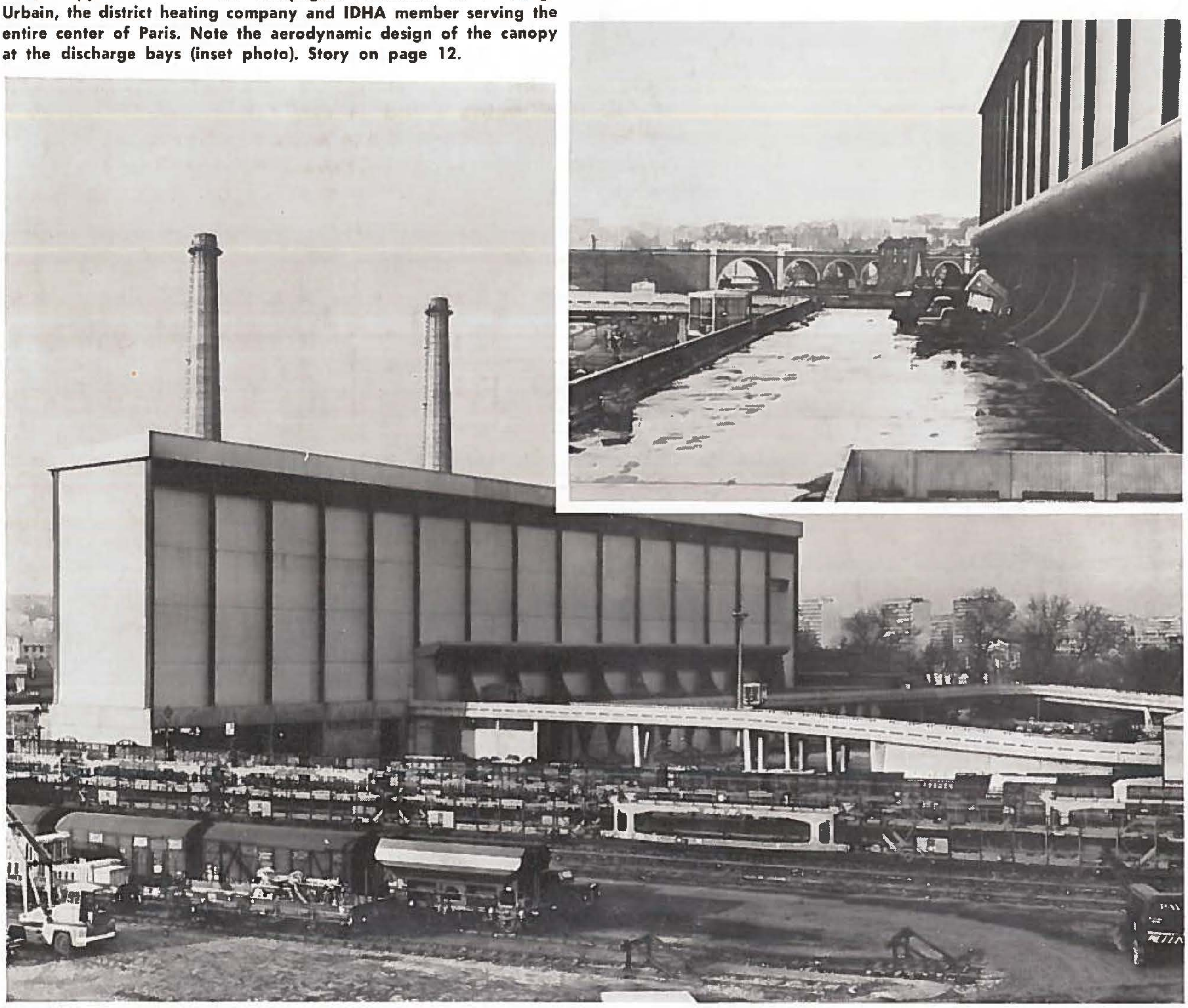
DISTRICT HEATING

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.



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WORLD-WIDE INTEREST IN DISTRICT HEATING

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Papers and Authors

"District Heating For Existing Cities As Well As New Towns and the Use of Refuse Incineration As A Base Supply For the Heating" by O. Morch and J. C. Moller, Denmark.

"The Utilization of Solid Waste As A Source Of Energy For District Heating And Cooling Systems" by Robert M. and Herbert E. Beningson, Combustion Equipment Associates Inc., New York, N.Y.

Old Cities and New Towns

In Denmark where no natural sources of coal, oil or gas exist, all fuel has to be imported and it has been necessary to find methods which would extract the maximum of usable heat economically. For heating purposes, district heating has now been successfully used for about 50 years. Today 30 per cent of all dwellings in Denmark are heated from central boiler plants, and a prognosis says that 40-45 per cent will be covered by 1975. Danish homes are fully heated and district heating meets the requirement of people who want heating and hot water available all year round. This increases the demand for heat but against this demand is decreased by the effective insulation standards required by law since 1961. One hundred per cent of new homes and 70 per cent of existing homes are double glazed.

The author breaks down the percentages of capital cost for a normal district heating plant as follows:

	Per Cent
Site, building, chimney	11
Boiler room installations	22
Mains distribution with valve chambers and drainage	43
Services mains	10
Isolating valves, meters, etc.	9
Further expenses (professional fees etc.)	5
	100

Not only housing is served but also hotels, shops, offices, factories, hospitals, schools and churches. In some cases, streets and shopping areas are heated but process loads are very rare. The heat supply is used for radiator heating as well as for warm air and air conditioning systems.

The heating medium is water and it is circulated within two temperature ranges:

LPHW with a flow temperature of 85 C (185 F), return temperature of 55 C (130 F) or
HPHW with a flow temperature of 175 C (350 F), return temperature of 95 C (200 F).

As a rule, the latter systems will be chosen for plants in high buildings and those with large individual consumers, whereas LPHW systems will be preferred for plants with many small consumers.

The first examples given by the author are of district heating systems in existing towns. One is that of the City of Aalborg, Denmark, with 155,000 inhabitants.

Heat is sold by the main power station, on the national grid, to the municipality which undertakes the distribution and also runs the oil-heated boiler houses functioning as sub-stations. At the power station, the district heating water is heated in heat exchangers by pass-out steam from the turbines. Eighty per cent of the city is district heated and the plant is still being extended. The combined thermo-electric

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production is advantageous. The effective efficiency of the power plant can, by a combined heat production, be raised from 33 per cent to over 70 per cent. As a result, the price for heat is low.

Horsens

The town of Horsens, Denmark (45,000 inhabitants) has its district heating plant owned and operated by a co-operative association and is still under construction. The capital cost of the scheme, which is still in process of development, is estimated at about 50 million D.Kr—£2.8 million.

The system used is LPHW, fed direct to the internal installations. The consumption is metered in each connected house by water meters and charged per m^3. The usual connection charge of about 20 per cent of the capital cost is paid by the consumers. The heat charge is 1.18 D.Kr per m^3. Using the average annual draw off, the standing charge will amount to the equivalent of 14.7d/therm. The fact that 20 per cent of the capital is paid by connection charges makes comparison with UK prices difficult, but the Danish price is nevertheless a favourable one.

All over Denmark heavy fuel oil is used in district heating plants. For a consumption of 7,000 tons or more per year, the price for oil of 1000-1500 sec. Redwood is 100.00 to 105.00 D.Kr/metric ton, equivalent to 5.6d to 5.9d/gal.

Nottingham

Turning to the British scene, the author described the City of Nottingham (population 309,740), where an extensive development scheme has begun and is planned over the next two decades. Coincident with the redevelopment and the demand for better heating standards, the Corporation has decided that the city's refuse should be disposed of by incineration when the present controlled tipping sites are used up, there being no further suitable sites available.

A suitable site for the heating and incinerating plant was found at Eastcroft on property already owned by the City. Initially it was decided to build a combined district heating and incinerating plant at Eastcroft, but during the design phase it became possible to take over an existing boiler plant and incorporate this in the system. The eventual boiler plant output will be in the region of 500 M lb/hr of steam. The district heating and incineration plant's power requirement will be met by turbo-generators which will pass out into direct contact heat exchangers to feed the district heating at 290 F.

Three distribution systems emanate from the boiler plant.

(a) The main distribution system, which is high temperature hot water and will feed development north of the boiler plant, including the main residential area, new civic centre and shopping centre.

(b) A low-pressure steam distribution from the turbine pass-out, which will serve factories within a small radius of the boiler plant. This supply will assist in maintaining the required turbine pass-out flow rate necessary for the high power requirement of the incineration plant.

(c) A high-pressure steam distribution feed from the boiler plant header reduced in pressure will feed the factories located some distance from the boiler plant.

Refuse Incineration As Base Supply

The author then turned to the specific problems involved in the use of refuse incineration as a base supply for heating.

When burning refuse, it is reduced in volume to about eight per cent, and therefore only a small area is required for tipping the sterile and odourless residue.

A careful analysis must be made of industrial and domestic waste before an incinerating plant is designed, as the calorific value varies from town to town and country to country.

For Nottingham, a current gross calorific value of about 4000 Btu/lb seems realistic.

Regarding the incinerator itself, the essential element is the grate. In the combustion zone, the temperature rises to about 1000 C (1800 F). The difficulty in supplying sufficient oxygen to all combustible parts in the inhomogeneous material demands an air excess of about 1.7-2.0 depending on the type of plant. Excess air is also required to ensure a complete combustion of the volatiles. As excess air is not desirable from a heat utilisation point of view, the aim must be to find the optimum figure. In this exercise, the complete and smokeless combustion usually has priority over the heat recovery.

The function of the grate can be considered in three phases. The first, ignition, requires heat to be in contact with the incoming damp refuse and controlled non-violent supply of primary combustion air possibly preheated.

The second phase—combustion—requires agitation to ensure that no zone is shielded from the burning mass. An even bed depth assists in good distribution of primary air, which can then be kept to a minimum. Secondary air is necessary to combust fly particles and volatile gases.

The third phase—final burn out—requires a fairly intense bed temperature with a small degree of primary air. Agitation will assist the distribution of the incandescent elements in the bed to ensure good contact with the organic elements. This is also assisted by a reasonable bed depth.

The capital cost of an integral boiler unit is generally higher than a unit comprising a refractory furnace and a separate boiler unit. It has, however, some important advantages.

(a) (1) Higher overall efficiency.

(2) Facility to provide super-heated steam for use with turbo-generators, resulting in considerable saving in running cost.

(3) Saving in capital and maintenance costs for refractories.

(b) A water-cooled furnace assists in solidifying the sticky gases and reduces considerably contamination to convection tube surfaces.

(c) A low velocity zone prior to the gases passing through the main convection tubes causes a proportion of the fly ash particles to drop out of suspension, reducing again convection tube fouling.

(d) Water tube walls with a thin refractory cover adjacent to the grate prevent clinker adhesion and scaling. Erosion of the tubes will occur, but a thick gauge tube should be used and the maintenance cost is normally less than with air-cooled silicon carbide refractories.

Recovery of the heat can take place in various ways. If the plant is used only for the production of LPHW and HPHW for district heating, a circulation system can be used.

For a plant of the size of Nottingham with a comprehensive consumption of electricity, it is economical to produce electricity for internal use. In this case, the boilers must produce steam suitable for turbines. The consumption of electricity as bought from a power station may amount to £100,000 per annum and this can be produced by local generation for about £50,000 inclusive of interest and depreciation, a saving of £50,000 per annum against an amended capital cost of £130,000.

The overall thermal efficiency of an incinerator is about 55 per cent. The traditional boiler plant has a higher efficiency of about 80 per cent. From a combined plant, the price per useful therm to the consumer can be only about 60 per cent of the normal cost for heat, taking an ideal ratio between heat load and refuse to be disposed of.

The question of heat rejection is significant. It can be arranged in different ways: cooling towers, river water, or air condensers, but rejected heat is a complete loss. If heat storage is used, this loss can be minimised by averaging out the daily fluctuation. This also gives a more economic operation when the conventional boilers are on line.

When producing electricity in backpressure turbines before the steam is used for district heating in cascade heaters, the heating output is reduced only by approximately ten per cent. Only approximately one-quarter of the electricity produced this way is required to run the plant, so there is a margin to do something else with. For example, sewage can be cleaned. Energy from a combined plant can be used for a plant based on electrodialysis as the method of cleaning the water.

There is also a method of electrolysis, developed by the Norwegian professor Dr. Foyn, which will clean the sewage of 97 per cent of the phosphates and nitrates and will chlorinate the water at the same time. This is a much higher standard of cleaning than can be achieved with traditional biological filters which leave most of the phosphates in the filters.

Cost

It is pointed out that the combination of incineration, heat production and sewage cleaning is to the public good. The cost of burning refuse without waste heat recovery will be at least £1 2s. 6d. per ton and often higher. With income from sale of heat, refuse burning costs can be greatly reduced.

If all refuse from a town is burnt in an incinerator and the same town is fully heated, the output from the incinerator would cover six to eight per cent of the heat consumption over a year.

A new type of incineration is being developed in Denmark, called "Destrugas." It aims at producing gas from refuse, but a considerable amount of heat is produced as well. The gas can be supplied to the town gas system or be burned in the district heating boilers, giving great flexibility. A test plant has been built which functions as follows.

The refuse is decomposed through heating to approximately 1000 C in vertical retorts. About 0.45 m^3 gas is produced per kg refuse. The gas extracted has the average composition shown below.

	Per Cent
Hydrogen	54
Carbon monoxide	10
Methane	10
Hydrocarbons	2
Oxygen	1
Carbon dioxide	23

After carburetting with 3.4 per cent butane, the calorific value of the gas will be approximately 4500 Kcal per N m^3 and the gas can be used mixed with ordinary town gas.

Experience in the U.S.

Solid wastes in the United States amount to more than 200 million ton/year of out-of-place materials that everyone helps to generate and almost no one wants. The present annual direct costs for solid waste collection and disposal are in excess of $4.5 billion, this sum being distributed through the present tax structure or payable by special user charges to public or private groups.

Since it is clear that it will be necessary to recycle or use the tremendous amounts of generated solid wastes it would appear that waste heat utilisation is technically and economically feasible. As the principle of incineration utilisation to produce waste heat is developed, the potential for a central, total energy and district heating complex becomes economically attractive.

Such a utility complex could be composed of a natural gas engine-generator system whose flue gases could be used to produce low-pressure steam, domestic hot water, and power to drive certain auxiliary equipment, an incinerator/waste heat boiler system and also to provide approximately five million Btu/ton of refuse burned. This energy would then be distributed through the district heating system to provide heat and absorption cooling to the connected structure.

The authors give the major components of any incineration/unit heat system as:

(1) Raw feed and storage system
(2) Preprocessing system
(3) Incinerator feed system
(4) Incinerator-boiler system
(5) Pollution control system
(6) Steam distribution system.

There are two basic approaches to handling solid waste prior to incineration—preclassify or raw feed. Raw feed systems are the standard for municipal incineration. There is a crude separation of what is referred to in the United States as bulky waste—cars, tree stumps etc. from normal municipal waste. This separation is primarily due to the size of the incinerator charging gate, and the retention time required for flame reduction of the material. In cases where it is planned to use solid waste as fuel for energy generation, it is unacceptable owing to the poor combustion characteristics of such furnaces.

Preprocessing of the solid waste is believed to be an absolute necessity, if even a quasi-satisfactory combustion furnace is to be designed. A number of preprocessing steps

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should be involved in the feed system. In a shopping centre, for example, the solid waste which is 95 per cent dry could be picked up in a mobile unitised train. The tipple-hopper cars could act to preclassify the solid waste by limiting their length to five ft and thus no waste larger than this would be delivered to the incinerator-boiler. The tipple car-train would deliver its load of solid waste (approximately 600 lb per car has been found to be ideal) to a vertical wide-mouth receiver unit.

The receiver should have divergent walls (one inch per lineal foot), to avoid bridging and then deliver the solid waste to a controlled-fed conveyor system (cfcs). A controlled-rate conveyor system is an absolute necessity for successful operation of a high-speed shredder. The cfcs can also act as a classifier in that very dense material, such as bar stock, electric motors, steel plates, which could markedly increase wear on the shredder, are allowed to "fall through" a gravity trap prior to the shredder. The conveyor should be equipped with a variable-speed drive system for precise control of the feed rates. In some applications in which metal recovery may be an economic factor, the final conveyor drive could be equipped with a magnetic drum which further preclassifies the solid waste prior to it entering a shredder.

Solid Waste Preprocessing

Preprocessing shredders can be categorised into three basic types. The first is a crusher in which the solid waste is literally crushed by traversing through a series of massive gears which smash and resmash the material until it is reduced to the selected size range. Such systems require large horsepower and rather massive internal components.

The second system is essentially a hammer-mill which shreds the solid waste by impact against a series of hammers against a solid stator element. It is characterised by medium speed and medium horsepower requirements. These systems have had exceptionally high hammer maintenance expenses.

The third, which has proved successful, is a modified pivoted hammer-mill moving at high speed between a rotating element. This results in a ripping and tearing action which rapidly reduces the solid wastes to the selected size range. Many experiments were undertaken before proper design was finalised.

Incinerator

After discharge from the shredder, the shredded, homogenised solid waste can be discharged to a vacuum-pneumatic duct where it is picked up and lifted into a storage bin. Since the solid waste from a shopping centre is dry, there are few odour problems. It is extremely important that storage bins have slightly diverging walls. It is found that the bridging problem is of some magnitude but it can be solved in this way. If sprinkler protection is required, it should be installed uniformly approximately one foot below the upper bin section. However, the potential fire hazard is minimal due to the compaction of the shredded solid waste and lack of air circulation in the covered storage bin.

The shredded waste can then be gravity-fed to a pneumatic feed system which sprays the material into the incinerator-boiler unit. The supply ducting should be divided into at least two water-cooled feed gates to prevent "humping" of fuel on the grate.

Incinerator-Boiler System

Although the principles of proper combustion have been well-known and understood by American boiler manufacturers, the authors maintain that these principles have rarely been applied to incinerators. As a result, incinerators, especially of the apartment-house design have been condemned and in many cases barred in the U.S. Only recently have firms begun to design incinerators as combustion furnaces first and incinerators second. In Europe, modern municipal incinerators are designed for much higher burning temperatures, adequate mixing of air with the fuel, and an eye toward improved operating efficiency. The addition of efficient air-pollution control equipment has permitted these installations to be installed within the communities, thus greatly reducing a major cost factor in solid waste management—transport.

It is therefore necessary to design an incinerator-boiler system as a combustion system incorporating the basic principles of time, temperature, and turbulance to achieve not only good burning efficiency but minimal particulate discharge and resultant air pollution.

When the solid waste has been shredded and homogenised, it can be treated in a manner similar to wood chips and sawdust. In one instance, it has been possible to utilise a conventional steel firebox with long waterlegs modified for side feeding. In preference to a metal grate, the unit can use a refractory checkerboard grate which greatly reduces the maintenance costs. Ash removal should utilise pneumatic feed system energy to accomplish removal. A horizonal fire-tube boiler drum can then be set on top of the combustion chamber to receive both radiant and convection heat transfer. Large diameter convection tubes are required to prevent fouling of the heat transfer surfaces. In most cases, a three-pass drum has been found to be the most satisfactory.

In the convection portion of the incinerator-boiler unit, steam at a pressure of approximately 13 lb/in.^{2} was produced. This steam was then piped to either the district heating system or to low-pressure absorption refrigeration machines. No provisions for no-load conditions are made since the load study revealed that this condition did not exist.

Air Pollution Control

The flue gases, after they have given up the majority of their heat, exit at a temperature of approximately 325 F (163 C). These gases, although relatively low in particulate levels are then sent into a multi-jet wet scrubber of a design that has no internals which could be clogged or eroded by foreign matter. Therefore, a very low pressure drop is designed into the scrubber and the required fan horsepower is very low (10 hp). The scrubber thus allows the installation of this system in any locality to meet even the most stringent air pollution regulations. In most localities the overflow water from the scrubber is drained into the sanitary sewers. In cases where the laws do not allow direct drain, the waste water is processed through a thin-bed sand filter before the water is sent to the sanitary sewers.

Finally, the scrubbed flue gas is exhausted into a metal chimney of short height. The resulting effluent is not visible and there is no smell.

The authors conclude that the rapidly developing technology combined with systems engineering principles will permit the design, installation and operation of pollution-free incineration. In addition, the most complete recycling of wastes can be incorporated to a system even as small as 2000 lb/hr. □