Incineration of Refuse in Hong Kong

J. A. WALLACE
Public Works Department
Hong Kong

ABSTRACT

Incineration of refuse has been forced upon Hong Kong by the pressure on the use of land and the nature of the refuse has presented certain problems common to incinerators working in the tropics.

This presentation briefly describes the history of incineration in Hong Kong and the facilities installed to date with an outline of experience with them. It goes on to deal with the design and selection of the new Kwai Chung Incinerator which is intended to incorporate all the lessons learned from experience in dealing with the high moisture content refuse of Hong Kong.

INTRODUCTION

Hong Kong is a British Crown Colony. It is also a rocky appendage consisting of 400 square miles of hinterland and islands on the south coast of China. Lying as it does just within the tropics 114° East and 22° North means that summer temperatures of 30° - 35°C. (86° - 95°F.) with humidity regularly reaching beyond 95% are the normal experience. In 1972 there were 2,807 mm (112 inches) of rain, most of which fell between May and September and 1973 exceeded all others in recorded rainfall, over 3,200 mm (126 inches) having fallen by the end of October. On the other hand between November and March sunny cool days make an invigorating contrast to the long hot and wet summer.

At the end of 1972 the total estimated population of Hong Kong was 4,103,500 in an area not more than half the size of Greater London. But this is not all for only 20 percent of the land is suitable for agricultural use or occupation so that four-fifths of the population live in the twin cities of Victoria and Kowloon along the narrow coastal strips on either side of Hong Kong harbour. On one side the site is flanked by the steep hills of Hong Kong Island and on the other by the hills of the Kowloon peninsula, both rising quickly to near 600 m (2,000 ft.). The steep slopes have discouraged urban sprawl; in its place we have tall buildings and congestion, indeed the highest urban density in the world. Over 3 million people live in less than thirteen square miles of built-up land (1968) at a density of about 250,000 persons per square mile or about ten times the density of New York City. Even that does not tell the whole story for in Mongkok in Kowloon population density rises to about 400,000 per square mile where in common with other parts of Kowloon one or more resettlement estates may each house 40,000 or more people.

REFUSE COLLECTION AND DISPOSAL

When typhoons, which can strike any time between May and November are added to the facts of congestion and climate in general it will be seen that refuse collection and disposal pose some considerable problems.

Responsibility for collection and disposal of refuse lies with the Urban Council working through the Urban Services Department of the Government and on whose behalf the Electrical and Mechanical Office of the Public Works Department operates the incinerator plants. Since April 1973 the Civil Engineering Office of Public Works Department has also taken over the main tip at Gin
Drinkers Bay (or Lap Sap Wan) converting it and the subsidiary tips at Chau Tau, Ngau Tam Mei, and Shuen Wan to controlled land fill operation. A search for further possible controlled tips within easy reach of the urban areas is currently in progress and although suitable sites are hard to find it is being pressed with vigor in view of the lower costs resulting from this method of disposal.

The Public Health and Urban Services Ordinance lays on the Urban Services Department the duty of collecting refuse daily from each household in the urban area; as part of their brief they collect waste from all the markets in Hong Kong and it is customary to collect one “basket” of refuse daily from factories in the urban area. Also in order that trade waste should not be dumped indiscriminately and illegally it is accepted free of charge at the incinerator plants at times of day when the press of Refuse Collecting Vehicles has somewhat subsided. Looking through the records of the incinerators it is noted that besides household and trade refuse the incinerators deal every day with about 30 tons of animal droppings from the abattoir lairages, 20-30 dead dogs and cats plus 600 rats from the Urban Services street and pest controls, together with 70-80 tons of market waste from the meat, fish and vegetable markets. Kennedy Town Incinerator too must be the only opium smoking incinerator in the world as it has on a number of occasions been the scene of the destruction of large quantities of opium seized by the Preventive Service. On one of these occasions some years ago 6 tons were destroyed at Kennedy Town under very, very, strict security conditions.

An average of 3,000 tons of refuse is collected and disposed of daily, about 2,000 tons of it by incineration. The daily, in some cases twice daily, collection of refuse enforces a method of collection which has a considerable effect on its condition when received at the incinerator plants. Refuse Collecting Vehicles tour on-street collection points to which refuse is brought at scheduled times. Here it is loaded; but open baskets of refuse waiting for
loading may be subjected to tropical rain for as much as two hours, in which time it is possible more than an inch of rain may fall. The way in which it is brought to the collecting points also has a significant effect. Every household must deliver its own refuse to the collecting point and while a very great number of households Chinese or European have at least one servant, the “amah”, who may do this, there exists a whole corps of elderly Cantonese women “private refuse collectors.” These for a fee of HK$5 - HK$10 (US$1 - US$2) per month from each household collect the daily quota of refuse and deliver it to the collection point less anything which can be sold i.e. clean cartons, tins, paper etc. However there will be few clean newspapers, cartons, reusable beer bottles or cans with tops, for the “amah” will already have removed these. Early every month a veritable wall of tidily bound newspapers appears in the entrance drives of many blocks of flats; the South China Morning Post, Hong Kong Standards and China Mails of the previous month awaiting the pleasure of the dealer. In spite of this there is always a shortage of wrapping paper in Hong Kong and although many smaller shops will still indiscriminately wrap pur­chases in old copies of the Sing Tao Jit Pao, the South China Morning Post, the Los Angeles Times or the Chicago Tribune etc., these last being imported for the purpose.

Thus when the refuse finally reaches the incinerator plant the burning characteristics on discharge to the bunkers are likely to be between 550 and 1,400 kilocalories per kilogram (1,000 - 2,500 BTUs per lb.) with a moisture content ranging between 40 percent and 65 percent according to the time of year and the weather. The rhomboid diagram in Fig. 1 indicates the limits within which the burning characteristics of the refuse fall.

**HISTORY OF INCINERATION IN HONG KONG**

Hong Kong’s refuse disposal problem is seriously compounded by the high price of land, and as in the late ’50s it was realised that the life of the main tip at Gin Drinkers Bay was strictly limited it was decided to inves­tigate the possibilities of incineration. At that time large batch plants were envisaged and enquiries were made for two but a proposal was also received from Messrs. John Thompson Industrial Construction Ltd. who had recently become the United Kingdom licencee for the Vølund System of continuous incineration. The Vølund System had been in operation in Denmark from 1932 and Switzerland from shortly afterwards, but had not at that time been applied in Britain on a large scale.

Further consideration showed this system to be more clearly aligned to Hong Kong’s needs than the batch process and in due course orders were placed with Messrs. John Thompson Industrial Constructions Ltd., for the Kennedy Town and Lai Chi Kok ‘A’ incinerator plants both of 750 tons per day normal maximum capacity.

**TYPE OF PLANT**

The Vølund System in its complete form not only in­cludes a furnace with a stepped moving grate but incorpo­rates a rotating kiln for final burnout with a bypass duct arranged so that about one third of the combustion gases are drawn past the incoming refuse in order to dry it. Owing to the ever increasing calorific value of refuse in Europe one or both of the latter features are sometimes omitted, but at that time the nature of Hong Kong refuse strongly indicated the desirability of both kiln and by­pass. They were accordingly incorporated into both Kennedy Town and Lai Chi Kok ‘A’ incinerator plants.

It was then necessary to consider means of gas cooling prior to the grit collectors to enable the latter to be operated at 400°C. (750°F.). Three main methods are available from which to choose:

- Evaporative cooling by water sprays
- Waste Heat Boilers
- Air Infiltration

Of these the cheapest method of gas cooling is probably by water spray conditioning towers. However for two 750 tons a day plants over 3,000 tons of clean fresh water is required and none is recoverable. At that time, one of acute water shortage in Hong Kong, this alone precluded consideration of spray cooling which even today would be regarded with considerable disfavour. The discharge of so much moisture into the atmosphere in addition to the high quantity already in the gases from the refuse would also have produced exceedingly persistent emission plumes likely to cause a considerable annoyance to the public.

Waste heat boilers on the other hand require only make up feedwater, reduce the gas temperature efficiently and can be used for power generation if a convenient outlet exists.

Air infiltration has the merit of simplicity but as the gas weight is increased by a ratio of more than 2:1 the size and running costs of the gas cleaning plant are thereby increased. Here for once the low calorific value of Hong Kong refuse was a favourable factor in that only a relatively small quantity of gases are produced by it. It was therefore determined to use Waste Heat Boiler cooling as far as possible with air infiltration to make up the balance. Outlets for the power generated by an in-house turbo-generator set were investigated and at Kennedy Town it was found that an adjacent abattoir could absorb a certain amount of both power and steam, the remaining
FIG. 1 HEATING VALUES OF CRUDE REFUSE

Based on: Heating Value = 8300C - 1100W Btu/lbs
               = 4600C - 610W KCals/Kg

where C and W are fractional proportions of combustible and water content of the crude refuse

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<thead>
<tr>
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<th>Annual Average</th>
<th>Worst</th>
<th>Best</th>
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<tbody>
<tr>
<td>Moisture Content</td>
<td>55%</td>
<td>65%</td>
<td>40%</td>
</tr>
<tr>
<td>Combustible Content</td>
<td>26%</td>
<td>20%</td>
<td>35%</td>
</tr>
<tr>
<td>Ash &amp; Inert Content</td>
<td>19%</td>
<td>15%</td>
<td>25%</td>
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turbine output being used to run the incinerator and the larger induced draft fans needed for gas cooling. At Lai Chi Kok 'A' the use of all the excess heat in the gases was proposed for a 2 MGD desalination plant was to be built in conjunction with the incinerator and boiler sizing was in proportion. At the last minute it was decided not to proceed with the order for the desalination plant although the boiler plant was under construction. Nevertheless outlets for power still remained as a water supply pumping station was being built nearby, a compost plant was included with the incinerator and in due course it was intended that a second incinerator plant would be built alongside the 'A' plant to which power could be supplied.

SIZE OF PLANTS

750 tons per day maximum throughput had already been decided upon as being required from the outset, and continuous three shifts working for as many days per year as possible was assumed as axiomatic. It was therefore considered that the total capacity should be provided by three furnaces with a fourth normally under maintenance but available for use at times like Chinese New Year when refuse collections double. Maintenance was of course a major preoccupation because of the remoteness from manufacturers service departments and the absence of suitable specialist contractors in Hong Kong. The plants were therefore provided with 25% standby in furnaces and gas cleaning plant, cross connected so that any one of these might be off load for cleaning and maintenance at any time without reducing the rated capacity. Stemming from this maintenance commitment a high proportion of all operators are artisans in order that all regular maintenance and the annual overhauls of the plants may be carried out by the plant staff without outside assistance. In passing it may be mentioned that operating experience and minor modification to the plants since commissioning has so increased the availability that Kennedy Town prior to its “annual” overhaul in February 1972 had run continuously for over two years.

When consideration of the foregoing was incorporated into the design Kennedy Town and Lai Chi Kok 'A' plants took shape with the following outline specification:

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Table 1 (Continued)</th>
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<tbody>
<tr>
<td><strong>Furnaces</strong></td>
<td>Four John Thompson Valund incinerators with kiln and bypass. 10% tons per hour maximum capacity each. Three normally in use on 24 hour operation.</td>
</tr>
<tr>
<td><strong>Draft Plant</strong></td>
<td>Four 20,000 cu.ft./min. Forced draft fans, one for each unit with interconnecting ducts.</td>
</tr>
<tr>
<td><strong>Grit Collectors</strong></td>
<td>Four 140,000 cu.ft./min. induced draft fans discharging in pairs into east and west chimneys, drawing from grit collectors in pairs.</td>
</tr>
<tr>
<td><strong>Ash Disposal</strong></td>
<td>Four Howden Multivortex two stage multicyclone grit collectors interconnected so that any three incinerators may operate with any three grit collectors.</td>
</tr>
<tr>
<td><strong>Kennedy Town</strong></td>
<td>Two 24 in. submerged belt conveyors passing below outlets from kilns.</td>
</tr>
<tr>
<td><strong>Lai Chi Kok 'A'</strong></td>
<td>Discharging to an inclined 18 in. dry band ash conveyor, magnetic separator over.</td>
</tr>
<tr>
<td><strong>Steam Power Plant</strong></td>
<td>Discharge from bunker by luffing belt conveyor to barges or road vehicles as required,</td>
</tr>
<tr>
<td><strong>Kennedy Town</strong></td>
<td>One 48 in. submerged belt conveyor — then as above,</td>
</tr>
<tr>
<td><strong>Lai Chi Kok 'A'</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Boilers</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Evaporation</strong></td>
<td>Four John Thompson Valund incinerators with kiln and bypass. 10% tons per hour maximum capacity each. Three normally in use on 24 hour operation.</td>
</tr>
<tr>
<td><strong>Pressure</strong></td>
<td>Four 20,000 cu.ft./min. Forced draft fans, one for each unit with interconnecting ducts.</td>
</tr>
<tr>
<td><strong>Superheat temp.</strong></td>
<td>Four 140,000 cu.ft./min. induced draft fans discharging in pairs into east and west chimneys, drawing from grit collectors in pairs.</td>
</tr>
<tr>
<td><strong>Feedwater temp.</strong></td>
<td>Four Howden Multivortex two stage multicyclone grit collectors interconnected so that any three incinerators may operate with any three grit collectors.</td>
</tr>
<tr>
<td><strong>Gas in-temp.</strong></td>
<td>Two 24 in. submerged belt conveyors passing below outlets from kilns.</td>
</tr>
<tr>
<td><strong>Gas out-temp.</strong></td>
<td>Discharging to an inclined 18 in. dry band ash conveyor, magnetic separator over.</td>
</tr>
<tr>
<td><strong>Draft loss</strong></td>
<td>Discharge from bunker by luffing belt conveyor to barges or road vehicles as required,</td>
</tr>
<tr>
<td><strong>Steam Power Plant</strong></td>
<td>One 48 in. submerged belt conveyor — then as above,</td>
</tr>
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</tr>
<tr>
<td><strong>Lai Chi Kok 'A'</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Boilers</strong></td>
<td>Natural Circulation</td>
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<tr>
<td><strong>Evaporation</strong></td>
<td>2 Drum Water Tube Waste Heat</td>
</tr>
<tr>
<td><strong>Pressure</strong></td>
<td>6,800 kg/hr (15,000 lbs/hr)</td>
</tr>
<tr>
<td><strong>Superheat temp.</strong></td>
<td>13,900 kg/hr (30,500 lbs/hr)</td>
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<tr>
<td><strong>Feedwater temp.</strong></td>
<td>17 Kg/sq.cm. (240 psi)</td>
</tr>
<tr>
<td><strong>Gas in-temp.</strong></td>
<td>295° C. (550° F.)</td>
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<tr>
<td><strong>Gas out-temp.</strong></td>
<td>140° C. (280° F.)</td>
</tr>
<tr>
<td><strong>Draft loss</strong></td>
<td>775° C. (1,450° F.)</td>
</tr>
<tr>
<td><strong>Steam Power Plant</strong></td>
<td>820° C. (1,500° F.)</td>
</tr>
<tr>
<td><strong>Kennedy Town</strong></td>
<td>430° C. (820° F.)</td>
</tr>
<tr>
<td><strong>Lai Chi Kok 'A'</strong></td>
<td>430° C. (820° F.)</td>
</tr>
<tr>
<td><strong>Steam Power Plant</strong></td>
<td>Draft loss 64 mm (2.5 in.)</td>
</tr>
<tr>
<td><strong>Kennedy Town</strong></td>
<td>76 mm (3 in.)</td>
</tr>
<tr>
<td><strong>Lai Chi Kok 'A'</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Turbo-Alternators</strong></td>
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EXPERIENCE WITH THE PLANTS

Initial experience during the first wet season after Kennedy Town was started up (1967) showed the alarming phenomena of a steam cloud over the refuse on all three grates indicating failure to dry the extremely wet (60 percent - 65 percent moisture content) refuse. Steps were taken to deal with this by re-arranging the bypass to direct a greater quantity of combustion gases more closely over the refuse on the drying grate, drawing a proportion of the combustion gases down through the refuse thereon, increasing the oil burned to as much as 450 litres (100 gallons) per hour in each furnace and lengthening the residence time by adjusting the rotational speed of the kiln. These measures eventually enabled extremely wet refuse to be dealt with (65 percent moisture content and 550 KC/Kg. 1,000 Btus/lb.) although it has been found prudent not to attempt to burn at a rate of more than 550 tons per day with three furnaces under these circumstances. In times of very prolonged wet weather it is now normal to have the fourth furnace on load to maintain 650 - 675 tons per day throughput.

In the furnaces little trouble has been experienced with fouling, the brickwork has lasted well and only now, seven years from commissioning, is a major renewal of furnace and kiln brickwork being contemplated. On the
FIG. 2A(ii) KENNEDY TOWN INCINERATOR PLANT

FIG. 2A(iii) LAI CHI KOK 'A' PLANT
other hand enough small repairs have been necessary to the common cross duct to justify the installation of dampers isolating off load sections thus enabling repairs to be effected without shutting down. No external corrosion has been experienced with generator tubes in the boilers but a small number of oxygen corrosion pits developed in the steam drums. This problem was overcome by cutting extra holes in the internal baffles to improve the water circulation and by increasing the sodium sulphite dosage to the boiler water. Erosion of the first row of superheater tubes was experienced at Lai Chi Kok ‘A’. Various remedies were tried including reversing the direction of flow of steam through the superheater elements but for some time these experiments had little effect. Eventually it was found that the trouble could be cured by welding protective strips to the leading faces of the tubes. It was also concluded that the soot blowers were too close to the tubes and so were resited further away. Subsequently it was found that an initially rapid erosion of the protective strips diminished after a period thus giving a more acceptable tube life.

Deposits of dust have caused a number of problems, different in different parts of the plants. In the ductwork before and after the boilers so much dust was found to fall out of the gases that hoppers had to be constructed along the major part of their length. The same dust led to considerable external fouling of the boilers at Kennedy Town and this continued until some generator tubes were removed from the first bank and the casings modified to provide a free fall for dust at the entry to the tube nests. In the primary cells of the multivortex grit collectors the dust has formed a deposit on the metal surfaces so tenacious that the only satisfactory method of removal has turned out to be the use of high pressure (6-8,000 psi) water jets. When jet cleaning is performed the surfaces are rendered so clean that no trace of deposit remains to form a base for new layers. This has enabled the cleaning interval to be lengthened but each unit is still ready for cleaning after four weeks of use.

Lai Chi Kok ‘B’ — The third incinerator to be built in Hong Kong is immediately alongside the Lai Chi Kok ‘A’ plant and shares the site with the former incinerator, a compost plant, and a Vehicle Service Station for that part of the Government fleet of vehicles operating in the area. Once again the need to make the best possible use of land does not allow for any space to be wasted. Construction of this plant was started in 1970 and completed earlier this year. It is an improved and simplified version of the ‘A’ plant without boilers, all gas cooling being by air infiltration. The disadvantages of air infiltration were appreciated but as there was ample boiler power at the ‘A’ plant there could be little or no outlet for steam or power for this would in any case be provided for both plants from the ‘A’ station. Fresh water although not in such
FIG. 3A(i) LAI CHI KOK 'B'

FIG. 3A(ii) LAI CHI KOK 'B' WITH 'A' PLANT IN BACKGROUND
short supply as formerly was still far too valuable a commodity to use for gas cooling. Hence air infiltration cooling of the gases was accepted in this instance. Once again the plant is fitted with a kiln and bypass for burnout of the wet refuse. In this application the plant is built in the now usual form of separate streams for each incinerator. In view of the resulting inability to cross-connect, and to counteract the likelihood of grit collector fouling as related above, the collectors have been constructed of four sub units each. In this way any one of the four sub units per incinerator line can be open for cleaning without the incinerator itself being taken off load.

**Lai Chi Kok ‘B’**

As Lai Chi Kok ‘A’ except as below. (No boilers or Turbine; power supplied from Lai Chi Kok ‘A’.)

- **Cranes**
  - Morris 6 ton overhead grab cranes with Clamshell grabs of 2 tons capacity each.

- **Furnaces**
  - John Thompson - Vølund incinerators with kiln and bypass in independent lines without cross connection. 10% tons per hour per unit continuous rating. All areas and volumes 10% percent in excess of previous plants.
  - Draught plant 10 percent increase in capacities over previous plants.

- **Grit Collectors**
  - 4 Howden Multivortex two stage grit collectors arranged for on-load cleaning and fitted with replaceable primary cells.

- **Ash Disposal**
  - 4 submerged belt conveyors each .92 M (36 in.) wide discharging to dry band conveyor system to ash bunker, with same means of discharge as for Lai Chi Kok ‘A’. Emergency ash pit with crane over.

**DISCHARGE OF GASES FROM THE PLANT CHIMNEY**

Since the commissioning of the Lai Chi Kok ‘A’ plant tall housing developments have been built to the west of the plants and only a short distance away. The plumes from the ‘A’ plant chimneys normally rise well clear but in some weather conditions and when the wind is from the east (the prevailing wind during the summer) they may drift low over the apartment buildings. At that time of the year humidity is very high, frequently exceeding 95 percent, so that the vapour in the plume is absorbed extremely slowly and remains a very visible “plume-ulus”. For the ‘B’ plant it was therefore decided to use the following guidelines on chimney design:

- Single Multiflue Chimney
  - Height: 91 M (300 ft.)
  - Height extensible later to: 122 M (400 ft.)
  - Exit velocity: 15.3 M/S (50 ft./sec.)

The chimney is now in use at 91 M (300 ft.) and it has been built in such a way that the ‘B’ plant uses two of the flues. The remaining two flues are reserved for the ‘A’ plant if it should be decided at a later stage to discharge the gases therefrom also at the higher level. At the same time it may be possible to extend the stack to 122 M (400 ft.) but this is dependent among other things on the installation of new landing aids for the approach to Kai Tak runway. Connecting the ‘A’ plant in to this chimney would of course need a major rearrangement and extension of the ductwork together with a possible need for additional induced draught fan power, while the whole question of grit collector types and efficiencies would have to be carefully evaluated at the same time in the light of conditions then existing.

**KWAI CHUNG INCINERATOR PLANT**

The need for this plant has existed for some time but as frequently happens in Hong Kong land shortage meant that the only available and suitable site was at the bottom of the sea at the time of selection. In these circumstances there was ample time to draw on operating experience with the existing incinerators to prepare a specification tailored to the particular conditions of refuse, climate and usage in Hong Kong.

Because of the ever increasing quantity of refuse and the scarcity of sites it was decided that the plant should be capable of dealing with 900 tons per day to make the very best use of the available site.

**FURNACE**

While the Vølund type grates and kiln had given satisfactory service in the existing plants it was realized that there were now several other types of grate available whose manufacturers advocate burnout by different means. To widen the field of enquiry it was decided to give consideration to the alternatives provided certain criteria regarding refuse drying and burnout were observed. The possibility of using electrostatic precipitators for grit collection was also sufficiently likely for it to be prudent to keep the gas volume at the entry to the gas cleaning plant to the minimum possible. It is still impracticable to use water spray cooling in Hong Kong, so once again steam raising plant and power generation were envisaged with the surplus steam being condensed in air cooled condensers.

**PRE-DRYING TREATMENT**

The wide and frequent rapid variations in the moisture content have resulted in fluctuations in the time required...
for drying and combustion, the net effect being sub-
standard burn out unless the charging rate can be corrected in
time to compensate for such fluctuations. It is evident that the concept of drying by radiation and convection from the flame is only partially effective, for little more than the top layers of the refuse bed receive treatment and, under some conditions, the under layers may still be high in moisture content upon the burning grate prior to the kiln. Thus even with a reciprocating grate, disturbance and turn over of the under layers are difficult when dealing with refuse containing a high moisture content.

A further very noticeable effect is the retardation of both drying and the combustion of released volatiles above the bed when large quantities of moisture vapour are contained within the combustion chamber.

From these observations, it was concluded that it was essential in the incineration of Hong Kong refuse to incorporate in any new plants, effective and flexible means of pre-drying, such treatment taking place in a chamber independent of the combustion chamber proper.

**COMBUSTION AIR**

Apart from air heated in the side cooling member of the furnaces combustion air at ambient temperature is supplied to the existing plants, and whilst this is perfectly satisfactory for the incineration of European refuse, it was evident at a very early stage that preheated air is necessary in Hong Kong. Considerable stress is therefore laid on this and on the alternative or parallel provision of hot gas for drying.

**GRATE COMBUSTION RATINGS**

The grates and kiln upon the existing plants were sized from a combustion rating adequate for refuse having a moisture content in the order of 50/54 percent. However it was too high for moisture contents in excess of this and in view of the frequency with which the refuse is found to be well in excess it was considered that the combustion rating required review. In doing so due recognizance was taken of the published experience of Mitsubishi Heavy Industries Ltd. in Japan who had related combustion chamber rating against the lower heating value of the refuse. Their findings showed that effectively to deal with refuse having a L.H.V. of 525 K.Cals/Kg. (65 percent moisture content) the combustion rating necessary was in the order of 150 K.Cals/sq.meter/hour combustion air being at a temperature of 300°C. (570°F.). This rating is half that required for present day European refuse and consequently would necessitate a grate area twice the size of that included in a European incinerator for a similar throughput of refuse by weight. The lower heating value of 525 K.Cals/Kg. is of course at the extreme end of the range expected and increase in heating value up to the design figure of 1360 K.Cals/Kg. requires an increase in combustion rating and a reduction of the necessary residence time within the system. A fully flexible grate system is therefore necessary to accommodate these variations in order to maintain constant throughput and an acceptable burnout standard.

The rotary kiln provided on the existing plants has proved eminently suitable for this purpose by virtue of the available variation in speed and consequent variation of residence time in the final burnout stages. It was decided, therefore, that on future plants the overall combustion rating should be decreased and the rotary kiln should be incorporated unless it could be shown that equal flexibility was obtainable by other means. It was considered that a nominal combustion rating midway between those appropriate for refuse values of 525 and 1,360 K.Cals/Kg. would be adequate, i.e. an overall figure of 215 Kgs/sq.metre/hour (44 lbs./sq.ft./hour) based on the effective grate area. The flexibility provided by the kiln or other burnout methods, would then be needed to accommodate the whole range of calorific values.

**GAS COOLING**

Similarly in deciding on the boiler specification the ability to burn refuse without outage was regarded as paramount and the efficiency of steam generation of but secondary importance. In this connection the inhomogeneous nature of refuse is known to lead to localized and transient reducing atmospheres above the grates in spite of fully adequate primary and secondary air supplies. A number of corrosion failures in water-wall tubes close above the grates of integral boiler plants are known to have occurred in Europe and which have been attributed to a nonuniform furnace atmosphere combined with glowing fly ash deposits. The knowledge that Hong Kong’s refuse is particularly varied and unpredictable in detail led to the opinion that integral boilers would be extremely vulnerable to such attack and that local conditions would greatly magnify downtime from such a cause. Being of this opinion and bearing in mind the above priorities waste heat boilers were once again specified, but with forced circulation to counteract the effect of transient and localized variations in gas temperatures across the boilers.

**GAS CLEANING PLANT**

When consideration came to be given to the gas cleaning plant information was also received that major housing developments are intended downwind of the plant and that some of these may be on relatively elevated sites. In
consequence electrostatic precipitators were finally specified to give an efficiency which would reduce the dust emission concentration to a level comparable with plants anywhere in the world.

GENERAL

Early in 1973, tenders were invited for the plant which was to comprise four separate units, each having a capacity of 300 tons of refuse per day. Under normal conditions three units would be in operation 24 hours per day, 7 days per week, the fourth unit being on standby duty.

The expected composition and lower heating values of the refuse to be treated was as shown in Fig. 1, and from which it can be seen that the overall range would be:

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<thead>
<tr>
<th></th>
<th>Worst</th>
<th>Average</th>
<th>Best</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moisture (%)</td>
<td>65</td>
<td>55</td>
<td>40</td>
</tr>
<tr>
<td>Combustible (%)</td>
<td>20</td>
<td>26</td>
<td>35</td>
</tr>
<tr>
<td>Ash and inerts (%)</td>
<td>15</td>
<td>19</td>
<td>25</td>
</tr>
<tr>
<td>Lower Heating Value (K.Cals/Kg.)</td>
<td>525</td>
<td>860</td>
<td>1360</td>
</tr>
</tbody>
</table>

The required guaranteed performance standards were:

(a) That the plant with one incinerator stream on standby and not in service should be capable of a throughput of 900 tons of crude refuse per day over any continuous period of seven days.

(b) The air dried residue from the grate, free of ferrous metals, should contain by weight not more than 0.3 percent putrescible or fermentable substance and not more than 5 percent combustible matter.

(c) The maximum dust discharged with the flue gas into the chimney should not exceed 0.23 grammes/cubic meter at N.T.P. (dry).

Tenders for the plant were received from manufacturers in Canada, France, Japan and the United Kingdom, and after evaluation, the contract was eventually awarded to Messrs. Clarke Chapman-John Thompson Ltd., Wolverhampton, England.

This Company had been responsible for the installation of the previous plants and their Design Engineers were fully aware of the variations from European practice which would be necessary for satisfactory performance with Hong Kong's blend of refuse.

TECHNICAL SYNOPSIS OF THE PLANT

An outline of the plant in diagrammatic form is illustrated in Fig. 4.

The refuse is transferred from the reception pit to the incinerator charging chute by grabbing cranes and initially enters a separate drying chamber which consists essentially of two Völund grates of the reciprocating type surrounded by a refractory enclosure.

With this chamber drying will be effected by:

(a) Radiation from gases emanating from the combustion chamber proper passing over the raw refuse bed and drying the top layers.

(b) The passage of recirculated flue gas at a temperature of 280/300°C. (530/570°F.) through the raw refuse bed drying the under layers.

FIG. 4 FLOW DIAGRAM—GAS & AIR, KWAI CHUNG INCINERATOR PLANT.
Ventilation drying by the passage of either hot flue gas or air had been successful in Japan for some considerable time. In this instance, the choice of flue gas as the drying medium was made for the following reasons:

(a) It minimizes the burning of easily combustible materials during the drying process by retardation of ignition so that the maximum heating value of the refuse is retained for the combustion process within the combustion chamber.

(b) More drying heat can be applied than with hot air as higher temperatures can be obtained.

(c) The specific heat of flue gas with its higher moisture content is higher than that of air.

The advantage in using recirculated flue gas is however slightly affected by the fact that the grate materials and supporting framework have to be constructed from materials capable of withstanding possible corrosion and deformation.

Sufficient moisture will be removed in the drying process to ensure that, upon discharge from the drying grate, the refuse will be in a self supporting condition from a combustion aspect irrespective of the condition at entry.

The moisture vapor released during the process will enter the incinerator bypass duct through openings located in each side wall of the chamber.

The introduction of drying gas will only be necessary with refuse worse than average value, it being theoretically self supporting at average value and above without the necessity for such treatment.

From the drying chamber, the refuse is discharged into a vertical drying chamber where further drying takes place from contact with the flow of hot gas rising from the combustion chamber. In falling, there will also be a tendency for any agglomerated refuse to break up.

From the drying shaft, the treated refuse falls on to the grates of the combustion chamber, where the incineration process commences with final burnout to the condition required taking place in the kiln.

Preheated combustion air at a temperature of 230/250°C. will be introduced into the combustion chamber both undergrate through the riddlings hoppers and overgrate through high velocity nozzles.

Variations in the value of the raw refuse entering the drying chamber will be sensed by temperature change within the chamber and modulation of the supply of undergrate drying gas to match the change of refuse value will be under the control of such a temperature signal.

The admission of drying gas will, however, have a tempering effect upon the drying chamber temperature and to compensate for this, additional heat will be provided by oil from the oil burners located within the chamber. The input will be modulated from the same temperature signal utilized for modulating the drying gas.

Theoretically, the supply of drying gas and oil should only be necessary for refuse values between 525 and 860 K.Cals/Kg. and through this range a set point temperature of 550°C. (1,020°F.) is maintained within the chamber. Above the mean refuse value, although gas and oil should not be required, a small quantity of drying gas will continue to flow to maintain the duct work at temperature and also allow the controls to immediately react should the refuse value worsen. Similarly, the oil burners will not be shut off, but maintained on “low fire” or “on/off” control. At these conditions, the drying chamber temperature will be allowed to find its own level.

Decrease in refuse value below the average will also result in an increase in gas flow from the drying chamber and variable resistance in the form of a damper is provided within the bypass duct.

With a constant input of 12.5 tons of raw refuse per hour, there will be a variation in the quantity of moisture removed in the drying chamber with each variation in refuse quality, and consequently the weight of refuse entering the combustion chamber will also vary.

To maintain a constant set point temperature within the combustion chamber, the combustion air would also have to be modulated. To eliminate this added control loop which could create operational difficulties, the combustion air quantity will be set at a constant value irrespective of any variation in refuse quality between worst and average, this quantity being based upon that required for average conditions.

Such a procedure affects temperature as the refuse value worsens, and to compensate for this, additional heat is provided by means of an oil burner located within the combustion chamber, this being controlled from a temperature signal at a set point of 850°C. (1,550°F.).

With an increase above the average value of the incoming refuse and drying gas and oil at their minimum flow rates, the combustion chamber temperature will rise and will be allowed to do so until the maximum temperature of 950°C (1,740°F.) is reached. At this point, the combustion chamber temperature control will change over and modulate the air quantity for maintenance of the 950°C. set point.

To enable combustion to take place in the rotary kiln and also limit the temperature of the combustion products, further air is required which is introduced through the transition box between the burning grate and kiln, side ports and seals. For physical and thermal reasons, this air is at ambient temperature and supplied by a separate fan. Control of the air supply is determined by the kiln outlet gas temperature and this is maintained at a set point of 950°C.

Flue gas from both bypass and kiln then enter the
FIG. 5 FLOW DIAGRAM — STEAM, FEED, & CONDENSATE.

"after burn" chamber where mixing takes place prior to entry into the radiant section of the waste heat boilers.

**WASTE HEAT BOILERS**

These are of the forced circulation type, chosen to enable the arrangement of the convection tube banks to be used and ensure that a safe flow of water is obtained through the tubes under the varying conditions of heat input. The steam and water mixture returns to the steam drum where separation is carried out by a series of cyclone separators.

The boiler enclosure is formed from welded water walls with fins welded between, and provides a fully water-cooled enclosure from the vertical entrance to the radiant inlet chamber to the outlet from all of the convection surface.

The convection heating surface is arranged in the form of pendant elements with vertical tubes, the pitching of the elements being such that the gas velocity is maintained at no more than 8 meters/second maximum. Such a configuration minimizes build up and erosion of the tubes by the dust and grit carryover, and also enables any dust fall out within the boiler to fall clear of the heating surfaces and into the hoppers below the boilers.

A superheater has been incorporated and this, once again in the form of pendant elements, is located at the rear of the boiler where it will be subject to the lowest gas temperature. Coupled with the low degree of superheat required, the possibility of corrosion will be reduced to a minimum.

The steam conditions required at the superheater outlet are 260°C. (500°F.) at 17.9 Kg/cm² (255 lbs./sq.in.). In the event of low steam flow under adverse conditions, a higher steam temperature could be experienced and therefore a design figure of 370°C. (690°F.) has been based upon.

A gas air heater is mounted in a vertical gas pass after the superheater, the air entering the heater having been initially preheated by a steam air heater in order to maintain acceptable metal temperatures within the gas air heater and minimize corrosion.

The flue gas temperature required at the outlet of the air heater is 300°C. (570°F.) irrespective of the incinerator throughput and quality of refuse. Control of this is accomplished by a system of dampers arranged in bypass ducts around part of the convection heating surface, the effectiveness of this then being modulated to elevate or depress the outlet gas temperature to the required value.

In the design of the boiler, due cognizance has been taken of the four main types of corrosion which can be experienced, namely:

(a) High temperature liquid phase corrosion,
(b) Corrosion due to nonuniform furnace atmosphere,
(c) Corrosion by HCl,
(d) Low temperature or dewpoint corrosion,
and the design parameters incorporated, both physical and thermal, should reduce the possibilities of attack by any of these. In particular the effects of (b) have influenced the choice of a waste heat boiler rather than an integral boiler.

The generated steam feeds a back-pressure turbine coupled to a brushless, salient pole alternator having an output of 2,000 kW. Exhaust steam is condensed in a low
pressure air/steam condenser and live steam surplus to the
turbine requirements is condensed in a separate high press­
ure air/steam condenser, the condensate being returned
to the deaerator.

A separate saturated steam main supplies steam to the
steam air heater associated with each incinerator unit, the
condensate also being returned to the deaerator.

The flue gas discharged from the air heater at a
temperature of 300°C. (570°F.) is directed into an
electrostatic precipitator having an efficiency of 96.7
percent, and providing a dust outlet concentration within
the gas of 0.23 grammes per cubic meter at N.T.P. (dry).
This concentration is equivalent to a dust emission by
weight of 11 Kgs/hour (24.5 lbs/hr) incinerator or 0.88
Kgs/ton (1.95 lbs/ton) of refuse burned.

A single multi-flue chimney will be provided, each
incinerator line having its own flue in order to maintain
high efflux velocities over the range of operating condi­
tions. The actual chimney height is to be 122 meters
(400 ft.) and the efflux velocity from each flue at design
condition 23 meters/second (75 ft./sec.).

DISPOSAL OF BULKY REFUSE

There are numerous occasions when it is necessary to
incinerate bulky refuse such as furniture, mattresses,
 bamboo crates and chicken baskets and similar burnable
waste items which are oversized for direct feeding
into the incinerator charging hopper. In addition
the incinerators are called upon from time to time to deal
with debris from illegal structures removed by the Re­
settlement section of the Housing Department. At the
present time these are dealt with either by being cut up
into pieces of a suitable size for feeding to the charging
hopper or by the use of special refuse collecting vehicles
which break up refuse into small pieces in the loading
process. Two types of these vehicles have been experi­
mented with, one with a rotating drum forcing refuse past
a plate, and one where articles are broken up by a comb­
ing action; a number of the latter are now coming into use.
When performance of these has been evaluated in practice,
it is possible that the need for a static crusher or shears
will be avoided. However, if it becomes apparent that a
need still exists the design of the incinerator plant has
been so arranged that a heavy duty bulky refuse crusher
or shears can be installed to deliver suitably sized pieces
into a bunker directly from outlet of the machine.

So far no doubts are entertained regarding the ability
to dispose of bulky waste by one or other of these
methods, with one exception — bamboo chicken crates.
Several thousands of these are delivered every day to the
Hong Kong Markets and there discarded! These baskets,
used to transport live chickens to market, are always
circular in shape — constructed of very open weave split

FIG. 6 TOP  A GRAB LOAD AT KENNEDY TOWN

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FIG. 6 BOTTOM  KENNEDY TOWN — END SHEETING REMOVED AND PILING IN PROGRESS FOR CONSTRUCTION OF NEW UNIT.

SECTION THROUGH UNIT — KWAI CHUNG
bamboo — and come in many sizes from two feet diameter and eighteen inches high with a hole at the top about a foot across, to baskets nearly five feet wide and three feet high. The nature of the split bamboo defies most crushers and shears and in machines with a tearing action often remains unbroken to return partially to shape in an incinerator charging chute and so cause a blockage. Unqualified success has so far only attended cutting up by band saws used almost exclusively for this purpose. Shears can however deal with these baskets provided positive contact between blades is preserved at all times. The eventual choice of a means of dealing with future bulky refuse thus rests on the ability to deal with the humble bamboo basket.

Kennedy Town — Additional Incinerator Line — While considerable developments have been proceeding in providing an incinerator plant for Kowloon the disposal of refuse on Hong Kong Island still presents a considerable problem. So far little success has attended a search for suitable tipping sites or sites for further incinerators. Hence, and notwithstanding the very restricted site, a fifth incinerator line is being constructed at Kennedy Town Incinerator. The unit can just be worked in on the west side of the plant. When completed in late 1975 it will provide a further 250 tons per day capacity. The unit is very similar to those of Lai Chi Kok ‘B’ and is not connected to the others at Kennedy Town in any way except for the submerged ash conveyors and where the effluents enter the ducts to the west chimney. The restricted site, the nature of the underlying foreshore and the need to maintain the output of the existing plant throughout the building period has required the most careful organization to overcome the succession of construction problems presented. Construction is now well in hand and it is expected that installation of the plant will commence in the autumn.

ACKNOWLEDGMENTS


Messrs. Clark Chapman — John Thompson Ltd. for the details of furnace design.