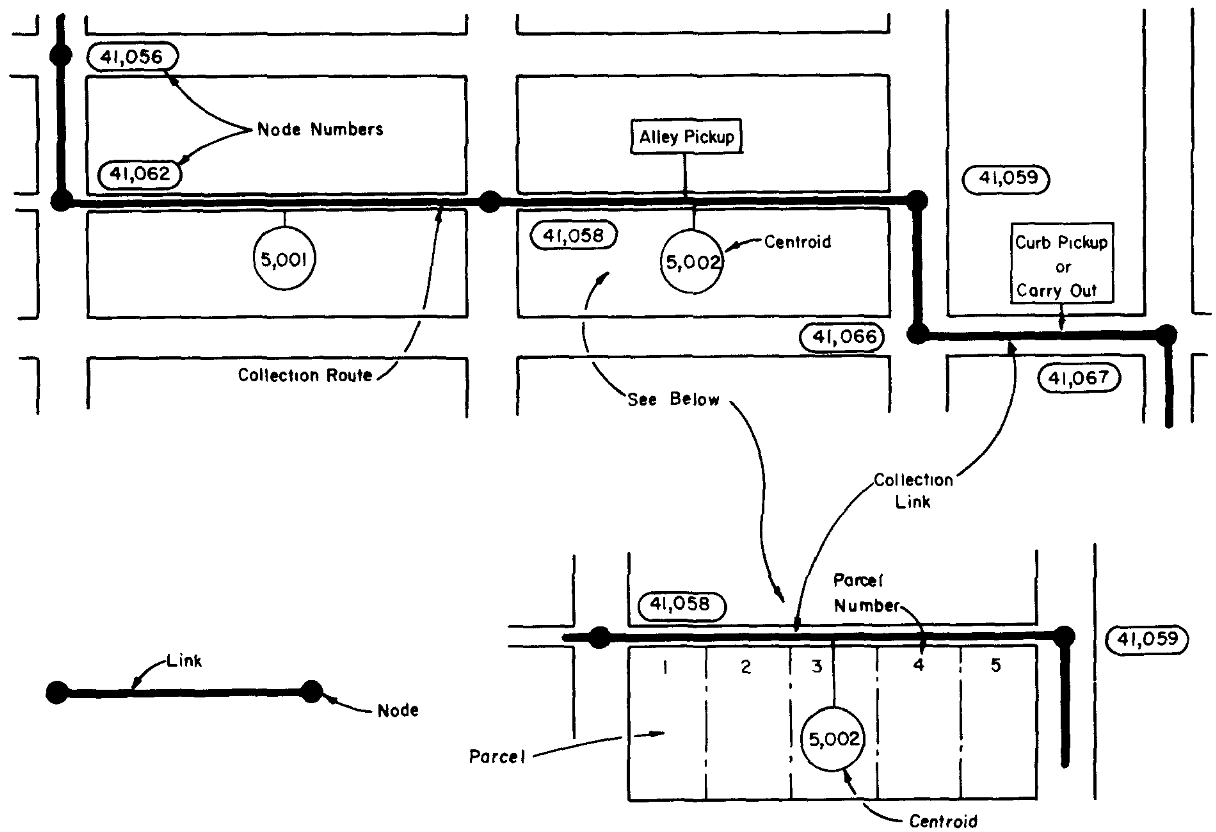

Figure 1. Network coding system used to describe route and to relate the weight of solid waste collected to land use.

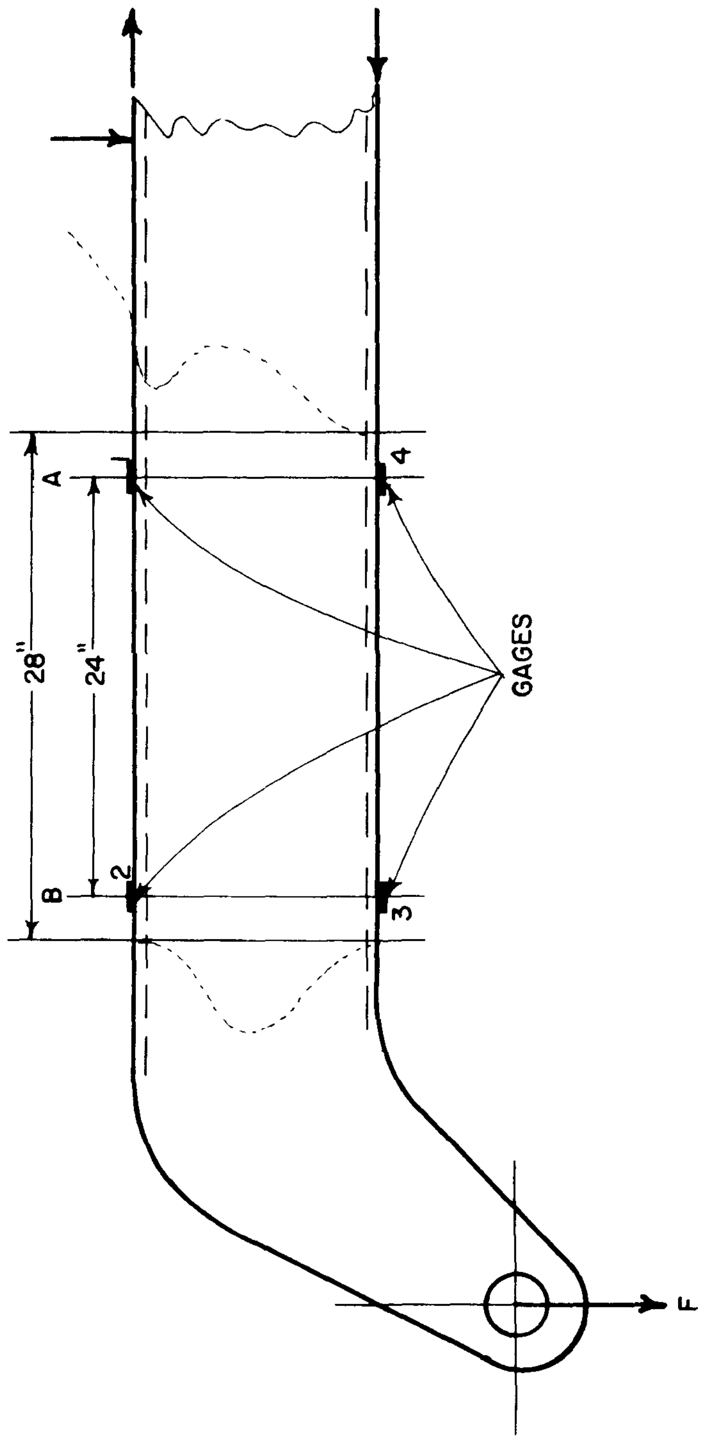

Figure 2. Upper arms of lifting fork.

built-up beam changed shape with use, spot welds began to separate, and the assumption of a "uniform beam" in bending became less and less accurate.

Another problem was that the bridge output was low and had to be amplified before it could be transmitted. The stability of the amplifiers and the resolution of the transmitter were questionable. To maintain the accuracy required, frequent calibrations had to be made. To improve the transducer, a number of changes had to be made. The beam section was not in "uniform bending" as first assumed. The transducer output was low.

A study of the calibration charts revealed what a later test verified: that the upper gauges (the two located at A in Figure 2) remained linear at all loads. Based on this fact, a different method was used. Each arm was considered to be in simple bending (Figure 4). Two strain gauges of the proper type were placed as near as possible to the point of maximum bending and were put in such a position that other stresses would not affect the gauge output. Both the right and left arms were made as identical as possible. The four gauges of the two arms were made into a full bridge (Figure 5), temperature was compensated, and moisture sealed.

The new strain gauge configuration increased gain by a factor of 2 over the previous system. The increased length of the moment arm and other improvements increased bridge output by a factor of 5 over the original system. Another benefit brought about by the change was the increased simplicity, which made it easier to temperature compensate the leads and to protect them from moisture and injury. Calibration revealed the system to be linear. This increased gain and linearity was gained at the cost of some ease of operation. The truck operator must make sure that the moment arm remains unchanged (same conditions as when calibrated) and that the load does not touch the truck while a reading is being taken. The results of this experiment proved to be highly successful. Although responsibilty was placed on the truck operator, the accuracy had been improved and continued to improve as the operator became better acquainted with his job.

Later refinement of strain indicator equipment used digital strain indicators that would operate directly from the truck battery. This reduced the system to simply a transducer and digital strain indicator (Figure 6).

Data Collection Procedures

Experiments were also conducted to develop a means of automatically transmitting the solid waste data from a mother truck

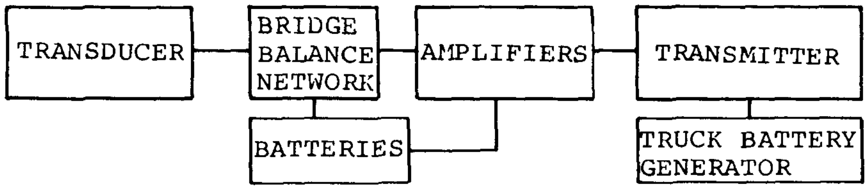

Figure 3. Balancing network.

in the field to a receiving unit located in the city's computer center (Figure 7). A prototype transmitting and receiving unit was developed by the city of Wichita Falls which required the use of the city's IBM 1800 traffic control computer for storing the solid waste data generated daily. Several problems were encountered with the automatic transmitting and receiving system. Consistent data transmission was not received because of malfunctions in the transmitting unit. Unfortunately, the IBM 1800 computer had to be out of service for routine maintenance during hours when traffic conditions were off-peak. Since those hours coincided with peak hours of solid waste data collection, continuous data storage could not be maintained. This equipment was expensive to buy and required considerable upkeep. These problems were eliminated by attaching the new transducer to a digital strain indicator and having the truck operator take the reading and report it to headquarters by two-way radio. The voice transmission system operates as follows: When the train is loaded, the train operator (refuse crew leader) radios the sanitation clerk, giving the identification number of his equipment and the sequence identification number at the location where he is loaded. The time and identification numbers are recorded by the sanitation clerk on the proper form. When the driver of the mother truck (refuse unit leader) is ready to dump the train, he radios the sanitation clerk, giving the identification number of the equipment that is being dumped and the weight. The sanitation clerk then completes the form by recording the time at which the train is being dumped, the identification number, and the weight. The voice transmission system has proved to function consistently and with a high degree of accuracy. The use of the radio has presented no problems and to date no maintenance on the equipment has been required.

At the end of the collection day, all of the data from the various train dumps are keypunched for computer input. In addition to this information, the following data is also prepared for computer input: data on gas, oil, and repair costs for each piece of equipment; downtime (if any) for each piece of equipment.

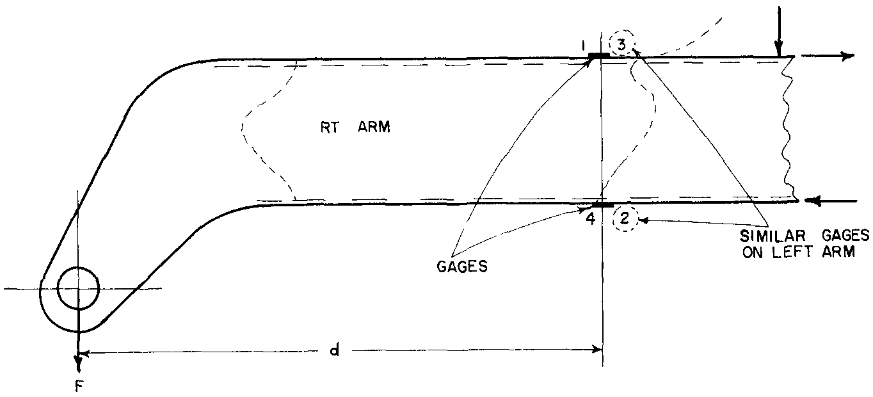

Figure 4. Bending moment.

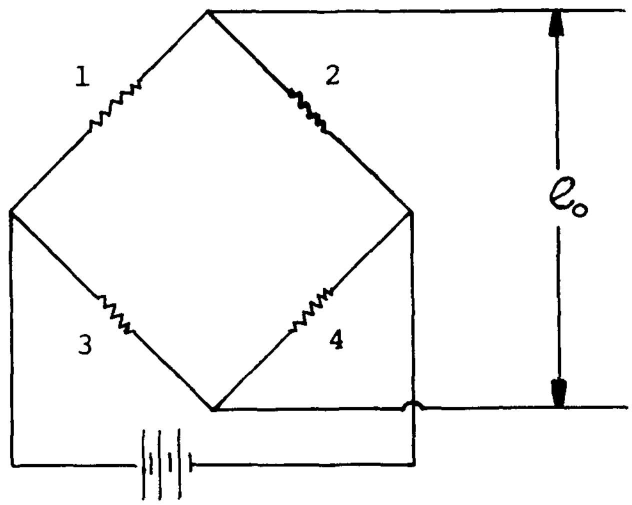

Figure 5. Bridge network.

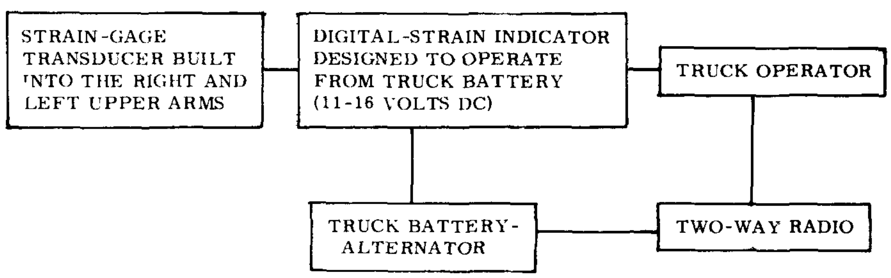

Figure 6. Diagram of the transducer and strain indicator.

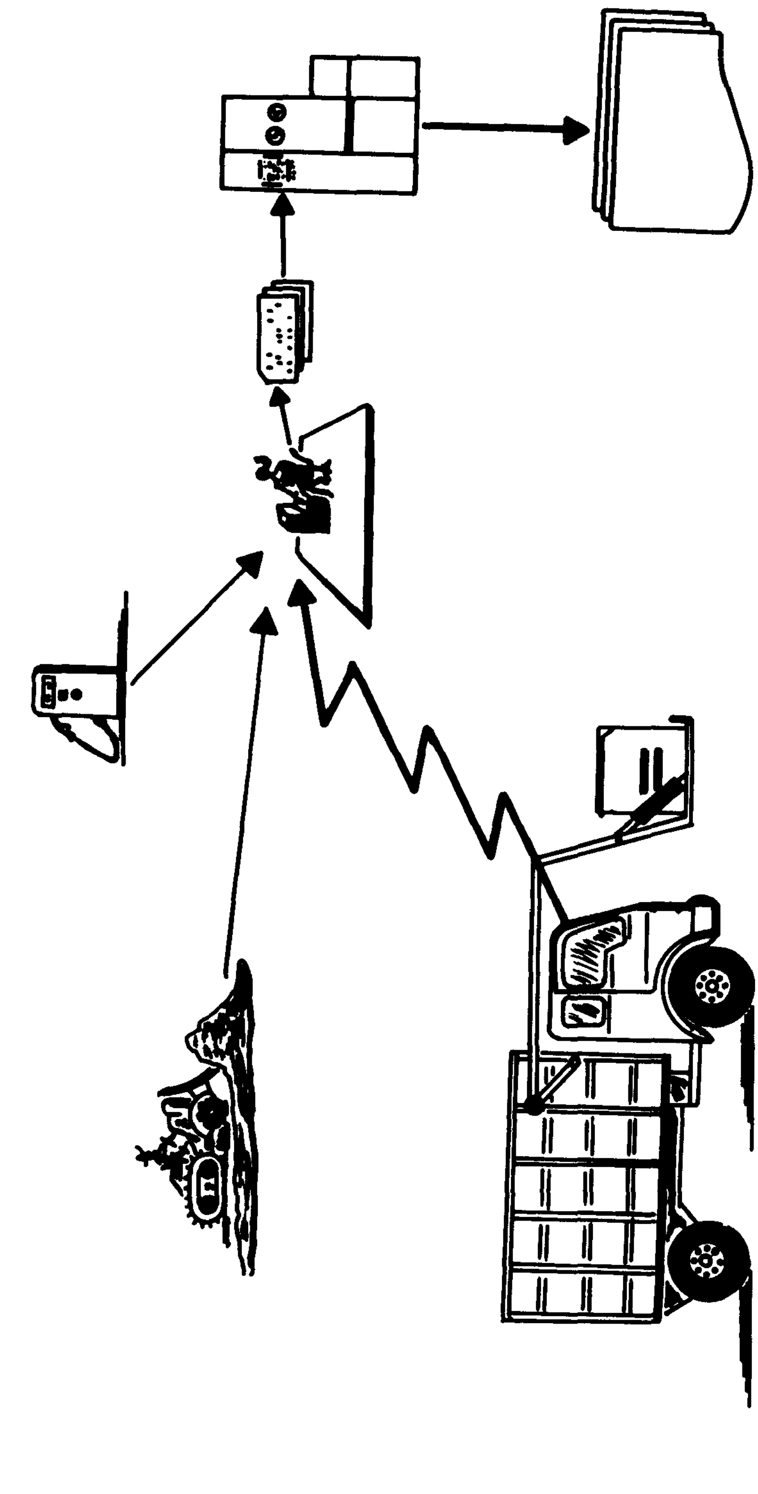

Figure 7. Solid waste data flow.

Computer Programs

A battery of computer programs was prepared to process the solid waste collection data on a daily basis. A basic flow chart of these programs is illustrated in Figure 8.

The programs process the data and produce daily management reports on the solid waste collection. Examples of the output of the computer programs are illustrated in Tables 1 through 3. The information provided in the reports provides an excellent set of data for management control and for relating land-use activities to generation rates.

ROUTE SELECTION AND EVALUATION

After studying collection, it was determined that two basic tools were needed to assist in optimizing the operation. One was a technique for selecting a collection route through a network of streets and alleys that would contain a minimum number of noncollection links. The second tool needed was a means of simulating collection over a given route and evaluating the amount of equipment and time required to collect over the route. Two tools were then developed: the first called the route selection program and the second, the route evaluation program.

Route Selection Program

The input to the route selection program is a coded street network. The network is coded in terms of links (Figure 1). For each link, the following data is available:

1. A-node and B-node
2. length of the link
3. designation of the link as a collection or noncollection link
4. designation of the link as an alley or street link.

The computer program is given a starting node and then proceeds to search a collection route through the street network. The search is governed by an algorithm that seeks to minimize the noncollection distance at each decision point.

The output of the route selection program (Table 4) permits the plotting of the route on a street network if desired. A deck of link cards (one card for each link) is also produced for input to the route evaluation program. Various starting nodes may be specified if desired, and a route will be generated for each starting node.

TABLE 1
CORRECTED WEIGHT CENTROID OUTPUT RECORDS
(REPORT FORMAT - SWMIS)

DATE 31170

MOTH TRK ID NBR ********	EVENT TIME *****	EVENT DATE *****	EVENT NODE *****	CONTAINR ID NBR ********	NET WEIGHT ******	WEATHER CODE *******	LAND FILL SITE NBR *********	LOAD TRAIN WAIT TIME **********
3407	925	31171	40140	3114	318	2	2	5
3407	926	31171	40140	3113	587	2	2	6
3407	927	31171	40140	3112	635	2	2	7
3407	931	31171	50320	3116	703	2	2	1
3407	934	31171	50320	3117	683	2	2	4
3407	935	31171	50320	3115	568	2	2	5
3407	943	31171	99999	4023	144	2	2	0
3407	951	31171	60370	3119	712	2	2	1
3407	952	31171	60370	3118	664	2	2	2
3407	955	31171	60370	3120	703	2	2	5
3407	956	31171	60370	3006	414	2	2	6
3407	1002	31171	70760	3121	597	2	2	2
3407	1005	31171	70760	3122	616	2	2	5
3407	1006	31171	70760	3123	577	2	2	6

TRUCK NBR 3407 DUMPED AT 1020
TRK NET WAS 7920 CTNR NET WAS 8230
THE ADJUST FACTOR WAS 96.2%

DATE 31170

TABLE 2
COLLECTION AND COST DATA, TRAIN ROUTE NO. 242
(REPORT FORMAT - SWMIS)

NODE	TIME OF DAY	WTHR CODE	WEIGHT (LBS)	DISTANCE (MILES) COLL	DISTANCE (MILES) NON-C	COLLECTION TIME IN MINUTES	CENTROIDS FIRST	CENTROIDS LAST	CENTROIDS NUM	PARCELS NUM	PARCELS AREA	LAND USE DATA (BY ACTIVITY) ACT. CODE	TOTAL AREA	NUM PAR	NUM EST	NUM RES	FLOOR AREA
12166	0951	2	2493	3.0	2.1	51	3411	7914	15	98	3792596	1000	3057796	88	125	125	306479
												4000	0	0	19	1	5195
												9000	734800	10	10	0	0
												6000	0	0	5	1	2144
12202	1134	2	2440	1.6	1.0	92	7847	7895	11	109	1063400	1000	1055900	108	108	108	159443
												6000	0	0	1	0	252
												9000	7500	1	1	0	0
25594	1416	2	2383	3.0	4.3	162	7993	1280	31	180	2291157	1000	1729849	148	151	151	165314
												9000	436160	27	30	2	1606
												4000	13020	1	8	3	0
												5000	99328	3	5	0	6346
												6000	12800	1	3	0	2676
*** TOTALS ***			6613	8.7	9.3	316	1786	1280	74	447	6666340					425	

********** COST DATA **********

GAS	OIL	SUPPLIES	REPAIRS	PERSONNEL	OVERHEAD	DEPRECIATION	TOTAL COST	COST PER 100 LBS COLLECTED
0.0	0.0	0.0	0.0	42.00	4.11	3.25	49.36	0.75

EQUIPMENT		EMPLOYEES	
	3006		692
	3118		2054
	3119		2841
	3120		
	3306		

TABLE 3
SUMMARY OF ALL COLLECTIONS, MARCH 11, 1970
(REPORT FORMAT - SWMIS)

ROUTE TYPE	ROUTE NUMBER	WEATHER CODE	TIME (MINUTES)		WEIGHT (POUNDS)			TOTAL COST	COST PER 100 POUNDS COLLECTED
			COLLECT	WAIT/TRANS	FILL SITE 1	FILL SITE 2	TOTAL		
MOTHER TRUCK	221		482	0			9208*	37.86	0.41
TRAIN	240		311	0			6352	51.44	0.81
TRAIN	241		299	0			6594	50.81	0.77
TRAIN	242		290	0			7056	52.27	0.74
TRAIN	243		316	0			6613	49.36	0.75
** TOTALS **	221	2.0	482	0	0	35823	35823	241.74	0.67
PACKER TRUCK	277	2.0	330	45	7400	0	7400	51.06	0.69
PACKER TRUCK	282	2.0	425	15	2780	0	2780	52.74	1.90
*** CITY VEHICLE TOTALS ***			1237	60	10180	35823	46003	345.54	0.75
*** PRIVATE TRUCK TOTALS ***					0	0	0		
*** ALL VEHICLE TOTALS ***					10180	35823	46003		

* -- WEIGHT FOR MOTHER TRUCK PROPER INCLUDES ONLY FIXED CONTAINERS

TABLE 4
ROUTE SELECT PROGRAM
COMPUTER GENERATED ROUTE
(STARTING POINT 20760, JAN. 16, 1971)

(TO) NODE	NON-COLLECTION DISTANCE	COLLECTION-LINK DISTANCE
32150	190	
32147		530
32133		410
35680		500
35727	60	
31838	70	
35730	70	
32049	90	
32052		920
32083		570
32097		440
32195	170	
32066	440	
32018	180	
35713		440
31998	180	
31970		160
31998	160	
32004		420
31998	420	
31970	160	
31919	170	
31905		440
31886		460
31936	180	
35694	130	
31953		460
32780		300

TOTAL NON-COLLECTION DISTANCE # 2,670

TOTAL COLLECTION LINK DISTANCE TRAVELED # 6,050

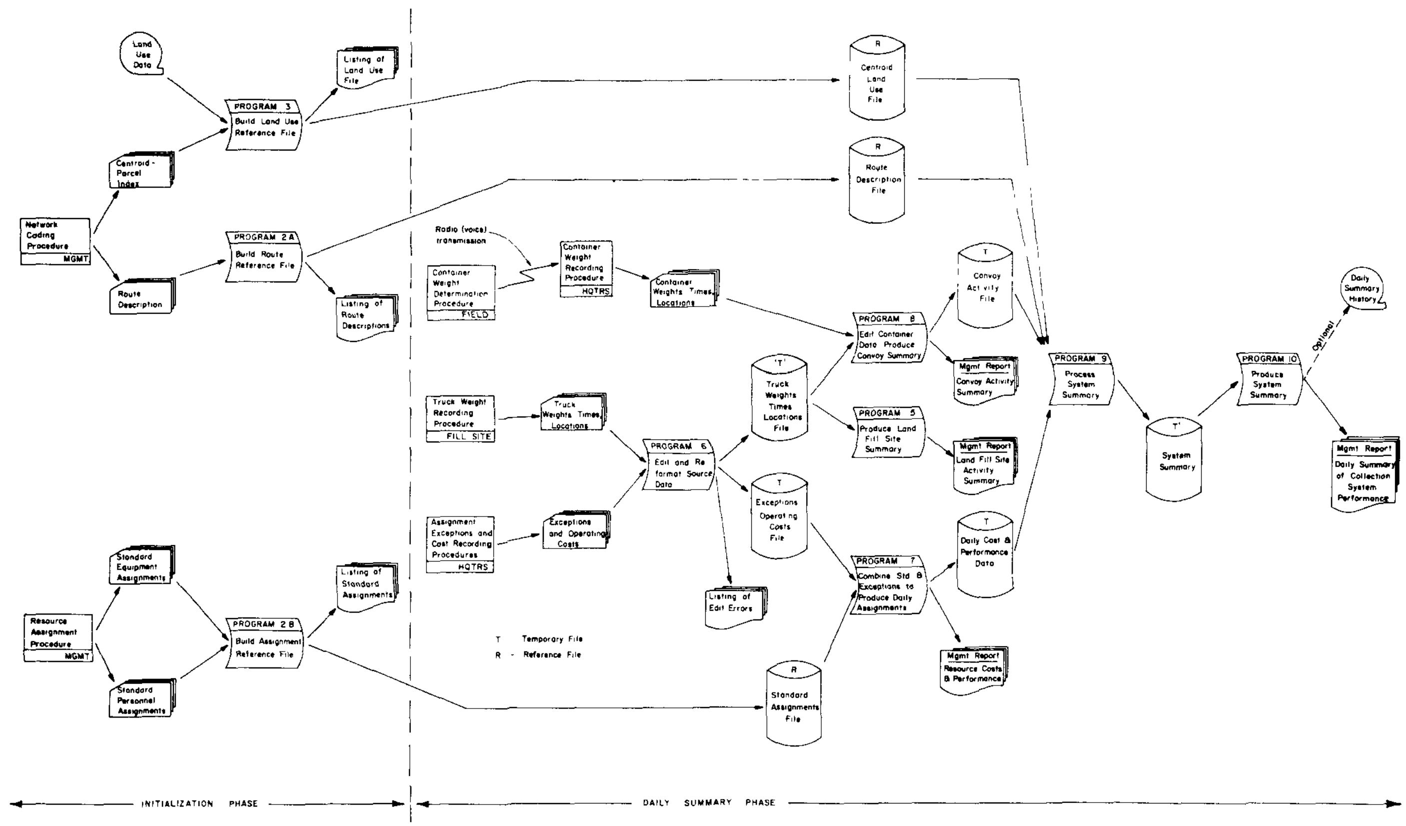

Figure 8. Flow chart for the Solid Waste Management Information Systems (SWMIS), Wichita Falls, Texas.

Route Evaluation Program

After a route has been determined by the route selection program, it is then input to the route evaluation program to determine the amount of equipment and time required to collect the route. This program is actually a simulation program that estimates the following information for each link in the route: (1) amount of solid waste produced in each collection link; (2) collection time for each collection link; (3) travel time for each noncollection link.

The program processes the links one at a time and cumulates both the elapsed time and the amount of solid waste collected. When a predetermined amount of solid waste is collected, the program calls for a train dump. The program logs the information on the dump and then continues through the links until another dump is required. In this manner, the collection operation is continued until a predetermined amount of time has elapsed. At this point, a new train is introduced and the simulated collection is continued in a like manner until the route is completed.

When the route is completed, a report is produced that permits evaluation of the collection operation (Table 5). From this information, it is possible to determine the amount of equipment to be assigned to the route for collection in a given period.

The program is capable of taking into account variations in the number of days since the last collection, residential density, generation rates, and collection procedures. The conditions to be simulated are input on a control card at the beginning of each simulation.

The complete set of route selection and evaluation programs are illustrated in Figure 9.

SIMULATION MODEL

As previously indicated, one of the major objectives of the project was to develop a simulation model of the total collection operation. This model was to be capable of simulating the interaction of the collection vehicles, mother trucks, and disposal activities. The model was also to produce summary information on the total collection operation that could be used for management and planning. Some anticipated uses of the model are: (1) to compare various techniques of solid waste collection; (2) to define the need for specific equipment characteristics such as capacity, speed, etc.; (3) to examine scheduling and

TABLE 5
ROUTE EVALUATE OUTPUT TRAIN NO. 1

LOAD NUMBER 1
****

START COLLECTION NODE NUMBER #16042
END COLLECTION NODE NUMBER #16056
TOTAL WEIGHT COLLECTED #3878 POUNDS
TOTAL TIME REQUIRED #106 MINUTES
NON-COLLECTION DISTANCE #2125 FEET
COLLECTION DISTANCE #6225 FEET
NUMBER OF DWELLING UNITS SERVED #218
TOTAL COLLECTION TIME (CUMULATIVE) #106 MINUTES
COLLECTION TERMINATED ON TRAIN CAPACITY

LOAD NUMBER 2
****

START COLLECTION NODE NUMBER #16056
END COLLECTION NODE NUMBER #14145
TOTAL WEIGHT COLLECTED #3769 POUNDS
TOTAL TIME REQUIRED #95 MINUTES
NON-COLLECTION DISTANCE #3175 FEET
COLLECTION DISTANCE #5125 FEET
NUMBER OF DWELLING UNITS SERVED #199
TOTAL COLLECTION TIME (CUMULATIVE) #201 MINUTES
COLLECTION TERMINATED ON TRAIN CAPACITY

LOAD NUMBER 3
****

START COLLECTION NODE NUMBER #14145
END COLLECTION NODE NUMBER #10032
TOTAL WEIGHT COLLECTED #3858 POUNDS
TOTAL TIME REQUIRED #164 MINUTES
NON-COLLECTION DISTANCE #17524 FEET
COLLECTION DISTANCE #8850 FEET
NUMBER OF DWELLING UNITS SERVED #238
TOTAL COLLECTION TIME (CUMULATIVE) #365 MINUTES
COLLECTION TERMINATED ON TRAIN CAPACITY

SUMMARY - TRAIN NUMBER 1
****

START COLLECTION NODE NUMBER #16042
END COLLECTION NODE NUMBER #10032
TOTAL WEIGHT COLLECTED #11505 POUNDS
TOTAL COLLECTION TIME #6.1 HOURS
TOTAL NON-COLLECTION DISTANCE #22824 FEET
TOTAL COLLECTION DISTANCE #20200 FEET
TOTAL NUMBER OF DWELLING UNITS SERVED #655

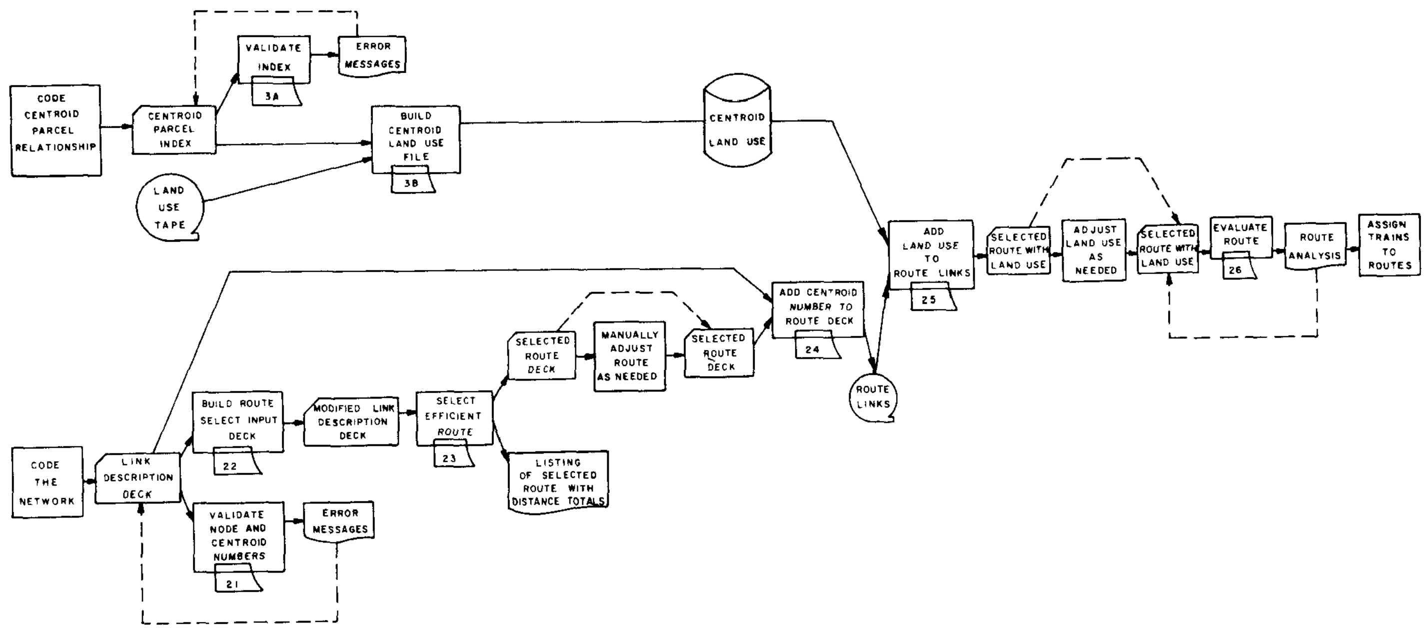

Figure 9. Flow chart for route selection and evaluation system.

queuing problems and to optimize overall operations; (4) to develop data for decisions on disposal sites or transfer stations.

Logic

The logic of the simulation model is based on integrating the daily operations of the collection units in the system to obtain a description of the system's operation. A calendar of events that mark the start of each activity in the system's operation is constructed. Associated with each event in the calendar are: (1) the time at which it occurs, (2) the type of activity which is to start, and (3) the identification number of the collection unit involved. In general, the time of occurrence is computed by adding the duration time for the collection unit's preceding activity to the time that the preceding event occurred. The type of activity is determined by the operational sequence of the collection unit. The fundamental operational sequences of a train and a mother truck are shown in Figures 10 and 11, respectively.

Beginning with the earliest event on the calendar (the start of the collection day), the duration of the subsequent activity and values for the variables that depict the operation of the collection unit involved are calculated. These data are used to update the performance statistics of the collection unit and to determine the time when it will begin its next activity. The time of occurrence of the collection unit's next event is then placed on the calendar. The process is repeated until there are no more events left on the calendar indicating the end of the collection day.

The performance statistics for each collection unit are cumulative totals of the performance variables such as total amount of solid waste collected and total waiting time. At the end of the collection day, summaries of these statistics are output as a basis for evaluating the system's performance. The process is repeated for each collection day to be simulated.

Components

The computer program of the simulation model consists of the following components: (1) event table, (2) clock, (3) activity subroutines, (4) utility subroutines, (5) input, (6) output, and (7) main program. The interaction of these components is illustrated in Figure 12, and a brief statement of the function of each follows.

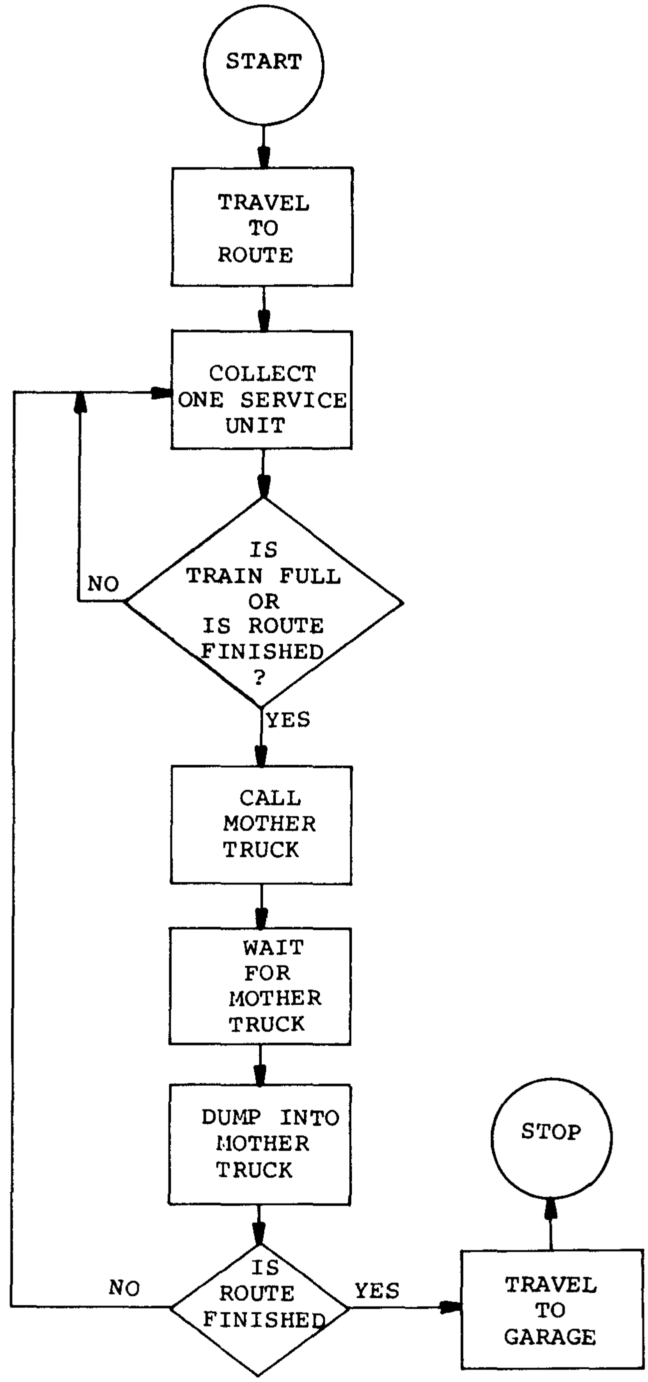

Figure 10. Operational sequence for a train.

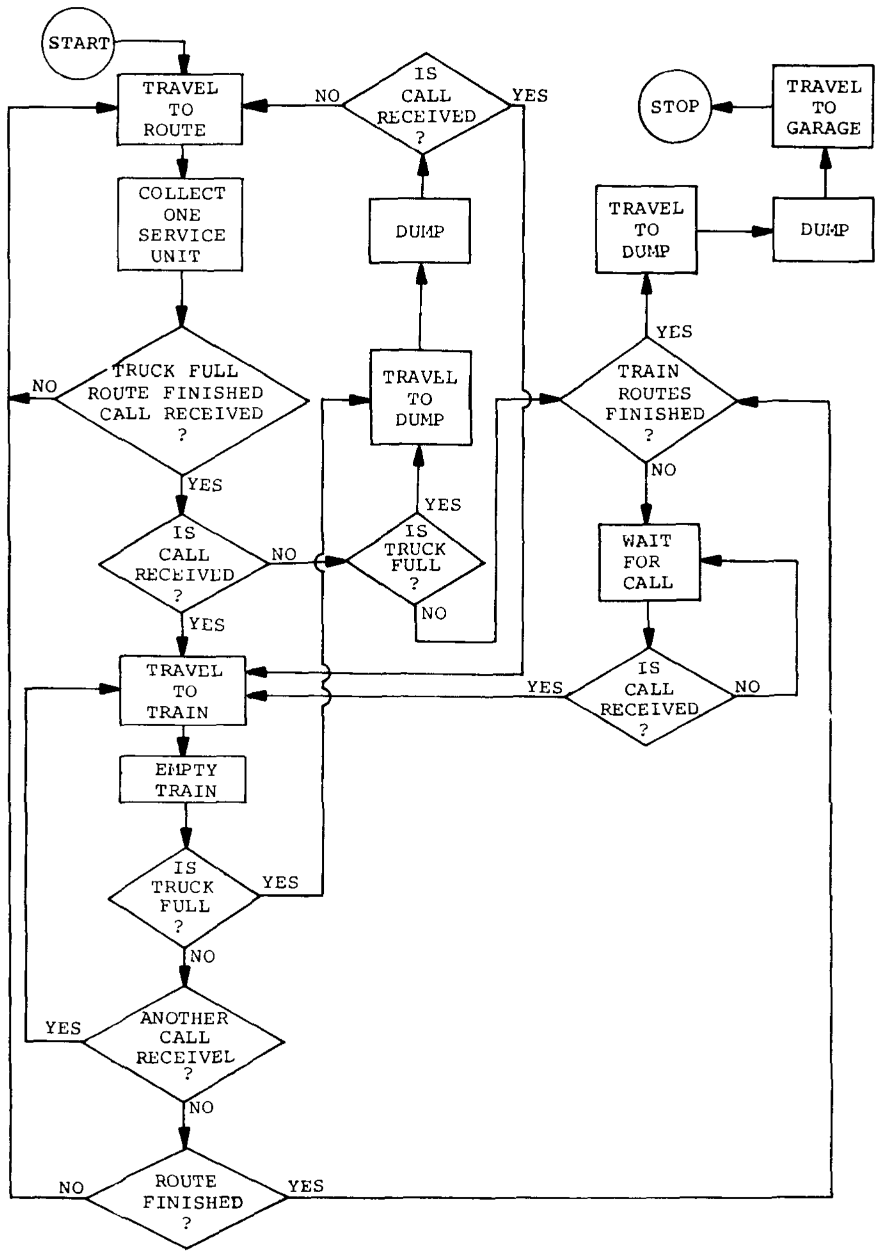

Figure 11. Operational sequence for a mother truck.

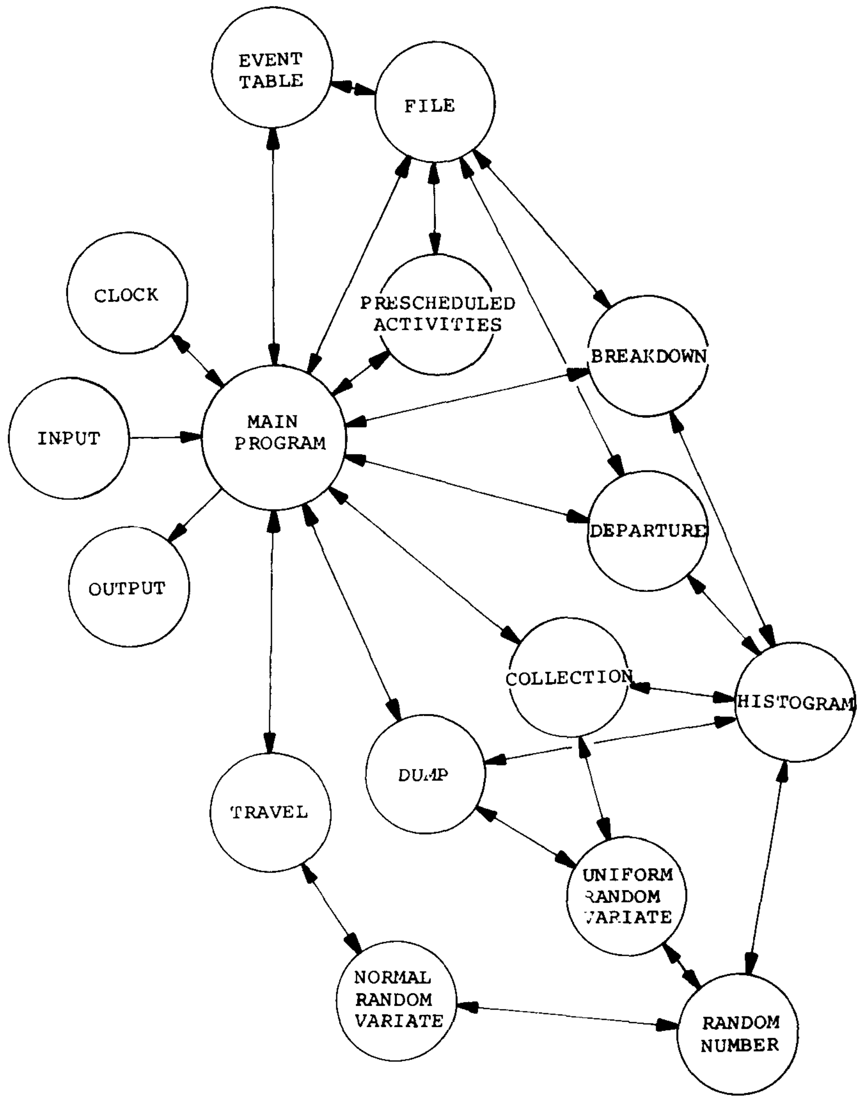

Figure 12. Schematic of the simulation model.

Event Table. The event table contains the system's calendar of events for the collection day. The time of occurrence of each event is stored in chronological order along with the type of activity associated with it and the identification number of the collection unit involved.

Clock. The clock measures the time of the collection day. The clock time is initially set at zero and then advanced to the time of occurrence of the earliest event in the event table. When all computations pertaining to the event have been executed, the event is said to have occurred. The clock is then advanced enough to cause the next most imminent event to occur. The clock is similarly advanced until the last event of the day has occurred.

Activity Subroutines. The activity subroutines are used to determine the duration of the activities and the performance of the collection units involved. The following subroutines comprise this set.

1. Departure subroutine, which establishes the time that each collection unit will leave the headquarters to start its collection day.
2. Travel subroutine, which computes the length of time it will take a collection unit to travel from one place to another and the distance between the two points.
3. Collection subroutine, which calculates the length of time it takes a train to collect the solid waste along a particular route until it either becomes full or the route is completed. It also computes the distance traveled during collection and the amount collected.
4. Dump subroutine, which determines the length of time it takes for a mother truck to (a) dump a fixed container, (b) dump a train, and (c) dump at the landfill site. The amount of solid waste dumped is also computed in each case.
5. Breakdown subroutine, which predicts the occurrence, type, and duration of collection unit breakdowns that will occur during the collection day. This information is filed in the event table.
6. Prescheduled-activities subroutine, which files events in the event table that define any activities scheduled for a particular time during the collection day (lunch breaks and routine maintenance stops, for example).

Utility Subroutines. The utility subroutines are called by the main program and by the activity subroutines to perform certain common operations. They consist of the following:

1. File subroutine, which places events in the event table in chronological order.

2. Random number subroutine, which generates a random number from a uniform distribution over the range (0,1).

3. Uniform random subroutine, which generates a value for a random variable that is defined by a uniform distribution over any finite range.

4. Normal random subroutine, which generates a value for a random variable that is defined by a normal distribution with any finite mean and variance.

5. Histogram subroutine, which generates a value for a random variable that is defined by a probability distribution expressed in the form of a histogram.

Input. The input portion of the program defines the collection system and conditions to be simulated. This definition includes (1) the specification of the system's collection units, collection routes, headquarters, and landfill sites; and (2) the description of the operating characteristics of the collection units and the environment.

Output. The output portion of the program summarizes the performance of the collection system that provides a basis for evaluating the system.

Main Program. The main program controls the overall simulation by coordinating the functions of the other components of the program. Once the description of the particular system to be simulated is input, this coordination is accomplished by integrating the operational sequences of the collection units. To do this, the main program maintains the event table and the clock. When it is time for an event to occur, the main program removes it from the event table and calls the appropriate activity subroutine to determine the duration and performance of the activity. It then updates the performance statistics of the collection unit involved and has the unit's next event filed in the event table. Then the clock is moved up to the time of occurrence of the next most imminent event in the event table, and the process is repeated. When all of the events have occurred, the main program provides for a summary of the system's performance during the simulated collection day to be output.

TABLE 6
SAMPLE SIMULATION MODEL OUTPUT

```
1336  MT. NO. 9 TRAVELS TO THE LANDFILL SITE FROM NODE NO. 4401.
      TRAVEL TIME = 13 MINUTES.
      DISTANCE = 15825 FEET.

1341  MT. NO. 10 TRAVELS FROM NODE NO. 15327 TO TRAIN NO. 6 AT
      NODE NO. 15859.
      TRAVEL TIME = 3 MINUTES.
      DISTANCE = 5812 FEET.

1341  TRAIN NO. 5 STARTS TO COLLECT AT NODE NO. 15327.
      WEIGHT COLLECTED = 2806 POUNDS.
      COLLECTION TIME = 46 MINUTES.
      COLLECTION DISTANCE = 8150 FEET.
      NON-COLLECTION TIME = 41 MINUTES.
      NON-COLLECTION DISTANCE = 14125 FEET.
      NUMBER OF DWELLING UNITS COLLECTED FROM = 87.

1344  MT. NO. 10 DUMPS TRAIN NO. 6 WHICH HAS BEEN WAITING AT
      NODE NO. 15859 FOR 11 MINUTES.
      DUMP TIME = 5 MINUTES.
      WEIGHT DUMPED = 2719 POUNDS

1347  TRAIN NO. 8 CALLS MT. NO. 10 AND STARTS TO WAIT AT NODE
      NO. 13111.

1347  TRAIN NO. 2 CALLS MT. NO. 9 AND STARTS TO WAIT AT NODE
      NO. 11598.

1348  TRAIN NO. 7 CALLS MT. NO. 10 AND STARTS TO WAIT AT NODE
      NO. 13304.

1349  MT. NO. 10 TRAVELS FROM NODE NO. 15859 TO TRAIN NO. 8 AT
      NODE NO. 13111.
      TRAVEL TIME = 3 MINUTES.
      DISTANCE = 8862 FEET.

1349  TRAIN NO. 6 STARTS TO COLLECT AT NODE NO. 15859.
      WEIGHT COLLECTED = 3049 POUNDS.
      COLLECTION TIME = 49 MINUTES.
      COLLECTION DISTANCE = 4100 FEET.
      NON-COLLECTION TIME = 7 MINUTES.
      NON-COLLECTION DISTANCE = 2750 FEET.
      NUMBER OF DWELLING UNITS COLLECTED FROM = 113.

1349  MT. NO. 9 ARRIVES AT THE LANDFILL SITE AND DOES NOT HAVE
      TO WAIT TO DUMP.

1349  MT. NO. 9 DUMPS AT THE LANDFILL SITE.
      DUMP TIME = 7 MINUTES.
      WEIGHT DUMPED = 11126 POUNDS.
```

TABLE 7
SAMPLE OUTPUT, SIMULATION MODEL:
SUMMARY REPORT OF TRAIN NO. 1

```
    PARAMETER DATA
    **************


    NUMBER OF DAYS SINCE
      LAST COLLECTION = 4
    MONTH = 3


    TRAIN NO. 1 (CAPACITY = 2500 LBS. ROUTE NO. 236M. CONVOY NO. 1)
    ***************************************************************


AVERAGE TOTAL LENGTH OF COLLECTION DAY . . . . . . .    563 MINUTES
  AVERAGE TRAVEL TIME  . . . . . . . . . . . . . . .     43 MINUTES
  AVERAGE COLLECTION TIME  . . . . . . . . . . . . .    248 MINUTES
  AVERAGE NON-COLLECTION TIME  . . . . . . . . . . .     72 MINUTES
  AVERAGE DUMP TIME  . . . . . . . . . . . . . . . .     36 MINUTES
  AVERAGE WAITING TIME . . . . . . . . . . . . . . .    164 MINUTES
  AVERAGE PRESCHEDULED ACTIVITY TIME . . . . . . . .      0 MINUTES
  AVERAGE DOWN TIME  . . . . . . . . . . . . . . . .      0 MINUTES


AVERAGE TOTAL DISTANCE TRAVELED  . . . . . . . . . . 155227 FEET
  AVERAGE TRAVEL DISTANCE  . . . . . . . . . . . . .  75253 FEET
  AVERAGE COLLECTION DISTANCE  . . . . . . . . . . .  34975 FEET
  AVERAGE NON-COLLECTION DISTANCE  . . . . . . . . .  44999 FEET


AVERAGE TOTAL WEIGHT OF SOLID WASTE COLLECTED  . . .  16533 POUNDS

AVERAGE TOTAL NUMBER OF RESIDENTIAL UNITS SERVED . .    538

AVERAGE FLOOR AREA OF RESIDENTIAL UNITS SERVED . . .   1426 SQUARE FEET

AVERAGE TOTAL COST . . . . . . . . . . . . . . . . . $98.41

AVERAGE TOTAL COST PER 100 LBS . . . . . . . . . . . $ 0.60
```

TABLE 8
SAMPLE OUTPUT, SIMULATION MODEL:
SUMMARY REPORT OF MOTHER TRUCK NO. 9

MOTHER TRUCK NO. 9 (CAPACITY = 7000 LBS. CONVOY NO. 1)
****

AVERAGE TOTAL LENGTH OF COLLECTION DAY	674 MINUTES
AVERAGE TRAVEL TIME	312 MINUTES
AVERAGE COLLECTION TIME	238 MINUTES
AVERAGE DUMP TIME	105 MINUTES
AVERAGE TIME WAITING TO DUMP TRAINS	0 MINUTES
AVERAGE TIME WAITING AT DUMP SITE	19 MINUTES
AVERAGE PRESCHEDULED ACTIVITY TIME	0 MINUTES
AVERAGE DOWN TIME	0 MINUTES
AVERAGE TOTAL DISTANCE TRAVELED	447822 FEET
AVERAGE TOTAL NUMBER OF TRIPS TO DUMP SITE	11
AVERAGE TOTAL WEIGHT OF SOLID WASTE COLLECTED	89975 POUNDS
AVERAGE WEIGHT COLLECTED FROM TRAINS	73477 POUNDS
AVERAGE WEIGHT COLLECTED FROM FIXED CONTAINERS . .	16498 POUNDS
AVERAGE TOTAL NUMBER OF TRAINS DUMPED	28
AVERAGE TOTAL NUMBER OF FIXED CONTAINERS DUMPED . . .	21
AVERAGE TOTAL COST	$56.30

TABLE 9
SAMPLE OUTPUT, SIMULATION MODEL:
SUMMARY REPORT OF CONVOY NO. 1

AVERAGE TOTAL TIME	2989	MINUTES
AVERAGE TOTAL TRAVEL TIME	491	MINUTES
AVERAGE TOTAL COLLECTION TIME	1311	MINUTES
AVERAGE TOTAL NON-COLLECTION TIME	222	MINUTES
AVERAGE TOTAL DUMP TIME	264	MINUTES
AVERAGE TOTAL TRAIN WAITING TIME	682	MINUTES
AVERAGE TOTAL TIME MT WAITS TO DUMP TRAINS . . .	0	MINUTES
AVERAGE TOTAL TIME MT WAITS AT DUMP SITE	19	MINUTES
AVERAGE TOTAL PRESCHEDULED ACTIVITY TIME	0	MINUTES
AVERAGE TOTAL DOWN TIME	0	MINUTES
AVERAGE TOTAL DISTANCE TRAVELED	1028831	FEET
AVERAGE TOTAL TRAVEL DISTANCE	756863	FEET
AVERAGE TOTAL COLLECTION DISTANCE	137725	FEET
AVERAGE TOTAL NON-COLLECTION DISTANCE	134243	FEET
AVERAGE TOTAL NUMBER OF TRIPS TO DUMP SITE	11	
AVERAGE TOTAL WEIGHT OF SOLID WASTE COLLECTED . . .	89975	POUNDS
AVERAGE TOTAL WEIGHT COLLECTED BY TRAINS	73477	POUNDS
AVERAGE TOTAL WEIGHT COLLECTED BY MOTHER TRUCK .	16498	POUNDS
AVERAGE TOTAL NUMBER OF TRAINS DUMPED	28	
AVERAGE TOTAL NUMBER OF FIXED CONTAINERS DUMPED . .	21	
AVERAGE TOTAL NUMBER OF RESIDENTIAL UNITS SERVED .	2387	
AVERAGE FLOOR AREA OF RESIDENTIAL UNITS SERVED . .	1287	SQUARE FEET
AVERAGE TOTAL COST	$459.39	
AVERAGE TOTAL TRAIN COST	$403.09	
AVERAGE TOTAL MOTHER TRUCK COST	$ 56.30	
AVERAGE TOTAL COST PER 100 LBS.	$ 0.51	

TABLE 10
SAMPLE OUTPUT, SIMULATION MODEL:
SUMMARY REPORT OF COLLECTION SYSTEM

AVERAGE TOTAL TIME	5969	MINUTES
AVERAGE TOTAL TRAVEL TIME	966	MINUTES
AVERAGE TOTAL COLLECTION TIME	2639	MINUTES
AVERAGE TOTAL NON-COLLECTION TIME	447	MINUTES
AVERAGE TOTAL DUMP TIME	531	MINUTES
AVERAGE TOTAL TRAIN WAITING TIME	1355	MINUTES
AVERAGE TOTAL TIME MT WAITS TO DUMP TRAINS . . .	0	MINUTES
AVERAGE TOTAL TIME MT WAITS AT DUMP SITE	31	MINUTES
AVERAGE TOTAL PRESCHEDULED ACTIVITY TIME	0	MINUTES
AVERAGE TOTAL DOWN TIME	0	MINUTES
AVERAGE TOTAL DISTANCE TRAVELED	2057108	FEET
AVERAGE TOTAL TRAVEL DISTANCE	1513172	FEET
AVERAGE TOTAL COLLECTION DISTANCE	275450	FEET
AVERAGE TOTAL NON-COLLECTION DISTANCE	268486	FEET
AVERAGE TOTAL NUMBER OF TRIPS TO DUMP SITE	22	
AVERAGE TOTAL WEIGHT OF SOLID WASTE COLLECTED . . .	181965	POUNDS
AVERAGE TOTAL WEIGHT COLLECTED BY TRAINS	147992	POUNDS
AVERAGE TOTAL WEIGHT COLLECTED BY MOTHER TRUCK .	33973	POUNDS
AVERAGE TOTAL NUMBER OF TRAINS DUMPED	56	
AVERAGE TOTAL NUMBER OF FIXED CONTAINERS DUMPED . .	42	
AVERAGE TOTAL NUMBER OF RESIDENTIAL UNITS SERVED .	4774	
AVERAGE FLOOR AREA OF RESIDENTIAL UNITS SERVED . .	1287	SQUARE FEET
AVERAGE TOTAL COST	$920.32	
AVERAGE TOTAL TRAIN COST	$807.51	
AVERAGE TOTAL MOTHER TRUCK COST	$112.81	
AVERAGE TOTAL COST PER 100 LBS.	$ 0.51	

The simulation model is now fully operational. With minor modifications, it can be used to simulate any type of collection operation. Some examples of the output from simulating the collection operation of two train convoys (eight trains and two mother trucks) on a given day are illustrated in Tables 6 through 10.

This project has been supported by demonstration grant No. G06-EC-00135 from the Environmental Protection Agency, pursuant to the Solid Waste Disposal Act as amended.

A REVIEW OF THE PROBLEMS AFFECTING THE RECYCLING OF SELECTED SECONDARY MATERIALS*

THE RECYCLING INDUSTRY has been in existence in one form or another for centuries. Wherever it has been economically practical to recover waste materials and return them to the manufacturing stream, the industry has performed this necessary and useful function well. Only those scrap materials that are widely dispersed or contaminated, making collection and segregation unfeasible, have been lost or incompletely utilized. In the present period of National concern and involvement with the environment, however, the need for more complete recycling of our natural resources has been recognized by the public in general.

The following is a short review of recycling practices in the six nonferrous metal categories covered in the Battelle study plus textiles and paper. Discussions of some of the problems involved and a few suggestions for increasing recycling are also included.

A simplified diagram describing the flow of primary and recycled metals is shown in Figure 1. The metal ore moves from mine to primary smelter. The resulting intermediate metal or chemical goes to a product manufacturer and ultimately to the end user. The scrap generated in the course of manufacturing a product is called prompt industrial scrap; obsolete scrap is that which is recovered from a product that has completed its useful life. Both flow through the scrap processor to a secondary smelter and back to a manufacturer. Some scrap, largely prompt industrial, is returned directly to the primary producer. The flow of textiles and paper is quite similar.

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*Prepared and presented by the National Association of Secondary Materials Industries, Inc., and *Battelle Memorial Institute.*

ALUMINUM

Recycled aluminum accounted for almost 20 percent of the total commercial aluminum supply in 1969. Table 1 shows the relative amounts of prompt and obsolete scrap recycled that year. The scrap available for recycling is given in terms of recoverable aluminum content. All of the data presented were taken from Battelle's preliminary report to National Association of Secondary Materials Industries and are based on Bureau of Mines data or Battelle estimates.

TABLE 1

ALUMINUM RECYCLED IN 1969*

[In thousands of tons]

Type of scrap	Aluminum available for recycling	Aluminum not recycled	Aluminum recycled
Imports	26	---	26
Prompt industrial scrap	855	---	855
Obsolete scrap	1,334	1,160	174
Total	2,215	1,160	1,055

*Based on data contained in Battelle's preliminary report to NASMI.

Nearly all prompt industrial scrap is recycled. Because it is usually generated in large quantities, is uniform in composition, and is located at known industrial sites, prompt scrap is a very desirable raw material. Low-aluminum-content scrap, such as drosses, probably does escape recycling, but the amount is thought to be relatively small

Very little obsolete aluminum scrap is recycled. Estimates show that only 15 to 20 percent of the aluminum available from obsolete scrap was recycled in 1969, a total of about 175,000 tons. What happened to the million tons of obsolete scrap that was not recycled? Aluminum thrown out in household garbage still exists in various landfills. Other obsolete scrap is collected in aircraft graveyards and collection yards as parts of autos, trucks, various appliances, etc.

If the quantity of recycled aluminum is to be increased, attention must be directed to making the recovery of obsolete scrap economically feasible, and to expanding and developing markets.

There are three major problems faced by the secondary aluminum industry: packaging containerization, air pollution, and

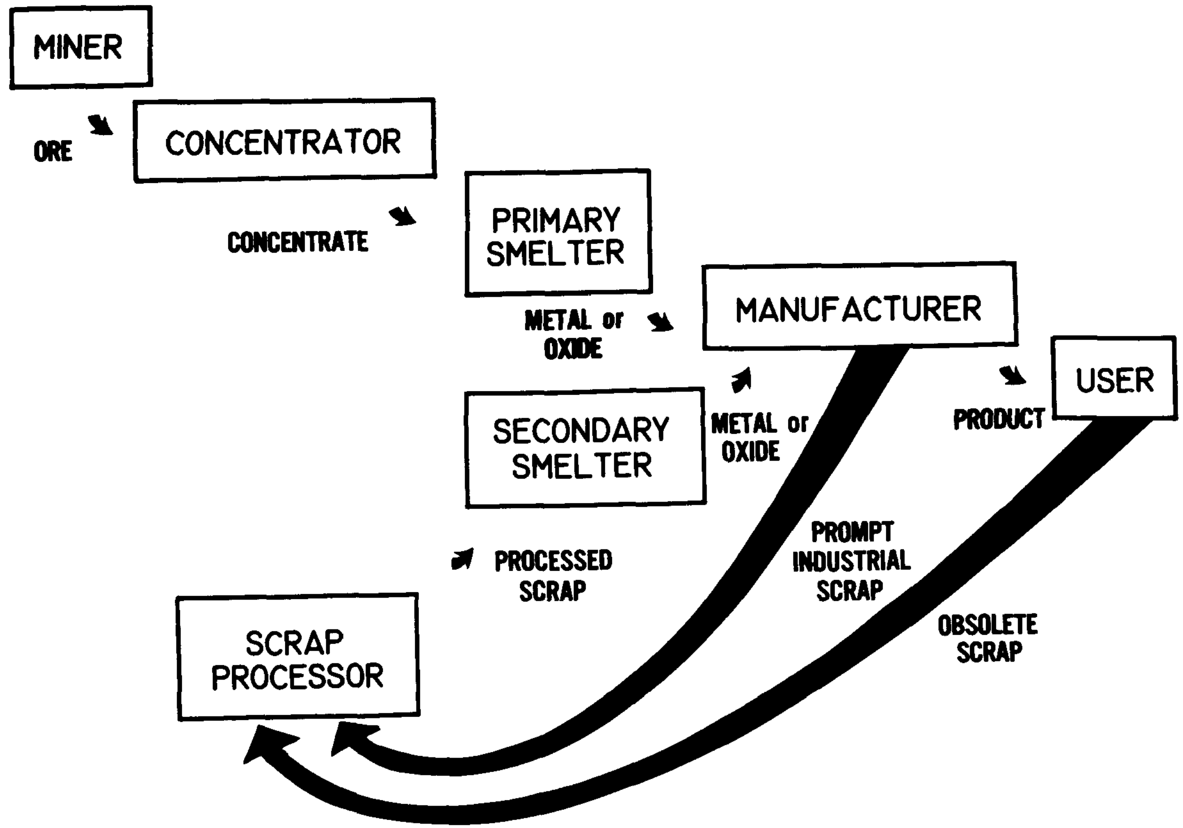

Figure 1. Flow of primary and recycled metals.

a need for new markets. The first problem directly affects the amount of aluminum recycled and can be measured quantitatively. About 500,000 short tons (s.t.) of aluminum were used in beverage and other packaging materials in 1969. Yet almost none but the small amounts gathered by promotional and voluntary campaigns were put back into aluminum production. Aluminum cans typically are thrown away by the consumer, mixed with waste from industry and other institutions, and forever lost under landfill. Also, as we all know too well, aluminum cans are littered along public highways.

It is difficult to quantify the effect that air pollution and the need for new markets has on the economic viability of the scrap processing industry. Pollution problems resulting from smelting scrap aluminum and converting it to secondary aluminum ingot casting alloys has caused smelters to purchase expensive, maintenance-prone equipment. Lack of stable, uniform regulations may mean that smelters will purchase equipment that will not qualify under future pollution regulations.

If the growing supply of scrap is to be utilized, new markets for obsolete aluminum must be developed, or present markets expanded. To date, however, obsolete aluminum scrap is used for only one major product--casting alloys--and there is no evidence that new markets are on the horizon.

COPPER

Since the United States must import copper from other countries that are often politically unstable, an efficient system to recycle copper is of great importance from an economic and a strategic viewpoint. Currently, recycled copper in various forms represents about 46 percent of the total consumption of copper.

In 1969, almost 2.5 million tons of copper was available in scrap (Table 2); but only about 1.5 million tons, or 68 percent of the available copper supply, was recycled. Over 960,000 tons was not recycled.

Three basic problems affect the recycling of copper--obsolete cartridge brass products, copper magnet wire, and wire insulation removal. The first two problems directly affect the amount of copper recycled. The third, wire insulation removal, creates an economic problem because of the high cost of such processing and the expensive pollution control equipment required.

Cartridge brass is used for small arms and artillery shells in military applications. Almost 100 percent of all cartridge brass used at domestic training bases can be recycled, but artillery and small arms shells used in combat are scattered over many square miles of land. This scrap is easily recognized as being valuable, yet about 77,000 tons of copper contained in cartridge brass, or about 31 percent of the total used cartridges, are not being recycled.

Magnet wire is used as windings in motors and generators. Motors use copper in varying amounts, according to the size of the motor. Copper windings are surrounded by the motor casing and wound inside an iron core. Separation of copper from the armature, except for very large motors, is difficult and expensive. About 145,000 s.t. of copper used in motor windings are not being recycled presently.

Most wire and cable is usually insulated or covered with such materials as lead or polyvinyl chloride. To be recyclable, the insulation must be removed and, because of stringent air pollution regulations, processors must use either incineration equipment with suitable pollution controls or mechanical methods such as cable stripping or fragmentizing.

TABLE 2

COPPER RECYCLING IN 1969*

[In thousands of tons of copper content]

Type of scrap	Copper available for recycling	Copper not recycled	Copper recycled
Copper wire and tube	850.9	151.8	699.1
Magnet wire	158.0	144.5	13.5
Cartridge brass	204.9	77.5	127.4
Other brass	1,088.1	495.7	592.4
Additives and others	153.0	96.9	56.1
Total	2,454.9	966.4	1,488.5

*Based on data contained in Battelle's preliminary report to NASMI.

NICKEL

Nickel resources in the United States are even smaller than copper resources, yet the United States is a major consumer of nickel. Currently, recycled nickel represents about 30 percent of the total consumption of nickel in nickel alloys other than stainless steel.

In 1969, about 60 percent of the nickel available in scrap was not recycled. Nickel in electroplating materials represented about one-third of the unrecycled scrap. Nickel is used as an undercoat for chromium in various plated products. Thickness of the metal varies from 0.004 in. for various small appliances to 0.0016 in. for automobile bumpers. The percentage of nickel in each of these products is small, but the number of products for which it is used is very large. Virtually none of the nickel used in plated products is recycled.

ZINC

Of all the metals studied, recycled zinc provided the smallest portion of the Nation's total need for that metal. In 1969 only 12 percent of zinc consumed was supplied by recycled zinc.

Only about 14 percent, or 182,000 tons, of the available zinc scrap was recycled in 1969 (Table 3). Most of this was, however, prompt industrial scrap. Only 4 percent of the obsolete scrap was recycled, less than 10 percent of the old die castings were recycled, and none of the zinc in galvanized steel was recovered as such.

TABLE 3

ZINC RECYCLING IN 1969*

[In thousands of tons]

Type of scrap	Zinc available for recycling	Zinc not recycled	Zinc recycled
Prompt industrial scrap	208	67	141
Obsolete die castings	353	320	33
Obsolete galvanized scrap	390	390	---
All other obsolete scrap	320	312	8
Total	1,271	1,089	182

*Based on data contained in Battelle's preliminary report to NASMI.

Four basic problems are involved in the recycling of zinc. The first three problems are quantitative in nature and illustrate three different situations.

The first problem occurs with prompt industrial zinc scrap, which had a recycling rate of only 68 percent in 1969. Of the 67,000 tons that were not recycled, nearly all were in the form of galvanized clippings. The clippings are recycled as steel, and the zinc is usually lost in the flue gases. A process for degalvanizing the clippings has been developed, but is not yet commercial. This may allow recycling of the zinc in the future.

The second major problem is obsolete galvanized zinc which is not now recycled but perhaps will be in the future. Much of it corrodes and is washed away over the years as it protects the base metal. This will never be recycled. In the future, however, the zinc remaining on the galvanized scrap when the steel is recycled may be collected as flue dust and recycled.

Old zinc die castings are the third problem, but they offer the best possibilities for increased recycling of zinc. Steel shredders hold promise for separating much of the die casting scrap from the steel of junked autos and appliances.

Air pollution control, the fourth major problem in zinc recycling, has little or no direct effect on the recycling rate. It does, however, affect the economics of recycling. Not only may some smelters find it difficult to finance the purchase of pollution control equipment, but operating costs can be unusually high because of the high chlorine content of the flue dust and the dust's buoyancy.

LEAD

Lead, another metal studied, has a high rate of recycling - almost 42 percent of the available scrap was recycled in 1969. Lead in metallic form is virtually indestructible and generally finds its way back into the industrial stream. On the other hand, tetraethyl lead and other lead chemicals are almost never recovered. If pollution control devices can be developed that will permit use of leaded gasoline in automobile engines, the lead might be collected and recycled.

PRECIOUS METALS

Recycled precious metals are an important part of the total supply. In 1969, the percent of total supplies recycled were as follows:

Silver	40 percent
Gold	30 percent
Platinum	15 percent

About 74 percent of prompt gold scrap from jewelry and art manufacture, and from dental and other industrial operations is recovered and recycled (Table 4). Obsolete scrap, however, has a recycle rate of only 40 percent. Surprisingly, this rate is not much different than base metals like copper and lead. The recycle rate for silver and platinum is also comparable. A large portion of the prompt industrial gold scrap that is not recycled is in the form of brazing alloys and coatings where only a small amount is present in a large, complex piece of equipment.

Typical of the problems encountered in recycling precious metals is the loss of silver by photo processors. No economical method exists for recovering this type of silver scrap. For gold scrap, better standards and identification methods are needed along with some means of economical recovery. The major problem in recycling platinum is losses of jewelry and other personal items that are not readily identifiable.

TABLE 4

GOLD RECYCLING IN 1969*

[In thousands of troy ounces]

Type of scrap	Gold available for recycling	Gold not recycled	Gold recycled
Jewelry and art industrial scrap	1,020	80	940
Dental and other industrial scrap	650	90	560
Obsolete scrap	800	480	320
Total	2,470	650	1,820

*Based on data from Battelle's preliminary report to NASMI.

PAPER AND TEXTILES

The problems constraining the recycling of paper and textiles loom large in the overall solid waste picture.

Considering paper first, it should be noted that in 1969, Americans consumed more than 58 million tons of paper and paperboard. Approximately 11 million tons of paper and paperboard were recycled during 1969 in the form of paperstock. Thus the recycle rate was about 18 percent in 1969, though this rate has been as high as 24 percent during the past decade.

By definition, paperstock is wastepaper that has been collected from many different types of generators in the residential, commercial, or industrial sectors, then sorted or processed and put into marketable form.

Figure 2 identifies major known end uses for paperstock in

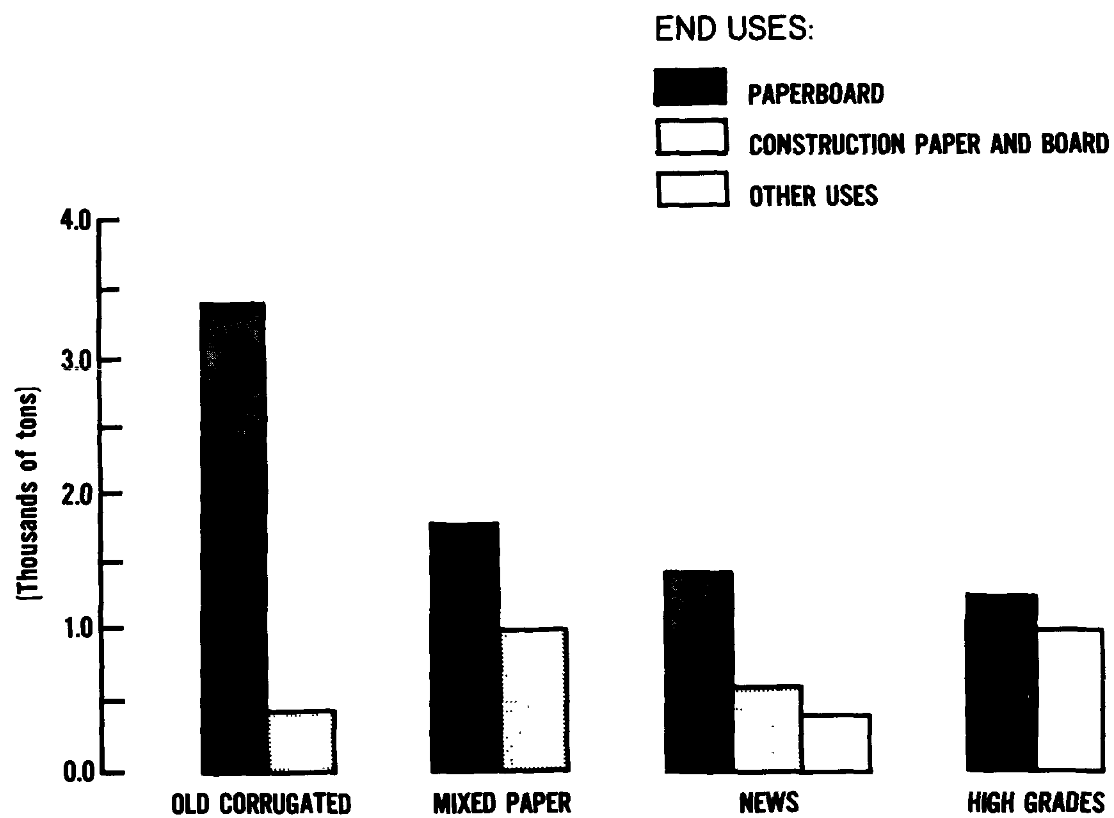

Figure 2. Tons of paperstock consumed in the U. S. in 1969, by end use and type. (Based on data contained in Battelle's preliminary report to NASMI.)

1969. Significantly, more than 70 percent of all paperstock consumed in 1969 was consumed by paperboard mills - principally by those producing combination ply boxboard used in the production of folding cartons. This end-use has also been the major consumer of those two general categories of paperstock--mixed papers and old corrugated--which represent the greatest challenge to maximizing solid waste utilization.

Probably the most exciting new development over the past decade has been the successful operation of newsprint de-inking mills. These mills are currently consuming old newsprint at a rate of more than 400,000 tons a year.

The Battelle study identified a great many problems that limited recycling. None, however, in Battelle's judgment, can match the significance of the relatively declining demand for paperstock's largest traditional application, combination paperboard (Figure 3). While total paperboard production increased about 108 percent between 1960 and 1969, production of combination grades increased only a scant 569,000 tons, or about 8 percent. Clearly, there has been a marked increase in user preference for paperboard and paperboard end products made substantially from virgin fibers.

Battelle is recommending various approaches to solving the problem of declining demand for products made from paperstock. Perhaps the most promising are the efforts already initiated by NASMI to encourage government and big industrial buyers to change their specifications and accept recycled paper and paperboard in some of the large volume end uses.

A somewhat similar situation exists with regard to the problem of recycling textiles. Although approximately 3.4 billion lb of waste textiles are recycled each year, another 3 billion lb is either being dumped or incinerated. Traditionally, the major markets for textile waste have included paper, vulcanized fiber, reprocessed wool, wiping cloths, padding, and batting. Some 600 million lb of waste textiles are currently being discarded per year after the wastes have been shipped to users by brokers, sorters, or processors. These discarded materials are principally the man-made fibers incorporated into the blends that are difficult if not impossible to recycle with existing technology.

Again, textile recycling, like paper recycling, has been constrained by a number of factors. Among these are the proliferation of fiber blends, which has added to the sorting and separation problem and resulted in increased operating costs. Figure 4 shows the trends in the consumption of natural versus man-made fibers in textiles. Man-made blends now account for more than

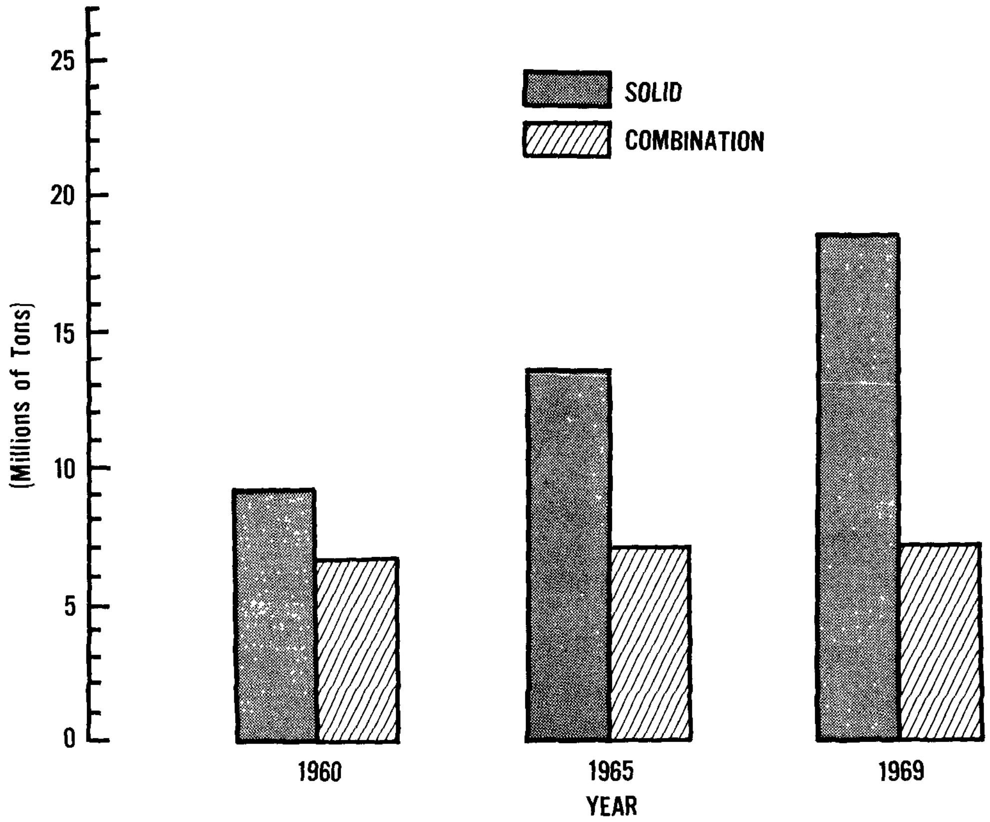

Figure 3. Trends in the production of combination and solid wood-pulp paperboard. (Based on data contained in Battelle's preliminary report to NASMI.)

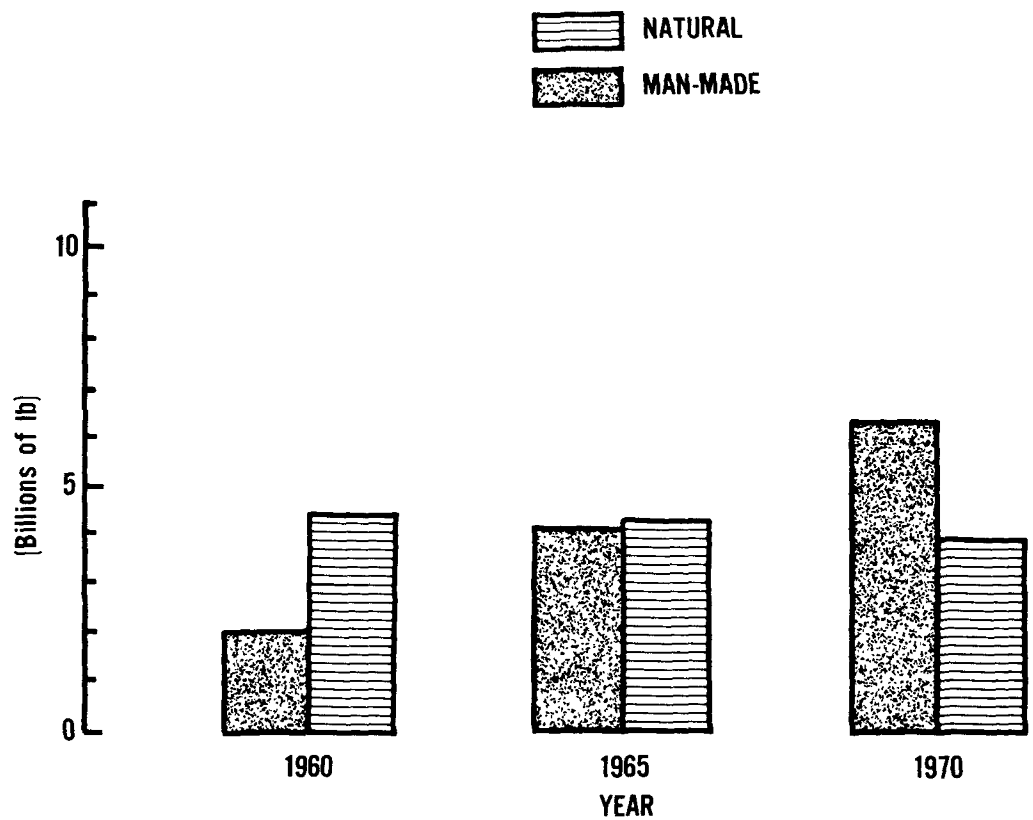

Figure 4. Trends in the consumption of natural and man-made textile fibers. (Based on data contained in Battelle's preliminary report to NASMI.)

60 percent of total consumption compared with 31 percent a decade ago.

The Wool Labeling Act has also been a major barrier to increased recycling of textile waste. Finally, loss of markets for cotton-mill waste to synthetic foam materials, and competition from nonwoven disposable wipers with rag wipers have adversely affected opportunities for increased recycling.

In summary, it is obvious that the problems and situations inhibiting the recycling of waste materials are many and varied. Some are simply collection problems in which transportation costs prevent or reduce the flow of scrap materials to a processor. Others are largely technical problems that require more sophisticated techniques for identifying and sorting scrap more efficiently and economically.

While the secondary materials industry recognizes that it must continue to take the lead in affecting increased recycling, the policies and actions of various government agencies can play a major role in achieving the desired goal. Two areas are particularly important. One involves so-called "blanket" purchasing specifications that cover broad commodity types. NASMI has made efforts to initiate a review of paper product specifications. Government and industry specifications for metallic raw materials effectively restrict the use of secondary metals without due regard for the performance characteristics of specific end products. Government should also study possible action to modify the constraining effects of various legislation on recycling particularly in the textile industry.

The second area requiring government action concerns pollution control codes and regulations that may not recognize the inherent peculiarities and problems of the secondary materials industry. A small processor, for example, may need assistance in acquiring the necessary pollution control equipment. Or, regardless of company size, unique technical problems in smelting operations might require lengthy research programs to develop effective, economical control devices.

Hopefully, through a joint industry-government-public effort the economics of recycling can be improved so that even the waste materials of marginal value may find their way to a useful new life.

This project has been supported by demonstration grant No. G06-EC-00282 from the Environmental Protection Agency, pursuant to the Solid Waste Disposal Act as amended.

AN APPROACH TO FERROUS SOLID WASTE

*William J. Regan III**

MANKIND TODAY faces the greatest environmental crisis in his history. Though technology has given us a quantity of life which has brought us to the highest standard of living yet known, the quality of life has been seriously threatened. Pollution, land misuse, and natural resource depletion have grave social and economic implications for all of us. And those engaged in solid waste management have a vital role in alleviating these problems.

Solid waste is daily increasing as a major national environmental concern because of its accelerating rate of generation and increased disposal problems. By the end of this day, another 10 million tons of solid waste--a social and economic problem that belongs to everyone--will be generated. Only a small amount of it will be collected and adequately disposed. In 1 year, the amount of all solid waste generated exceeds the total productive output of the American steel industry over the past 50 years. The discards of our society threaten to eventually bury those who created it.

Some solution must be found for the mountains of solid waste engulfing our Nation. Four basic alternatives exist for solid waste management:

1. To continue polluting. This solution is obviously unacceptable for both environmental and economic reasons.
2. To make greater use of biodegradable materials. Such a step has some merit but is limited in its use because of economic and technological factors.
3. To develop new uses for solid waste in its present form. This approach offers limited applications.
4. To recycle as great a portion of the solid waste as possible. This is the most promising alternative, both environmentally and economically.

Recycling, the conversion and reuse of discarded products in the production of new, offers the best potential alternative for improving both our environmental and economic climate. Five basic reasons exist for the economic recycling of solid waste:

*Battelle Memorial Institute.

(1) alleviation of mounting solid waste problems and costs; (2) conservation of natural resources; (3) use of an economic raw material source; (4) aesthetic and health considerations; and (5) avoidance of economic dislocations within supplying industries.

Rather than giving details of the various sources and components of the 4 plus billion tons of solid waste generated annually in this Nation, this presentation will be directed to one part of the whole--ferrous solid waste. Ferrous solid waste is defined as iron and steel products and materials that have served their intended purposes and are therefore available for other uses. The proportion that is processed and recycled is defined as ferrous scrap, a useful material of value; that which is discarded becomes ferrous solid waste, to date a useless material of no value.

ESTABLISHING A STUDY OF FERROUS SOLID WASTE

Recognizing the vital importance of recycling to our national welfare, the Federal Office of Solid Waste Management Programs and the Scrap Metal Research and Educational Foundation of the Institute of Scrap Iron and Steel, Inc., contracted with Battelle Memorial Institute in 1970 to conduct a major study that would define the problems and seek their solutions for increasing the movement and use of ferrous solid wastes by recycling. In this way, planning for the health of the Nation and for the ferrous scrap industry could be based on sound principles that would recognize the various interests involved. Solutions to the problems are difficult, but the first step must be a comprehensive definition of these problems.

The Institute of Scrap Iron and Steel

The Institute of Scrap Iron and Steel was established in 1928 and is the largest association in the world in the recycling field. Its membership is made up of approximately 1,300 processors and brokers of iron and steel scrap and allied members. Member firms handle more than 90 percent of all purchased scrap consumed in the United States and exported--a $3 billion annual industry. The ferrous scrap industry provides three major services to our Nation: (1) reclamation, or recycling of the discarded ferrous products of our society through processing them into raw materials valuable for new products; (2) conservation of natural resources through the utilization of these reclaimed materials; and (3) beautification of the landscape through the removal and elimination of these discarded materials.

Recognizing the need for increased research in the reclamation of ferrous metallics, the Institute formed the Scrap Metal Research and Education Foundation in 1967. The Foundation's main objective is to place more emphasis on the research function within the industry.

For a great number of years the Institute, through its Special and Standing Committees, research contracts, government agencies (including the Bureau of Mines of the Department of the Interior and the Bureau of Domestic Commerce of the Department of Commerce), consumers and suppliers, the American Iron and Steel Institute, and foundry associations has evaluated, discussed, and worked on numerous technological, operating, and marketing problems of the scrap industry.

Study Objectives

Our study has four basic objectives: (1) to provide a data base on the present iron and steel scrap processing and brokerage industry; (2) to examine those factors that inhibit the scrap industry from performing a more comprehensive role; (3) to identify opportunities for increased recovery and recycling of ferrous solid waste; and (4) to point up opportunities for the ferrous scrap industry to contribute even more effectively to the solutions of the Nation's metallic solid waste problems. The study's scope covers the iron and steel scrap processing and brokerage industry, processing methods, the use of ferrous scrap in all types of iron and steel plants and for other smaller uses, and the important technical and economic factors that have a bearing on the future use of ferrous scrap and the disposal of solid waste from the ferrous scrap industry.

INDUSTRIAL USE OF FERROUS SCRAP

Much ferrous material would become ferrous solid waste were it not for the iron and steel scrap industry (Figure 1). Scrap represents approximately 50 percent of the ferrous metallic input to steelmaking furnaces. The remainder is pig iron, a product of blast furnaces. All along the production line, scrap is generated and recycled back to metallic input. The problem arises when the end product has fulfilled its usefulness. It is then

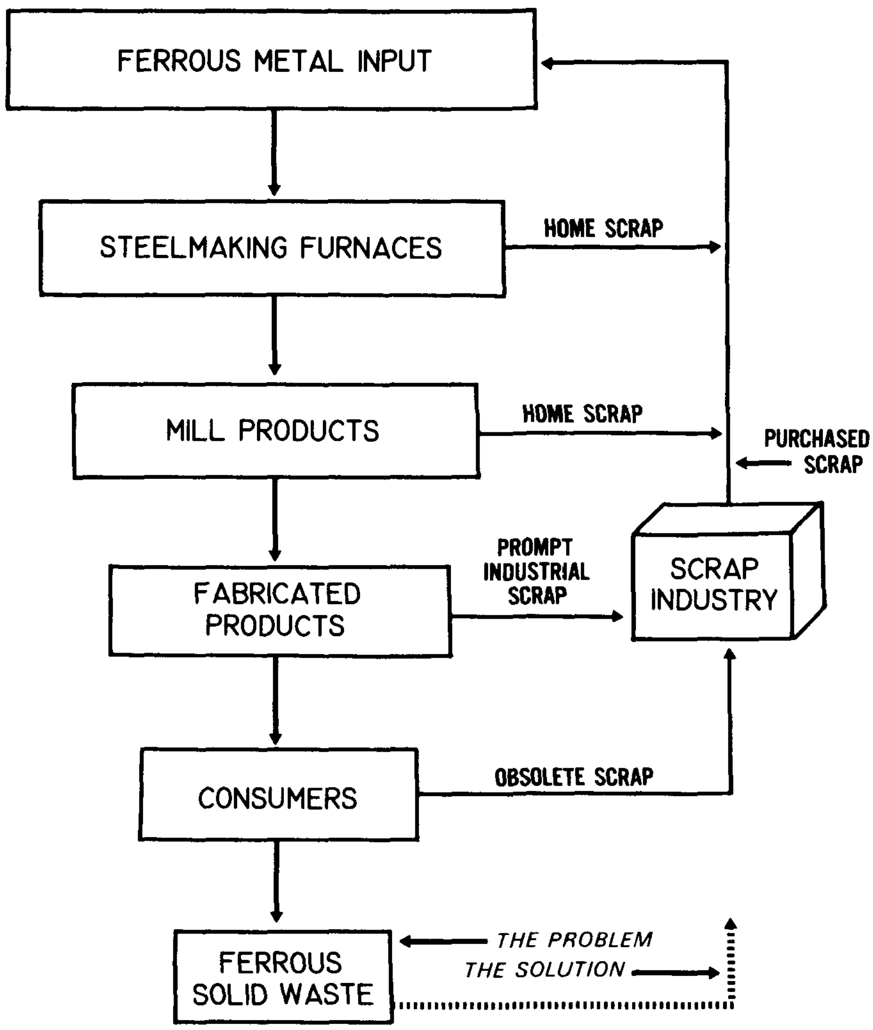

Figure 1. Flow of ferrous materials in the steel industry, the major market for scrap. (With modification, the chart is also applicable to the iron and steel castings industry, the other major scrap market.)

that the alternatives present themselves: recycling as obsolete scrap, or disposal as ferrous solid waste. The first alternative provides a solution to the conservation of natural resources and alleviates disposal problems and costs. The second alternative becomes a problem for solid waste management.

Though it is difficult to quantify, there is little question that the reservoir of iron and steel no longer serving its original function and available for conversion into scrap far exceeds the current demand for such products. Abandoned autos, discarded consumer white goods, urban demolition projects, and cans in municipal solid waste are all too apparent. Ferrous solid waste remains a major untapped source of valuable materials. As we underutilize this significant resource, we consume our irreplaceable natural resources. Each ton of pig iron used in iron and steelmaking, which could be replaced with a scrap input, uses 1.6 tons of iron ore and agglomerates, 0.9 tons of coal, and 0.2 tons of limestone and dolomite. Ferrous solid waste, ready for manufacture into scrap, has already used these materials and requires no further drain on natural resources.

FACTORS AFFECTING DEMAND FOR FERROUS SOLID WASTE

Use of any resource is based on economic supply and demand principles. Since there is an adequate supply of available ferrous solid waste that could be converted into ferrous scrap, attention must be concentrated on the demand for it. The portion of potential ferrous solid waste that can be economically recycled will be recycled.

Basically, the higher the demand is, the greater will be the economic transfer of ferrous solid waste to scrap products for recycling. It is a theme of the scrap industry that scrap is bought by consumers rather than sold by dealers or brokers; that is, demand cannot usually be created, but must await a need of the marketplace.

There are many factors that influence demand for scrap. They include (1) growth and production levels of consuming markets; (2) iron and steelmaking technology; (3) quality of both the scrap products and the steel products; (4) price of scrap compared to alternate sources of metal; and (5) availability of alternate metal sources, both internal (such as blast-furnace hot metal and home scrap) and external (such as direct-reduced ores). The first two of these factors are examined briefly.

Growth of Consuming Industries

The major markets for iron and steel scrap are the domestic steel industry (75 percent), the iron and steel castings industries (15 percent), and foreign customers in those industries (less than 10 percent) (Figure 2). In 1970, 85.2 million tons of iron and steel scrap were consumed domestically, and an additional 10.6 million tons were exported. Scrap imports are minor, averaging around 0.3 million tons annually.

Typically, "home scrap" generated during the production of iron and steel accounts for 60 percent of domestically consumed scrap, and "purchased scrap" makes up the remaining 40 percent. Of the purchased scrap, about one-third is prompt industrial scrap, and the remainder is obsolete scrap, our major area of concern (Figure 3).

Domestic markets for scrap have not kept pace with the growth of the American economy that has spawned ferrous solid waste, nor are they expected to in the future. As measured by gross national product and industrial production, our economy increased by 65 percent over the past decade, but iron and steel production grew only 35 percent. Over the next 15 years, GNP is expected to increase at an annual rate just short of 4 percent, but the growth of iron and steel is anticipated to be less than 3 percent. The three basic reasons for this lag in growth are well known-- a significant import balance in steel mill products, the replacement of iron and steel by competitive materials, and the increased use of lighter ferrous products with improved properties. These trends are not expected to change materially in the future.

Of even greater significance is the fact that although the ratio of total scrap iron to pig iron used in steelmaking has remained fairly constant at 50:50 (Figure 3), the purchased scrap proportion of total scrap has not kept pace (Figure 4). Much of this trend can be attributed to the decreasing product yield from ingot, a situation that increases home scrap availability and reduces the demand for purchased scrap.

Iron and Steelmaking Technology

Ferrous scrap is used by these industries as one of two major iron inputs to iron and steelmaking. The other input is pig iron, or as it is called in its liquid state, hot metal. The proportion of one input to the other is basically dependent on the type of steelmaking furnace and practice being used, although scrap price and hot metal availability are other key considerations.

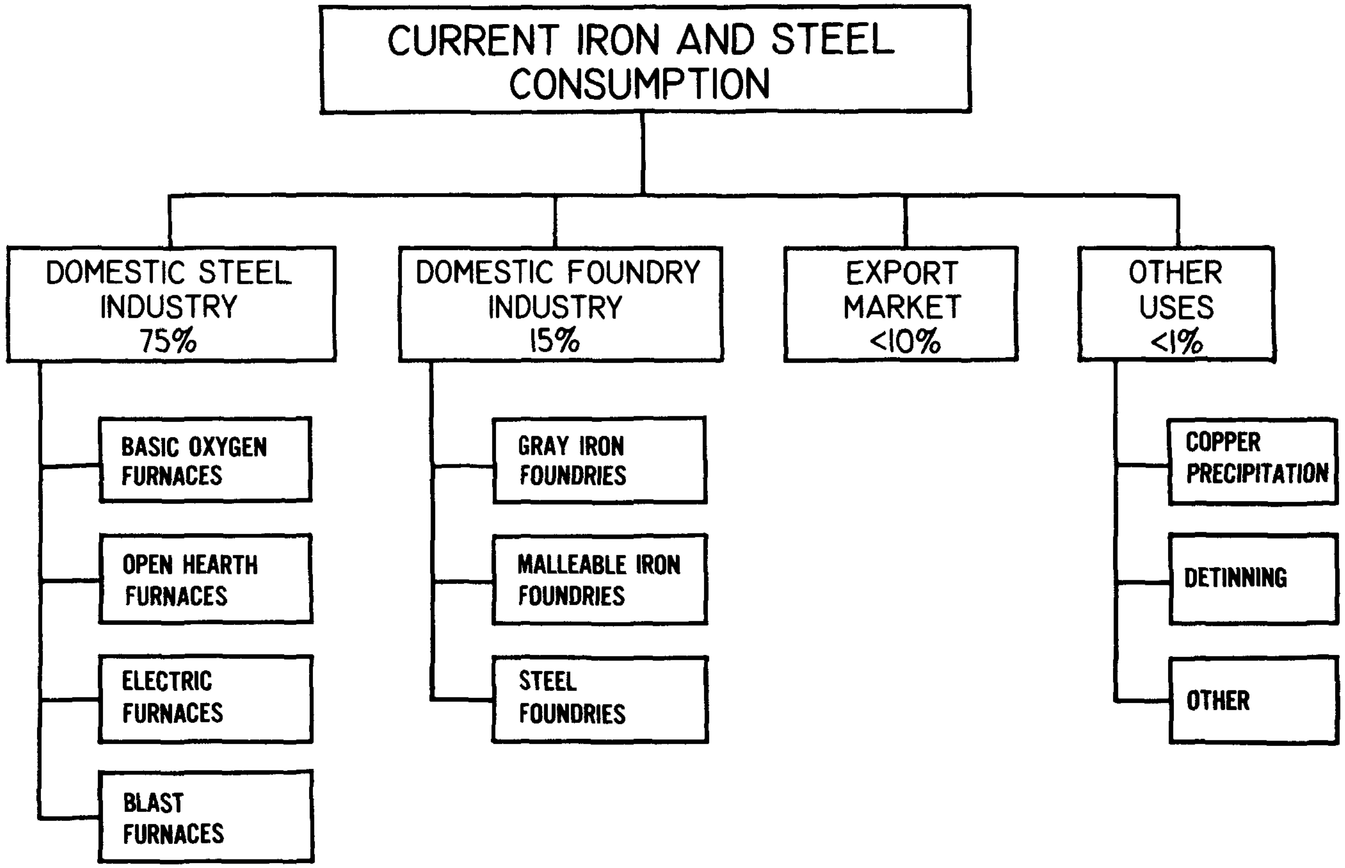

Figure 2. Markets for iron and steel scrap.

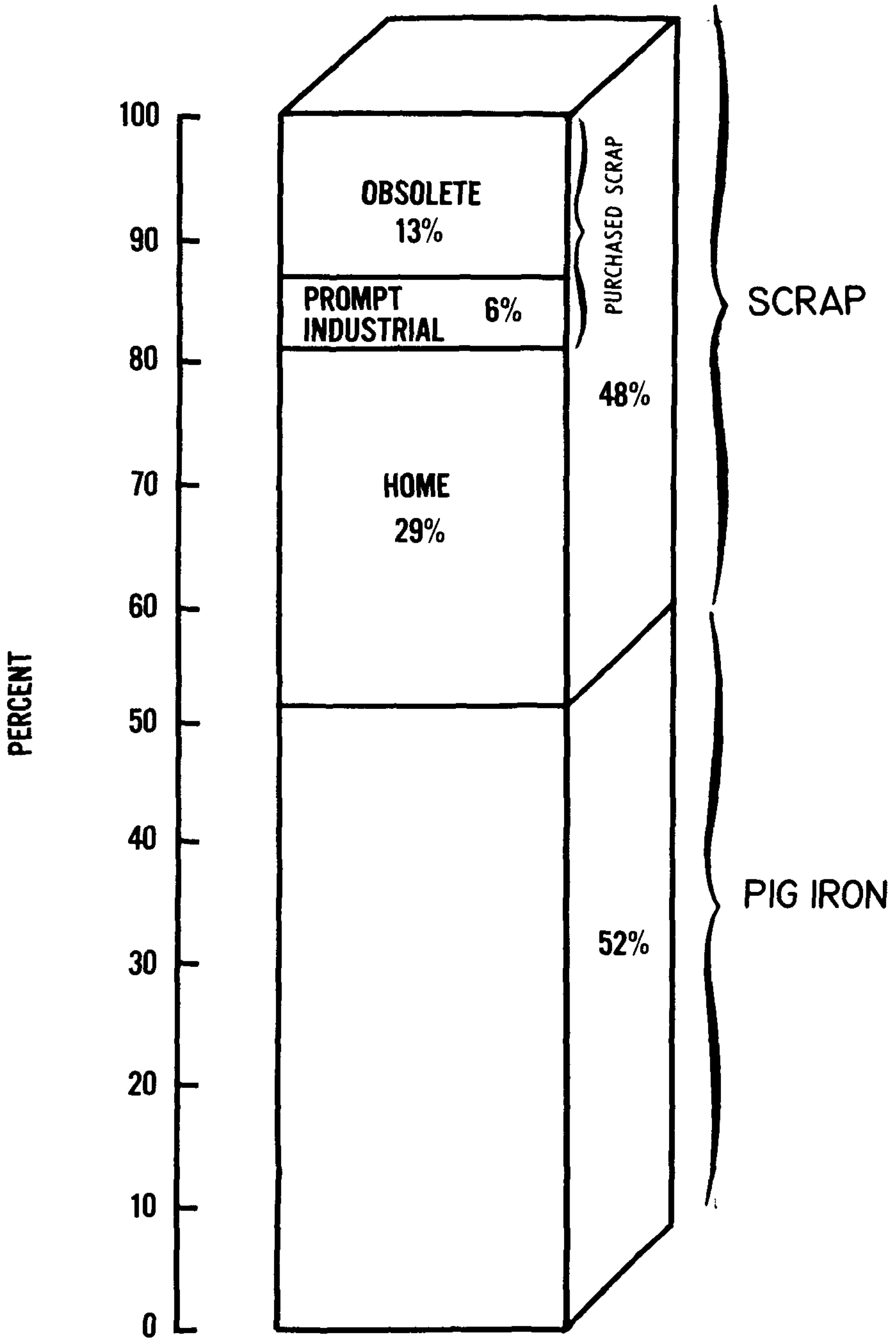

Figure 3. Input of ferrous metals to steelmaking.

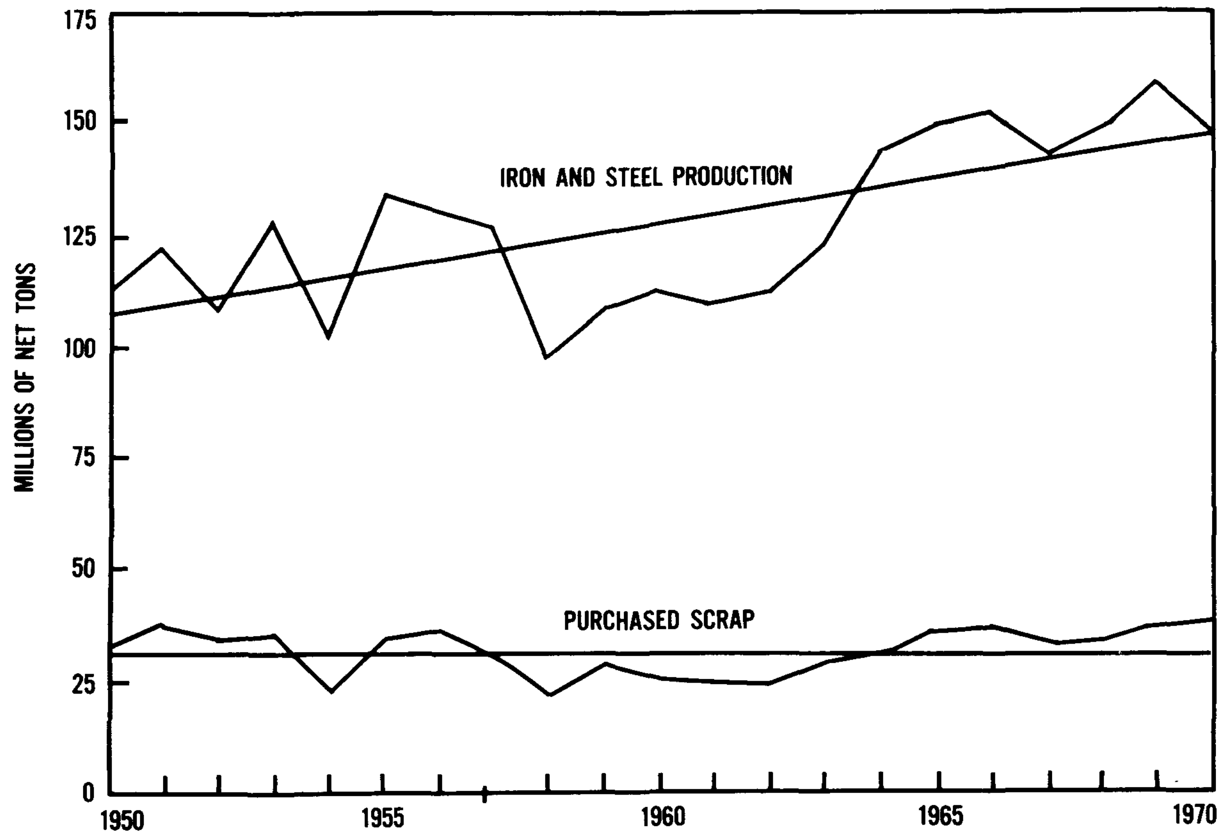

Figure 4. Production of steel ingots and iron and steel castings versus purchased scrap, 1950 to 1970.

For example, the ratios of pig iron or hot metal to scrap are as follows: the basic oxygen furnace uses a ratio approximating 70:30; the open-hearth, 55:45; the electric arc furnace, 2:98; and the cupola furnace, 15:85 (Figure 5).

The dominant steelmaking furnace today is the relatively low-scrap-consuming basic oxygen furnace, but electric furnaces are producing an increasing share of raw steel. In the foundry industry, the cupola dominates, although pollution considerations are favoring increased electric furnace melting.

The change in type of furnace used has had a dramatic impact on scrap requirements. For example, only 10 years ago, 90 percent of all steel was produced in the scrap-hungry open-hearth; in 1970, less than 40 percent was produced there (Figure 6). Three other major technological trends affecting scrap demand are (a) continuous casting, which lowers the amount of home scrap produced because of increased yields; (b) direct-reduced ores, which are a potential substitute for scrap as a ferrous charge material; and (c) scrap preheating, which allows a greater proportion of scrap to be used in the basic oxygen furnace.

The Iron and Steel Scrap Industry

The vital link between ferrous solid waste and its potential markets is the iron and steel scrap industry. It is made up of approximately 2,000 individual firms operating about 4,000 establishments. The industry is classified by the Department of Commerce as wholesale trade, though based on our studies, it would be more accurately labeled "manufacturing." Over half the firms have processing equipment. Processing firms range in size from small local operations that employ fewer than 10 persons, have a minimal amount of processing equipment, and ship less than a thousand tons a month, to the large, geographically spread, capital-intensive firms doing over $100 million of business annually. Total sales of the iron and steel scrap industry exceed $3 billion, and employees number about 40,000.

The primary function of the scrap industry is to assemble unprepared scrap, process it to quality specifications, and market it to the iron and steel industries. Firms are classified basically as either processor/dealers, who convert the material, or brokers, who buy from dealers or industrial accounts and sell to the markets. Of the 2,000 firms indicated above, about 1,800 are processor/dealers, 150 are processor/brokers, and about 50 are pure brokers. The industry is separate and distinct

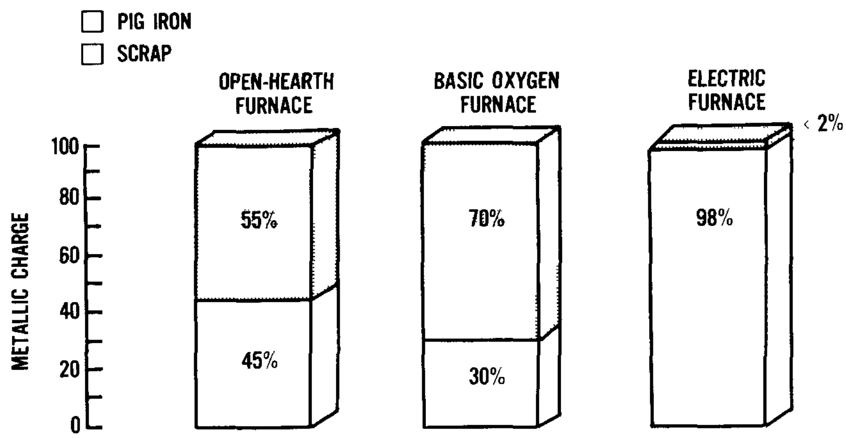

Figure 5. Consumption of scrap and pig iron in various steelmaking furnaces, 1969.

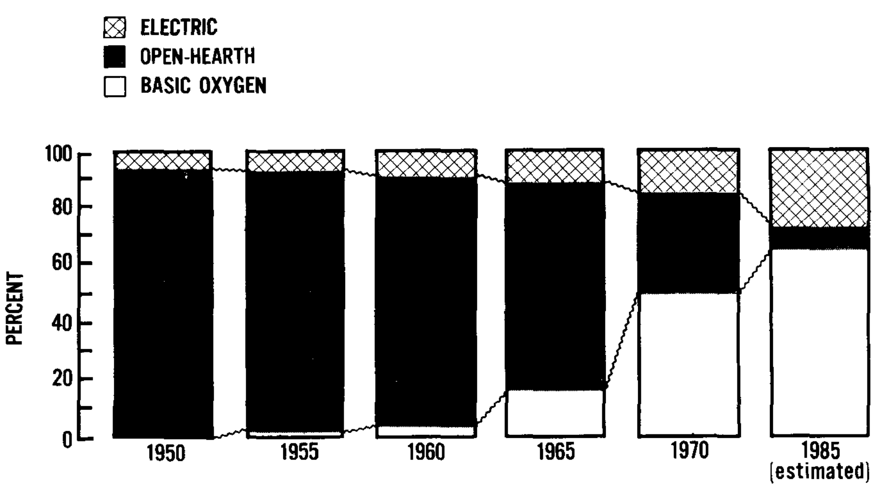

Figure 6. Types of furnaces used in steelmaking, 1950 to 1958.

from two other businesses, auto wrecking and junk collectors, often mistakenly included with the scrap industry. They are sources of material for the scrap industry.

Two basic trends occurring in the industry with implications for ferrous solid waste are the development of more sophisticated processing equipment to produce higher quality material and the consolidation of firms.

Three major pieces of equipment have contributed to the upgrading of scrap processing equipment. The 1940's witnessed widespread installation of hydraulic balers able to bundle the increasing amount of light, flat rolled material. In the late 1950's the hydraulic guillotine shear and conveyor systems provided properly sized and segregated scrap. The best was yet to come in the 1960's with the advent of shredding or fragmentizing equipment that can produce the most uniform scrap yet developed from complex consumer goods. This progress has been expensive. A continuous flow of material through this equipment is required for profitable operation--and scrap demand often is not sufficient to provide such a flow. Consolidation within the industry has resulted in fewer firms doing more business for both financial and market reasons. The fringe operators are disappearing and unfortunately, also some who served the vital collection function of gathering from small sources.

Further insight into the problems of the scrap industry may be provided by a brief examination of two specific sources of ferrous solid waste--junked autos and steel cans--and a few specific problems that inhibit increased recycling of ferrous solid waste.

Junked Autos

There are approximately 20 million junk cars in the United States today. About 75 percent are in the inventories of auto wreckers and scrap dealers. With sufficient economic demand, these cars will eventually move into the scrap cycle and provide valuable raw materials for new iron and steel products.

The remaining 25 percent are abandoned automobiles, primarily located in small cities, towns, and rural areas. They are a blight to our landscape and represent underutilized resources. Because of their location and condition, the cost involved in getting them to an auto wrecker or scrap processor far exceeds the return that could be expected. A number of approaches are possible, most of which have the basic elements of the General Motors test program conducted during 1970 in the Traverse City, Michigan, area. These elements include community action, centrally located auto wreckers, stripped and flattened autos prepared for shipment to a scrap processor, and finally, shipment.

But again, the crux of the problem is demand. The attention being given to improved collection methods, flattening and subsequent shipment by special rail and truck equipment, incineration, shredding systems, and other methods to improve quality will not move one abandoned auto at a price enabling profit unless there is sufficient demand.

Steel Cans

Steel containers, though less than 2 percent of the total municipal and industrial solid waste generated annually in the United States, are nevertheless a highly visible portion of that waste and an obvious target for ecological attack. Economic dislocations are threatened within supplying industries through "ban the can" movements. Discarded containers are, however, a prime potential source of raw material for recycling.

The ferrous content of this waste approximates 7.5 percent by weight of which steel cans account for over half of all discarded steel containers. Cans alone represent an annual loss of ferrous resources in the neighborhood of 5 million tons, although some recovery, estimated to be less than 10 percent, is made for copper precipitation purposes.

Various recovery methods are under study. Tests have been underway in the steel and foundry industries, in cooperation with the can companies, to determine where collected steel containers can best be recycled. Hopefully, an economic use for can scrap in the steelmaking cycle can be found.

Additional Obstacles to Recycling Ferrous Solid Waste

In addition to the inherent demand factors of market growth and technology, there are at least three major obstacles to recycling ferrous solid waste.

Scrap Price Volatility. Scrap is the only major input to iron and steelmaking that exhibits significant price volatility. Costs of all other items such as coal, iron ore, limestone, labor, and utilities are substantially known on an annual basis and allow for financial planning. The price of scrap, however, has varied significantly in recent years. Scrap price is an important cost consideration for all mills, but in particular for electric furnace and cupola operations.

For example, No. 1 heavy melting scrap, often used as a model of price movement, began in 1969 at $27 per ton and climbed steadily to $37 by the end of the year. Last year, it ranged from less than $35 to $47 per ton. These are tough conditions under which to run a business, both for the scrap industry and for its consumers. Almost without exception, scrap prices were cited as a major contributing factor to low profits in 1970 year-end reports of steel companies. Faced with this type of price volatility, it is little wonder that some companies make conscious attempts to design scrap out of their manufacturing processes.

Two potential solutions, actually being employed with coal and iron ore, are long-term contracts and ownership interests. Such suggestions have met with mixed reactions among members of both the scrap and iron, and steel industries.

Transportation Costs. The movement of goods is an increasing cost for most industries, but in the scrap industry it is critical. This factor alone is responsible for the diminishing distance from which a dealer can accumulate unprepared scrap (ferrous solid waste) and transport it after preparation to its final market. Rising transportation costs obviously add to an accumulation of waste. In addition, the basic material with which a dealer must metallurgically compete for iron units--iron ore--is claimed to receive favorable rail-rate treatment. For example, iron ore averages a ferrous content of 60 percent, while scrap contains 90 percent iron. Thus, it is argued that an equitable rate differential of 1-1/2:1 would seem justified. The scrap rate is, however, 2-1/2 times that of iron ore.

A significant contribution in the area of transportation has been the development of the portable auto flattener, which can compress an ordinary auto hulk to a 12- to 15-in. slab. Moving from location to location as the need arises, the flattener allows flat bed truck transport of 16 to 24 compressed hulks compared to 5 to 6 uncrushed hulks. Increased transport of auto hulks allows for a greater supply for shredder operations, which depend on high volume operations because of their large capital investment.

Quality Considerations. The iron and steel industries, under increasing pressure from their customers to upgrade their products, have in turn increased their demands on the scrap industry for more homogeneous and consistent products. The steel product mix has shifted from heavy sections toward thin-gauge, flat-rolled products. The heavy sections can tolerate more variation in their composition and therefore their manufacture can tolerate more variable input materials. In addition, the increasing importance of alloy and coated steels and the increasing complexity of finished products made from a variety of materials is complicating still further the preparation of consistent quality scrap.

There is little difficulty in using home scrap or prompt industrial scrap, since both are generally homogeneous in composition. The problem occurs with obsolete scrap, which comes from heterogeneous sources and is difficult to handle in such a manner that uniformity is maintained in the end product. The problem must be dealt with if ferrous solid waste, or potential obsolete scrap, is to be utilized.

The scrap industry has responded by improved segregation and preparation methods, as previously noted. But with a ready supply often existing of home, prompt, and prime obsolete scrap, the consumer is under no pressure to take potential problem scrap. These secondary grades therefore pile up.

Considerable work must be done to determine realistic quality specifications for scrap products with both the user and processor in mind. In addition, more consideration must be given to the design of end products that can be economically recycled after fulfilling their original use.

CONCLUSIONS

This paper has briefly examined solid waste in general and ferrous solid waste in particular. We have looked at its sources, its markets, and the vital link which has the capability of bringing the two together--the scrap industry. Demand has been defined as the key factor in accomplishing our goal of making ferrous solid waste an asset rather than a liability. Achieving this goal is, however, extremely complex and frustrated by many problems.

Recycling is therefore our approach to ferrous solid waste. Solid waste processing and recovery may never become economic in the classical sense, but this should not be a deterrent to continued development of solid waste recovery technology. The uneconomic aspects and social costs of current disposal-oriented solid waste management systems provide strong motivation for increased recovery and utilization. We remain confident that the social, economic, and technological forces that created this waste can also make it a resource.

This project has been supported by demonstration grant No. G06-EC-00298 from the Environmental Protection Agency, pursuant to the Solid Waste Disposal Act as amended.

SYMPOSIUM ON SOLID WASTE DEMONSTRATION PROJECTS: SOME REFLECTIONS AND EVALUATIONS

*Frank Bowerman**

LADIES AND GENTLEMEN, I don't intend to recap these last 3 days. You and I have lived through the experience; in addition, a fine set of proceedings will be published. So instead, I would like to give you, very briefly, my evaluation of the worth and the meaning of this symposium. If I were to choose a title it would be, "We've come a long way, Baby!" And I would ask you to joint the "Solid Waste Liberation League," because now, for the first time in two decades of experience, I don't have to apologize for our profession. Nor do I have to seek public recognition of solid waste problems. At last it is unnecessary to beg fruitlessly for Federal, State, and local support. Nevertheless, let's not forget that we are still a poverty-stricken second cousin when we compare solid waste research and demonstration funding to water and air pollution funding. Despite this, we have done much with the little that we have had. For that and for other reasons, I judge this symposium to be a very meaningful milestone in the progress of the Federal Office of Solid Waste Management Programs.

I further judge this symposium to be a clear and public documentation of a successful effort on the part of the Federal solid waste project to:

1. Generate innovative technologies in solid waste management. You have seen examples of that in the fine papers presented during these last 3 days.
2. Accelerate the transformation of research into systems of sufficient scale that hardware and economics can be studied.
3. Tap the talents from a wealth of diverse technologies.
4. Expedite the publication of meaningful and useful reports.

In brief, this has been an important conference and I'm pleased to have been here and shared in it.

*Director, Environmental Engineering Programs, University of Southern California.

One area not covered as well as it could have been is the socioeconomic scene. The social, political, and economic aspects of solid waste management may very well be the fly in the ointment in trying to solve urban problems. What we have talked about these last 3 days are "hard" technologies, along with a few examples of system evaluation and computer programming of complex solid waste management systems. Some speakers - Mr. Porter, for example--who described the system he was developing in Des Moines, told us of some of the troubles encountered and some of the solutions that have been devised to overcome social, political, and economic problems. May I suggest that the Office of Solid Waste Management Programs, through its demonstration grant program, take a more active interest in utilizing the talents of social scientists, political scientists, and other professionals who have these peculiar and necessary talents?

The need for such help became very evident during some work which I was doing with the consulting firm, Engineering-Science. We were performing a demonstration project in Orange County, California; the title of the contract was "Maximum Utilization of Sanitary Landfills Through Integrated Regional Planning." Orange County is an area with an ongoing and very successful landfill operation; but as part of the study, we had promised the Federal Office of Solid Waste Management Programs that we would attempt to develop a means for achieving better interagency cooperation. We really didn't know exactly what we were getting into when we wrote the proposal offering to do something so different from hard technology studies and system evaluation. To promote better understanding, we first scheduled a 2-day meeting of the top officials from government, private industry, and Chambers of Commerce--men and women representing the leadership of Orange County. These top level people agreed to travel to San Diego for a full Friday and Saturday. This separated them from their home bases by about 100 miles so that they wouldn't be bothered too much by telephones and other interruptions. We asked them for a Friday and Saturday because Friday was a working day, contributed by their organization, and Saturday was to be a personal contribution. We wanted the participants to feel that they were contributing on a voluntary basis and not just filling a job requirement. One member complained the whole time because he missed a golf game scheduled for Saturday morning, but most of the 30 participants were good natured about the "lost weekend," and nearly all came away feeling that the experience had been worthwhile. A small but highly vocal minority felt that it was a total waste of time.

What did we do? On our team was a behavioral scientist who understood the technique of sensitivity training. Sensitivity training means different things to different people, but we applied it only as a means of forcing dialogue among the participants. The mechanism of dialogue revealed some of the aspirations, fears, worries, concerns, likes, dislikes, etc., of the real-life players in Orange County government and industry. The behavioral scientist and I acted as a team. I was the "old solid waste practitioner," and he asked the necessary prodding questions. The behavioral scientist knew the kinds of questions that would most likely goad the participants into a response. Some of the responses really surprised us. A few of the participants seemed eager to take each other apart, but the challenges were largely figurative. As a result of the somewhat heated reactions that occurred during the 2 days, some of these leaders of government, industry, and the community began to recognize the reality of the other person's problems. There was an increased awareness and acceptance of other points of view. A number of participants told us later that they returned to their jobs with a clearer understanding of how their own interests related to the interests of others in Orange County, particularly in the field of solid waste management. We should do much more of this type of nonengineering activity. Though the Orange County experience was something less than a total success, it was at least a start.

On the hardware side of the conference, it was particularly interesting to me that an engineer in the relatively isolated and small community of Scottsdale, Arizona, came up with some very exciting, innovative technologies in the collection of solid waste. Yet we haven't had anything comparable from the people in Detroit or from old-line collection-truck manufacturers. I compliment Mark Stragier for his ingenuity and commend him for being able to accomplish more single-handedly than an entire industry.

And so, once again, it is my conclusion that this meeting has been an important milestone in documenting the history and development of solid waste management technology through demonstration grant operations. I trust that it will be the first in a series of annual symposia of equal success. May I commend Richard Vaughan, Hugh Connolly, John Talty, Dick Lonergan, and the other talented people in the Division of Demonstration Operations. Praise is also due to Ralph Black, for the excellent communications and publications support, and to Tom Jones, who plans a "right on" program.

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