# DISTRICT HEATING

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## REFUSE INCINERATION—HEAT RECOVERY PLANTS: ENGLAND JAPAN

## ANNOUNCING THE NEW IDHA "MEMBER" SEAL



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# Nottingham Refuse Incineration and District Heating Scheme

On September 20th Nottingham City officially opened its refuse incineration complex and the extensive district heating scheme powered by heat generated from the combustion of the City's waste. The logic of a scheme such as this is simple and obvious, and it is an encouraging sign to see it being put into practice on such a grand scale.

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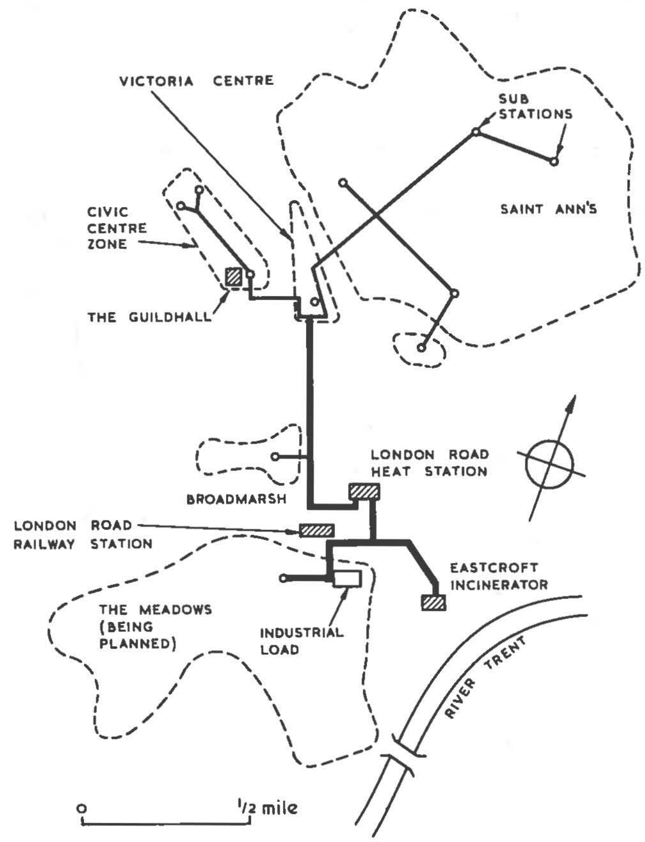


*Fig. 1*—Map showing geographical layout of the district heating scheme.

In an age when packaging is considered an art form, with aesthetic value based on the premise 'the more the better,' refuse disposal is becoming an increasingly painful headache for many local authorities, with tipping space becoming both scarce and expensive. Nottingham Corporation has turned this discomfort to their advantage by burning the city's rubbish, and at the same time generating heat to meet the demands of a large sector of the city. Their £5 million Refuse Incineration and District Heating Scheme, a project undertaken jointly with the National Coal Board, is the biggest of its kind in Great Britain.

The gross calorific value of refuse has been increasing in recent years, with the maximum approaching one-third that of coal, and the future trend is upwards.[1] With improving technology in the field, refuse incineration thus has considerable potential, but estimates by a D.o.E. Working Party on Refuse Disposal in 1971 indicated that about 15 per cent of local authorities incinerated their refuse and this level would rise to only 20 per cent by the early 1980's.[2] The Nottingham Scheme therefore has considerable pioneering importance to demonstrate that, with the thoughtful utilisation of waste heat, capital intensive incineration plant can be an extremely worthwhile investment in the future.

It seems logical, when disposing of large quantities of material with a reasonable calorific value, to make some use of the substantial amount of heat released on incineration. The amount of refuse from a given area is fairly constant throughout the year, therefore the ideal situation occurs when there is a constant base load to absorb the energy produced. Heating is a seasonal demand with a high winter load and a low summer one, and is obviously not tailored to meet the above requirement. Electricity demand is also seasonal, but the variation is far less marked and the existence of a significant year-round base load makes this a logical outlet for incineration waste heat. The electricity generating authorities, however, do not appear to share this opinion and so far have practically ignored refuse as an acceptable fuel to be utilised in the national interest. In view of this situation, electricity generation was not pursued as the prime mode of waste heat recovery at Nottingham.

In 1967, when it was decided to incinerate, Nottingham was planning a major programme of urban renewal extending over a considerable number of years and covering large areas of housing ranked as sub-standard. It was therefore decided, after a feasibility study was carried out by Associated Heat Services Ltd. (an associate company of the National Coal Board) and Pell, Mørch and Partners, Consulting Engineers, to utilise the waste heat from incineration to provide district heating for the proposed new housing estates. In addition, heat was to be used for Council offices, educational establishments, and commercial premises, with plans for supplying industrial steam loads as well. As mentioned above, the application is somewhat less than ideal. The heat production-load diagram (Fig. 2) shows that during the summer months most of the heat produced must still be wasted, while top-up heat is required during the winter.

A secondary source of heat was thus necessary to supplement the incinerator output in winter, and to act as standby to the incinerator during the summer maintenance operations. The initial scheme included a coal fired station as the secondary heat source, sited in the same complex as the incinerator, but during the planning stages a redundant power station in London Road, formerly operated by the Boots Pure Drug Co., became available. This had boilers and back-pressure turbo-generators of suitable capacities, so the station was purchased, reconditioned and brought into the scheme. The use of coal as the secondary fuel ensures a long-term market for the local mines and the generators at London Road are capable of supplying the total electricity needs of the whole scheme, two important bonuses for the planners.

The commissioning of the scheme was timed to coincide with the housing and commercial developments in the city centre, and all the new buildings are connected to the hot water mains. At a later stage, the neighboring urban districts of Beeston and Stapleford, Carlton and West Bridgford, and the Basford Rural District Council have agreed to share the use and cost of the incinerator. This will bring the population served (from a refuse disposal point of view) up to 460,000 and the input of refuse to the maximum plant capacity of 180,000 ton per year. By 1980, when the scheme is scheduled to be completed, the heating load will be equivalent to 13,000 homes.

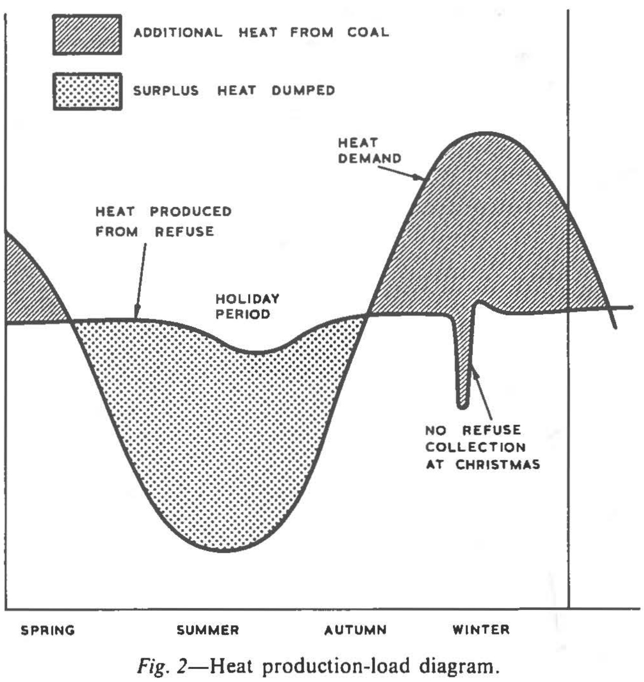


*Fig. 2*—Heat production-load diagram.

**Eastcroft Incineration Complex**

The incineration complex is sited at the City Engineer's Department main works and vehicle maintenance depot at Eastcroft. The design of the building by Pell, Mørch & Partners, assisted by their parent partnership Pell, Frischmann & Partners, is purely functional to satisfy the operational requirements, provide the necessary storage space for refuse and residuals, and protect the plant from the elements. Consulting Architects Messrs. Rosenberg & Gentle have, however, conspired with the consulting engineers and the City to produce a fairly attractive building, as incineration plants go. The structure of the building is a combination of *in-situ* reinforced concrete and structural steelwork. Externally concrete surfaces have a board-marked finish, while the steel framework is clad with plastic coated steel sheeting and steel roof decking in dark blue and grey. The structure, the main elements of which can be seen in Fig. 3, has been designed to house four lines, but has been equipped initially with two, each capable of handling 11.5 tonne of refuse per hour.

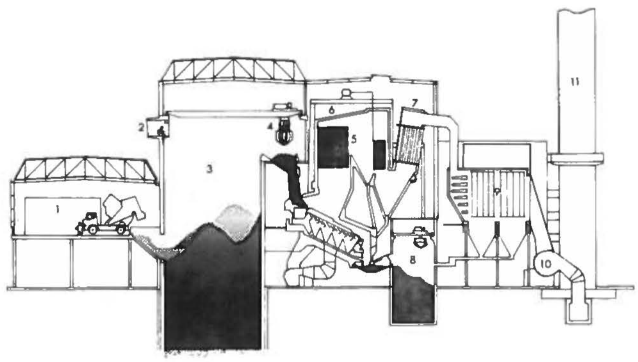

*Fig. 3*—Cutaway sketch of Eastcroft Incinerator: (1) Reception hall with truck at tipping bay (2) Crane control cabin (3) Refuse silo (4) Grab crane (5 and 6) Boiler with pendant superheaters (7) Multi-tube waste heat boiler (8) Residuals silo (9) Electrostatic precipitator (10) Induced draft fan (11) Chimney.

The reception hall, 7 m above ground level, is reached by a two lane semi-circular access ramp. From this level refuse is tipped directly down an inclined chute into the refuse silo. Vehicles then leave the building by way of a single lane ramp at the other end of the hall, returning to the weigh-bridge at the entrance exit to the site. They are weighed entering and leaving to give the weight of refuse delivered, although regular users' vehicles will be tared so that the weight of refuse can be calculated from a single weigh-in.

The two compartment refuse silo has a capacity of approximately 13,500 $m^3$ (17,500 $yd^3$), or about 4250 tonne of refuse. Two Vaughan cranes equipped with cactus type grabs are operated from a control cabin built high into the south wall of the silo. These are used to trim and level the incoming refuse to obtain maximum storage capacity and feed the refuse into the boiler chutes. The operation must be carried out such that the refuse is constantly circulated so that it is disposed of from all depths in the silo, avoiding excessive putrefaction and decomposition heat from the lower levels.

Although the reception hall and refuse silo extend the full width of the four boiler lines, the boiler hall at this stage only covers boilers 1 and 2, with 3 and 4 to be added when required. The appointment of the contractors for the incinerator boilers was largely influenced by the choice of basic design of grate. Tenders received covered various types of grate including sliding reciprocating, rocking, horizontal moving, and continuous rotary drums, and the relative advantages and disadvantages of each were carefully studied. It was found that a grate providing a 'tumbler action' had a considerable advantage over other types in that it prevented a rapid burn through of an area of the grate containing highly combustible material, leaving a hole in the fire bed with consequent loss of air to other sections. It also prevented the opposite effect if, for example, a large amount of wet market refuse was loaded onto the grate.

Most of the large successful incinerators on the Continent, as well as the GLC incinerator at Edmonton, use the inclined tumbling action grate which mixes the refuse thoroughly, avoiding the above difficulties. Taking into account all the factors, the consultants and the acting City Engineer recommended the Martin stoker. This is manufactured in Munich, and handled under license in the U.K. by Head Wrightson Process Engineering Ltd., who were accordingly awarded the contract for the grates and boilers.

The boilers are essentially of water tube design with membrane wall construction, and each consumes 11.5 tonne of refuse per hour. The hot combustion gases (800 C) transfer heat by radiation to the water walls of the combustion chamber and the pendant superheaters, and by convection to the multi-tube waste heat boilers at the rear. Each boiler line produces 7.6 kg/s (60,000 lb/h) of steam at 2.7 MPa gauge (400 lb/in.$^2$ g) and 371 C (700 F). The gases pass through Lodge Cottrell electrostatic precipitators where all fine dust particles are removed, then on to a 91.5 m (300 ft) high concrete chimney. This is insulated internally with a 225 mm (9 in.) thick wall of moler brickwork, and is divided into two separate shafts by a similar wall of moler brick.

Ash and incombustibles are removed from the boilers via a ram and water trough to the residuals silo, into which dust collected from the precipitators also passes. This silo is equipped with a smaller version of the Vaughan grab crane which is used to transfer the residuals either directly to skips or to the metal reclamation unit, where an electromagnet is used to salvage ferrous metal from the waste. The volume of the refuse is reduced to approximately 10 per cent and the inert residuals can be used for in-fill purposes.

The boilers are capable of firing on coal middlings as well as refuse. In the unlikely event that refuse is in short supply (although a strike of collectors could create this situation) the refuse can be supplemented or replaced by middlings to keep the incinerator boilers functioning. Animal carcasses are not fed into the main incinerator as it was found that they were not always completely burned. A separate Plibrico incinerator on the Eastcroft site is provided for this purpose.

**London Road Heat Station**

The purchase of the London Road Heat Station (Fig. 4) determined to a large extent the operating conditions for the low and high pressure steam systems. High pressure steam is transmitted through the main between Eastcroft and London Road and can also be supplied to the Meadows area to potential industrial loads. The steam raising plant at the Heat Station itself consists of three Babcock & Wilcox cross tube marine water tube boilers, fired on smalls from the Gedling Colliery, each with a maximum continuous rating of 5.7 kg/s (45,000 lb/h) of steam at 2.4 MPa gauge (350 lb/in.$^2$g) and a final temperature of 344 C (650 F). The area of the site is sufficiently large to accommodate two additional boilers of 10 kg/s (80,000 lb/h) capacity which are planned for future installation.

*Fig. 4*—London Road Heat Station.

During its life as the Boots Station, a number of modifications were made to the two back pressure turbines so that there was a choice of low pressure steam conditions at the exhaust end. After due study, the nominal conditions were fixed at 400 kPa gauge (60 lb/in.$^2$g). These turbines and their associated generators were originally manufactured by the British Thomson Houston Co., since absorbed into the General Electric Co. (GEC), who accordingly undertook the overhaul of the two units with modifications and extensions to the control gear.

The generators are both rated at 1.5 MW, but because of the turbine modifications one can only produce an output of approximately 1.0 MW, giving a maximum generating potential of about 2.5 MW. Since the total power demand of Eastcroft with two lines running, the system pumping load, and the Heat Station is of the order of 1.5 MW, there is ample spare capacity when both generators are running and it is not necessary to operate in parallel with the main grid. When the smaller capacity generator is out of service, the larger can just about cope with the demand but it would be prudent to run in parallel with the grid at such times. If the larger capacity generator is out of service it is essential to draw on grid supply and a demand of 600 kVA is available for this purpose.

The main pump house is also sited at London Road at the rear of the Heat Station. The ground floor accommodates the main circulating pumps, five of which are fixed speed, two variable speed, together with electrical and other ancillary equipment. On first floor level are two direct contact heaters (selected rather than indirect contact calorifiers) which convert the steam into primary main hot water. A nitrogen pressurisation vessel, used to cushion variations of pressure in the primary mains in the event of, say failure in the electricity supply to the circulating pumps, is located with the heaters on this floor. At roof level are four air cooled dump condensers, each with two speed control so that, when the waste heat from Eastcroft is in excess of the system's requirements, surplus heat can be dumped to atmosphere at eight alternative rates.

**District Heating**

The geographical layout of the district heating scheme can be seen in Fig. 1. The northern part of the initial development is fed by 405 mm (16 in.) high pressure primary hot water mains. These run west along the canal (Fig. 5), then turn north to the new Victoria Centre on the site of the old Great Central Railway Station. On the way, they feed the large commercial development at Broad Marsh via connections. This branch represents a potential connected load of 10.5 MW (35,000,000 Btu/h) and it may eventually be extended to take in the People's College of Further Education.

At Victoria, the main distribution system splits into three sections. The first of these feeds the Victoria Centre itself, which comprises large enclosed shopping areas with heated pedestrian malls together with high rise residential flats, the total connected load being 22.5 MW (75,000,000 Btu/h). The second branch feeds the St. Ann's housing re-development, which is being rebuilt in 12 phases and is about 60 per cent complete at present. The total housing and amenities represent a connected load of 42 MW (140,000,000 Btu/h), and certain adjacent loads such as the Victoria Baths and a hostel can conveniently be connected into St. Ann's at a later stage. The third branch is to a large development area known as the Civic Centre. This includes public buildings, such as the Guildhall and the Polytechnic, as well as certain commercial loads to give a total connected load in the region of 36 MW (120,000,000 Btu/h).

*Fig. 5*—Looking east along Nottingham Canal towards London Road, the high pressure hot water mains can be seen on the right bank and in the foreground.

The main development in the southern section is known as the Meadows. This is fed by a separate system running partially along the same route as the interconnecting steam mains between Eastcroft and London Road before branching south. Adjacent to the Meadows are potential major industrial loads which may be fed with either high pressure steam, low pressure steam, or a combination of both. Thus the southern artery to the Meadows comprises high and low pressure steam mains and condensate return. The Meadows housing area, on which construction work is just commencing, will contain approximately 2900 dwelling equivalents with a connected load of approximately 30 MW (100,000,000 Btu/h).

**Mains Systems**

Installations of buried distribution mains through old streets, which already conceal an intricate network of other services, can be a difficult and expensive operation. The problem was eased considerably in Nottingham by obtaining permission from British Waterways and British Rail to run primary flow and return mains through their property, and this has resulted in mains running through old railway tunnels (Fig. 6) and even bridging the tracks at one point.

With both high and low pressure steam available at the London Road Heat Station, there was a choice between these two steam conditions or hot water for both the primary links to the main areas of consumption. In the northern sector hot water was selected, the flow temperature at peak demand being 140 C (280 F) with a system pressure differential of 690 kPa (100 lb/in.$^2$). Advantage is taken of the system circulation pressure to provide anti-flash margins, and the flow temperature selected permits adequate temperature differentials for both direct and indirect sub-station heat exchange applications, minimising the size of the primary mains and therefore heat losses. At each substation the secondary mains water temperature is obtained by direct mixing of primary flow and secondary return water, to suit the temperature requirements of that particular area. Pressure is likewise adjusted by pressure control valves to suit the needs of the site. To enable stable pressures to be maintained, the primary mains operate on a constant volume basis, and the thermal inertia effect of the large volume of water circulating in the primary serves to stabilise the temperature.

In the southern sector, as mentioned above, potential industrial loads exist. This, combined with the site's proximity to Eastcroft, made steam the first choice rather than hot water, at least up to the Meadows main sub-station. Both high and low pressure steam are taken there to satisfy all types of industrial demand, and hot water for the secondary mains is produced from the low pressure steam, again by direct contact, to leave maximum high pressure availability for electricity production.

Depending on the nature of the ground, etc., the primary mains are either pipe-in-pipe or pipe-in-duct systems. In very wet ground, the pipe-in-pipe system is employed with an all welded steel outer casing protected from corrosion by a heavy duty wrapping of layers of fibre glass tissue impregnated with coal tar base enamel. In areas where ground-water is minimal, the pipes are run in concrete ducts. Calcium silicate is used as insulation in all cases because of its ability to retain its characteristics after repeated saturation and drying. With the lower temperatures and pressures on the secondary mains, simpler and cheaper forms of construction are possible. A variety of systems have been used which basically employ polyurethane insulation material contained by PVC or GRP jackets.

**Control and Metering**

The basic philosophy of the central supervisory and control system is that the continuously manned zones, i.e. Eastcroft and London Road, would not require external control, but that supervision be given on all major operating and alarm conditions. All other plant is under the complete control and supervision of the Central Control Room located in the turbine hall at London Road.

The Bailey supervisory system has the capacity to receive and diagnose up to a thousand transmissions in a three minute period, giving analogue or status information on all relevant parameters. The transmissions are automatically compared with safe reference settings, and in the event of an alarm condition details are recorded on a teleprinter. The unique facility of this system is its capability of assembling sets of conditions into various relative patterns which are more meaningful to the control operator. A maximum of 99 different mimic displays can be accommodated, with a maximum of a thousand transmissions. At present, less than half this potential is being utilised, allowing for additional capacity requirements in the future.

In the case of large point loads which are supplied by their own sub-stations or plant rooms, heat consumption is measured by mechanical integrating type heat meters, read on a monthly or quarterly basis. Domestic tenants pre-pay on a fortnightly basis when bulk meters are read in the sub-sections. Clorious proportioning meters in the individual houses are read on an annual basis and the tenants receive a rebate or adjusting account, depending on the quantity of heat consumed during the year.

**The Future**

The housing re-development at St. Ann's is scheduled for completion in 1976, and the Meadows by the middle of 1979. By this time, taking into account the additional incidental loads, it is anticipated that the total connected

*Fig. 6*—Heating tunnels being installed within the old railway tunnel leading to Victoria Centre.

load will be 132 MW (440,000,000 Btu/h), the equivalent of about 13,000 dwelling units, and Eastcroft should be burning about 200,000 tonne of refuse per year.

**Consultants, Architects, etc.**

The Nottingham scheme was financed jointly by Nottingham Corporation and the National Coal Board and is operated by Associated Heat Services Ltd. The planning was carried out by Pell, Mørch & Partners in collaboration with their two clients. They acted as consultants to both the City and the NCB.

Mr. R. C. Huxford is Manager of the District Heating Branch of the NCB which was closely involved in the design of the scheme. Overall control of the scheme is exercised by the City Engineer, Mr. John M. Gill, on behalf of the City of Nottingham.

For the civil and structural design of the Eastcroft incinerator, and modifications and additions to the London Road Heat Station, Pell, Mørch & Partners were assisted by their parent partnership Pell, Frischmann & Partners, with Rosenberg & Gentle as Consulting Architects.

The internal heating systems in the dwellings were not the responsibility of the main consultants, but were designed and installed by the Heating Section of the Nottingham City Engineer and Surveyor's Department.

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