Issy-les-Moulineaux solid waste incineration plant in Paris, France which supplies steam to the Compagnie Parisienne de Chauffage Urbain, the district heating company and IDHA member serving the entire center of Paris. Note the aerodynamic design of the canopy at the discharge bays (inset photo). Story on page 12.
INCINERATION

AN ENGINEERING APPROACH TO THE WASTE DISPOSAL CRISIS

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PART I

Whatever manouches eventually turns to waste. Primitive man polluted his immediate environment and when the pollution became intolerable, he moved away, leaving his wastes behind to be disposed of by natural processes.

Civilized societies have reversed this procedure — man now stays and the wastes are removed. In many ways, however, his solutions to the problem of waste disposal are hardly more sophisticated than those of primitive man, who could afford the luxury of total disregard of the problem.

Our gaseous wastes are discharged into the atmosphere to be carried away by the winds. The result is pollution of this very atmosphere. Liquid wastes are dumped into rivers and streams to be carried away by the water. The result, again, is pollution of these rivers, one of our great natural resources. Solid refuse is trucked out of town and dumped, to lie as a blight on the countryside. These crude solutions can no longer be tolerated.

Fortunately, as the problem of inadequate waste disposal becomes increasingly difficult to ignore, we are beginning to cope with it. The disposal of solid wastes is engaging the attention of our legislators. Stringent laws are being enacted to guard against air and water pollution. The important factor, however, is time, for the vigorous growth of our society is on the brink of being inhibited by our inability to dispose of our wastes safely, economically, and without inconvenience to area residents.

Waste Generation — The Statistics

The average amount of waste generated each day in the United States is estimated to be 4½ lb for every man, woman and child. The rate of generation is soaring from 3 lb in 1940 to an estimated 5½ lb by 1980. It is staggering to contemplate that by 1980, with population increasing rapidly, over 270,000,000 tons of waste will be generated in this country each and every year. In addition, the specific volume of the waste generated is also increasing.

There is a positive aspect to the increased amount of waste, however. With the growing affluence of our society, a greater proportion of wrapping material comprises the make-up of wastes. This type of waste material has an improved calorific value — currently 5,000 to 5,500 Btu per lb, with an estimated future value of 7,000 Btu per lb. Modern disposal methods should take into consideration the utilization of this heat energy.

Current Methods in the United States

The most common acceptable method of refuse disposal is sanitary landfill. However, since World War II, and particularly in the last decade, our cities have spread until the open space between them has practically disappeared. As a result, the crisis point of available land for fill is rapidly being reached.

Composting of refuse, and its use as a fertilizer, is another acceptable method, but it is unpopular with farmers in the United States. However, even if the objections could be overcome and the economics of the process improved, composting could dispose of only a small portion of refuse. Compacting and use of the refuse as a building material is another method under development, but this also could not account for more than a fraction of the total.

The most promising method of disposal for the future would seem to be incineration, with incinerators designed...
to reduce and dispose of waste within the following minimum parameters:

1. Reduction of weight to 10 to 20% of the initial weight.
2. Reduction of volume to approximately 5% of the initial volume.
3. Generation of a residue which is sterile in all respects and which can be used for landfill or other purposes without risk of contamination of the ground waters and without creating vermin or insect pests.

In addition to the primary objectives, the incinerator installation should be located as close as possible to the population center to permit economical refuse collection systems. The incinerator must not be a neighborhood nuisance. Complete absence of odors and complete compliance with the most stringent air pollution control criteria are an obviously essential part of incineration engineering. Efficient operation in terms of labor required and the possible sale of steam or high temperature hot water which can be generated in the incinerator are important economic considerations.

**U.S. Incineration — Its Failings**

Measured against these standards present incineration practices in the United States are hopelessly primitive. The incinerator is considered a necessary evil to be installed as far as possible from inhabited areas. The result is excessive waste collection costs. Plants are poorly operated and cleanliness is lacking more often than not. Operating costs are excessive as a result of the manual labor used to keep the fires going. Maintenance and repair costs are also very high and breakdowns frequent. Stacks are low and air pollution equipment is almost non-existent, with the result that air pollution is usually high.

In only a very few cases are attempts made to remove the heat liberated, and in these the approach to design is primitive and unsophisticated. The use of independent waste heat boilers in the flue outlet from conventional incinerator furnaces has lead in general to unsatisfactory, and in some cases disastrous, results.

If we are to face, as we must, this critical problem of waste disposal in the coming decades it is obvious that a new approach as well as a new sense of the importance of the problem must be generated. Fortunately many European cities have developed methods and equipment which provide an excellent guide for a future incineration program.

**European Methods of Incineration**

European countries, faced with high population densities and little vacant land, have focused their attention on the engineering of incinerator boiler plants since 1945. They are now building the fourth "generation" of such plants, and it is interesting to see that the designs developed in various countries are quite similar.

Many of the new plants are located within residential areas and even, where appropriate, adjacent to hospitals. This is possible because the plants are spotlessly clean, with no odor and no nuisance factor. As in this country, strong objections were initially raised by property owners faced with having an incinerator as a neighbor, but because of the high engineering standards and clean and efficient operation of the plants such objections have virtually disappeared. The cost of refuse collection is minimized because of the proximity of the incinerator to areas of high waste generation, and the heat generating plant is brought closer to the consumer.

Most modern European plants combine incineration with steam generation. In the newer installations, the incinerator furnace is water cooled and the incineration takes place within the boiler. Steam generation provides one of the best methods of cooling down the gases so that they may be efficiently processed in air pollution control devices. The revenue thus gained from the sale of steam is a welcome but secondary consideration.

The criteria for modern European plants are far more stringent than American standards, and they are strictly enforced. The European air pollution control codes require that the flue gases discharged into the atmosphere shall not contain more than 0.04 grains of dust per cu ft of gas at 70 F. This is the equivalent of less than 0.10 lb per 1,000 lb of gas collected for 50% excess air. The American ASME recommendation is 0.85 lb, with our most stringent codes recommending 0.35.

The residue from the incinerator must contain more than 3.0% combustible constituents and no more than 0.2% of putrescible matter.

To comply with these standards, electrostatic dust collectors have become standard throughout Europe. Also, the plants are equipped with stacks from 400 to 500 ft high.

All of this is accomplished with a minimum of operating labor. No manual handling during the combustion process is required. The incinerator plant is treated in the same manner as a modern steam or electric generating plant with central control panels, automation where appropriate and even television cameras to scan the fire and indicate to the operator the state of combustion within the furnace.

In instances where there is a market, scrap metal is removed from the residue and sold. In addition, the ash is sold as a filler for road building or it is sintered and turned into a product that can be used as aggregate.

European incineration engineering has reached its present high level of development by overcoming the multitude of problems that are encountered in 20 years of operating experience. Corrosion, erosion, and slagging have all been handled through intensive research and development efforts. The newer plants incorporate the results of these efforts and shutdown time has been cut to a minimum.

An ever-increasing volume of waste material, as well as the imminent inability of our present methods to cope with it, are facts of life that must be recognized. Clearly, a new approach to the design, installation and location of incineration plants— at present the most feasible method of waste disposal — is indicated.

**PART II**

**Design Parameters for Incineration System Construction**

**Design Parameters**

Any engineering, economic, or aesthetic discussion of incinerator design must begin with a statement of the ultimate goal: the efficient disposal of solid waste material without causing air or water pollution or nuisance to the community.

(Continued)
What To Do With The Heat Generated?

To meet proper air pollution standards so that the incinerator is not a liability to the neighborhood, a flue gas cleaning device is essential. These devices are costly at best, but when used on gases that are at the high temperature that results from incineration, they are prohibitive. Therefore, the first step is to extract the heat from the gas stream.

The old method of reducing gas temperature by dilution with air is no longer feasible since the cost of the equipment to deal with the tremendous volumes of diluted gases is prohibitive. Therefore, the first step is to extract the heat from the gas stream.

There are two methods of doing this: the wet method and the dry method.

The wet method utilizes the principal of evaporation of water, which is then wasted to the atmosphere. It has the disadvantage of wasting both the water and the heat. In addition, unless the flue gas is reheated after passing through the precipitator or scrubber and before being discharged into the stack, the water is discharged from the stack in the form of unsightly white billows. The reheat equipment, however, adds cost and complexity to the operation.

In the dry method, the refuse is burned in a combination incinerator-boiler and the heat is transferred to steam or high-temperature water in the incinerator furnace itself.

Obviously, the dry method is preferable where steam or high-temperature water can be used to serve heating, refrigeration or industrial processes. But even where there is no ready market for the heat except within the plant itself, most economic analyses indicate that it is the preferred method for plant capacities exceeding 100 tons of refuse per day. And from an engineering and operating point of view, it is a more desirable system in many ways.

Incinerator-Boiler Design

Until quite recently the typical system in the United States, when steam was generated in an incinerator plant, has been to use a refractory type incinerator furnace with a waste heat boiler installed in its flue outlet. This arrangement has been totally abandoned in latest European practice for several important reasons: refractory maintenance problems are inherent in the conventional incinerator furnace; these problems are further complicated by serious corrosion and slagging when a waste heat boiler is connected to a hot gas stream at temperatures at which the fly ash particles carried over with the flue gas are still in a liquid or plastic state.

The problems are further magnified when the steam or hot water generator is a conventional unit designed for gas, oil, or coal firing. Here, the tube arrangement encourages deposits formed by the fly ash in the flue gases leaving the incinerator; in a short time these deposits will plug up gas passages, forcing shutdown of the incinerator.

The incinerator boiler must be an integral unit. In effect, the refuse is burned in the furnace of a water-wall type boiler. This arrangement permits pre-cooling of the gases through radiation to the water walls before they leave the furnace and come in contact with the convection tubes, where additional heat is extracted.

What are the Features of a Modern Boiler-Incinerator Plant Recommended for American Use?

1. Steam pressures should not exceed 450 psig and temperatures should not go above 450-500 F. Superheaters should be avoided. These limitations will maintain temperatures below the zone in which high-temperature corrosion can occur.

2. The furnace should have a short drying or ignition arch and a long and low burn-out arch. In the latter, the gases should be brought forward counter to the movement of the burning refuse into a throat in which high turbulence is maintained.

Secondary air is introduced in such a way as to increase the turbulence in the throat and produce intensive mixing, thus eliminating local reducing atmospheres. Excess air should not exceed 80-100%.

The combustion chamber above the throat should be tall and vertical and have a low gas velocity to reduce entrainment of particles. The walls should be an integral boiler heating surface. The water walls should terminate above the stoker bed or if brought down to the stoker level should be refractory coated in the flame area to avoid reducing-atmosphere corrosion. Furnace temperatures should not be lower than 1,500 to 1,800 F.

The surface of the water-walled furnace should be designed to lower the flue gas temperatures at the furnace exit into the convection tube bank to below the ash softening temperature, in order to avoid slag deposits.

3. The boiler must be designed specifically for incinerator duty, preferably with only one pass to avoid changes in the direction of gas flow. Tubes must be widely spaced and arranged in line with low gas velocity and unobstructed gas flow. The generator should be provided with soot blowers and the gas flow arranged so that the fly ash removed from the tubes is not carried along with the gas stream.

The boiler drum must be designed to absorb sudden surges resulting from unpredictable heat releases in the furnace when highly inflammable material is charged. The boiler should be kept hot when not being fired to prevent low-temperature corrosion caused by condensation on the outside of the tubes.

4. Stokers providing mild agitation or a tumbling action of the refuse should be used. Grate openings in the stoker should be minimal to produce high air back pressure to overcome resistance through a closely packed refuse bed and so that a low siftings loss results. The depth of the fuel bed should be about 2 ft, and its resistance to air flow should be low in comparison to resistance in the grate, to maintain uniform air distribution. Stoker loading is made dependent on the calorific value of the refuse, with a uniform heat release maintained.

5. The electrostatic dust collector must be designed with adequate length and arranged to maintain a uniform gas distribution with moderate gas velocity, so that sufficient dwell time is available.

The gas temperatures must be maintained within a zone which is high enough to avoid localized corrosive condensation, but not so high as to reduce the effectiveness of the dust collector.
1. Tipping area
2. Receiving and storage pit
3. Traveling crane
4. Crane operating room and cab
5. Standby crane
6. Charging hopper
7. Stoker
8. Water walled furnace
9. Steam drum
10. Convection boiler surface
11. Gas exit
12. Electrostatic dust precipitator
13. Induced draft fan
14. Chimney
15. Ash receiving hopper and scraper
16. Ash conveyors
17. Remote control operating room
18. Auxiliary equipment rooms

Cross-Section of Typical Modern Incineration Plant

Plant Design

The general arrangement of the plant with respect to materials handling, refuse storage, and removal of residue must be studied carefully.

1. The design of the storage pit must be coordinated with refuse collection and the heating plant operation. The pit volume and the crane capacity must give the crane operator sufficient time to continuously blend the low and high grade refuse which is delivered to the pit.

2. Bulky or hard to burn waste such as lumber, tires, furniture and household appliances should not be charged into the incinerator but should be first passed through a crusher or shredder. This equipment should be installed at one end of the pit. The discharge from the crusher should be fed back to the main pit to be mixed by the crane operator with the remainder of the refuse in the pit.

3. Industrial refuse should be kept out of municipal refuse unless prior analysis has determined that it is not liable to cause corrosion and other problems.

4. Combustion air should be drawn out of an enclosed refuse pit area to maintain a negative pressure inside, so that all odors are confined.

5. The residue handling system is subject to considerable wear. Therefore, so that the incinerators do not have to be shut down in case of conveyor failure, a dual system, to provide 100% standby, should be installed.

Residue should be kept moving since it is liable to cement if stored for too long a time.

Design of a modern waste disposal incinerator which meets high performance criteria involves solving problems of combustion, heat transfer, and air pollution. Obviously the mechanical engineer plays an essential role in the design of the entire facility. Since proper operation of the plant is his responsibility, he should in fact be the manager of the design team of engineers, architects, and systems analysts.

PART III

Incinerator Serving Paris, France at Issy-les-Moulineaux

After more than twenty years of experience, “fourth generation” incinerators are now in operation in Europe. The most modern of these are to be found today in Paris, France. One of the largest incinerators, the Issy-les-Moulineaux plant, located southwest of Paris on the banks of the Seine has been in operation for seven years and could well serve as a model for our larger cities or regional solid waste disposal planning.

Four Furnaces Handle More Than 500,000 Tons of Waste Per Year

The Issy-les-Moulineaux plant includes four furnaces, each of which was designed to burn 18 metric tons per hour (1 metric ton = 2,200 lb). In 1967, this installation had disposed of more than 500,000 metric tons of a lower heating value of approximately 1,800 kcal/kg (3,240 Btu/lb).

At this plant the question of utilizing the heat to generate power has been resolved in the affirmative, contrary to present general practice in the United States.

Actually, it is important to understand that this question often is badly posed in this country. The question is not whether such plants can generate steam or electricity at a price competitive with plants built solely for this purpose, but whether the generation of power can reduce the cost of solid waste disposal after deducting credits for the sale of power. In other words, it is important to investigate whether the revenue from the sale of steam or electricity is higher than the investment charges, the maintenance, and operating costs of the supplementary equipment required to re-

(Continued)
cover the waste heat (boilers, water treatment, turbo generators, transformer stations). In general, this is the rule in Europe when the plants are fairly large.

**Smooth, Clean, Efficient Performance is the Modus Operandi**

In operation, the collection vehicles discharge the refuse into a 7,850 cu yd pit which corresponds to two days collection capacity. Each of the nine discharge bays can be closed and this is done at the end of the morning when collection has terminated. (Only certain bays will be opened for the rare trucks discharging in the afternoon.) The pit is maintained under a negative atmospheric pressure with all combustion air being drawn from the pit. Consequently, no dust spreads to the outside.

From the pit, wastes are fed into the furnace charging chutes by orange peel type grab buckets of 6.5 cu yd capacity operating from two traveling cranes.

These cranes were designed to be capable of transferring refuse from the end of the building to railroad or trailer trucks so that in case of a plant breakdown or overload the excess can be removed by rail or road.

The four furnaces are identical. Each contains a stoker of the Martin type which provides a continuous rumbling of the refuse through the alternating movement of fixed and mobile bars. Each stoker is divided into three sections, each of which contains 15 steps. Each stoker is 20' 8" wide and 27' 8" long. Surface area is 570 sq ft. Aided by an extracting roller, the ashes fall by gravity into a water trough from which a piston operated pusher discharges them onto a belt conveyor.

The furnaces are an integral part of the boiler and are formed entirely by water walls. The upper and lower drums have a length of approximately 29 1/2 ft and a diameter of approximately 5 ft. The boiler surface is of the order of 10,700 sq ft and the superheaters add about 8,500 sq ft. Each furnace has been provided with oil burners for start up; however, these have never been used.

**Combustion is so Efficient that Smoke is Barely Visible**

Combustion air taken from the refuse pit is brought into the combustion chamber by twenty-one compartments under each stoker. Secondary and tertiary air, injected as required at various points of the furnace, can attain a magnitude approaching that of the primary air. On leaving the boilers, the combustion products pass through electrostatic precipitators of two fields which have an efficiency of more than 98%. As a result, smoke emerging from each of the two 260-ft chimney stacks is hardly ever visible. The exception occurs on cold days when the vapors condense.

**By-Product Steam is Sold to the Paris Utility**

Steam is generated at 925 psi and 770 F. Capacity of each of the four units is 88,000 lb/hr. The four boilers discharge into a common header from which all the steam passes into a back-pressure turbine which expands the steam to approximately 285 psi. This turbine drives a 9,000-kw generator. Steam leaving this turbine is sold at 285 psi to the Compagnie Parisienne de Chauffage Urbain, the district heating company which serves the entire center of Paris. If the district cannot absorb all the steam, the surplus is taken to a second turbo generator — this one a condensing set of 16,000-kw capacity. The capacity of this set does not suffice to absorb all the steam generated by the four units; however, it has been established that in Winter the district heating system absorbs the greater part and in Summer steam generation is lessened as a result of the reduction of refuse. This also permits the successive shutting down of each unit for a month of annual overhaul and maintenance.

**Even the Residue is Sold**

After incineration, the residue is taken to a 2,000-cu yd storage area where it is sold, generally for road construction. When economic conditions are favorable, the ferrous content (particularly cans, old bicycle frames, etc.) is extracted by a magnetic process. It should be noted that the concept of this incineration plant does not provide for sorting refuse before incineration. The furnaces are capable of burning everything that the collecting vehicles contain, even such bulky objects as mattresses and sofas.

During 1967 the plant was able to sell 1,100,000,000 lb of steam and generate 75,000,000 kw hours of electricity of which part was used in the incinerator plant itself. The remainder was sold to the Electricité de France to whose grid the incinerator plant is connected by a transformer station and a 65 kv cable.

**$23 Million to build; $2.18 per U.S. Ton to Operate**

The incinerator cost 115,000,000 francs to construct ($23,000,000). In 1967 the operating costs including all taxes and general costs were about 24 francs per metric ton ($4.37/U.S. ton). Subtracting a gross revenue of 16 francs ($2.92), the cost, exclusive of capital investment, came to about 8 francs per ton ($1.46).

As a result of operating experience, certain furnace modifications were made during the first years of operation. These increased the 24-franc gross operating cost to approximately 28 francs per ton with a resultant net cost of 12 francs per ton ($2.18).

Other modifications included installation of a second fly ash silo, a third demineralized water tank as stand-by, a fourth filter for the Seine River water before treatment.

It would be interesting to speculate whether an incinerator plant without heat recovery would have been more economical. All studies indicate that in such a case, it would have been necessary to provide very costly devices to cool the gases so they could be treated in a dust collector and that the net costs per ton of refuse under the economic conditions available in Paris would have been significantly higher. Any estimate must, of course, depend on local conditions. However, it seems certain that when the incinerator plant exceeds a certain minimum size the generation of steam or of electricity becomes an important consideration.

**Future Plants are Even More Promising**

The recently completed Ivry incineration plant, located in Paris, is even larger than the Issy plant. The same engineering concept employing similar furnaces has been used in this plant. However, in order to decrease the construction and operating costs, an even more sophisticated solution has been adopted. There will be only two furnaces, but their capacity will be doubled. In consequence a single chimney stack is sufficient and the plant is considerably simplified in its overall arrangement. Steam is generated at higher characteristics. Pressure is brought up to 1280 psi and the temperature to 875 F.
For the generation of electric power it was considered preferable to install only a single turbo generator of 64,000 kw capacity. However, a very high steam extraction rate after the first stage will permit the unit to supply the needs of the district heating system as well as the power distribution with greater flexibility. At Issy-les-Moulineaux obviously the condensing set cannot be started up instantaneously when a sudden reduction in demand of the district heating system occurs.

The cost of the plant was slightly higher than 150,000,000 francs ($30,000,000). However, it is hoped that the operating costs will be slightly lower than those at Issy-les-Moulineaux.

OPERATING STATISTICS

1. Air Pollution

a) The legal limit of dust loading in France is 1.5 grams per standard cubic meter (0.615 grains per std cu ft or 1.16 lb per 1,000 lb of flue gas). The limitation of the dust emission per chimney is 300 kg/hr (660 lb/hr), thus, Issy-les-Moulineaux with two stacks has a legal limit of 600 kg/hr (1320 lb).

b) The dust collectors were guaranteed to have an efficiency of 98% for a raw-gas loading of 4 grams per standard cubic meter (1.64 grams per std cu ft). Thus, dust loading in the effluent was guaranteed not to exceed 80 milligrams per standard cubic meter (0.0328 grains per std cu ft) under normal furnace operations. At the tests the stack loading was found to be only 17 to 31 milligrams per standard cubic meter (0.00637 to 0.0171 grains per std cu ft). This corresponds to an efficiency of better than 99%. During forced operation the dust loading was found to be double.

Total dust emission from the incinerator plant is in the order of 85 kilograms per hr (187 lb/hr). These results have been obtained with electrostatic precipitation.

2. Quality of Combustion

a) The unburned carbon in the residue, including fly ash, was measured to be 3% (against a guarantee of 5% by the constructor).

b) The putrescible matter in the residue was guaranteed to be less than 0.5%. Tests indicate it to be 0.1%.

However, the test procedure is extremely imprecise and it was by visual inspection of a sufficiently large sample that this figure was obtained.

3. Composition of Refuse

A detailed analysis of a sample, as large in size and as representative as possible, indicated the following for dry refuse.

- Combustible matter: 50.6% (of which 28% is paper)
- Incombustible matter: 16.3%
- Elements non-classified: 33.1%
  - [Elements smaller than 8 mm (5/16'')]
  - [Ash larger than 8 mm (5/16'')]

The moisture content varies considerably following the seasons. In general, it is between 30 and 45%. The calorific value also is variable, mostly due to the varying moisture content. On the average, it is between 1800 and 1850 kcal per kg (3,240 to 3,330 Btu per lb lower heating value).

4. Gas Temperature

a) At the top of the primary combustion chamber: 1,700 F.

b) At entry to the superheaters: 1,525 F.

c) At entry to the convection bank: 1,165 F.

d) At entry to the electrostatic precipitators: 465 F.

5. Dimensions

The overall dimensions of the building are 557 x 252 ft with a total area of 72,600 sq ft. However, the part of the building containing the four furnaces is only 308 x 197 ft, including the charging floor for the collection vehicles under which the repair and maintenance shops are located. The total area of the site which includes a vast courtyard and rail sidings occupies 2.4 acres.

6. Staffing

The operation consists actually of a little more than five shifts. In each shift, the personnel breakdown is as follows:

- 1 station chief
- 2 watch engineers
- 4 firemen
- 2 crane operators
- 1 weigh master
- 3 men to handle the residue and the courtyard in general.

7. Operating Cost

The operating cost is broken down as follows:

<table>
<thead>
<tr>
<th>Thousand Francs</th>
<th>Thousand Dollars</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating personnel</td>
<td>2,400</td>
</tr>
<tr>
<td>Maintenance personnel</td>
<td>2,000</td>
</tr>
<tr>
<td>Materials</td>
<td>1,600</td>
</tr>
<tr>
<td>Energy costs</td>
<td>1,500</td>
</tr>
<tr>
<td>Disposal of overload and residue</td>
<td>700</td>
</tr>
<tr>
<td>Other operating costs</td>
<td>2,600</td>
</tr>
<tr>
<td>Overhead</td>
<td>3,600</td>
</tr>
</tbody>
</table>

h) Amortization and financial charges

- Included in this figure is 1,200,000 francs or 240,000 dollars participation in the general overhead cost of administrative agency (Electricité de France).

- 7,500 | 1,500 |

Less revenue from steam electricity, residue and scrap sale

- 8,100 | 1,620 |

Total Net Cost

- 13,600 | 2,720 |

(Continued)
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Toral tonnage handled — 513,000 metric tons (564,300 U.S. tons). Of this, the plant incinerated only 506,000 metric tons (556,600 U.S. tons). The difference was sent to a sanitary landfill, either by truck or by rail and the corresponding costs are included above in the "other costs.”

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8. Method of Operation and Control

The station chief supervises the entire operation. The two watch engineers supervise the numerous instruments and controls. They are aided by the firemen, who circulate continuously throughout the plant, either to check the operation of the furnaces and boilers or to pay particular attention to any "alerts" that have been signalled by the alarm system.

9. Railroad and Truck Loading Facilities

Railroad and truck loading facilities permit sending to a sanitary landfill the refuse not dumped into the incinerators. This provides a "safety valve" for the 15 days of annual shutdown as well as those periods when refuse deliveries exceed plant capacity. (see cover photo).

From this and the foregoing discussions, it is obvious that design of a modern waste disposal system involves expertise and creative engineering of a high order. Besides the problems of esthetics and economics, the mechanical engineer must solve problems of combustion, heat transfer and air pollution. In fact, the mechanical engineer plays an essential role in the design of the entire facility. Since successful operation of the plant is his responsibility, he should obviously be the manager of the design team of engineers, architects and system analysts.