ABSTRACT

Construction of the new refuse incineration plant in Coventry is in progress and the paper describes the processes which established the need for the plant and led to the selection of the site, the acceptance by nearby residents of that site as suitable for the purpose, and the decision to proceed with construction. The factors which determined the selection of a particular plant capacity and led to the selection of a particular refuse burning and boiler system are examined. The grate and boiler system, gas cleaning, ash handling systems and building features are described, together with the contractual arrangements for construction.

INTRODUCTION

Coventry lies in the Midlands of England, about 100 miles northwest of London and 25 miles east of Birmingham. Although an ancient city known to have existed for more than 1000 years, it began to grow in size and population only 50 years ago and has expanded rapidly since the end of the Second World War to its present population of 350,000. Growth has primarily been caused by the arrival of workers attracted to the City by the high wages which may be earned in the City's automobile manufacturing plants. These high wages have made Coventry one of the most affluent cities in Britain.

Growing affluence leading to an increasing standard of living has had its effect upon the garbage production in the city. Central heating systems have replaced the traditional solid fuel heating appliances in homes; food is increasingly bought in packaged and processed form; things which might previously have been saved and stored or burnt domestically now find their way into the garbage bin and become a part of the problem to be solved by the Municipal Authority.

In Britain the Public Health Acts make it the duty of municipal authorities to provide a service for the collection and disposal of household refuse, for the removal of abandoned automobiles and to provide centers in each area to which members of the general public may themselves bring items of bulky waste, garden refuse, etc. for subsequent disposal by the municipal authority. These services are provided in Coventry by the City Engineer's Department which arranges refuse collections from domestic premises at weekly intervals and from commercial premises in the City Center and elsewhere more frequently. In addition, items of bulky waste are removed on request by a separate service. All these services are available to the citizens without special charge, the costs being met out of the general levy of rates and taxes. There is no legal obligation upon British municipal authorities to remove trade and industrial waste and services directed to these materials are generally provided by private contractors, although facilities are provided by the municipal authority, for the disposal of trade waste delivered to the disposal point, a charge being levied per ton delivered.

SELECTION OF DISPOSAL METHOD

The rates of refuse production in the United Kingdom are much lower than those reported for the United States.
In 1970 the production of household refuse in the City of Coventry was 0.95 kg/head/day as compared with a national average figure in the United States in 1968 of 2.54 kg/head/day. The rate of generation is increasing, but this is to some extent hidden by the changing nature of refuse which is reducing in density and thereby giving an apparent stability in terms of weight generated. Current refuse density in Coventry is about 146 kg/m³ but this is expected to become approximately 117 kg/m³ by 1980, after which the density is expected to remain fairly stable. It is estimated that the volume of refuse generated per head is currently increasing at 5 percent per annum. Once the density has stabilized, the increase in volume will be matched by an equivalent increase in weight.

For the purposes of making a sensible analysis of the needs of the City in respect to refuse disposal, a curve has been plotted showing the anticipated growth in refuse yield based upon:

1. Population growth as predicted by the City Planning Officer;
2. Refuse production increasing at 5 percent per head/year in volume; and
3. Refuse density reducing to 117 kg/m³ by 1980 and then stabilizing.

Fig. 1 shows the estimated growth of refuse volume and of refuse tonnage.

At the present time the City's refuse is disposed of by sanitary landfill methods at sites within 6 miles of the point of collection and this allows the material to be taken directly to the tipping sites by the collection vehicles. These nearby sites are approaching exhaustion and any future landfill sites would lie at greater distances from the City. In order to determine the most appropriate course of action for future disposal, a detailed appraisal of alternative methods was made in 1968 which led to a full economic assessment of three alternative courses of action. The assessment took into account all the costs of collection of refuse, its treatment and its final disposal, related to each alternative. The three methods of disposal subjected to this examination were:

1. Collection and transport in the collection vehicles to tipping sites at an average distance of 10 miles from the City Center and disposal by methods of sanitary landfill.
2. Collection and transport from the collection area to a point near the City Center, pulverization of the refuse at the central site, transport of the pulverised material to tipping sites at a distance of ten miles from the City Center and tipping of the pulverized material at these sites.
3. Collection and transport from the collection area to a point near the City Center, incineration at the central site and disposal of the incinerated material at sites within three miles of the incinerator.

The results obtained from this economic appraisal are shown in Fig. 2 and indicate that while sanitary landfill was initially more advantageous, growth in refuse requiring treatment led to its displacement by incineration as the most advantageous disposal method, the advantages increasing with the passage of time. The assessment suggested that 1973 was the year in which the operation of a major incineration plant would be likely to have become the most economic method. The City Council accepted that this should be their course of action and resolved that an incineration plant of the most modern type should be designed and constructed such that it could be commissioned in the financial year 1973-74.

SITE SELECTION

With the method of future disposal established, a study was made of various possible sites for the plant. Particular thought was given to the effect which the selection of a particular site might have upon the operating efficiency and cost of the refuse collection system. It became apparent that a site near the City
Center was desirable, that it should have good road communications and have easy access from a main road. The site finally selected lies approximately one mile from the City Center, is close to one of the City’s main radial roads and is in a location provided with some natural screening. The land was the site in 1878 of the first sewage treatment works serving the City and was still in use as a sewage storm water station planned for abandonment in 1971 with the completion of a new trunk sewer serving the area.

The City Council was very conscious of the alarm which would be caused to neighboring residents when it became known that a refuse incineration plant was to be constructed. At that time, late in 1968, the new techniques of refuse incineration and the very high standard of plants which could be achieved were known only to very few people in the United Kingdom. The mere name “refuse incinerator” would evoke opposition! It was, therefore, decided that the plant would be known as the “Waste Reduction Unit”. The cooperation of the local newspapers was obtained and articles were published explaining fully what was proposed, showing illustrations of high quality European plants and expressing the firm intention of the Council to build a plant which would be operationally efficient, of high visual quality and in a form that in its existence and operation would have no adverse effect on the environment of the neighborhood. Every householder in the area surrounding the proposed plant was circularized with a letter explaining the proposals and invited to attend a public meeting in a local school. At the meeting further explanations were given, a model was on display, films of various overseas plants were shown and many questions were answered. A large proportion of the local residents attended and were satisfied that there would be little detriment to their interests if the construction of the new plant went forward.

As a result of the steps taken to inform public opinion, no objections were made by any member of the public when the proposal was advertised as required by the Town and Country Planning Acts. Further publicity has been given throughout the development of the project at key stages so the public affected could be consulted and informed about the project.

**SIZE OF PLANT**

With continuous growth of refuse yield predicted, it was necessary to select a plant size which would meet the city’s needs for a number of years without need of enlargement, while limiting the excess capacity in the early years after completion. It was eventually decided that the plant should be so sized as to be committed to operate 12 shifts of 8 h each per week when dealing with the refuse that was predicted to require disposal five years after commissioning date. The curve of future growth indicated that this condition would be met if a plant were constructed with a capacity of 35 tons/h. It had been decided that a high degree of reliability was needed in the plant since the refuse collection system was to be reorganized in a manner which placed full reliance upon the continuous availability of a central disposal point. It was therefore considered necessary that the total capacity should be provided in three separate furnaces so that non-availability of any one furnace would reduce total disposal capacity by only 33 percent and allow disposal through the plant to continue without serious difficulty. These considerations led to the decision that the new Coventry Plant should comprise three furnaces each of 12 tons/h capacity.

The officers of the Department of the Environment were not happy with the basis of sizing which had been used or with the predictions of future growth which they considered excessive. Their view was that the selected size should be such that the plant could deal with the refuse expected in the year after commissioning when operating for 10 shifts per week. Happily the use of this method of sizing led again to a plant of approxi-
mately 36 tons/h so that the proposals which were in course of development were acceptable to the Department.

The availability of three 12 ton/h units allows a high degree of flexibility and, although the use of all three furnaces for 10 or 12 shifts per week was the basis of size selection, it is unlikely that the simultaneous firing of all three furnaces would in practice be adopted. It is more probable that the plant will be operated with two furnaces fired for 15 or 18 shifts per week with the remaining furnace held as stand-by capacity or be under maintenance. Fig. 3 gives some indication of the flexibility available and also of the manner in which the plant capacity will become committed to a growing extent with the passage of time.

**FURNACE SELECTION**

From the earliest stages of the project it had been accepted that the plant should be of modern moving grate design and that the requirements of the Clean Air Acts would necessitate the use of electrostatic precipitators. Practice in Continental Europe has generally associated refuse furnaces with steam raising plant and often with power generation, while in the United Kingdom practice has favored the use of spray towers for the cooling of the flue gases. The nature of the Continental plants has led to complex, high performance boiler systems with costs higher than are acceptable in the United Kingdom. Spray towers, while involving lower capital costs, have the following disadvantages:

1. The high cost of water consumed in the cooling process;
2. The loss of the valuable energy available in the hot flue gases;
3. The emission from the chimney stack of large quantities of water vapor giving rise to an unsightly steam plume; and
4. The difficulties of incorporating spray towers into a building design which is of high aesthetic quality.

The designers approached the matter of selecting the furnace equipment with a preference for a boiler system but feeling that it would be difficult to justify on economic grounds. This was particularly so since there was no immediate demand for any steam which might be produced and the heat would have to be dissipated to waste. Only if a boiler system less complex than those on the Continent could be devised would the costs be such as to make it economically viable.

Preliminary conversations were held with all of the contractors active in the field of incineration and their views on heat dissipation were particularly sought.

It became apparent from the discussions that a number of the contractors were conscious of the need for new thinking if refuse plants incorporating steam raising plants were ever to be viable in the United Kingdom and that some were developing proposals to this end. It was also clear that the use of at least some part of the produced steam within the plant could contribute towards the viability of such installations. The generation of electric power for sale is not a practical proposition in any but the very largest plants since the sale of electricity is a monopoly of the State Generating Boards and generation on the scale necessary only for plant use did not seem to us to be a suitable or economical course of action. It was, however, possible to effect substantial savings in the electric power which would need to be bought, if the major power-using station auxiliaries prime movers were powered directly by small steam turbines. This, in itself, could make a major contribution towards the economic justification of steam raising plant and it was adopted as a general design concept.

As a result of discussions extending over some months an outline performance specification was prepared. This covered the supply and installation of grates, furnaces, boiler equipment, forced draught fans and auxiliary equipment for three units each of 12 tons/h capacity. Tenders were invited from six of the contractors who seemed best able to meet the requirements set out in the
Specification. Tenders were received early in 1970 from all of those invited to tender, each contractor submitting an offer based upon his own interpretation of the most appropriate equipment necessary to meet the performance requirements. Brief descriptions of the nature of the various offers and the value of the bids is set out in Table 1.

Table 1

<table>
<thead>
<tr>
<th>Contractor</th>
<th>General Description of Proposal</th>
<th>Tender Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Reverse acting reciprocating grate with water walls followed by shell and tube heat exchanger (Grate supplied under German Licence)</td>
<td>£1,057,603</td>
</tr>
<tr>
<td>A1</td>
<td>Reverse acting reciprocating grate with water walls and Continental type four pass boiler system (Grate supplied under German Licence)</td>
<td>£1,717,705</td>
</tr>
<tr>
<td>B</td>
<td>Reciprocating grate in refractory lined chamber followed by rotary kiln discharging gases to waste heat boiler (Grate and kiln supplied under Danish Licence)</td>
<td>£1,101,905</td>
</tr>
<tr>
<td>C</td>
<td>Reciprocating grate with water walls and four pass boiler system (Grate supplied under American Licence)</td>
<td>£1,168,632</td>
</tr>
<tr>
<td>D</td>
<td>Reciprocating grate with water walls and four pass boiler system (Grate supplied under Japanese Licence)</td>
<td>£1,174,790</td>
</tr>
<tr>
<td>E</td>
<td>Roller Grate in refractory lined chamber followed by waste heat boiler (Grate supplied under German Licence)</td>
<td>£1,388,169</td>
</tr>
<tr>
<td>F</td>
<td>Reciprocating grate in refractory lined chamber followed by waste heater boiler (Grate supplied under Swiss Licence)</td>
<td>£1,550,000</td>
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</tbody>
</table>

Upon receipt of the tenders they were examined as to their technical content with particular reference to the lowest tenders received. At the same time, on the basis of information supplied by the various contractors, a detailed analysis was made of estimated costs for the operation and maintenance of the various systems proposed by Contractors A, B and D. The analysis took account of those factors which were likely to be variable between the contractors and ignored common factors. A further case was examined which assumed that the Scheme offered by Contractor B was modified by the substitution of spray tower cooling in place of the waste heat boiler. The results of the analysis are set out in Table 2.

Table 2

<table>
<thead>
<tr>
<th>Scheme</th>
<th>Capital &amp; Interest Costs</th>
<th>Maintenance Costs</th>
<th>Electrical Energy</th>
<th>Water Outgoings</th>
<th>Total Outgoings</th>
</tr>
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<tr>
<td>A</td>
<td>1,867,000</td>
<td>170,500</td>
<td>105,000</td>
<td>12,500</td>
<td>2,155,000</td>
</tr>
<tr>
<td>B</td>
<td>1,935,000</td>
<td>260,000</td>
<td>72,000</td>
<td>6,000</td>
<td>2,273,000</td>
</tr>
<tr>
<td>D</td>
<td>2,055,000</td>
<td>128,000</td>
<td>79,000</td>
<td>26,000</td>
<td>2,288,000</td>
</tr>
<tr>
<td>B (Spray Tower)</td>
<td>1,575,000</td>
<td>260,000</td>
<td>283,000</td>
<td>237,000</td>
<td>2,355,000</td>
</tr>
</tbody>
</table>

The result of the technical appraisal and the analysis of fifteen year operating costs confirmed that the offer of Contractor A was most advantageous in terms both of initial capital cost and of long term operating cost. In addition Contractor A’s scheme guaranteed the smallest quantity of flue gas requiring treatment and could be accommodated in a smaller building than could any of the alternatives. Tender A was therefore recommended and was accepted by the City Council.

In submitting their tenders the various contractors were required to guarantee a number of performance criteria. These were as follows:

1. That the plant should be capable of burning refuse of 2800 kcal/kg at a rate of 12 tons/h;
2. That the residue after combustion should contain not more than 4 percent weight of unburnt carbon, 0.2 percent by weight of fermentable material, and 0.02 percent of unburnt paper and paper char;
3. That the flue gas discharged from the furnace would exhibit characteristics no more arduous for treatment than those which the tenderer was required to state in his tender; and
4. That the plant would be available for operation for not less than the percentage of total time which the tenderer was required to state in his tender.

Failure to meet all or any of these guarantee requirements over a two year period after the completion of the plant will result in the imposition of severe financial penalties.

THE FURNACE AND BOILER SYSTEM

The furnace and boiler system to be incorporated into the plant is based upon the Martin Reverse Acting reciprocating grate. Each of the grates is 3.76 m in width and 8.05 m in length incorporating fifteen reciprocating steps. The designed burning capacity of each grate is 12 tons/h when fired with refuse having a
When fully assembled the panel sections comprise a gas combustion bed. The temperature of the hot gases leaving the combustion chamber is continuously welded to the tubes along its entire length with the exception of a short length immediately adjacent to the distributing and collecting headers.

The chamber is formed with conventional panel-type water walls intended primarily to receive radiant heat. The temperature of the gases on discharge from the heat exchanger section is guaranteed to be not higher than 325 °C at any design conditions. Steam generated in both the water wall and the heat exchanger sections of the boiler rises to combine in the common steam drum which is free-standing above the water wall section. The boiler system has a design rating of 44 tons/h of steam at a pressure of 17.6 kg/cm². The plant is designed to allow for the eventual export of all steam produced for use in heating and similar schemes but in the initial stages only that small quantity of steam required for use in the turbine driven plant auxiliaries will be consumed. The greater part of the heat produced must at this time be dissipated to waste through air cooled condensers located on the furnace hall roof. These coolers will operate initially on a closed loop circuit, the steam rising into the cooler by natural convection, being cooled and condensed during passage through the condenser tubes and then falling back in the form of high temperature water to return to the

calorific value of 2800 kcal/Kg. Since the Martin System of grate construction and operation has been described in papers read at earlier conferences, it is not necessary to give these details again. The grates to be supplied to Coventry incorporate all the standard, well-tried features usually provided in this equipment.

The grate is associated with a boiler system generally as shown in Fig. 4. The combustion chamber above the fire bed is formed with conventional panel-type water walls intended primarily to receive radiant heat. The chamber is 4.5 m long by 4.4 m wide and 12.0 m high internally and is formed with 76 mm O.D. steel tubes pitched at centers of 102 mm and formed with a 25 mm x 6 mm steel fin to the adjacent tubes. The fin is continuously welded to the tubes along its entire length with the exception of a short length immediately adjacent to the distributing and collecting headers. When fully assembled the panel sections comprise a gas tight chamber construction with an internal area of 220 m². The design provides for an average heat transference in this water wall section of 31,000 kcal/m²/h and for the production of up to 15 tons/h of steam when operating at the maximum design rate of combustion. The temperature of the hot gases leaving the combustion bed will be reduced by the heat transference effects of the water walls to not more than 840 °C in the most extreme combustion conditions.

Having passed upwards through the combustion chamber, the hot gases are turned through a water tube curtain, where a further 2 tons/h of steam are produced, to flow downwards and subsequently their direction is again reversed so that they may enter the heat exchanger section of the boiler in an upward flowing direction. It is anticipated that this second change of direction will lead to the deposit of significant quantities of the dust and grit suspended in the flue gases easing the subsequent problem of flue gas cleaning. Provision is made for the collection of such deposited material and for its discharge into the furnace ash discharging system.

The gases pass from this area into the shell and tube heat exchanger which consists of an outer tubular casing approximately 2900 mm in diameter within which there are incorporated 880 tubes each 63.5 mm O.D. and 6100 mm in length. The temperature of the gases on entry to the tubes has been regulated by the water wall section to a temperature below the freezing point of the particles and it is not anticipated that any difficulty will be experienced due to the formation of deposits of material difficult to remove on the inlet tube plate or in the tubes. The velocity of the gases passing through the tubes is in the range 19 m/sec to 30 m/sec and these velocities will be self-cleansing. In the event of any over-heating of the gases entering the boiler tubes, a facility exists for the introduction of cooling water to mix with the flue gases prior to entry, thereby ensuring that conditions of plasticity in the suspended ash particles which might lead to potentially dangerous build-up in the tubes or on the tube plate cannot arise. There is provision for automatic on-line soot blowing on the inlet tube plate by means of steam. Heat transference from the gases passing through the boiler tubes to the water contained within the shell will give rise to the production of 27 tons/h of steam when the plant is operating at maximum rating. The temperature of the flue gases on discharge from the heat exchanger section is guaranteed to be not higher than 325 °C at any design conditions.

Steam generated in both the water wall and the heat exchanger sections of the boiler rises to combine in the common steam drum which is free-standing above the water wall section. The boiler system has a design rating of 44 tons/h of steam at a pressure of 17.6 kg/cm².
steam drum for re-introduction into the boilers. The steam used to power the station auxiliaries will be condensed in a separate low pressure condenser and returned to the boiler steam drum through the feed water tanks and the feed pumps. The arrangement of the boiler and the pumpless cooling circuit is protected by a patent belonging to the main contractor for the furnace and boiler equipment, Head Wrightson Process Engineering Ltd.

As has been indicated earlier, the economics of steam generation in this plant are dependent upon the use of steam turbine drives upon a number of the larger station auxiliaries. Clearly, steam from the furnace boilers cannot be available to power these auxiliaries during the starting up of the plant and for this reason an auxiliary oil fired package boiler with an output of 7.8 tons/h of steam has been included in the proposal. This boiler will raise sufficient steam to power the auxiliaries on one furnace stream during the start up stage and until that furnace is producing steam at a sufficient rate to be self-supporting. The installation of such an auxiliary boiler is more economic in the British situation than the alternative of duplicating some of the turbine drives with electric motors due to the high installed load charges which would be payable to the Electricity Authority in respect of those motors which would seldom operate.

GAS CLEANING

In the initial stages of the project, it was intended to provide each furnace with its own electrostatic precipitator and induced draught fan. Concern to maximize flexibility and standby facilities caused this initial concept to be questioned and the provision of interconnection between a given furnace and more than one gas cleaning system was examined. This was found to result in unacceptable complexity but the examination showed that a system based upon two precipitators and two induced draught fans each rated to deal with the output from two furnaces could be provided at lower cost than three precipitators and fans each rated for a single furnace. Thus, 33 percent more capacity would be available for less capital outlay.

This knowledge led to the development of the scheme which has been adopted in which the gases discharging from the heat exchanger of each of the three furnaces is discharged into a common horizontal duct. From the common duct the gases are drawn into one of the two precipitators and thence through the induced draught fan to discharge to a horizontal duct which connects to the plant chimney. It is anticipated that for a substantial part of the life of the plant, operation will require the firing of only two furnace streams. In this circumstance the plant operators will have the option of passing all gas through a single precipitator and fan and ensuring 100 percent standby of gas cleaning equipment or may operate with the gases passing through the two precipitators. In this latter circumstance the standard of gas cleaning will clearly be higher than that for which the plant is designed.

The single point of concern in this revised arrangement was that there should be satisfactory balance of draught between the two furnaces which might be connected at one time to a particular induced draught fan. This aspect received much thought with the eventual adoption of a system which is aimed at simplicity and which reduces to a minimum the number of automatically controlled variables.

Each induced draught fan is rated to handle the maximum designed gas flow from two furnaces and give the pressure necessary to overcome the system losses and provide the degree of depression at the furnace outlets which has been called for by the furnace maker. The turbine driven fans are designed to run at constant speed and to give this maximum output when the radial vane control is in the fully opened condition. The radial vane control is capable of being set in only two positions, that for maximum output and that necessary to give gas flow and appropriate pressure to deal with only one furnace operating at maximum design condition. The induced draught fans are fixed output machines for two known settings.

Thus the induced draught fans will create the conditions at the furnace outlets appropriate to maximum design combustion in those furnaces. Clearly the furnaces will operate at a point significantly below design maximum for the majority of time and therefore each furnace outlet is provided with an automatically operating damper which will impose excess head on the system at this point and thereby control the gas flow at the furnace outlet to that required for the actual operating situation at a given time. Control of the automatic damper is monitored by a closed control loop which maintains furnace pressure at the outlet, measured by a sensing device installed within the furnace area, within set limits. It is believed that this simple automatic system with only a single automatic adjustment will ensure optimum draught conditions within the furnace.

In the contract for the supply of the gas cleaning equipment a performance requirement was set which is related to the total weight of dust emitted to the chimney stack in the worst operating conditions. This limit is set at 15 kg/h for each furnace stream in operation which represents an operating efficiency of 96.5 percent.
RESIDUAL ASH AND CLINKER HANDLING

The tenders for the furnace equipment included provision for the handling and disposal of residual materials. The selection of a tender which incorporated the Martin grate meant also that the ash quenching and discharging equipment would be of the patented Martin design. The accepted tender provided for the discharge from this device to take place on to horizontal ash conveyors from which it was transferred to elevating conveyors. Both conveyors were to be duplicated and be of the rubber belt type. At the head of the elevating conveyors, the material was to be passed beneath overband magnetic separators and then the ash and the separated metals are passed to elevated storage bunkers. From the elevated storage bunker the ash was to discharge through plate conveyors to road vehicles for disposal off site. The stored metals passed downwards to a baling press and the metal bales would again be transferred to road vehicles for delivery to the metal merchants. The bunkers, baling press, etc. were to be established in a separate building connected to the main building by the elevating conveyor. This arrangement is shown diagramatically in Fig. 5-A.

It has always been clear that the Residuals Handling operation at the plant was one of the most critical factors in its potential injurious affection to the environmental amenities and after the acceptance of the tender, the consultant architect expressed concern at the separation of the ash handling building from the main building and asked that thought be given to the possibility of so amending the design as to allow its incorporation within a single building envelope. At the same time, visits were made to plants at Dusseldorf,
Amsterdam and Rotterdam where ash is disposed of through elevated bunkers discharging to road vehicles and these were clearly less satisfactory than one would have wished. Other systems seen at Nuremberg, Zurich, Basle and other centers using below ground storage bunkers with transfer to vehicles by means of grabbing cranes seemed to be more satisfactory.

A revised scheme was, therefore, evolved in which the residue handling could be incorporated in an extension of the refuse bunker building. The horizontal conveyors still conveyed the material to the eastern side of the building and transferred to elevating conveyors which moved the material into the extended bunker building. Crushers to reduce the size of the ash particles and clean metals were introduced at the change of direction of the conveyors. Magnetic separators removed the metals near the head of the elevating conveyors. The ash was deposited in a reinforced concrete bunker while the metals fell to a hopper feeding a baler situated in a basement level beneath the bunker building. The elevating conveyor system was housed beneath a reinforced concrete floor slab located at the same level as and giving access to the arrival and maneuvering area for the refuse collection vehicles. The ash removal vehicles would stand upon this floor slab alongside the ash bunker and would be loaded by the use of an overhead grabbing crane passing over the bunker and the loading area. The arrangement is shown in Fig. 5-B.

It was on the basis of this revised scheme that the consultant architect prepared his building scheme. The result was a most attractive building, but when estimates were prepared, the costs were considerably in excess of the sum provided. It was necessary to re-examine a number of aspects to reduce building costs and it was no longer found possible to extend the bunker building to house the ash handling equipment.

A further revision of the ash handling arrangement was made and the final scheme which has been incorporated into the project was evolved. Fig. 5-C shows this final arrangement.

The ash discharges from Furnace No. 1 and 2 into horizontal conveyors operating in a westerly direction while that from Furnace 3 passes on to a conveyor operating in an easterly direction, the material coming together at a chute in the center of the building where the residue is passed downwards through the crushing plant which is situated at basement level below the main furnace hall. The crushed ash discharges to elevating conveyors which pass beneath the discharge conveyors of Furnace No. 1 and 2 and raise the residue to a little above furnace hall floor level where there are overband magnetic separators. The ash is discharged southwards from the conveyor into a below ground level bunker while the metals discharge northwards into a similar bunker. The final handling of residues takes place in a narrow building attached to the eastern face of the furnace hall. An overhead grabbing crane operates throughout the length of this building loading ash from the bunker into road vehicles positioned south of the ash bunker and transferring metals into the baler feed chute located north of the metals bunker. The discharged metal bales are transferred to storage or to road vehicles by means of a second light weight magnet crane operating on the same runway track as the grabbing crane.

The enforced re-examination of the ash handling system leading to three separate schemes has led to the development of a most satisfactory arrangement which is the most economical in equipment cost and in building space requirement and has enabled the facility to be housed adequately and suitably.

**BUILDING FEATURES**

In designing the buildings to house the Waste Reduction Unit, the consultant architect has had to concern himself especially with the fact that the site of the plant is within one mile of the City Center and this has called for high aesthetic judgement. The requirements of the mechanical plant place the most fundamental constraints upon the architectural design but the architect has sought — and been given — the cooperation of the engineer in placing limitations upon the location of less fundamental items of mechanical plant thereby allowing greater freedom in the building design. The building which has been evolved is of great simplicity. The refuse bunker is of reinforced concrete construction with the upper level covered with aluminum sheeting. On the northern face the unloading positions are covered by a reinforced concrete canopy. All of the plant — furnaces, precipitators, fans etc., — are contained within a single cubic enclosure which is steel framed and clad with glass on three sides from floor to roof. The ash handling area is a low level brick structure on the eastern side of the furnace hall. A sculptured housing for the air-cooled condensers above the roof of the furnace hall has been used to bring interest to the simple building form while a shaped reinforced concrete chimney has a similar effect. The illustrations showing the model of the plant indicate the unusual and pleasing lines of the proposed building (Figs. 6 and 7).

**CONTRACT ARRANGEMENTS**

It was felt that there would be greater control by the engineer over the design development of the project if the works were to be undertaken as a series of inter-
related contracts rather than a single package contract for the whole scheme. As a result, tender documents were prepared and issued in an order dictated by the flow of information making their preparation possible and leading to the issue as the last major tender of the building and civil engineering contract, the preparation of this last contract being entirely dependent upon information which would become available after the appointment of contractors for the mechanical plant. This arrangement makes it necessary to arrange and co-ordinate liaison on site between the various contractors and responsibility for this liaison is accepted by the engineer. The contracts let are shown in Table 3.

At the time of preparation of this paper it is estimated that the likely total construction cost of the plant will be £2,650,000 ($6,350,000) giving a cost per installed hourly ton of £73,500 ($177,000) and per installed daily ton of £3070 ($7350) in terms of values ruling at mid-1971.

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Fig. 5B Ash handling — intermediate scheme.
Table 3

Contracts Let

<table>
<thead>
<tr>
<th>Contract No.</th>
<th>Description</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
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<td>1</td>
<td>Furnace and Boiler Equipment</td>
<td>£1,057,603</td>
</tr>
<tr>
<td>2</td>
<td>Flue Gas Cleaning Equipment</td>
<td>£251,617</td>
</tr>
<tr>
<td>3</td>
<td>Refuse Grabbing and Ash Handling Cranes</td>
<td>£136,863</td>
</tr>
<tr>
<td>4</td>
<td>Bulky Waste Shear</td>
<td>£39,718</td>
</tr>
<tr>
<td>5</td>
<td>Weigh bridge Equipment</td>
<td>£17,253</td>
</tr>
<tr>
<td>6</td>
<td>Refuse Bunker Doors</td>
<td>£36,550</td>
</tr>
<tr>
<td>7</td>
<td>Reinforced Concrete Chimney</td>
<td>£47,500</td>
</tr>
<tr>
<td>8</td>
<td>Power transformers and</td>
<td>£12,800</td>
</tr>
<tr>
<td>9</td>
<td>Electrical Distribution Equipment</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Building and Civil Engineering Works</td>
<td>£1,050,000 (Estimated)</td>
</tr>
</tbody>
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CONCLUSIONS

The comparatively long period between decision to construct a refuse incinerator plant and the desired commissioning date has allowed time to investigate and examine some of the accepted courses of action and for the development of variations and alternatives for some aspects. The aim has been to develop a flexible, reliable plant based upon the concept of steam raising which is economical in construction and operating costs. It is hoped that operational experience, when it becomes available, will make some contribution towards the design concepts for plants of this type and prove that incinerators with steam raising are as economical and as competitive as some of the alternatives.

Fig. 5C Ash handling – final scheme.
Fig. 6 Model of plant.

Fig. 7 Model of plant.