ABSTRACT

Many European refuse incinerators utilize the heat derived from refuse incineration for steam or hot water supply to district-heating systems or to certain industries for generation of electricity, for sludge drying, etc.

The design of five typical incinerators with heat recovery is outlined and the value of recovered energy in terms of fuel oil savings is tabulated.

INTRODUCTION

Over the past 15 years, 180 large-capacity refuse incinerators have been built in Europe to utilize the combustion heat for electrical generation, for district heating or for process steam. The reliable incineration of the masses of waste produced day by day and their transformation into sterile clinker is the task of public sanitation. Moreover, recovery of combustion heat is an important contribution from the national economic viewpoint as it saves primary energy such as coal, fuel oil or gas.

The idea to use the heat from refuse incineration is not at all new. Already, at the turn of the century, a beginning was made in the U.S. and Europe to build heat recovery refuse incineration plants.

For example, Abraham Brenner in “Combustion,” November 1974, reports on the Delancey Street Incinerator in New York City below the Williamsburgh Bridge. In this remarkable plant 1050 cu yd of “light refuse” were burnt every day in 1905. The steam produced at 150 psig was used to drive generators that furnished electric energy for arc lamps to illuminate the Williamsburgh Bridge.

The first European incinerator with heat recovery for electrical generation was built at Oldham (England) in 1896. In 1906, the steam produced by the Kiel (Germany) incinerator was used to dry sewage sludge.

In Central and Western Europe, there are in operation or near the point of being commissioned (Situation March 1978):

1. More than 300 modern incinerators for municipal refuse, housing 595 units, each with a burning capacity of more than 53 tons (48 t) per day. The total daily capacity of all these plants is approximately 127,000 tons (115,000 t).

2. One hundred eighty of these 305 incinerators with a total burning capacity of 96,500 tons (87,500 t) per day or 76 percent of the above mentioned 127,000 tons (115,000 t) are equipped with heat recovery facilities for steam, district heat, or electrical generation. These plants serve a population of approximately 100 million people. The heat recovered in these plants definitely means an equivalent saving in other primary energy.

Although in recent years some new methods for waste disposal have been put forward and part of them tested in pilot plants, the conventional “mass burning” process continues to have a vivid
topical interest, particularly as a consequence of rising oil prices, and in serious technical and commercial considerations for waste disposal the calorific energy contained in the refuse plays a far more important role than in the past.

This paper briefly describes five heat recovery plants differing in concept and size and summarizes operational experience over the past 3 years. During this period, the calorific or "heating" value of the waste incinerated in these plants was between 3700 and 4600 Btu/lb (7500 and 9600 kJ/kg). The parameter and criterion for a successful heat recovery is the equivalent quantity of light fuel oil saved by using refuse as fuel for primary energy.

The following plants are examined:
1. Rennes (France): Incinerator with hot water production for district heating.
2. Vienna-Spittelau (Austria): Heat and power station. Hot water production for district heating and electrical generation for in-plant requirements.
3. KEZO Incinerator at Hinwil (Switzerland): Power station with condensing turbine.
4. Paris/Issy-les-Moulineaux (France): Heat and power station with back-pressure, condensing turbines, and steam export for district heating.
5. Munich-North II (Germany): Refuse incineration in a power plant stream in addition to pulverized coal. Condensing turbine for electrical generation and hot water export for district heating.

EXAMPLE 1. DISTRICT HEATING STATION AT RENNES (FRANCE)

About 15 years ago, the suburban area of Villejean-Malifeu was built. The development included a hot-water type district heating network for all buildings (private dwellings — shopping centers — hospitals — university institutes).

![Diagram](image1.png)

FIG. 1 THERMAL SCHEMATIC OF THE RENNES PLANT

The district heating station comprises two separate facilities, i.e., the heating station proper and the adjacent incinerator. The heating station is equipped with two oil-fired hot-water boilers. The incinerator comprises two saturated-steam boilers of 400 psi (27.5 bar = 2.75 MPa) pressure and each burning 132 tons (120 t) of refuse per day.

The steam raised by refuse incineration is led to a hot water heat exchanger with a capacity of 67.5 million Btu/hr (71.2 GJ/h) arranged in parallel with the two boilers of the heating station. Occasional surplus steam is condensed in an air-cooled condenser.

The base load of heat generation is supplied by the incinerator while the daily and seasonal fluctuations of the heat demand are met by the oil-fired hot-water boilers.

The incinerator has been in permanent operation since 1968. It is owned by the company which also is responsible for the district heating system.

![Table](table1.png)

FIG. 2 OPERATIONAL RESULTS OF THE RENNES PLANT, 1974-1976

By using the calorific energy of the refuse, it was possible to save 40,600 to 43,200 barrels (6500 to 6800 m³) of light fuel oil each year, or the annual demand for heating and warm water of approximately 1000 one-family houses.

EXAMPLE 2. DISTRICT HEATING STATION VIENNA-SPITTELAU (AUSTRIA)

The venerable capital of Austria furnishes a good example for the purpose of this paper. Almost all of the refuse produced in the Vienna metropolitan area is disposed of in two incinerators with heat recovery. The more modern one (Spittelau, in operation since 1971) is part of a district heating station with in-plant power generation comprising two refuse-fired steam boilers,
one back-pressure turbine, and two oil-fired hot-water boilers.

The two refuse-fired saturated-steam boilers, each with a steam capacity of 87,300 lb/hr (39.6 t/h) at 470 psi (3.24 MPa), are connected with a 2.5 MW back-pressure turbine that generates the in-plant power requirements of the whole district heating station. The back-pressure steam passes through a heat exchanger where the 340 °F (170 °C) hot water for the district heating is produced. In periods of low heat demand (summer) the surplus steam is condensed in a water-cooled heat exchanger.

The two oil-fired hot-water boilers are in operation during peak load periods only.

The district heating network is being extended at present and will have a maximum capacity of 667 million Btu/hr (700 GJ/h) in its final stage.

In the past three years, about 80 percent of the district heat demand was met by refuse firing. This resulted in a yearly savings of between 152,000 and 198,000 barrels (24,000 and 31,000 m³) of light fuel oil. The average rate of operation of each refuse fired steam boiler over the past 4 years was 7300 to 7900 hr/year, which means an operational availability of each stoker-boiler unit of between 83 and 90 percent.

EXAMPLE 3. KEZO INCINERATOR AT HINWIL (SWITZERLAND)

This relatively small refuse-fired power station is an excellent example of the economic operation of a plant of modest size with heat recovery.

About 10 years ago, 24 communities of the uplands southeast of Zurich, with a total of about 155,000 residents, formed a cooperative to build the plant. As there was no possibility to make use of the heat in a district heating system or in the form of process steam, the steam is used in condensing turbo-alternators for electrical generation.

The first stage consisted of only one unit with a throughput of 132 tons (120 t) of refuse per day and one 2.43 MW condensing turbine. It went into operation in 1971. At full load, the boiler supplies 27,560 lb/hr (12.5 t/h) of steam at a pressure of 600 psi (41.2 bar) and a temperature of 750 °F (400 °C).

In the second stage, two units each burning 165 tons (150 t) of refuse per day and one condensing turbine of 8.5 MW were added. This extension was commissioned in mid-1976.

The total electricity generated, after deduction of the in-plant requirements, is supplied into the public network. This was in the order of 80 to 90 kWh per year per resident of the cooperative area or about 5 percent of the annual power consumption of the communities, without industrial power requirements.

The comparative savings in light fuel oil per year amounted to 39,000 to 46,000 barrels (6,200 to 7,400 m³) of light fuel oil.
HEAT RECOVERY FROM PLANT CONSUMPTION REfUSE INCINERATION II E AEFT DEUITION SAVERED BY OPERATIONAL YEAR RECOVERED. NET DI5TRICT HEAT - POPULATION OF COLLECTING AREA RESIDENTS OF LIGHT fUEL Oil EQUIVALENT AMOUNT OF LIGHT FUEL Oil PER YEAR US·TBARRELS SAVED BY (¢/MfY) US·GALLONS HEATRECOVERY FROM REFUSE INCINERATION PER RESIDENT (¢/MfY) US·GALLONS

FIG. 6 OPERATIONAL RESULTS OF THE KEZO-HINWIL PLANT, 1974-1976

The stoker-boiler unit of the first stage was in operation for 7500 to 7700 hr/year. The corresponding availability figure is 86 to 88 percent.

EXAMPLE 4. HEAT AND POWER STATION PARIS/ISSY-LES-MOULINEAUX (FRANCE)

The Paris region with its 5.2 million inhabitants has at its disposal three large-scale plants where about 1.75 million tons (1.6 million t) of refuse per year are incinerated. The combustion heat is recovered to supply district heat and generate electricity. One of these three plants is Issy-les-Moulineaux, situated at the river Seine in the southeast end of Paris. In operation since 1965, it is one of the first modern European plants with heat recovery from refuse burning. Originally, this plant had been designed to burn 441,000 tons (400,000 t) of waste per year, but actually the throughput exceeds 610,000 tons (550,000 t) per year.

FIG. 7 THERMAL SCHEMATIC OF THE ISSY-LES-MOULINEAUX PLANT

The plant is composed of four refuse-fired boilers each producing 88,200 lb/hr (40 t/h) of steam at a pressure of 770 psi (53 bar = 5.3 MPa) and a temperature of 770°F (410°C). In the first stage, the steam is expanded from 725 to 305 psi (5.0 to 2.1 MPa) in a back-pressure turbine set of 9 MW and then sent either to the Paris heating network or to the 15.9 MW condensing turbine. This arrangement allows high electrical production in periods of increased power demand or an increase of the more lucrative steam heat supply when required.

Owing to the increased refuse throughput and the optimized steam cycle arrangement, the heat utilization rate was high: In the course of the past years, for example, the comparative savings in light fuel oil was between 422,000 and 480,000 barrels (67,000 and 76,000 m³) per year.

A short glance at the total operational results of the three Paris incinerators in 1976 shows the following:

Refuse quantity incinerated was 1,630,000 tons (1,478,000 t) and the heat released by incineration alone was 104,600 MWh of electrical output and 2,217,000 tons (2,011,000 t) of steam for district heating. The electrical output was equivalent to the consumption rate of about 200,000 residents for household purposes. In addition, the steam supplied to the district heating network met 7 percent of the total heat demand of downtown Paris and 33 percent of the steam distributed by C.P.C.U. (Paris district-heating company). The equivalent savings in light fuel oil was approximately 1,193,000 barrels (190,000 m³) per year.

EXAMPLE 5. MUNICH-NORTH II POWER STATION (GERMANY)

In the four high-pressure blocks of the two power stations, Munich-North and Munich-South, refuse is burnt on large stoker grates to supple-
ment the heat released by pulverized coal (North) and natural gas (South). As an average, over the years, the refuse heat represents a minimum of 10 and a maximum of 25 percent of the total heat release of the Benson type steam boilers, according to their block size.

By integrating the refuse incineration equipment into coal-, oil- or gas-fired steam boilers of municipal power stations, specific capital and operational expenditures were cut down considerably as many of the plant facilities and operators are used in common by the two combustion systems.

Munich-North II went on line in 1966. This power station block is of particular interest because it could be a pattern for integration of a burning grate into pulverized-coal fired boilers. The “reverse-acting” grate of the North II block with a capacity of 44 tons (40 t) of refuse per hour is 37 ft (11.3 m) wide and 27.5 ft (8.4 m) long, so it would fit perfectly into the furnaces (most of which are a square section) of big pulverized-coal fired boilers.

Utilization of fuel heat is optimized by the high steam quality of 2560 psi/1005 F (176.5 bar = 17.65 MPa/540 C) and a 112 MW multiple tap-off condensing turbine.
FIG. 11 OPERATIONAL RESULTS OF MUNICH-NORTH II, 1974-1976

The particularly high thermodynamic efficiency expresses itself in a high savings rate for fuel oil, i.e., in 1976 Munich-North II saved 174,000 barrels (27,700 m³) and the total quantity saved for all Munich plants was 410,700 barrels (65,300 m³). During the past 3 years, the refuse heat yield from the four Munich power station blocks covered more than 10 percent of the annual municipal electrical consumption, industrial power requirements disregarded. When referred to one resident, this means a production of 160 to 170 kWh covering more than 18 percent of the household electrical consumption. In addition, approximately 3 percent of the heat demand of the very extended Munich district heating network is met by the heat from refuse incineration.

SUMMARY

One-hundred eighty incinerators built in Europe in the past 15 years feature heat recovery and have a total capacity of 96,500 tons (87,500 t) per day. The heat recovery from these incinerators is used to generate district heat, electricity, or process steam.

These incinerators serve approximately 100 million people.

The five incinerators analyzed in this paper demonstrated the following performance in 1976:

Refuse incinerated: 1,175,865 tons (1,066,760 t)
Light fuel oil savings: 939,545 barrels (149,345 m³)

Individual refuse fired steam boilers demonstrated an annual availability up to 90 percent.

ACKNOWLEDGMENTS

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– Société Bretonne d’Exploitation de Chauffage, Rennes, France
– Heizbetriebe Wien GmbH/Austria
– Kehrichtverwertung Züricher Oberland KEZO, Hinwil, Switzerland
– Electricité de France, Traitement Industriel des Résidus Urbains, Paris, France
– Stadtwerke München, Elektrizitätswerke München, West Germany

CONVERSION FACTORS

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Key Words
Energy
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Discussion by

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For the U.S. audience alerted by the “energy crisis” to the need to stop burying energy in landfills wherever feasible, this paper is a very welcome and concise update on an impressive variety of European plants.

In discussing European practice in which the authors have been and are leaders, no mention is made of corrosion of the heat utilization equipment. In most of these plants the reason for the omission is clear, there probably was no attack by chlorides on the boiler tubes for the following reasons:

Rennes:
Saturated steam – no high temperature exposure.

Vienna:
Saturated steam – no high temperature exposure.

Munich North I:
Only 20 percent of the heat input was from refuse, 80 percent was from pulverized coal.

Munich North II:
Only 18 percent of the heat input was from refuse, 82 percent was from pulverized coal.

Munich South IV and V:
Only 12 percent of the heat input was from refuse, 88 percent was from natural gas.
Furthermore the refuse-fired boiler does not generate steam but serves as a feedwater heater for the gas-fired steam generator.

Thus, for these listed plants the probable total lack of corrosion is a result of very prudent design made possible by local conditions that were astutely exploited.

In the case of the other two plants, Paris-Issy and Kezo-Hinwil, the above conditions do not apply. Both are high temperature, power generating plants. In the case of Issy it is well known that the 770 F (410 C) steam condition there, with no chloride dilution by coal gases, has caused superheater corrosion, although not enough to curtail plant operation much or to increase maintenance costs seriously. In the case of Kezo-Hinwil the corrosion experience is unclear. Availability of the first boiler, started up in 1971, has been 86 to 88 percent, indicating no serious loss of time for tube repairs. But steam temperature is 750 F (400 C). Has there been corrosion at Hinwil? Perhaps not. Possibly the design lessons learned in Europe in the 60’s have enabled this relatively new plant to escape appreciable corrosion. Maybe the boilers are so small that their naturally high surface-to-volume ratio enables more effective cooling of the gases before they reach the superheaters. Or maybe by 1968 or 1969 when this plant would have been designed, the superheater was placed far enough away from the furnace to avoid overheating the chloride deposits on the tubes.

In a paper on the Hinwil plant presented by F. Kuehn at the CRE Conference in Montreux, November, 1975, he stated about the second boiler, then being installed: “To safeguard against corrosion, the castable refractory in the furnace is raised somewhat.” Whether the wall tubes for Boiler No. 1 had actually had some corrosion was not stated.

Another unit, Zurich-Hagenholz-3, built in 1973 by the authors’ company has been remarkably free of corrosion, apparently in part because of judicious location of the superheater as described above.

AUTHORS’ REPLY

Although the subject of our paper centered on experience with heat recovery only, we would pick up Mr. Engdahl’s suggestion to report, in a concise manner, on experience regarding corrosion attacks in the plants discussed in the paper.

We are in a position to confirm Mr. Engdahl’s statements relating to the Rennes, Vienna, Munich-North II and Munich-South IV and V plants. In Munich-North IA and IB units, however, furnace wall tube wastage was found after several thousand operating hours with frequent overload periods. Corrosion was remedied by increasing the excess air rate and lining the furnace wall tubes by means of silicon carbide stamping mass.

In spite of the corrosion and erosion phenomena noted at Paris/Issy/Moulineaux incinerator (mainly provoked by operation with overload), this plant has been able to continuously increase its yearly burning rate over the design figure, from its start-up until today. Plant design was based on a yearly burning rate of 400,000 tons. In 1971, as much as 500,000 tons were treated. In 1974, this figure was 550,000 tons and in 1976 even 578,000 tons. Corrosion/erosion attack on the originally bare metal of the furnace
tubes was overcome by a lining of silicon carbide compound on the lower half of the furnace. It was also learned to overcome corrosion and erosion damages which occurred on certain superheater areas and apparently were due to the gas flow pattern, by providing protective shields over the entrance tubes and by designing a platen type superheater partially lined with silicon carbide compound.

By carefully preparing the scheduled superheater modifications which then were carried out during the annual revision periods, the plant management succeeded in maintaining availability rates of between 80 and 85 percent with this plant.

In the KEZO Hinwil I boiler, an unfavorable gas flow pattern is to blame for corrosion/erosion damage which, however, was limited to one point, i.e., the inlet tubes of the first gas-side superheater. As a matter of preventive maintenance, some pieces of tube are being replaced during every second annual revision. No breakdown of normal operation due to corrosion trouble has occurred so far, which means that a firm grip on this problem has been obtained.

On the superheater of KEZO Hinwil II boilers, no wastage has been noted as yet.