THE LARGE PLANTS FOR INCINERATION OF DOMESTIC REFUSE IN THE PARIS METROPOLITAN AREA

H. ROUSSEAU
French Electricity Board, T.I.R.U.
Paris, France

INTRODUCTION

In order to understand the place held by incineration in the treatment of domestic refuse of the Paris Region, it would be well to describe briefly the task assigned by the Department of the Seine to the French Electricity Board (E.D.F.), known as the T.I.R.U. (Traitement Industriel des Residus Urbains). The scope of its task shall also be discussed.

The Department of the Seine includes Paris (2,700,000 inhabitants) and more than 80 suburban municipalities (3,000,000 inhabitants). The capital and most of these cities have recourse to the T.I.R.U., which thus serves 4,800,000 inhabitants living in a roughly circular area of about 15 miles in diameter. Certain municipalities, generally with less dense population, still find it more economical to transport their refuse by their own means, to sanitary fills or by spreading it on fields as fertilizer. However, their number decreases with every passing year.

The quantity treated by the T.I.R.U. amounts to more than 1,600,000 metric tons annually, including certain industrial refuse accepted separately, the costs for which are covered by a special payment, reimbursing the Service for the additional costs resulting from it.

The quantity varies depending on the day of the week and the season. Refuse collection is daily in Paris, but is generally done only during working days in the suburban areas. This gives markedly smaller collections on Sundays and exceptionally large collections at the beginning of the week. In winter, the tonnage is greater than in summer, a period when the city dwellers take their vacations and when there are no ashes from individual or central-heating systems. The annual ash collections are decreasing. To sum up, the daily tonnage varies from more than 6,000 metric tons in the winter to less than 3,000 tons around August 15 (1 metric ton = 1.1 short tons).

Both composition and calorific value also change depending on the seasons, and from year to year. This gradual disappearance of central-heating ashes tends toward equalization during the same year.

At the same time a reduction of bulk density occurs because paper work tends to submerge civilization. The refuse bulk density is 200 to 250 kg/cu. m. (324-421 lb/cu ft).

The refuse composition has the following range in weight percent:

- Fines < 19 mm.
- Vegetable and putrescent matter
- Paper and rags
- Rubbish, combustible matter other than paper and rags
- Plastics
- Metals
- Glass

Lower calorific value: 1,600 to 2,000 Kcal/kg, (LHV 2880 to 3600 Btu/lb).
The heating value is increasing slowly from year to year.

In order to treat this refuse, the T.I.R.U. has four plants located around Paris and not far from the city boundaries, i.e. 3 to 5 miles from the center.

All four plants are equipped with incineration furnaces and are connected to the railway system, in order if necessary to be able to send ash residue to the sanitary fill. Fig. 1 shows the locations of these plants, as well as the collection area assigned to each.
The Ivry and Romainville plants can also prepare the resulting product for soil amendment by screening (0 to 75 mm.), scrap-iron removal and grinding. Out of the total, three-quarters (1,200,000 tons) are incinerated and the rest is divided equally between soil improvement and sanitary landfill.

The St. Ouen plant was restarted after reconstruction in 1954; the one at Issy-les-Moulineaux was also renovated in 1965; the Ivry-sur-Seine plant is in process of reconstruction, while continuing to operate until the middle of 1969. The very old Romainville plant, although it is still treating about 250,000 tons annually, will be closed down within a few years and does not merit a description, nor does the present Ivry plant.

PLANTS IN OPERATION

St. Ouen

The reconstruction of the plant, begun before the war, was completed in 1954. Designed for burning somewhat more than 200,000 tons annually, it includes four Volund furnaces, the boilers of which have suspended tube-nests for vaporization and superheating. It very quickly became necessary to increase its capacity to the utmost: the experience of the first years has permitted making numerous changes and improvements in order to do away with the bottlenecks preventing the optimum use of the sizes of the furnaces and boilers. At the same time, the shutdown periods for maintenance were reduced considerably.

The increase was achieved through the use of high quality materials, carborundum bricks and heat resisting cast irons and steel, larger equipment for the removal of ash under grates and boiler hoppers, quadrupled power to the air and gas-moving system, and better fly ash removal.

Thanks to all this, the capacity reached 395,000 tons in 1965. Unfortunately, it will diminish slowly in the future at a rate inversely proportional to the increase of the caloric value of the materials incinerated because the boiler can absorb only a limited amount of heat.

Fig. 2 shows a cross-section of the plant. The pit is set directly against the boiler house and two overhead traveling cranes serve the four supply hoppers without the intermediary of a conveyor belt. The ash and fly ash are evacuated by hydraulic flushing into basins, whence they are taken up by conventional grabs of the two portal cranes. The ash is generally sold for road infrastructure purposes.

Steam is generated at 26 atmospheres and 260 C (377 psi, 500 F). After being desuperheated it is entirely sold

FIG. 2 MAIN CHARACTERISTICS OF ST. OUEN PLANT

Annual capacity: 370,000 tons (407,000 net U.S. tons)
Refuse receiving pit: 3,500 cu m (4,580 cu yd)
Overhead traveling cranes: 2 with 3 cu m grapple (3.9 cu yd)
Power use:
Sale of steam for heating purposes: 50 t/hr at 20 atm and 230 C
(110,000 lb/hr at 290 psi and 446 F)
Steam generation – incineration units:
Number: 4 of 12 tons/hr (13.2 net U.S. tons each)
Furnace: Volund type
Boiler: 20 t/hr at 26 atm and 260 C (44,000 lb/hr at 377 psi and 500 F)
Dust collectors: multicyclone and washer

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to the municipal heating system or to an industrial client, since the plant does not have any turbo-alternators.

In addition to the St. Ouen plant, two other T.I.R.U. plants (Issy and Ivry) contribute to the supply of the municipal heating system. The three plants supply 40 percent of the requirements, but in a very unequal proportion depending on the seasons. In fact, the diagrams of steam production from refuse and the heating requirements are far from coinciding, as shown in Fig. 3.

Thanks to the high quality of the materials, maintenance is concentrated during a one-month period, each furnace being overhauled successively during the summer. The plant is entirely shut down only for two weeks, for maintenance of the joint facilities. Thus, each boiler remained in service an average of 7,150 hours during the past year. Because of the above improvements, the average daily incineration was increased to 13.4 tons, while the initial guarantee was only 8.5 tons.

Nevertheless, it should be said that at such an incineration rate, combustion is less complete. The proportion of residue produced exceeds 33 percent and the unburned products are increased to 18 or even 20 percent. However, the rate is adjusted below the level which would cause some residue to be unsaleable.

The thermal efficiency is acceptable. Last year, 460,000 tons of steam were sold, the yield being 1.63 ton of steam per ton of incinerated refuse. The boilers supplied 2.8 tons per hour each, i.e. at 91 percent of their rated capacity.

Therefore, the plant is a powerful one despite its design, which is already somewhat obsolete, and the operational results are satisfactory. The personnel employed is about 160 persons.

The operational cost is of interest only if abstraction is made of capital charges. The construction conditions, interruption due to the war, the subsequent monetary instability, and the numerous changes made during the first ten years of operation deprive the real investment costs of any significance.

As for annual operational expenses, including several periods of transfer to sanitary fill during shutdowns, maintenance, taxes and retirement pensions, as well as the overhead costs of the plant and of the central headquarters in 1966, were 33.88 francs per ton. The receipts, or 14 francs should be deducted, thus leaving a net operational cost of 20 francs per ton ($6.29 less $2.60 = $3.69 per 2000 lb ton).

Issy-les-Moulineaux Plant

This is the most recent T.I.R.U. plant, started up in 1965. It is also the most powerful one and both plants deserve, in this connection, a favorable rating in the world. As shown in Fig. 4, it includes a pit that can hold nearly two days of refuse collection and four furnaces supplied by two overhead traveling cranes, each carrying a 5 cu m (6.5 cu yd) polyp type grab.

The boilers are of the water-wall header type, and are an innovation as there is a free gas passage in the first two chambers. The gases then pass into the superheater and the evaporating tube nest to produce steam at 64 atm pressure and 410°C (927 psi, 770°F).

Two turbo-alternators produce electricity: the first, of 9,000 kW capacity, is of the back-ressure type and lowers the steam pressure from 50 to 20 atm (725 psi to 290 psi).
The steam is then directed to the municipal heating net­work or to a 16,000 kW turbo-alternator, of the conven­tional type. The switching depends on the needs of the moment.

The furnaces and boilers, both ordered in France, use the Martin grate "reverse-acting" repulsing the refuse up­stream in order to ensure effective mixing. The progress­ion, downstream, is by simply gravity. At the end of the grate the residue is moved along by an extracting roller whose rotational speed governs the thickness of the comb­ustion layer. The residue drops into a water-filled ash pit, whence a pushrod causes it to fall, after drip drainage, on a conveyor which carries the residue to the ash pit. Iron scrap is recovered by magnetic means, and it is sold separately.

Particular care has been taken with flue dust collection. The system is electrostatic, has an efficiency of more than 98 percent and extracts more than 50 tons of fly ash daily, so that no smoke wreaths can be seen above the 80 m (263 ft) high smoke stack.

The personnel is on the same order as at St. Ouen and the operation and maintenance are analogous; 11 months of operation for each furnace without any inter­ruption. Thus, except for the 15 days of plant shutdown for maintenance of joint facilities, such as the water intake system and the railway tracks, 4 furnaces are available dur­ing winter and 3 during the summer.

General operation has been excellent from the begin­ning and the results even exceed the expectations. During the 12 months ending on 31 July 1967, the plant burned 515,000 tons. Shutdowns for adjustment or because of malfunctions were extremely rare, since the operational duration of each furnace was more than 6,700 hours at the rate of 19.2 tons per hour. The residue production was

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**FIG. 4 MAIN CHARACTERISTICS OF ISSY-LES-MOULINEAUX PLANT**

- **Annual capacity:** 500,000 metric tons (550,000 net U.S. tons)
- **Refuse receiving pit:** 6,000 cu m (7,850 cu yd)
- **Overhead traveling cranes:** 2 with 5 cu m grapple (6.7 cu yd)
- **Power use:**
  - **Back-pressure turbo-alternator:** 9 MW – 50/16 atmos. (725/232 psi)
  - **Condensation turbo-alternator:** 16 MV – 18 atmos. at 280 C (261 psi, 536 F)
- **Sale of steam for heating purposes:** 130 t/hr at 21/16 atmos. (286,000 lb/hr at 304/232 psi)
- **Steam generator – incineration units:**
  - **Number:** 4 of 17 tons/hr (18.7 net 2000 lb tons/hr)
  - **Boiler:** Waterwall chamber type
  - **Evaporation:** 40 t/hr at 64 atmos – 410 C (88,000 lb/hr at 938 psi, 770 F)
- **Combustion grate:** Martin type
- **3 sections of 15 steps each:** Area = 53 sq m = 570 sq ft
- **Electrofilter dust collector, 2 fields:** 98 percent effic.

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27 percent to which was added about 4 percent of fly ash. The use of boiler power, designed for a higher heating power than is normally used today, has exceeded 75 percent with a mean evaporation of 33.8 tons/hr, i.e. a yield of 1.77 ton of steam per ton incinerated, with higher characteristics than at St. Ouen.

After some electricity is taken for the requirements of the plant itself (19 million kw hrs), the rest is sold to the general system of the French Electric Power Board (E.D.F.) (58 million kw hrs). The back-pressure unit was operated for 7,850 hours? the condensation unit, shut down when all the steam was absorbed by municipal heating, has nevertheless been operated for more than 5,000 hours. Their effective power varies considerably with outside conditions, particularly with the pressure demanded by the municipal heating system. On the average, it was approximately 50 percent, with production of 228 kw hrs per ton of steam, of which one fifth was by the back-pressure unit.

These results show the high technical level of this plant. Aside from the fuel used, the plant compares favorably with modern steam power plants.

It was considered desirable to install two television sets on each furnace. One camera observes the correct quality of the flames where the refuse is dropped from the chute onto the grate, the other observes the gradual burn-out of the residue on the last third of the grate, despite the blowing taking place there. As the TV receivers are placed in the control hall in the center of the plant, the operators can immediately correct any malfunction noted without having to wait for the reports of the intermittent patrols.

Accurate knowledge of the quantities burned is obviously the basis for evaluating the efficiency and, consequently, to ameliorate it. Overall data are not sufficient and one has to know what is burned in each furnace, almost at every instant. Weighing every bucket unloaded by the overhead traveling crane into one or other of the furnaces is effected by strain gauges, without any action by the crane operator, during the opening of the grab bucket above the supply hopper. Electric measurements so taken are automatically translated into weights. These weights, transmitted in code by a radio transmitter to the control room, are printed on a general sheet at the disposal of the operators. For an average weight of more than 2 tons per bucket, the accuracy is ± 25 kgs (55 lb).

No startup of such novel installations can be effected without incidents. In this particular case, these incidents were both rare and not serious. In particular, the grates and the residue removal system have functioned well and without any marked damage. The boilers also; however, the very nature of the refuse and its evolution might bring about serious disadvantages. A certain amount of corrosion has been noted at the base of the waterwalls, due undoubtedly to the chlorine contained in PVC plastics. First marks of corrosion were noted after 6,500 hours of operation. It was then decided to protect the waterwall headers by refractory concrete up to the tertiary air nozzle, over 9 meters (30 ft) of height. Experience will show whether this is sufficient. Furthermore, probes were placed at the top of the first chamber in order to analyze gas composition. More recently, the superheaters have been attacked at the elbow base. Metal protective shells have been put in place. All this, from an overall point of view, has scarcely slowed down the rate of operation.

Therefore, this plant marks a new advance in technical design, considerably lightening the work of men while raising their professional qualifications. The economic aspect of this evolution remains to be discussed.

The financial charges per ton incinerated depend mainly on the capital used (102 million francs or $21 million), and also on the interest rate, which varies from country to country and depends on the rate of depreciation. These rates may be calculated over a shorter or longer duration (20 to 25 years probably) and with a working out by constant annuities, including interest (which leads to a progressive depreciation charge, certainly insufficient) or by constant linear depreciation or by depreciation on diminishing values. The last one seemingly best reflects economic realities. Everyone may adopt the formula of his choice in order to evaluate the charge per corresponding ton.

The annual operational expenses for 1966, still burdened by various development costs, were 31.56 francs per ton ($5.85 per 2000 lb) overhead costs included. The receipts were only 11.70 francs ($2.17 per 2000 lb) or a net cost of a little less than 20 francs per ton ($3.68 per 2000 lb). However, the receipts have not then reached their normal level. As an indication, they were 15.60 francs ($2.89 per 2000 lb) during the first seven months of 1967. Therefore, one may expect a net cost close to 15 francs ($2.78 per 2000 lb) under normal conditions. Technical ameliorations procure obvious social advantages, and the increase in capital charges is largely compensated by the lowering of the net operational costs.

Ivry Plant

Having discussed the present situation, a few words should be said concerning the Ivry Plant, which will shortly be placed into service in place of the one built in 1927 and still operated under working and yield conditions which cannot go on much longer.
After the bids were examined, the same supplier as for Issy was chosen. The general design is the same, with a few exceptions briefly discussed hereafter (Fig. 5).

There will be only two furnaces instead of four but they will be twice as powerful. The Martin grates will include six spans instead of three, with 19 rows of grate elements instead of 15. Thus, the annual capacity of the plant will exceed 600,000 tons.

The rated pressure of the boilers will be increased to 95 atmospheres (1378 psi) in order to have steam at 75 atmosphere (1088 psi) and 470 C (878 F) at the inlet of the turbine, instead of the two units in cascade at Issy-les-Moulineaux. The 64 MW turbo-alternator will be single but will permit directing a very large amount of steam to the municipal heating system. The quantity of steam for the downstream part of the turbine can be lowered to 10 tons.

A single smokestack 100 m (328 ft) high will exhaust the flue gas from the two furnaces, after electrostatic dust collection.

Various improvements, dictated by experience or general technical progress, will also be made, particularly the correction of the lateral expansion of the grate elements by compensation units separating the span, and the control of grate movers and the ash pushrods by hydraulic cylinders.

The total cost of the plant will be approximately 150 million francs ($30.6 million). It should be placed into service in the middle of 1969 and will result normally in a lowering of the cost price, thanks to its greater simplicity permitting a certain economy of personnel, and to a still better efficiency particularly where the electrical components are concerned.

The T.I.R.U. program includes subsequent construction of other plants to meet the needs of the population. However, it does not seem as though the physical conditions will lead us to plan installations larger than those of Ivry.

FIG. 5 MAIN CHARACTERISTICS OF IVRY PLANT

Annual capacity: 600,000 tons (660,000 net U.S. tons)
Refuse receiving pit: 9,000 cu m (11,800 cu yd)
Overhead traveling cranes: 2 with 6 cu m grapple (7.8 cu yd)
Power use:
Taking up and condensation turbo-alternator unit: 64 MW — 75 atmos. at 470 C (1088 psi, 878 F)
Sale of steam for heating purposes: max. 230 t/hr at 21 atmos. (505,000 lb/hr at 304 psi)
Steam generation — incineration units:
Number: 2 of 50 tons/hr (2 of 110,000 lb/hr)
Boiler: Waterwall chamber type
Evaporation: 126 t/hr at 95 atmos. and 470 C (277,000 lb/hr at 1378 psi and 878 F)
Combustion grate: Martin type
6 sections of 19 steps: Area = 128 sq m (1375 sq ft)
Two-field electrofilter dust collector: 99 percent effic.