THE HOSPITAL ENGINEER

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DECEMBER 1969

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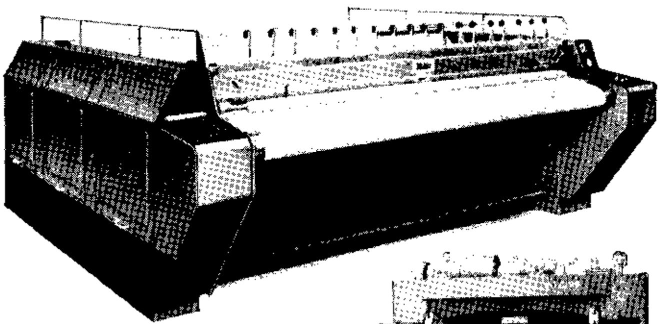

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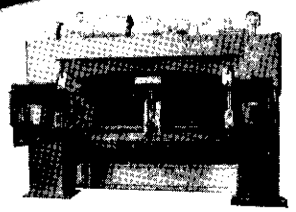

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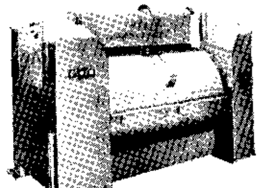

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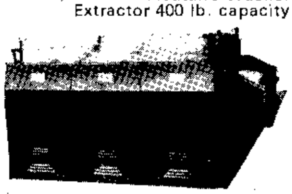

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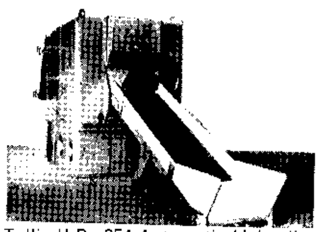

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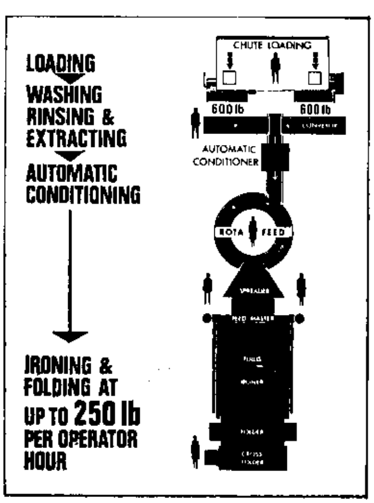

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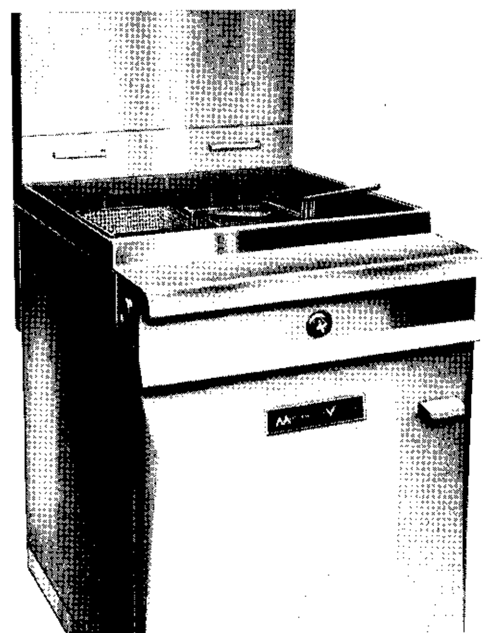

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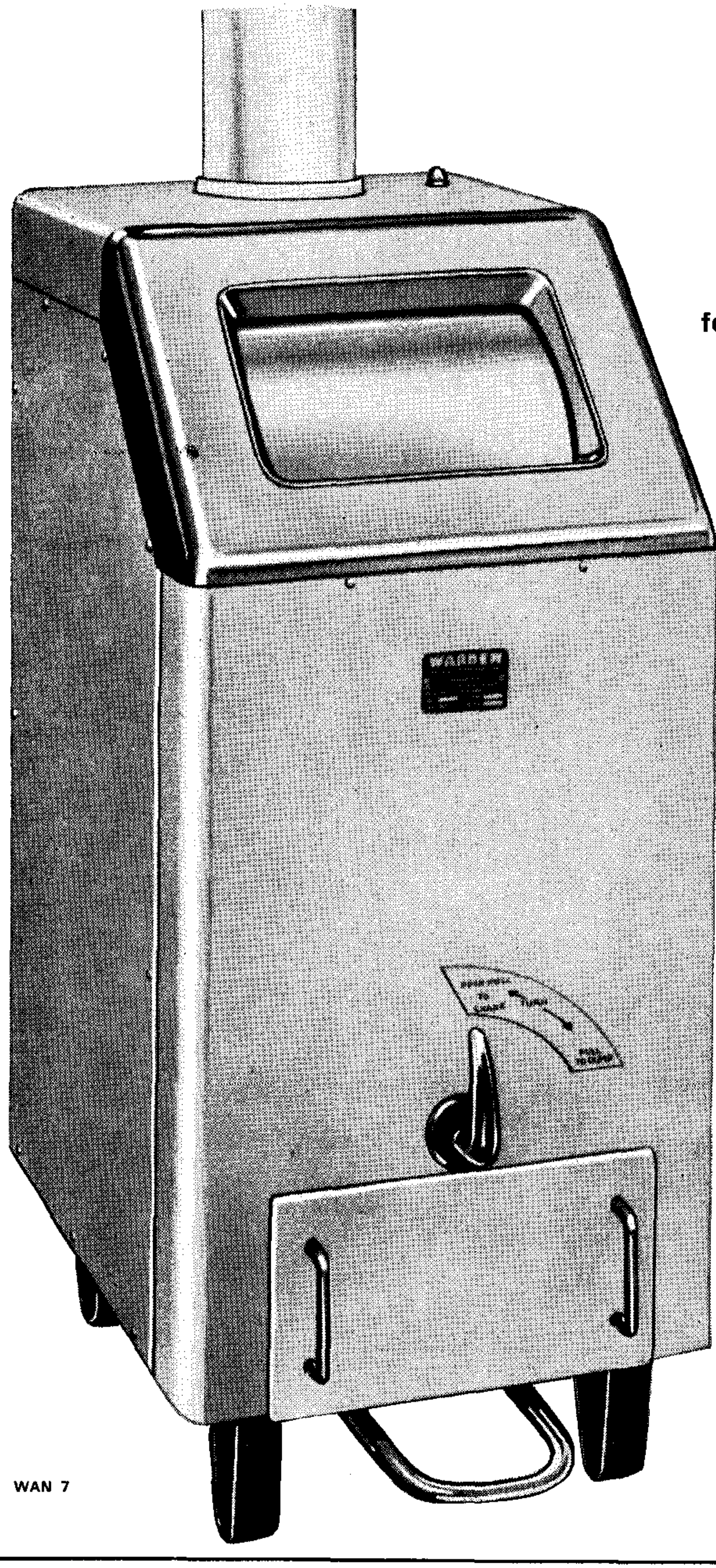

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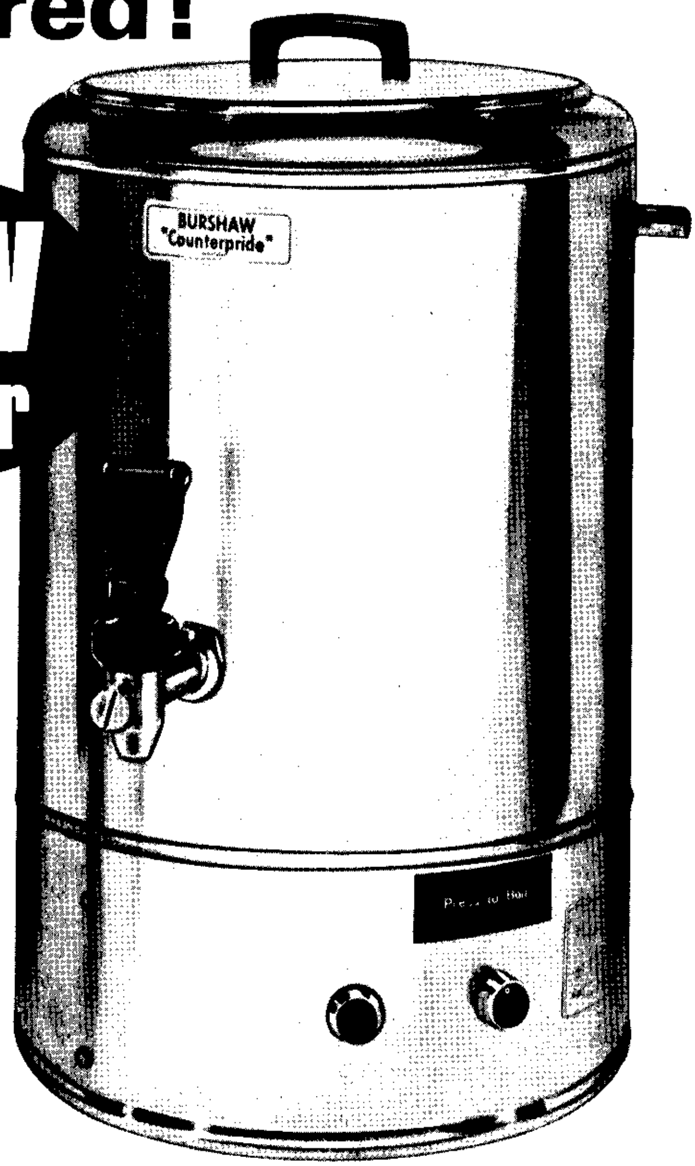

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Part 2

Evolution of the boiler and good boiler-house design

by S. B. Tyrer, M.I.Plant E., A.M.I.Hosp.E.*

Besides oil and coal there are, of course, other fuels which are used for boiler-heat generation. Town gas is very popular for small and medium installations; it is often attractive because there are no fuel-storage problems and a fully automatic system is easily achieved. Also in town areas in which clean-air zones are declared the low sulphur content of town gas compared with other fuels gives it a further attraction.

With the advent of 'off-peak' electricity, electrode storage boilers have become an economic proposition wherever this type of boiler is suited, such as in day-load systems for schools, offices etc.

Generally speaking, however, the majority of boilers are coal or oil fired, and the types of coal or oil in use create their particular peculiarities as to storage and burning techniques.

If we first consider coal fuel, it soon becomes obvious that there is more to firing a modern boiler plant than just tipping coal onto a grate and burning it. All coals are pregraded into sizes, and each grade has its own storage, delivery and burning properties and ash-disposal problems. Different types of coal from different coal fields are better suited to different burning applications, and in each case the plant-design engineer would be wise to consult fully with the National Coal Board before choosing any coal-handling, burning or ash-disposal equipment for his boiler plant.

Coals are usually considered in four groups: 'graded coals', 'small coals', 'dust' and 'pulverised'.

Graded coals are determined by the screening process of passing the coal through sieves. The grouping used is:

Groups	*Sieve size (round holes)*
large cobbles	6–3 in
cobbles	4–2 in
trebles	3–2 in
doubles	2–1 in
singles	1–½ in
peas	½–¼ in
grains	¼–⅛ in

Small coals are in general sized from 2 in down to ⅛ in, and to free these from dust they are often put through washers to give washed small fuel.

Coals are also different in their volatilisation and caking properties; any combination of these properties gives a type of coal its own peculiarities. Each fuel is best suited to a type of burning application, and what is a good method of burning one coal is not always good for another.

Generally speaking, hand-fired furnaces are better served with large coals and heavier ungraded fuels, since caking is not too important as it can be broken up manually. Graded coals can be used in underfeed or thrower-type stokers, and in chain-grate stokers for shell-type and small water-tube boilers and for large central-heating boilers etc. Anthracite is best suited for magazine boilers and hopper–gravity-fed boilers and stokers. Small coals are used with chain-grate stokers in shell boilers and also in pulverised-fuel burners in water-tube boilers.

If we think of automatic stokers then the size and rank of a coal are the two important factors affecting the stoker efficiency. Heavily caking fuel, especially smalls

*Technical Assistant, South-Western Regional Hospital Board

of rank 400 and 300, should not be used on any type of mechanical stoker as it produces large clinker which cannot be broken up and therefore burns inefficiently.

Over a range of boilers from 1 to 10 MBtu/h using travelling-grate and chain-grate stokers, washed smalls of no larger than 1 in with a high moisture content give good results. A good ash content in the fuel also helps to provide a cool ash bed and protects the grate against high heat radiation and damage. On boilers for over 10 MBtu/h coking stokers of the high- or low-ram principle are most effective. Very large water-tube boilers with high outputs and efficiencies make the use of pulverised fuels an economic proposition, with possibly their own pulverising plant and pneumatic ash-disposal systems.

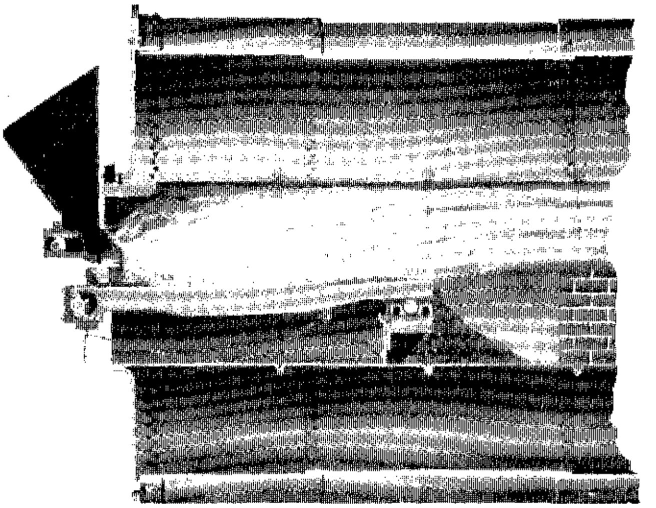

Fig. 1 Low-ram coal stoker firing a Lancashire boiler (photo: Hodgkinson-Bennis Ltd.)

Coal dust is generally used for manufacturing proprietary fuels for domestic stoves etc. A byproduct of coal is creosote pitch, or coal tar, which is a product used quite often as a boiler fuel in much the same way as any oil-fired boiler plant.

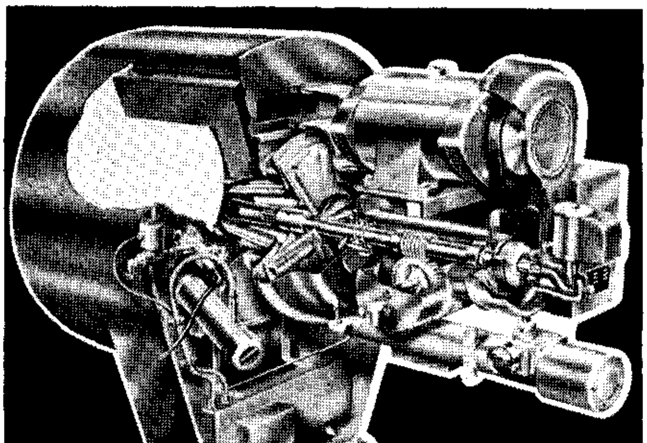

Fig. 2 Cutaway of rotary-cup burner unit

Oil firing has today taken over from coal in more and more boiler plants, mainly because of two factors. First, it is easily available, and once delivered into storage tanks by tankers its transfer to the boiler and its combustion are completely devoid of any further worries of handling because of its fluid state. Consequently the high maintenance costs of coal conveyance and ash removal are completely eliminated. Secondly, it is now priced to compete favourably with coal (taking into account its higher potential efficiency for boiler firing and the decrease in running and maintenance costs).

Fuel oils are graded by the amount they have been refined from the crude state. The more refined they become the less ash, sediment and water content there are left, which results in a slightly higher output rating for the more refined oils. The amount of refining the oil receives bears a direct relationship to its viscosity, and this factor is used in its grading. There are, as far as the commercial selling of oil is concerned, four classes of fuel which are suitable for industrial boilers. These are:

G: heavy oil, 3000 s viscosity.
E: light oil, 200 s viscosity
F: medium oil, 900 s viscosity
G: heavy oil, 3000 s viscosity

These viscosities are taken from the Redwood standard of viscosity at 100°F.

There are other fuel oils outside this range, such as light vaporising oils for domestic boilers and very heavy oils of up to 6000 s such as marine boilers use. Generally speaking, however, the four grades mentioned are those most used.

The efficient combustion of oil depends almost entirely on its ability to vaporise in air to form an air–oil vapour which burns without smoke to release the maximum energy content of the fuel. The air/oil ratio is very critical and its close control is the essence of good combustion. An oil burner is therefore the means of bringing the oil and air together at the pressure and temperature giving the correct conditions for good combustion within the furnace space. There are different ways of achieving this: the three most common systems of oil-burner design being rotary-cup burners, pressure-jet burners and air-pressure burners.

(*a*) The rotary-cup burner delivers oil along a stationary tube through a nozzle under pressure, at the correct temperature to suit the grade of oil used. The oil is injected onto a rotating cup which flings the oil under centrifugal action into a vapour which is mixed with the primary air to form the air–oil vapour for combustion. The primary air is also supplied by the burner using a fan: this constitutes about 15% of the volume of air required for combustion. The secondary air is either induced by the suction in the furnace in induced-draught systems or forced in in forced-draught systems. Rotary-cup burners are used on boilers of about 1·5 MBtu/h upwards, and are not recommended for smaller installations.

(*b*) The pressure-jet burners rely on a higher oil pressure and temperature than those used in the rotary-cup burner. The oil is less viscous owing to its higher temperature and the higher pressure forces the oil through a fixed nozzle which swirls the oil into a vapour which is picked up by the primary air provided by the burner fan unit. This type of burner can be used with the smallest boilers and in boilers of up to 25 MBtu/h quite successfully.

(c) Air-pressure oil burners use the principle of the pressure-jet nozzle, but instead of forcing the oil through under high pressure, the oil is under a lower pressure and is picked up by the introduction, within the burner nozzle, of a higher-pressure stream of air. This mixes the oil and the primary air within the nozzle tip and is already vaporised when it is injected into the furnace. This type of burner can give a long flame depending on the nozzle-tip design and the air pressure used, and is often chosen on furnace works as well as boiler plants.

The choice of burner is usually made by considering the requirement of the boiler plant. This means assessing the load characteristics required from each burner, and deciding whether the control of the burner should be on/off, or high/low firing, or modulating, and what degree of 'turn down' is required. The system-load characteristics have to be established, taking into account the maximum connected-load requirements, what the normal running load is in comparison with the maximum load, how quick the load recovery has to be, what load the burner is to carry on minimum load etc. All these factors are pertinent in deciding the type of burner to be used and the type of control required to run the plant most efficiently.

Boiler-house structures

After the selection of the boiler has been made and the fuel and the fuel burner have been selected, the questions of fuel storage, fuel distribution and combustion control have to be investigated, and this stage in the overall plant design usually dictates the final plant layout and boiler-house structural design.

Irrespective of the size of the system there is no reason why a boiler-house structure should not be as much a part of the design of the boiler plant as the boilers themselves. All too often the engineer is faced with an inadequate space without natural light or ventilation, with poor access, wrongly shaped and for no particular reason left below ground or hidden away in some remote corner of a complex—the engineer only being consulted long after the main design of the building is too far advanced

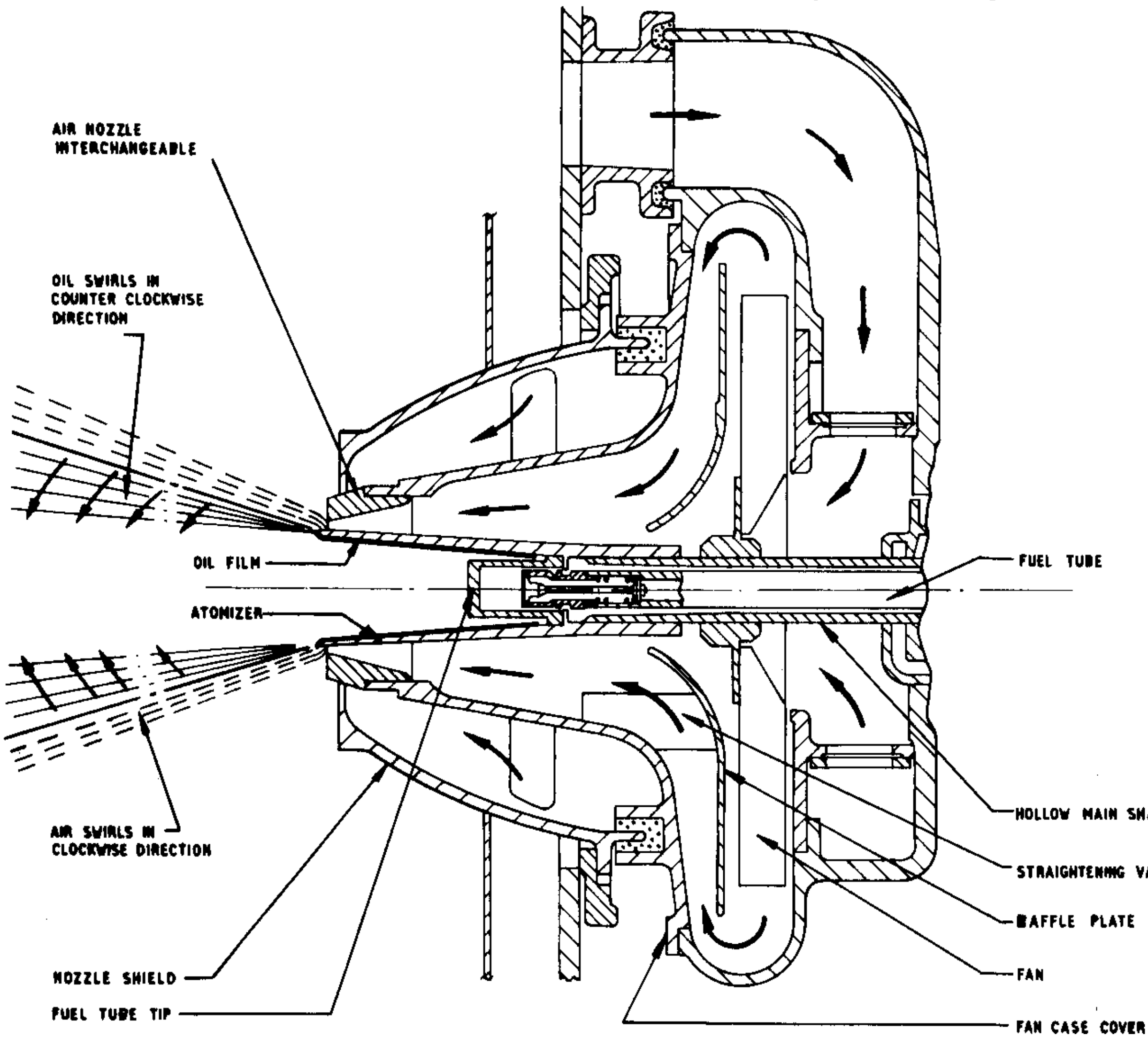

Fig. 3 Operation of rotary-cup burner (photo: Hamworthy Engineering Ltd.)

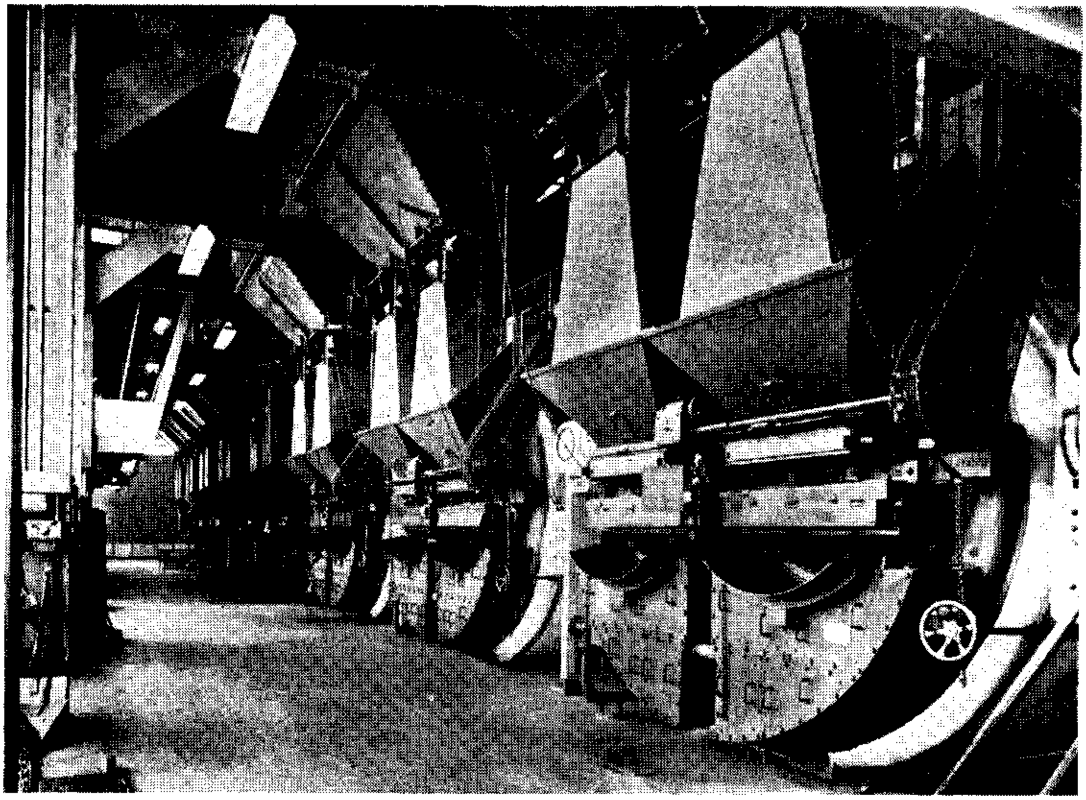

Fig. 4 Modern coal-fired Economic boiler plant (photo: Danks of Netherton)

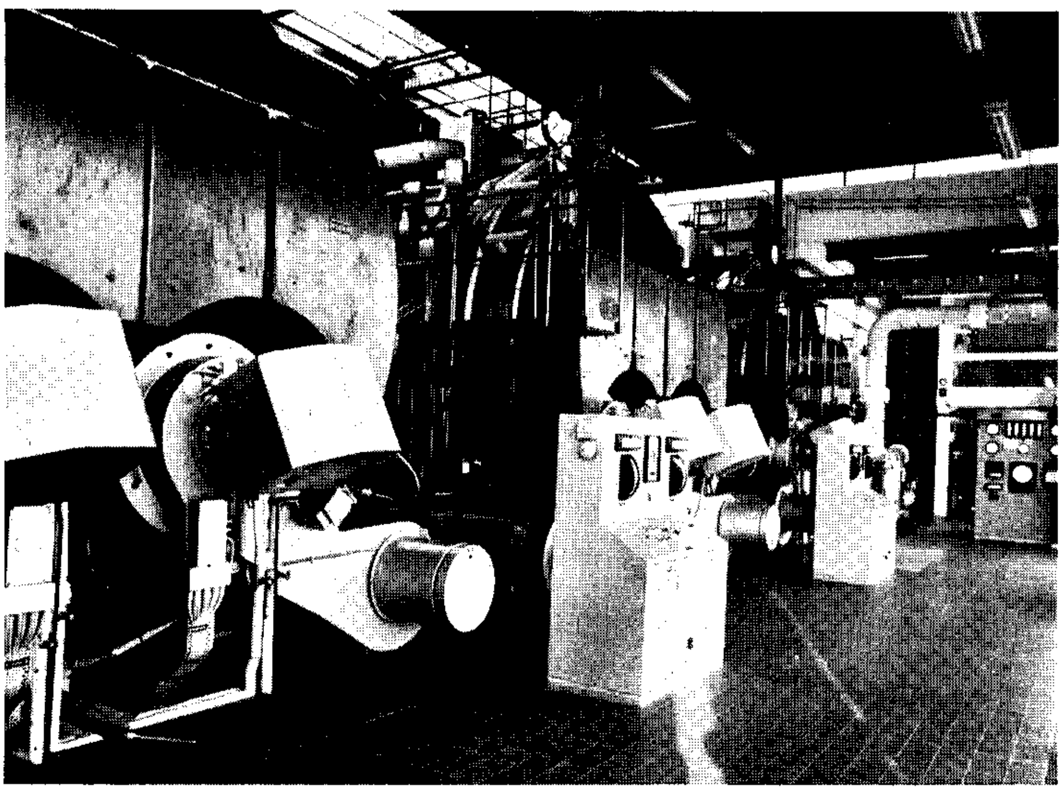

Fig. 5 Modern oil-fired boiler plant at Southmead Hospital, Bristol

to alter. To achieve the most economical engineering system for any plant or environmental-engineering services, it is essential that the engineer is brought into the early design discussions with the architect. Only in this way can he advise the architect of the values of extending the architectural features to accommodate the engineering system, and to provide, most of all, a functional boiler house, well positioned with good access, the right shape and height, and well ventilated and lit. In systems where the boiler-house complex is particularly large this is all the more important as fuel storage, and possibly ash-disposal plant, dictate the size and shape of the building. Also good road access is essential with the advent of larger tankers and coal-bunkering lorries.

Coal-fired boiler plants are less flexible than oil-fired designs inasmuch as the fuel bunkering for coal must be as close as possible to the boilers to keep the fuel transfer as short as possible. This is not as important in oil-fired installations because oil can readily be pumped any distance with only line heating and insulation as possible cost considerations. Coal elevators, screw feeders etc. are all heavy maintenance items and are costly to run; so the shorter these are the better. Ash-disposal equipment, though not as bulky as coal conveyors, should again be kept as short as possible to keep maintenance and running costs at a minimum.

Split-level designs in coal-fired boiler houses are always advantageous where site conditions permit, so that there is a downward flow from the coal-transport lorry to the bunker, from the bunker to the boiler, and from the boiler out to ash disposal. Using the downward system considerably cuts the cost of lifting coal and ash to boiler-feed hoppers and disposal trucks, and this can amount to a considerable sum over 12 months.

Regardless of the size of a boiler house it is essential that the plant is laid out to give adequate access for maintenance, which may involve the removal and replacement of any piece of equipment—including the boilers themselves. Obviously each boiler house has to be considered individually, but, generally speaking, a boiler requires at least its own length clear in front for general tube or flue cleaning and possible tube replacement. A minimum of one-third of the width clearance between boilers is required for access. Headroom is also important, and, when intermediate (5 MBtu/h) and larger boilers are being considered, high-level walkways and lifting gantries are a must for servicing crown valves etc.

Ancillary equipment, such as oil-pumping and heating units, feed pumps, pressurisation units etc. are all best housed in the boiler house, and require good access and facilities for maintenance. Good ventilation is one aspect of boiler-house design which is often neglected. It is essential that good ventilation is provided—to overventilate is better than to underventilate in any situation. With gas-fired boiler plant, or with any system of firing which relies on natural draught for its air requirements, where there is any doubt as to ventilation, such as in underground boiler houses, it is often advisable to supply air by an input fan to pressurise the space. On large installations which use forced- or induced-draught systems it is usually only required to ensure that there is adequate open area for the air to be drawn through.

In any event it is the responsibility of the plant-design engineer to ensure that the building structures associated with the engineering system, and, in particular, the boiler-house complex, are designed in sympathy with the engineering design.

Fuel—storage, distribution and combustion control

The two most common fuels used, coal and oil, require a certain amount of bulk storage adjacent to the boilers they are to serve. The amount largely depends on the fuel consumption of the boiler plant, and on the availability of its supply.

Coal is mined in this country and transported to depots in various local areas, where it is taken in road vehicles to the coal user's storage space. Larger power stations and some large industrial users have the facility of their own railyard to bring coal in direct, but this does not apply generally. Because of its bulky nature the moving of coal is both difficult and costly, and, therefore, it is in the best interests of the user to provide storage facilities in which the necessity for moving fuel after delivery is eliminated.

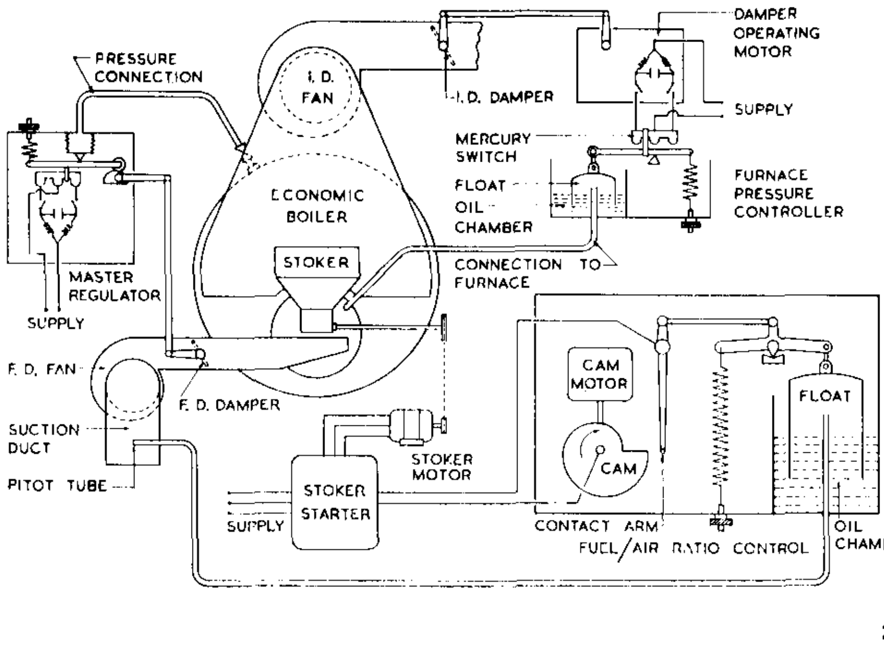

Fig. 6 Schematic of chain-grate stoker fitted with 'Unitherm' control system

Generally speaking a minimum of three weeks' supply is essential as a buffer between delivery and consumption at the heaviest demand period in the year, which usually coincides with the worst delivery period, which is the winter. It may be that more storage than this is required if the boiler site is remote from NCB coal-distribution centres. The NCB provides a first-rate advisory service in this assessment, and should always be consulted.

The most economic design of coal-fired boiler plant has all the fuel storage compounded in bays or hoppers, so that coal elevators or chutes can feed directly into the boiler hoppers, eliminating any intermediate coal handling. The boiler hopper is usually fed automatically, this is achieved by varying the delivery speed of the elevators, screws or buckets automatically, as the stokers are regulated, by variable-speed motors controlled by the output requirements of the boiler. The boiler air-supply fan or induced-draught fan is also linked to the controls to give only as much air as is required for good combustion. As the fuel burns to ash or clinker it falls from the fuel bed onto the ash bed and is transferred automatically or manually out of the boiler and away to the disposal point.

Most automatic-coal-stoker manufacturers offer a system of combustion control with their equipment, and it is necessary to select the control most suitable for the conditions of the plant to be served.

Oil, like coal, has generally to be transferred from local depots to the user's storage for use as required. Unlike coal, however (except possibly for pulverised coal), the storage and handling are much more simple inasmuch as once the fuel is pumped out of the tanker into the storage vessel its transfer to the boilers is much more easily controllable, is cleaner, and requires far less maintenance. It still has its problems, but, provided that these are appreciated at the plant-design stage and allowed for, an efficiently running plant will result.

Distillate gas oils of 35 s viscosity (Redwood No. 1; 100°F) can be stored in external storage tanks without insulation and without fear of freezing or sludging in our normal climatic conditions, and can be distributed by gravity to burners without heating. It is a very efficient fuel and should be used whenever possible on small installations. Its sulphur content is very low, so that it provides an ideal fuel in clean-air zones. It is normally used with pressure-jet burners and some low-air-pressure burners. Because there is no need to heat or pump this fuel to the burner it gives a high efficiency both in running and maintenance costs, as was shown earlier.

The residual oils, beginning with 200 s grade oil, are cheaper to buy than gas oil, and very good combustion can be obtained on much the same type of units. It can be fed by gravity 'dead-leg' distribution, but, depending on the type of burner unit fitted, may require preheating. If it is stored externally without storage heaters there may be a tendency in frosty weather to 'wax', causing stratification of the oil, which could give distribution problems. Lagging of the oil tanks is therefore advised if no storage heaters are used on externally sited tanks.

The heavier residual oils of 900 and 3000 s viscosity are usually heated to 100°F before delivery so that they are fluid enough to pump in and out of the oil tanker. Tanks sited either internally or externally should have heaters in them to keep the oil fluid. Outflow heaters are often used on the heavier types of oils; their distribution should be through a ring main pumped in and out of the heater to give a continuous circulation to the burner-supply pipes. These ring mains need to be line-traced with either steam or electrical heating coils, thermostatically controlled to prevent oil in the main from solidifying in the event of shutdown or oil-heater failure. The distribution temperature should be 100–120°F. When the oil is taken from the mains by the burner pump it is heated further to the temperature required by the burner for atomisation and firing. Flash points of heavy oil are in the range 180–220°F, roughly coinciding with the atomising-temperature range, which can vary with the type of burner used. Rotary-cup burners atomise oil at 180°F, whereas pressure-jet burners require 240°F as an atomising temperature.

Oil burners can be used fully automatically, using either the induced-draught system, which incorporates

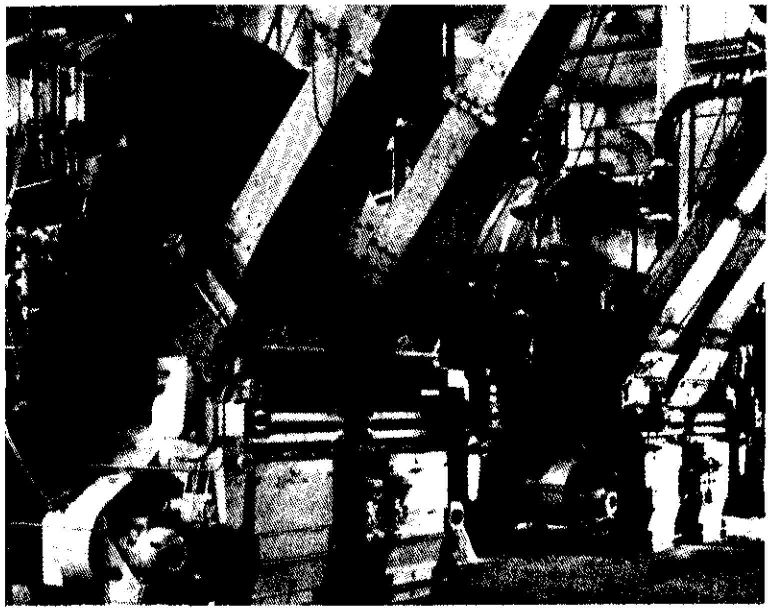

Fig. 7 Chain-grate stokers firing Economic boilers

the draught fan in the flue and 'induces' air through the boiler, or the forced-draught fan system, which incorporates draught fans in front of the furnace. Sometimes both systems are used together, the forced-draught fan being sized to provide the secondary air for combustion at a head to overcome the boiler gasways (which can be as high as 6 in on medium economic boilers). The induced-draught fan would be sized to handle the products of combustion, or flue gases as they are better known, and to provide the correct velocity to lift them out of the chimney, as will be described later.

In order to give good combustion control over the full range of burner turndown the oil and air supplies have to be closely regulated. This is achieved by linking the controls of the oil supply to the burner with the air supply. Burner manufacturers all have their own range of controlling equipment, as there are different ways of achieving the same end.

As can be appreciated, an oil-fired boiler, particularly a steam-generating boiler, can be a most dangerous piece of plant if not fully controlled at all times. Apart from the statutory requirements for pressure-safety blow-off valves, flue-gas-explosion doors etc., it is obviously essential that on a fully automatic oil-fired boiler there should be built into the burner controls a high degree of safety. Standard types of fully automatic burner controls consist of two main control features, the programming and supervisory control, and the running, or proportioning, control.

The programming and supervisory control ensures that the burner is started and stopped in such a way that the boiler is always safe, and while the burner is running the oil flame is continuously monitored by a photoelectric cell. The burner is shut down and 'locked out' in the event of flame failure, low boiler water, draught failure or any other safety factor which may be necessary in a particular application. The boiler-pressure switch (or thermostat in the case of hot-water boilers) is also interlocked, with this control shutting down the burner when a set pressure (or temperature) is reached. In this case, however, the burner is not 'locked out' but will automatically relight when the pressure falls by a preset amount (i.e. the differential of the switch).

The running or proportioning control takes over only when the flame has been established, and proportions the burner output under the influence of the boiler-pressure switch, or thermostat, which in its turn is dependent on the boiler load. There is usually an interlock (the low-fire relay) between the programming control and the proportioning control which ensures that the burner output is at low before the burner can start.

In twin-flue boilers the burners are started and stopped together, and also modulate together. Failure on any of the safety devices shuts down both burners.

When the burner is operating its output is varied by the boiler pressure or temperature, whichever is applicable. If the steam demand falls the boiler pressure rises, or if the water-temperature demand falls the boiler-water temperature rises which reduces the size of the burner flame, and vice versa.

It may be that, on process work or in other applications, the load is not variable and therefore modulating controls are not needed. On–off controls are quite normal in these cases, but they still carry the inbuilt safety features described.

Automatic burner controls usually have the facility of switching to 'hand control' to override any troubles which may occur in the automatic system.

Irrespective of the type of fuel burnt, one of the best methods of keeping a constant check on the efficient burning of fuel is to monitor the products of combustion. As can be appreciated, this involves a fair degree of chemical analysis and takes some time. There is a purpose-made apparatus called the 'Orsat' apparatus which is designed specifically to carry out the analysis, and a frequent check on individual boiler-flue gases will tell if a burner unit is set up correctly. A more convenient method to check good combustion is to monitor the CO_2 content of the flue gas. This can give a very good indication of the air/fuel ratio; a figure of 12–14% by volume is a normal running margin denoting efficient combustion.

The amount of control any boiler plant receives depends, over and above the statutory requirements for safety, upon the degree of efficiency required to give fuel economy, and on the saving in labour costs from replacing manual supervision with automatic controls.

Inevitably, sophisticated controls can increase the client's capital outlay quite considerably, but this cost can quickly be regained, usually over one or two years, by the savings in fuel costs due to increased efficiency and savings on labour supervision. The client, if made aware of this annual saving, usually sees the sense in outlaying the additional capital to gain in the long-term annual revenue savings.

Flues and chimneys

Any boiler plant needs to be efficient throughout its working range, whether it has one boiler onload or more. Having carefully ensured that the right boiler plant, fuel and burners have been selected for good economical combustion, it is equally important to ensure that the flue gases are properly carried away and dispersed.

As described earlier, coal-fired boilers emit flue gas at higher temperatures than do oil-fired boilers, and on natural-draught systems this affects the relative flue and chimney sizes. Coal-fired boilers usually discharge into a common flueway and chimney whose cross-sectional area is sized to give a discharge velocity on full load of 10–20 ft/s. The chimney height is determined by the volume and buoyancy of the flue gases. If only part of the boiler plant is functioning, obviously the volume of flue gases is reduced, and, therefore, the discharge velocity up the stack decreases. The velocity of the gases can drop to such a level that by the time they reach the chimney top their temperature has also dropped, thus reducing the buoyancy. Hence the velocity is again reduced, and this vicious circle can result in stagnant flue gases causing excessive sooting and highly corrosive acid condensation, which will lead to damage to flueways and stacks whatever their construction. Because of their high outlet temperatures, coal-fired multiboiler plants can successfully discharge into a single-flue stack system, but if it is known that very light loads will be used on occasions then a twin-flue system should be adopted.

Oil-fired boiler plants, because of their lower flue-gas temperature, deserve the consideration of individual flueways and multiflue chimneys so that each flue is sized to its own boiler output; so eliminating the 'smutting' and acid-formation problems encountered with single-flue chimneys. Oil-fired boiler flues should be sized to give gas velocities of 45–50 ft/s, and this can only be achieved by using either forced-draught or induced-draught fans, as previously described.

There is now, in addition, the Clean-Air Act to take into consideration when sizing boiler chimneys, and chimney heights are generally governed more by this than by the practicalities of flue-gas buoyancy. In order to comply with the Act it will be necessary to fit some form of grit arrestor in the flue system of coal-fired boiler plant; this must be taken into consideration when sizing flues and chimneys because of the increased resistances through them.

Most boiler and burner manufacturers will give the expected flue-gas volume, temperature and chemical analysis so that the flue and chimney may be adequately sized. The important points to remember are: short flueways between boiler and chimney with a minimum of acute bends, good cleaning access, good lagging to keep flue temperatures up and good gas velocities to eliminate the formation and collection of soot in flueways and chimneys.

Smoke-density detection equipment should always be used on individual flues if possible, to enable each boiler's air/fuel ratio to be correctly balanced so as to give good combustion—a clear chimney is a sign of good combustion.

Boiler feed water and feed-water treatment

Boilers serving closed heating systems using low-medium- or high-pressure hot water do not in fact boil the water and evaporate it as steam boilers do. The water is circulated and reused continuously with little or no make-up, and because of this the amount of impurity and dissolved gas in the water once released never increases and causes little damage to the boiler or to the system it serves. Poor venting of such a system can, of course, cause local air locking and oxidisation by aeration, but this is a design problem, not a water problem.

Steam boilers, because they continuously evaporate water, require continuous makeup, either wholly fresh, or partly so by the reuse of condensate-return water. Any dissolved or suspended impurities or gases in the water will be precipitated when evaporation takes place; the release of these elements and their subsequent chemical changes is the prime cause of rapid internal corrosion and scaling of boiler plant.

The chemical constituents affecting the influence of feed-water problems in boiler efficiency and maintenance are those of dissolved gases—these are all to a greater or lesser extent corrosive, and cause wasting of the boiler metal. The principal gases are oxygen, carbon dioxide (CO_2) and hydrochloric acid (HCl), all of which are very corrosive in solution. Oxygen in water is mainly derived from that in the atmosphere, and is released on boiling. When in solution or in a moist state oxygen is actively corrosive to metals, combining with them to form oxides. Corrosion in boilers due to dissolved oxygen is most active when the boiler is standing idle and containing water; severe wasting occurs on the water line. Boilers left idle are, therefore, better left either completely full or completely empty.

Corrosion by CO_2 causes scab formations on boiler-plate surfaces which, once established, will penetrate deeper by a continuous cycle of reaction between the iron carbonates first formed, which are decomposed into iron oxide and CO_2, and further carbonates formed by the released CO_2.

Solids, either in solution or suspended, are not in themselves corrosive, but by precipitation they inevitably bring about a reduction in boiler efficiency by the formation of heat-insulating deposits of insoluble compounds, in the form of scale. An over-concentration of soluble salts sets up foaming and priming, and, in extreme cases, may retard the circulation of the water in the boiler by noticeably increasing the density.

Waters are made hard or soft by the environments which they pass through after falling as rain, and the chemicals absorbed vary with the soil and rock formation of the area in which they collect.

The hardness of water is the amount by which it can destroy the lather-foaming power of soap, and is measured in Clark degrees of hardness. One degree of hardness is the equivalent in soap-destroying effect of one grain of calcium carbonate ($CaCO_3$) per gallon of water (there are about 438 grains to the ounce).

Hardness can be divided into temporary and permanent hardness. Temporary hardness is the amount of those bicarbonates of calcium and magnesium in solution which, on heating to a temperature in excess of 158°F, decompose into their respective carbonates by the expulsion of carbon dioxide. These carbonates, being only negligibly soluble, are precipitated to form a comparatively soft porous scale on boiler surfaces.

Permanent hardness is caused by the presence of salts which do not precipitate under normal boiling. These are usually calcium and magnesium sulphates and chlorides of sodium and magnesium, with any acids which may be present in the feed water. Under the higher pressures and temperatures of steam boilers these chemicals precipitate and form a very hard crystalline scale on boiler-plate and tube surfaces, which drastically reduces the heating-surface effectiveness. It also reduces orifices in control gear, which can lead to serious malfunctioning. Also scale on primary heating surfaces in fire-tube boilers causes local hot spots, which can result in complete tube rupture and a risk of explosion.

The traditional use of degrees Clark for hardness is now being replaced by the increased use of parts in 100 000 or parts in 10^6 (p.p.m). Instead of associating the water with the grains of calcium carbonate per imperial gallon, a direct proportion is used—one degree Clark is roughly equivalent to 14 p.p.m. The terms 'temporary', and 'permanent' hardness are being replaced by the terms 'carbonate' and 'noncarbonate' hardness.

The other factor affecting the measurement of water's acidity or alkalinity is the 'pH value'. This is the measure of the degree of acidity or alkalinity of water related to the concentration of hydrogen ions. Absolutely pure water contains 10^{-7} g ion/l of hydrogen and hydroxyl ions, and taking the negative log to base 10 of this value gives us pH 7, which denotes the neutral condition of pure water. Any degree above seven denotes an alkaline content of the water, below seven denotes the acidity of the water. The pH value of boiler-plant feed water should not be less than 8·5, with the boiler water itself at pH 9·5.

There are many different ways of treating feed waters to overcome the problems described; the treatment obviously differs with each individual case. The plant-maintenance engineer will be responsible for obtaining proper analysis of the feed water used, and it is advisable to engage a firm of water-treatment specialists to recommend the treatment required.

A summary of treatments are*:

(*a*) Chemical dosing

The most common and effective treatment for shell boilers and small water-tube boilers is the lime-soda dosing method. Calcium hydroxide (slaked lime), in the form of a milky solution, is added to the boiler feed water in the feed-water tank. This removes the CO_2 from the soluble calcium bicarbonate and results in the carbonates being precipitated. Permanent hardness is removed by the addition of sodium carbonate (usually as soda ash). This reacts with the calcium sulphate to form calcium carbonate, which is precipitated. The sodium carbonate becomes sodium sulphate which remains in solution. Other proprietary reagents can be used to the same effect, and are administered in various forms of dosing tank, or by direct injection.

(*b*) Base-exchange treatment

This treatment uses the property of natural or artificial zeolites, which, while themselves insoluble, when in contact with dissolved calcium and magnesium sulphates convert them into the respective bicarbonates, which are permanently soluble and non-scale-forming and can pass into the boiler. On boiling, these bicarbonates are decomposed into the carbonates, with the release of CO_2 which, as described earlier, is very corrosive. To overcome this the feed water is boiled, prior to entering the boiler, in special vessels. This drives off the CO_2 before the feed water is passed to the boiler.

(*c*) Colloidal treatment

This system of treatment relies on the properties of starch extracted from raw linseed or from other organic sources. This has the ability to hold the precipitated scale-forming solids in a colloidal mass, and so prevents them from settling out on the boiler surface, holding them in suspension in the boiler water.

(*d*) Blowing down

This is not in itself a treatment but is a necessary function required to complete the treatments described above.

All precipitated solids have to be removed from the boiler as they are formed, and the boiler water must be kept to a set density to stop priming and bad circulation, as will happen when the concentration of soluble salts increases the density of the boiler water. By blowing down the boiler water with the boiler under pressure for a predetermined period at regular intervals, suspended solids are removed and the boiler-water density is kept at a working level. The extent of blowdown can only be determined as an individual case taking into consideration the treatment used, and by the frequent checking of boiler-water density.

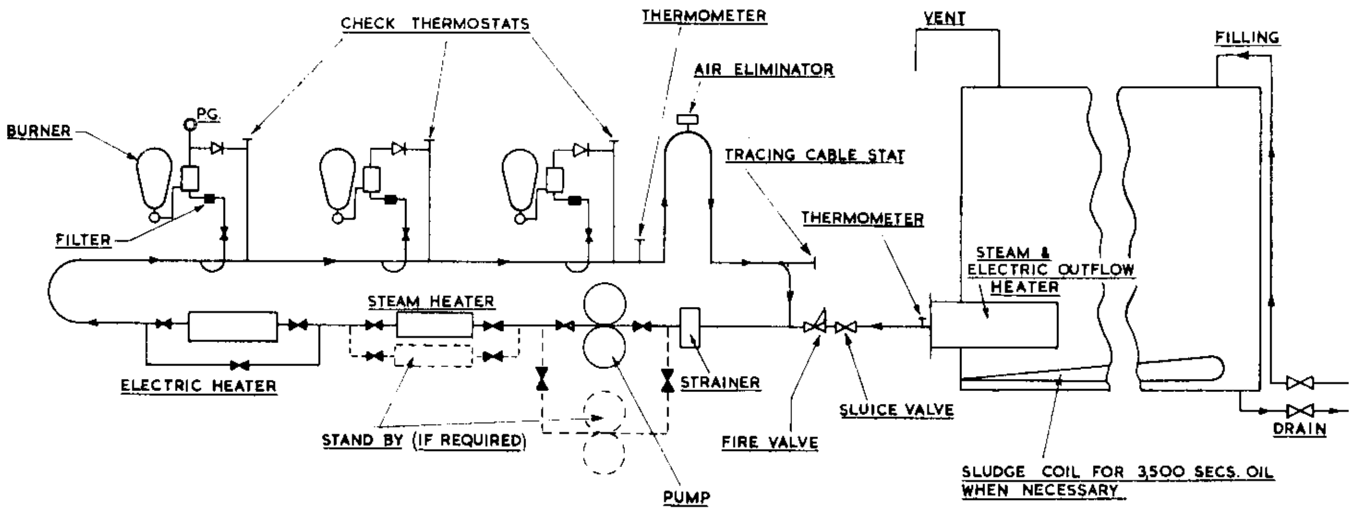

Fig. 8 Schematic of multiple-burner pipe layout with circulating pump

Conclusions

In compiling this report on the basic features of boiler-house and boiler-plant design it has not been the aim to present a text for designing boiler plant, but only to give an appreciation of the problems involved and of the way that they can be overcome by consultation with the right specialists and by a common-sense approach to the different aspects of the design problems of space and equipment requirements.

The prime message to all plant engineers engaged in the design of boiler-house plant is to design for running economy, but not at the expense of efficiency or maintenance capability. The client should get good value for his capital outlay--a well designed boiler-plant system will give a good return of capital in only a few years.

*WADE C. F.: 'Industrial boilerhouse efficiency' (Crosby Lockwood & Sons Ltd., 1954)

New Mulago Hospital, Kampala, Uganda

by J. Cushnagen, M.I.Hosp.E.*

Mulago must rate as one of the loveliest hospitals built, both from the aesthetic point of view, and also from the viewpoint of the hospital engineers. The buildings have been constructed on the natural slope of the ground, and although the main hospital is six storeys high, the entrances are actually on the 2nd and 4th floors.

The hospital was designed for 1000 beds, but with the great demand for treatment there are usually many more patients than the number originally catered for.

There are three main blocks of wards, at 90° to the main corridors. These are known as A, B and C blocks, and rise from floor 1 to floor 6. Each ward has its own doctor's rooms, treatment rooms, kitchen and other facilities.

On the opposite sides of the main corridors are administrative offices, chemical laboratories, the pharmacy, departments of surgery, gynaecology and obstetrics, paediatrics etc.; the five main operating theatres and the plaster room are on floor 1, in B block.

On the fifth floor, there are two gynaecology theatres, the two private patients' theatres are on the sixth floor, and the casualty theatre is on the third floor, with a separate entrance from the main building.

Air-conditioning plant for the main theatres is in the basement, below the theatres, while other plant, for the gynaecology and p.p. theatres, is on the roof.

The boiler house has five 1000 kW electrode boilers, with their ancillary-switchgear panels mounted close by, and also three 180 kW calorifiers supplying the laundry, kitchen etc. with hot water. Other plant rooms with two 150 kW calorifiers supply each ward block. Condensate pumps are installed in each of the plant rooms, and in the boiler house and the basement. Mr. Brian J. E. Brookes, A.M.I.Hosp.E., who is the Inspector of Works (Mechanical), is responsible for the hospital's engineering side, while Mr. K. W. McLean handles the air conditioning and some administrative matters relating to the maintenance department. The staff in the maintenance department numbers approximately 100, including electricians, plumbers, carpenters, painters, mechanics and porters ('mates').

All repairs and maintenance are carried out within the department, except perhaps for armature winding, and the occasional big job, which will not go into the lathe.

The hospital is so large, the equipment so complex, that the engineer officers rarely have a minute to spare. Call-outs seem to be numerous, but one realises on reflection that for a building of the size of Mulago, with all its ancillary buildings, institutional houses etc., much worse would happen in England in many of the very old hospitals. The maintenance department is responsible for the repairs and maintenance of all institutional houses (nearly 100), and also of 'Old Mulago'.

Old Mulago was the original hospital, with small buildings scattered over a wide area of Mulago Hill. It was intended, when New Mulago was built, to demolish the old buildings and to use the space for recreational and housing purposes. The tremendous demand, however, for diagnosis, treatment and hospitalisation has resulted in almost all of the buildings at Old Mulago being completely renovated and put back into use. This adds heavily to the department's already overburdened work load.

We have no problems regarding bad weather, and lost time in this respect is negligible. To the Ugandan, Kenyan or Tanzanian, who is born and bred in this atmosphere of sunshine and beauty, perhaps it does not mean much. To us, however, the sunshine and the beauty of the trees, shrubs and flowers that fill the huge areas around the hospital act as a stimulus, and in this frame of mind we work harder than we would do at home in the snow, rain and high winds.

One of the great pleasures the engineer officers particularly derive from New Mulago is the system of ducts which permeates every part of the hospital's underbuilding structure. Wide, well lit, dry and without pipes crisscrossing at all angles, they are a real pleasure to work in. Brian and I have on many occasions discussed different hospitals in the UK where the ducts have practically no lights, often 3 in of water, and a goodly number of pipes which were definitely put in the wrong place. (Each of us has scars to prove it!)

Uganda's building of new hospitals is rapidly expanding. In upcountry areas, many new 100-bed hospitals are being built to cater for the many patients who cannot get to Mulago. A helicopter is also widely used to transport patients in from outlying areas.

As is not the case in most hospitals in the UK, autoclaves, electronic equipment and many other specialised appliances come under our control for repairs. We have no 'makers man', as a rule to call on. This means that our indents for spares and so on must be figured out well in advance, and it also gives the officers a very varied experience in the repair and maintenance of many highly sophisticated types of apparatus.

A summary such as this obviously misses out a good deal, but if any of our members are interested in any special facet of hospital engineering at Mulago, they could contact either Mr. Brookes or myself.

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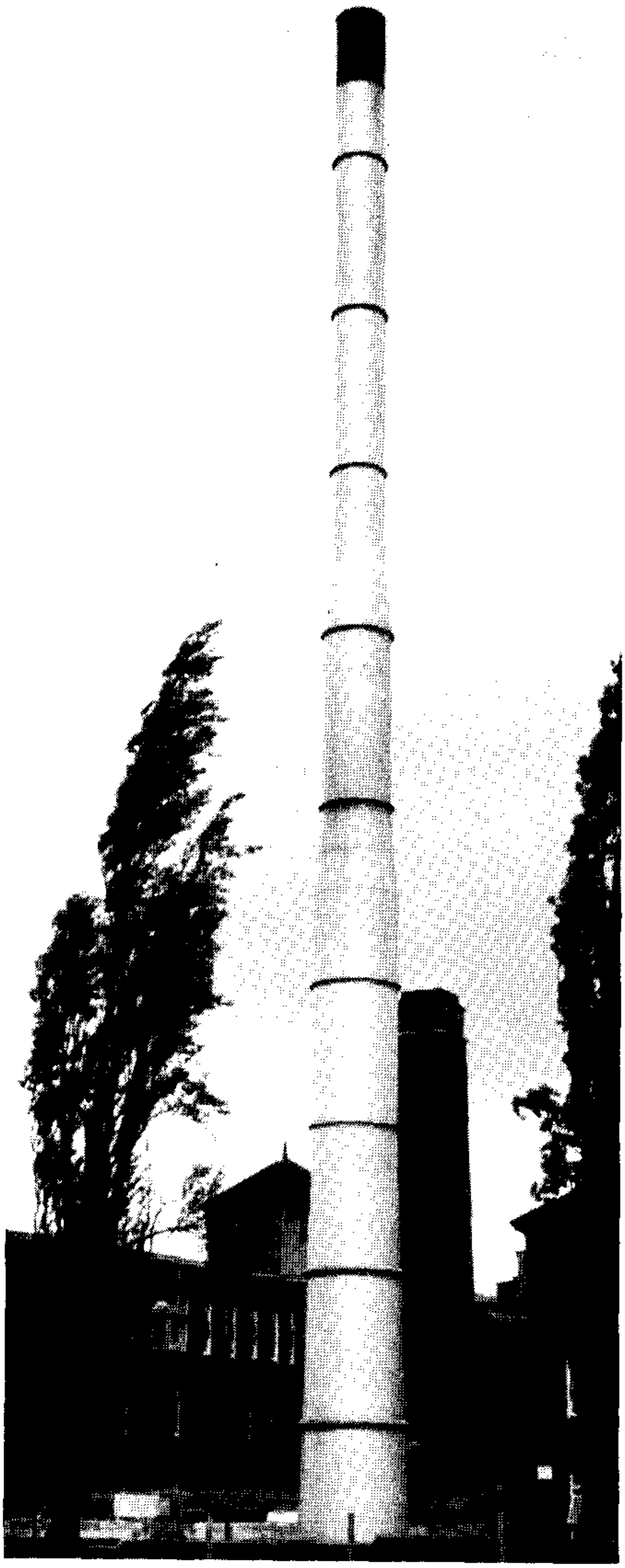
Fig. 1 180 ft steel chimney with insulating lining (King's College Hospital)

MODERN CHIMNEY DESIGN

by M. Beaumont*

This paper was presented to a meeting of the Midlands branch at Stratford upon Avon on the 5th September 1969.

1 Industrial chimney history

1.1 Introduction

Before I talk about the design of industrial chimneys I think that I should first give a very brief account of their history.

There is no record of the first industrial chimney, but it is generally considered that, after man discovered fire and found that it would keep him warm and cook his food, he discovered that he could forge metals in his fires, and then, no doubt, learnt that he could carry out smelting. This led to the development of a crude type of chimney to increase the draught in the furnace. This happened in prehistory or on the very fringes of the earliest records which we have, and virtually no further industrial-chimney development took place until the steam age.

The steam age came about owing to Man's need for minerals. Mining had been carried out in this country from before the time of recorded history—the tin, lead and gold mines of Cornwall attracted the first merchant adventurers, the Phoenicians. As one descends into the Earth one encounters water which percolates through the soil so that when a nonporous stratum is reached it causes flooding at that level. The need for the metals, and, in other parts of the country, for coal and iron ore, was so intense that it was necessary to burrow deeper into the earth, and so the menace of flooding became greater. To overcome this flooding pumps were used, but these were crude, cumbersome and inefficient pieces of equipment. They had to be worked by manpower, or, in some instances, by animal power. However, this was not enough and steam-operated pumps were first built during the latter part of the 17th century.

These were soon improved into quite efficient pumps—the steam age had begun. This improvement in the pumps

* Immediate Past President, National Federation of Master Steeplejacks and Lightning Conductor Engineers

also brought about improvements in the boilers, which were made larger and stronger so as to provide more steam and to work at higher pressures.

This new source of power heralded the industrial revolution, especially in the mills of Lancashire and Yorkshire. Until then these had used water power, which could not produce sufficient energy to run the larger and heavier machines that were being built, but steam gave virtually unlimited power. With the coming of steam came the industrial chimney. It was found that the taller the chimney the greater was the draught, and as boilers increased in size and efficiency so more draught was required.

At this time there were three traditional building materials: timber, stone and brick. Timber was, of course, useless for chimneys, but stone and brick could be, and were, used quite successfully, the choice of materials being dictated by the materials available. In Cornwall where stone was plentiful, this was used, and many of the old disused stone chimneys can still be seen in the Redruth area, some of them topped with brick extensions to increase the height and consequently the draught. Both stone and brick were used in the mill chimneys of Lancashire and Yorkshire, depending upon local availability. This was a prime consideration, for, as roads were poor, transport by road was both slow and costly. It was not until the coming of the railways that reasonably cheap transport became available.

These old mill chimneys were quite often massive structures. Some of them reached 200 ft high and even higher, and by about 100 years ago some had attained the height of 300 ft. They were built in a variety of shapes: square, rectangular, hexagonal, octagonal and circular. They often had massive masonry heads, there being a widely held, but erroneous, theory that a massive head improved the draught. With improvement in transport the stone chimney tended to die out as it was more expensive to build.

As the brickwork of the chimney was fairly thick, especially at the lower levels, the flue gases heated the interior far more than the exterior, causing the interior brickwork to expand. This expansion made the exterior of the brickwork crack, and it was a constant source of income to the old-time steeplejacks to fit steel retaining bands to prevent the cracks becoming wider, and also to point up the cracks. Once bands were fitted, they rusted in time and had to be painted, so that the fitting of bands was not only an immediate source of income, it was also a long-term policy.

To prevent, or at least to minimise, this trouble, firebrick linings were introduced. These consisted of firebricks, set in fireclay, built as an independent wall, generally 4½ in thick but sometimes 9 in thick, with a cavity of 2 in between the lining and the shell brickwork to allow for expansion, otherwise the same cracking effect would take place owing to the expansion of the firebricks. There was also the problem of sealing the gap at the top of firebrick work to prevent the flue dust from filling the cavity between the outer brick shell and the firebrick wall, which would again cause expansion problems. The sealing of this cavity was by no means easy, as firebricks have quite a large coefficient of linear expansion. If the shell brickwork corbelled out over the cavity a sufficient expansion gap had to be left. If it was too large a certain amount of flue dust could enter which, in due course, could cause expansion problems. If the gap was too small the vertical expansion of the firebricks would snap off the corbelled course of bricks and once again expose the gap.

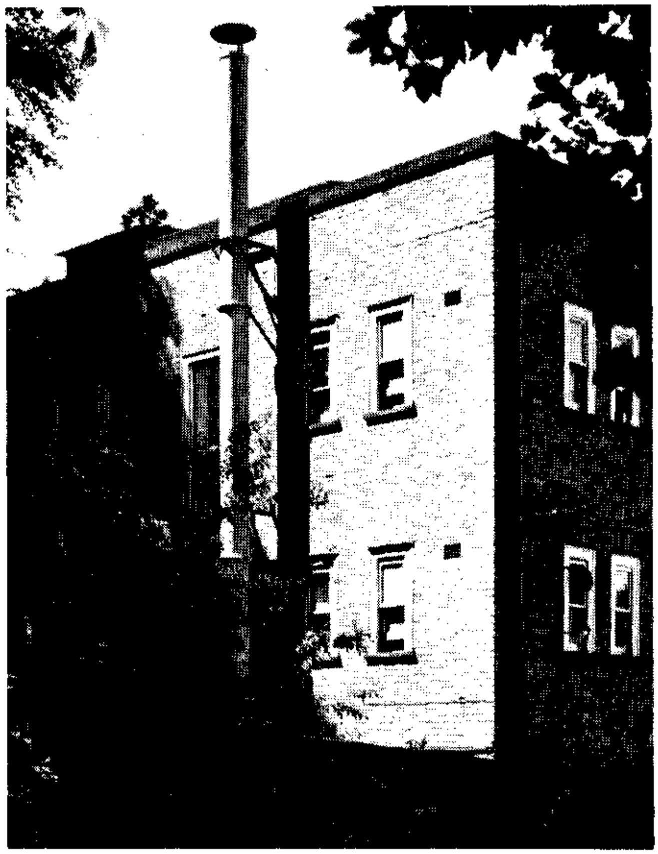

Fig. 2 Bracketed steel chimney, 30 ft x 14 in diameter (Harrow Hospital)

Until about the turn of the century virtually all chimneys were built from traditional materials, but at the end of the 19th and the beginning of the 20th centuries a new building material came into use—mild steel.

Steel had advantages and disadvantages. It was both cheaper and lighter, and could be erected far more quickly than a brick chimney could be built, but it had the disadvantage of requiring more frequent maintenance, and it had a shorter life, even though steel chimneys could be fitted with firebrick linings to prevent too much heat damaging the steel.

Steel did, however, gain quite a hold (Fig. 2), especially as new and smaller factories were being built, particularly in the light industries. Steel chimneys were also being used on a number of the new electricity-generating stations which were being built. The electricity generators of these were driven by steam turbines, which in turn were fed with steam produced in water-tube boilers. The boilers were equipped with large induced- and forced-draught fans so that high chimneys were not required to produce draught; the steel chimneys were fairly short, say 50 ft high, and were mounted on the structure of the boiler house, generally at fan-floor or roof level. Consequently, their light weight was a great advantage.

These early steel chimneys were of riveted construction and could be made in quite small diameters, down to 12 in diameter or so, to serve the smaller cross-tube and Economic boilers. The larger Lancashire-type boilers were still generally served by brick chimneys.

Between the First and Second World Wars, electric-arc welding came into more general use, mainly owing to the introduction of the coated electrode, and some of the smaller chimneys were made using this process, although the vast majority of the larger steel chimneys were still in the more traditional riveted form.

Reinforced concrete made its appearance before the 1914–18 war as a structural material, and chimneys were constructed from reinforced concrete with varying degrees of success, but between the wars it was developed to be a good and reliable type of construction for chimneys, other than for precast-concrete chimneys which presented a number of difficulties. In general, concrete chimneys were either partially or wholly fitted with a firebrick lining, very much as for brick chimneys.

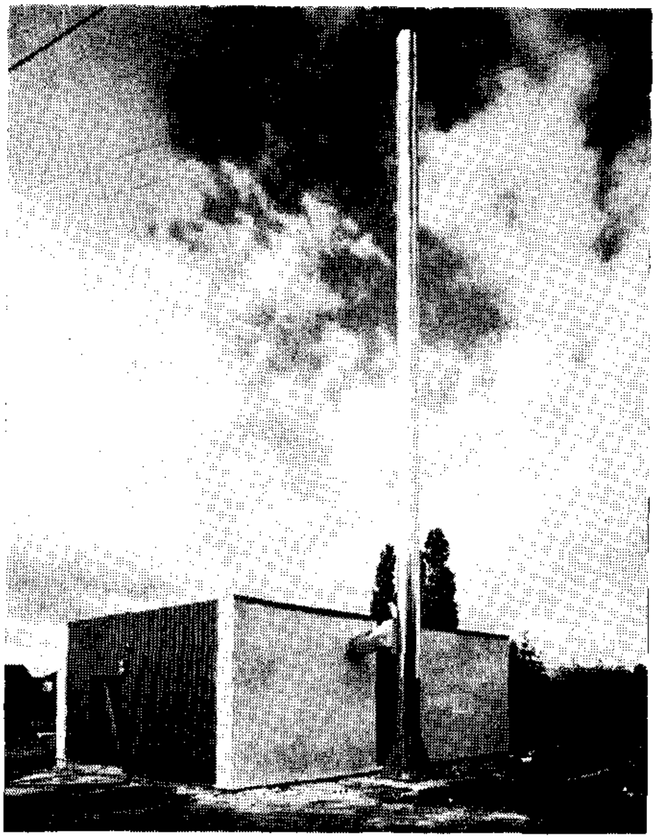

Fig. 3 Welded chimney fitted with aluminium insulating cladding, 55 ft x 18 in diameter (Thornbury Hospital)

Up until the end of the Second World War the great majority of boilers were fired with solid fuel, although after 1918 oil firing started to gain popularity. However, after 1945, owing to the increased cost of labour and transport, and consequently the increased cost of solid fuel, oil firing became far more popular.

1.2 Problems of oil fuel

Oil fuel has one great snag, however. Heavy fuel oil contains up to 4% sulphur, which after firing becomes SO_2 and SO_3. These gases have an acid dewpoint of about 290°F and when they come into contact with a cool surface they condense out and form dilute sulphuric acid, which attacks the inner surface of the chimney. In the case of a steel chimney this condensate attacks the steel and forms ferrous sulphate in the form of a spongy flake. These flakes become detached from the surface of the chimney and are carried away in the flue-gas stream, falling nearby in the form of black smuts which dirty washing and surrounding property, and cause complaints from neighbours.

This problem became so acute that some factory owners were threatened with, and in some instances actually served with, injunctions to prevent the use of their chimney. Such a threat was, of course, very serious and some factory owners reconverted from oil firing to solid fuel. This was a retrograde step, but it was essential to keep the factory in operation.

1.3 Insulated chimneys

British Petroleum, among other oil companies, carried out a great deal of research to prevent this 'smutting' as it was called, and a paper published by Lee and Randell of BP and Professor Blum of the BLRA indicated that the fitting of aluminium insulating cladding to a steel chimney prevented, or greatly minimised, smutting.

This type of insulation has proved very efficacious. For example, my company has fitted over 5000 steel chimneys with aluminium cladding (Fig. 3). It has the great advantage that the aluminium cladding can be fitted to existing steel chimneys as well as to new ones. A further adaptation of the aluminium cladding, to increase its efficiency, is to fit an insulating mineral-wool mattress beneath the cladding. There are other methods of insulating a steel chimney, such as making a double skinned chimney and filling the space between the two skins either with aluminium foil or with another type of loose-fill insulating material, but this can only be used on new installations.

All of these methods, however, are dependent on the heat loss through the cladding, for if the surface temperature of the inner shell which carries the flue gases drops below the acid dewpoint level, condensation will take place and smutting will occur. This loss of temperature is dependent on three factors: first, the effectiveness of lagging, secondly, the velocity of the flue gases, and thirdly, the inlet temperature of the flue gases. The effectiveness of the lagging controls the heat loss, the velocity of the flue gases is in an inverse ratio to the heat losses (i.e. the higher the velocity of the flue gases the smaller the heat loss) and the inlet temperature of the flue gases must be high enough that, after the heat losses described above, the shell temperature still remains above the acid dewpoint at the top of the chimney.

This phenomenon of acid condensation also takes place in brick chimneys but does not show up as quickly; the sulphuric acid attacks the inner face of the brickwork and, particularly, the mortar. The mortar can erode to such an extent that bricks become completely loose and will even fall under certain conditions.

The same problem occurs in concrete chimneys. The acid attacks the surface of the concrete, which spalls and exposes the reinforcing steel, which in turn is attacked by the acid and can in time completely disappear.

1.4 Clean Air Act

The Clean Air Act of 1956 brought about a great alteration to chimney design. Basically it laid down that the velocity of the flue gases should reach a required minimum and that the gases should be discharged at a certain minimum height depending on the size of the boiler, on whether it is fired with solid or oil fuel and on the density of the local air pollution. This has the tendency of reducing the bore so that the velocity of the flue gases is increased, and also increases the height. This is, of course, all to the benefit of the chimney manufacturer or builder, but it produces a number of problems.

Basically, steel and concrete chimneys are cantilever beams standing on end, stress loading and deflection both increase greatly as the length is increased and the diameter decreased, and they eventually reach uneconomical proportions. A brick chimney is just a pile of bricks which are held in position by their own dead weight, and once again deflection can cause insurmountable structural-design problems, for besides being able to withstand their own dead weight all chimneys are affected by the applied wind loading, which can be considerable.

1.5 Flue-gas velocity and its influence on chimney design

It is necessary to maintain the flue-gas efflux velocity, which is relatively easy if the principle of one boiler to one chimney is followed. If two boilers are connected

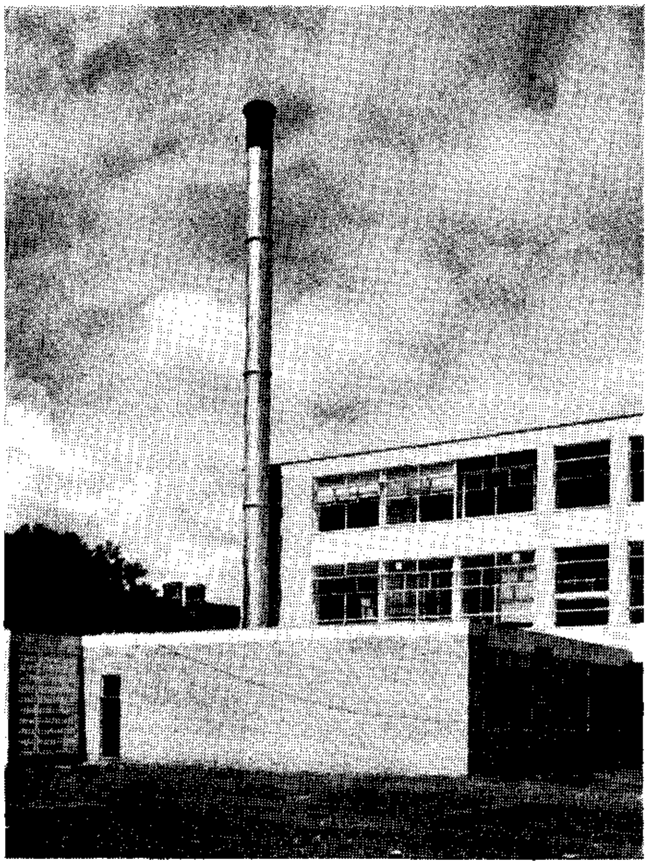

Fig. 4 Brick-lined concentric chimney, 110 ft x 46¼ in diameter. The outer chimney is aluminium-clad, and the diameter of the inner chimney is 15¼ in

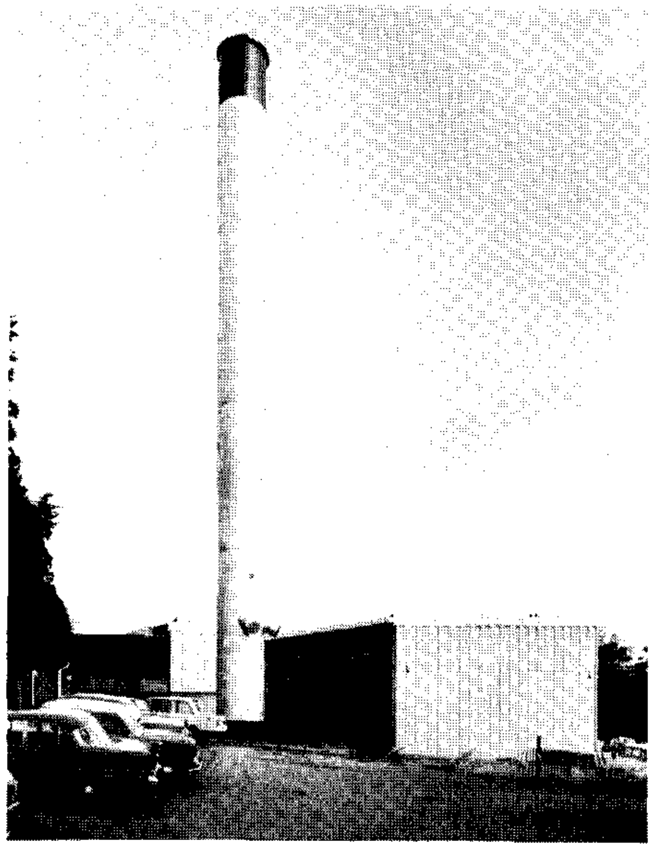

Fig. 5 Painted and sandblasted multiflue chimney, 100 ft x 81 in diameter, fitted with one 24 in, two 21½ in and one 12 in diameter inner chimneys. The largest inner chimney has a monolithic lining giving an inner bore of 20 in (Torbay Hospital)

to one chimney, and when they are both on full load the gas velocity reaches the desired speed, then if only one boiler is on full load the flue-gas velocity falls to half of that required. If the second boiler is on half load the flue-gas velocity drops to one quarter of that desired, and smutting conditions are almost certainly produced owing to the lack of velocity. However, small-bore chimneys produce structural difficulties which are virtually insurmountable from an economic point of view.

One of the first attempts to overcome this difficulty was by fitting a midfeather or partition for the whole height of the chimney, but this brought its own troubles due to expansion—one side of the chimney became hot and the other remained cool if only one boiler was onload. On uninsulated steel chimneys this was not too serious, as the steel shell cooled very quickly, but this caused smutting troubles. If the chimney was insulated the shell remained warm and smutting did not take place, but one side, being hot, expanded and the other side, being cool, did not. Consequently, the chimney acted as a bimetallic strip and the top deflected owing to expansion. In one case a 70 ft chimney deflected as much as nine inches when only one boiler was onload. I do not consider that this is a practical design; my own company discarded this type of chimney with the midfeather or splitter plate, or, as it is sometimes called, the segmented chimney, as undesirable some years ago.

After the discarding of the segmented chimney the next development was the concentric chimney. In this there is an inner insulated chimney which is connected to one boiler, with a concentric outer chimney insulated with aluminium cladding (Fig. 4). There were, of course, certain design problems relating to linear expansion, but these have all been successfully overcome. This is proving to be an excellent design, especially if the plant consists of one large and one smaller boiler, or of three boilers of the same size. In the latter case the inner chimney serves one boiler and the outer chimney serves the other two; thus the maximum flue-gas velocity can be obtained whether one, two or three boilers are in use.

However, if there are a number of boilers of varying sizes and a great flexibility of boiler loading is required, as in a hospital, it is most advantageous if each boiler has its own chimney. Because of structural limitations these cannot always economically be made selfsupporting. It is possible, however, to encase them all in a common shell which carries the structural load. To prevent heat dissipation the space between the chimneys and the outer shell is filled with a loose fill of insulating material. All chimneys are designed to expand independently of each other, and are so insulated that there is no metal-to-metal contact between the inner flue-gas-carrying chimneys and the outer structural shell (Fig. 5). This design can be made with multiple variations, and, if required for aesthetic reasons, the outer shell can be fitted with aluminium cladding. Alternatively, the outer shell can be built of concrete, but this type of construction is certainly heavier and generally more expensive than if a steel outer shell is used.

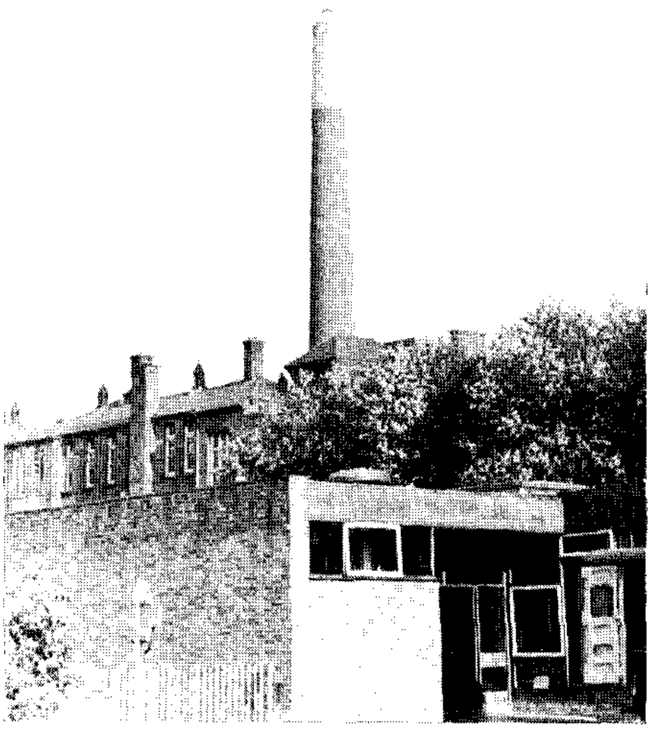

Fig. 6 Brick chimney converted by the addition of an inner steel chimney. The top of the original chimney was faulty, and was rebuilt to its present height of 141½ ft (St. Mary Abbott's Hospital)

This type of chimney is gaining great popularity among forward-thinking engineers. One of its very great advantages over other types of multiflue chimneys is that should one of the inner flues wear out, and it must be remembered that no flue is everlasting, the loose insulating fill can be drained out, the defective inner flue removed and a new flue installed. If necessary, this work can be carried out when the other inner flues are onload.

A variation of this design can be obtained by fitting inner steel chimneys inside existing brick, concrete or steel shells and similarly insulating them. This is particularly useful when changing from, for instance, a bank of coal-fired Lancashire boilers to a number of oil-fired Economic boilers (Fig. 6).

All the chimney designs mentioned above are covered by British patents.

1.6 Plastics chimneys

One of the types of chimney not described so far is the plastics or glass-fibre chimney. Some remarkable results have been claimed for these, but at present, in general, they are of far more use as fume exhausts than as boiler chimneys, mainly because of the flue-gas temperatures. In general, the upper temperature limit of the best plastics chimneys is given as about 500°F. Now this, in itself, is quite a high temperature for flue gases on triple- or quadruple-pass Economic or package boilers, but one has always to consider what happens should the flue-gas temperature overreach this figure. This is possible if the boiler tubes are not cleaned correctly or often enough, or if, in a hard-water area, the water-softening plant does not work correctly, so that the tubes become covered with scale and do not transmit sufficient heat to the water. The temperature of the flue gases then rises considerably, and their heat is transferred to the plastic which reaches its upper temperature limit and can become brittle, causing the chimney to collapse. It has also been found from experience that some of the plastics chimneys which have been claimed to withstand a temperature of 500°F have in fact failed at considerably lower temperatures.

Plastics chimneys in general have little structural strength and have to be fitted with guys or supported in a steel tower, the latter, of course, being somewhat costly. There is also some evidence that they smut. They have the advantage of being very light, but generally they tend to be far more expensive than steel chimneys. However, research in the plastics field is advancing almost daily, and there is no doubt that the technologists will in due course find a solution to the problems which at present beset them.

2 Factors in chimney design

In my opinion there are two factors in the design of a chimney. The first is the operational design and the second is the structural design.

2.1 Operational design

First, I believe that the most important consideration is the gas velocity in the chimney. In my opinion the minimum gas velocity, when the boiler is on maximum turndown, should not be less than 15 ft/s. That is, if this is when the boiler is on half turndown, the gas velocity on full load would be 30 ft/s. If the boiler is on one-fifth turndown the gas velocity would have to rise to 75 ft/s at full load.

Secondly, height. Basically this is controlled under the Clean Air Act as laid down in the Memorandum on chimney heights, and, as previously mentioned, this generally results in a chimney being far higher than it would have been formerly.

Thirdly, the insulation must prevent the inner surface of the shell of the chimney from dropping below dew-point. I would emphasise here that acid condensation will take place on the inner face of the chimney whether it be steel, concrete, plastic or brick if the temperature of the inner face of the shell falls below dewpoint level. The insulation must be of sufficient thickness and efficiency to combat the falling temperature of the flue gases during their passage through the chimney; this falling temperature is related to both the velocity of the gases and to the height of the chimney.

Fourthly, if the flue-gas inlet temperature is too low no amount of insulation will prevent the condensation of flue gases. To protect the inner surface of the chimney it is necessary to provide a barrier between the flue gases and the internal surface. This can be done in a number of ways to be discussed later, but it must be remembered that all linings are consumable and none will last forever.

2.2 Cold-air inversion

Attack by condensation can be brought about by cold-air inversion at the top of the chimney. This is especially prevalent when the chimney is on light load. The plume of gas does not have enough bulk or sufficient velocity to completely fill the bore of the chimney, cold air enters on the windward side and descends the bore, mixes with the hot gases and cools them to the level where they condense out so that the condensate attacks the chimney. It is generally because of this effect that the top of a chimney deteriorates before the lower levels.

On all types of chimney cold-air inversion can be prevented, or greatly reduced, by the fitting of a truncated cone, or venturi, as it is generally called, to the top of the chimney. The venturi normally has a slope of 15° to minimise back pressure, but it must be appreciated that the fitting of a venturi will cause a certain amount of resistance owing to the reduction of the outlet area. This resistance has to be balanced against the thermal lift of the hot gases, especially when on full load, to ensure that the additional resistance does not cause more pressure on the system than can be dealt with by the burner (Fig. 7).

In certain applications it is sometimes necessary to insulate the venturi to prevent condensate attack.

2.3 Structural design

This is a fairly simple matter. It is purely the correct application of basic engineering principles coupled with a considerable amount of knowhow (Fig. 1). A British Standard has been issued entitled 'The design of steel chimneys' (BS 4076). This standard took nearly four years to prepare, and I am pleased to say that I was responsible for getting the British Standards Institution to undertake this work, and I also served on the committee. The standard contains a great amount of information, and I would most strongly recommend that whenever it is proposed to design or specify a steel chimney this standard be used.

One very great advantage of the steel chimney over other forms of construction is the speed with which it can be made, erected and put into use. After a steel chimney has been erected it can be used immediately, whereas both brick and concrete chimneys have to dry out, which needs to be a lengthy process, otherwise structural faults can develop.

Another advantage is that with the present rate of industrial development a process which is absolutely new can be completely outmoded in ten or fifteen years, the plant then being either redundant or in need of very great expansion. A brick or concrete chimney is then a liability which costs a large sum of money to remove, whereas a steel chimney can either be quickly and economically dismantled for reuse or, alternatively, it has scrap value.

Work has recently started on a standard for the design of concrete and plastics chimneys. I am also a member of this committee, but I feel that it will be some years before the standard is produced.

I do not anticipate that a standard will be produced on brick chimneys, as the design of these, although basically by rule of thumb, is quite sound and has proved its value over the last 250 years or so. It must also be remembered that, owing to their high cost, brick

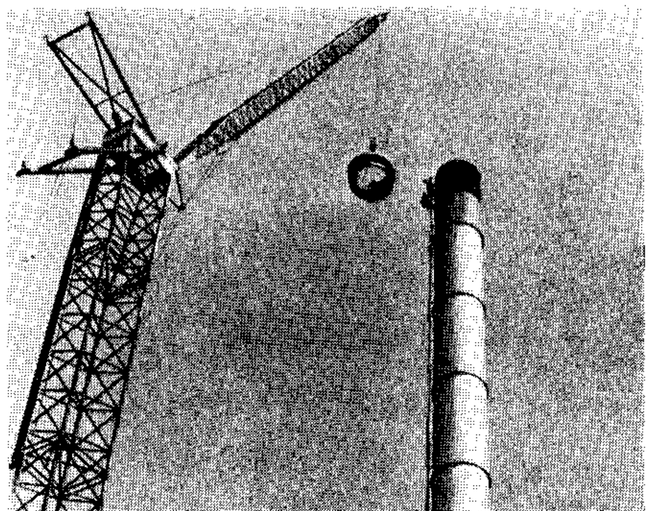

Fig. 7 Erection of venturi on a chimney measuring 225 ft x 102 in diameter

chimneys may be considered to be obsolescent.

An alleged new type of chimney is making a come-back. This is the precast concrete chimney. It is gaining a little ground, particularly in small chimneys up to say 50–60 ft high, at the expense of the traditional brick chimney. In fact, it is more or less specified by 'modern' traditionalists. I do not consider that this type of chimney is of a sound engineering design—I have in the past seen various serious structural failures in this type of chimney, some of which have deteriorated into a highly dangerous condition.

3 Corrosion

I will now elaborate on the problem of the corrosion which can take place in a chimney, and the ways it can be prevented or minimised.

As I see it, there are three types of corrosion: atmospheric, mechanical and chemical.

3.1 Atmospheric corrosion

Owing to our location in the upper half of the temperate zone of the northern hemisphere, with a huge land mass on the one side and a vast ocean on the other, we do not have a set weather pattern. It is a well known fact that our weather is variable, sometimes bad, sometimes worse! It is fairly temperate but we do have what seems to be a considerable amount of rain. Although our annual rainfall is moderate compared with some countries, it is fairly evenly spread throughout the year. In other words, we do not have a dry or a wet season. It is basically permanently wet.

To a steeplejack, rain is a mixed blessing. It causes him to get wet, which is uncomfortable, but it also corrodes and erodes chimneys, and so helps to provide him with his bread and butter.

The action of weather on chimneys can be summarised as follows:

Brick chimneys

Rain attacks the jointing mortar and causes it to corrode. This occurs on the whole of the exterior and, to some extent, on the top few feet of the interior. If the brickwork of a chimney is cracked, rain can enter the crack, which, if followed by frost, freezes and expands, thus increasing the crack in both depth and length.

Frost can also cause spalling damage to the surface of brickwork.

Concrete chimneys

A monolithic concrete chimney is a cantilever structure standing on end. Consequently, it must deflect under wind load. This deflection causes hair cracks to form on the surface of the chimney and rain is drawn into these cracks by capillary attraction. Again, if this is followed by frost it causes the face to spall and the cracks to extend. If the rain gets as far as the reinforcing steel the steel corrodes. The build up of rust spalls the face of the concrete, thus exposing more reinforcement, and the damage progresses 'by the square'.

A precast concrete chimney is again a cantilever structure standing on end but with a difference in this case. The precast concrete is made in a works under closely controlled conditions, and as such is dense and of very good quality. When the wind causes the chimney to deflect, the chimney bends in the way that a lobster does: i.e. the segments remain solid but the joints bend. Hair cracks appear in the horizontal joints, the joints fail and the reinforcement can be attacked as in the monolithic chimney.

There is one serious factor which can affect the precast type of concrete chimney if it is constructed in such a way that the reinforcing bars are in one continuous run. If a vertical reinforcing bar parts owing to corrosion and load, it fails for the whole length of the chimney instead of just locally. Thus, if enough bars fail the chimney becomes a stack of building blocks, only stable because of their dead weight. As the chimney is designed as a cantilever, under strong wind conditions there is tension on one side; so there is a chance of its collapsing.

Plastics chimneys

As these are fair newcomers to the chimney world not a lot is known about them under operational conditions, but it is known that they can, under certain circumstances, work harden owing to deflection, and consequently become unsafe.

Steel chimneys

Owing to the nature of their construction steel chimneys are visually affected by the weather more rapidly than any other type of chimney. Bare mild steel will show signs of rust after a few hours, and this will increase until in time the steel is totally consumed.

3.2 Mechanical corrosion

There are basically three types of mechanical attack upon a chimney: heat, abrasion and wind loading.

3.2.1 Heat

If a material is heated it expands; this expansion causes many types of problems.

Brick chimneys

If too much heat is applied to the inner face of a brick chimney the inner face will expand, but, as the heat transfer rate is slow, the outer face will not expand to such an extent. This will cause tension in the shell which, if large enough, causes the shell to crack. The cracking will, besides damaging the bricks, also permit attack by the weather.

Too much heat can also cause the inner face to spall owing to local expansion problems. This can be very serious.

To prevent attack by heat, firebrick or insulating-brick linings are used, but, as previously mentioned, provision must be made for the expansion of the lining. These expansion problems do not normally occur when an insulating-brick lining is used, but insulating bricks will not withstand such high temperatures as will firebricks. In special cases in high-temperature chimneys, both types of lining are used.

Concrete chimneys

The effect of heat on concrete chimneys is similar to that on brick chimneys.

Plastics chimneys

If too much heat is applied to the inner face of a plastics chimney, two things can happen. Depending upon the nature of the resin used in its construction, it will either harden or soften. If it hardens too much it becomes brittle and will not withstand shock or deflection loads. If it becomes soft, the result is obvious.

Steel chimneys

Steel can withstand far higher operating temperatures than can unprotected brick, concrete or plastic, but at elevated temperatures it can spall.

3.2.2 Abrasion

Abrasion can be extremely serious as it is insidious—quite often the first sign of this type of attack is a hole in the side of the chimney. It is mainly brought about by grit particles from solid-fuel boilers being carried in a fast-moving gas stream impinging upon the chimney surface. This is especially noticeable at points where the gas stream changes. The particles of grit are projected against the side of the chimney, since because of their mass and velocity they are thrown to the outside of the gas stream when it changes direction.

This type of attack does not normally take place on chimneys serving oil-fired boilers but is prevalent with solid-fuel and p.f.-fired boilers, especially if there are high gas velocities owing to forced or induced mechanical draughts.

Abrasive attack can take place on brick, concrete, plastics or steel chimneys. The results become obvious far more rapidly on plastics or steel chimneys owing to their relatively thin shells compared with the much thicker shells of brick or concrete chimneys.

3.2.3 Wind loading

When a strong wind blows on any type of chimney the chimney will deflect to a certain extent depending upon its height, diameter and construction.

Brick chimneys

Wind loading on a brick chimney will cause it to deflect and, in fact, brick chimneys do deflect far more than is normally expected. To a steeplejack on the top of a tall brick chimney the swaying can be quite noticeable, and this swaying can produce cracks. Normally these follow the line of least resistance; i.e. the mortar. This results in zig-zag cracks, whereas heat generally causes the bricks themselves to crack.

Once again, rain can enter these cracks with the results referred to above.

Concrete chimneys

Normally, in well designed concrete chimneys, serious cracks due to deflection do not occur, but small hair cracks most certainly do. These can in due course cause spalling of the surface and rusting of the reinforcement as previously described

Plastics chimneys

Owing to the low yield point of plastics materials all plastics chimneys have to be supported either by guy wires or within a structure which carries the wind load. There have been cases, however, of plastic chimneys deflecting despite their supporting guys, for no guy can be 'bar tight'. This has caused work hardening, embrittlement and subsequent collapse.

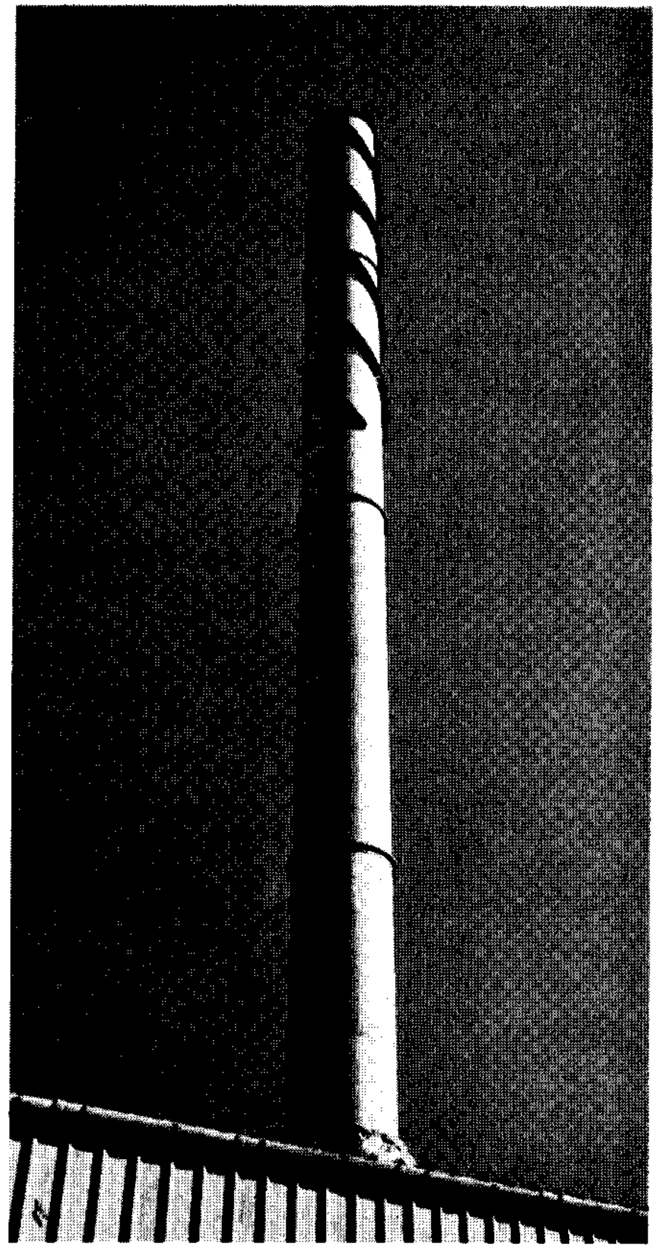

Fig. 8 Three aerodynamic helical fibreglass stabilisers fitted to the top 30 ft of a 3-flue 88 ft chimney (Forest Gate Hospital)

Steel chimneys

Deflection caused by wind does not normally matter in a steel chimney as the steel has a high modulus of elasticity and will normally return to its original position without damage. Occasionally with self-supporting steel chimneys, owing to the design of the chimney and conditions brought about by the topography of the surrounding district, wind-excited oscillations can occur. These, if they are severe enough and continue for a long period, can cause failure of the chimney, either by the fracturing of the jointing bolts in the flanges owing to continual reversing of the stresses brought about by rapid oscillations, or from metal fatigue in the shell brought about in the same manner. This, of course, can cause collapse. (See Fig. 8.)

3.3 Chemical attack

This type of attack causes considerably more damage than the combination of both atmospheric and mechanical attack. It is the basic cause of smut emission as well as being the main source of corrosion in all types of chimney.

I have described the cause of chemical attack. The acid condensate will attack all types of chimneys, but it attacks them in various ways.

Brick chimneys

The acid will attack both the bricks and the mortar. The amount that it will attack a brick depends on the density of the brick and on the amount of liquid it will absorb. The softer the brick the more acid it will soak up; there have been occasions when extremely dense 'acid-resisting' bricks on the inside face of a chimney have been penetrated to a depth of more than an inch by acid.

Generally, however, it is the mortar which suffers most from the attack. Brick chimneys are normally built from gauged mortar; i.e. sand, cement and lime. This mortar is, to a certain extent, hygroscopic, and hence will absorb the acid which destroys it. It is often possible to remove the bricks from the inner face of a brick chimney by hand owing to the complete deterioration of the mortar. There are instances where the acid has percolated right through to the outside of a three-brick wall (27 in) of a chimney and has then run down the outer surface.

When a brick chimney is out of plumb, especially if it 'leans' for part of its height, this is normally due to acid attacking the mortar. With this type of defect a chimney normally leans into the prevailing wind. This is because the windward side is the colder, and thus the acid is more likely to condense out and attack this side rather than the lee, or warmer, side.

Concrete chimneys

The effect of acid on the interior of a concrete chimney is virtually the same as on a brick chimney. It enters through hair cracks or is absorbed into the surface, reaches the reinforcing bars, which it destroys, and can finally reach the outside of the chimney.

Concrete chimneys do not normally 'lean' as do brick chimneys.

Plastics chimneys

These can also be affected by acid condensation. There are instances of fibreglass-reinforced plastics chimneys which have corroded from ¼ in thick to paper thin in less than two years owing to acid attack.

Steel chimneys

Uninsulated steel chimneys are, of course, very adversely affected by acid condensate as previously described.

4 Prevention of corrosion

4.1 Atmospheric

In the case of atmospheric attack a barrier is placed between the irritant and fabric of the chimney.

Brick chimneys

One of the earliest methods to prevent weather attack on the outside of brick chimneys was to paint it with boiled oil. This penetrated into the surface of the bricks and mortar and formed a barrier. It did wear away in time but was nevertheless quite simple, cheap and effective. It has now been replaced by the application of a clean silicone sealer, which while more expensive is more effective and lasts far longer.

It was not normal to treat the interior of brick chimneys in this way but they were sometimes coated with tar to prevent condensate attack.

Concrete chimneys

The best way to prevent weather attack on the exterior is to paint the whole of the outer shell with a silicone sealer, and then to apply a siliconised chlorinated-rubber paint. This seals the hair cracks and prevents rain water being absorbed through capillary attraction.

As with brick chimneys, concrete chimneys are not normally treated on the inside.

Plastics chimneys

Normally no exterior protection treatment is given to plastics chimneys, but the shell can be pigmented during manufacture if required.

Steel chimneys

To prevent corrosion from weather on the outside of a steel chimney, there are several different treatments. First, the old and well-tried method of painting. It is, of course, essential that the surface is clean before the application of the paint, but the selection of the correct type of paint is as important. For low-temperature chimneys a good bituminous paint is as good as anything. It will withstand temperatures up to about 400°F quite well, it is cheap, and as it never sets to an enamel-like hardness it can accommodate expansion of the steel shell. If, however, the temperature goes too high it will burn off and the chimney will soon show signs of rust.

For higher temperatures a good aluminium paint is usually used. This will generally withstand temperatures of up to 600–650°F, which is hot for a boiler chimney, but if the temperature rises higher than this it will tend to flake off as it cannot accommodate the expansion of the steel. For very-high-temperature chimneys, i.e. over 650°F, it is almost impossible to find a suitable paint. This is despite paint manufacturers' claims; although no doubt these claims are made in all sincerity, they are normally based on laboratory experiments rather than practical field tests.

There are a few kinds of paint for high-temperature chimneys which are as good as the manufacturers claim, but these often require site mixing, very special cleaning of the chimney which is not normally practicable, bringing the steel up to a certain temperature after the first coat and holding it at that temperature for a certain time for curing, and so on. This is all very well in a laboratory, but not in the field.

A second method is to shot blast, metallic spray, and seal with a silicone sealer at the works. This is very effective on the exterior of steel chimneys, but is somewhat expensive.

A third method is to apply an outside cladding of aluminium. This normally insulates, prevents corrosion, and only requires very little maintenance.

4.2 Mechanical

This is normally achieved by the barrier method. A consumable barrier is used inside the chimney. This can be dense brick, firebrick or gunned concrete, and it prevents the abrasion of the chimney shell. The lining is, of course, consumed in time but it can always be replaced.

Mechanical damage from heat is prevented in the same way; a barrier of firebricks, insulating bricks, castable refractory or gunned lining is used. This type of lining can be applied to brick, concrete or steel chimneys.

4.3 Chemical

Brick and concrete chimneys

Internal corrosion is normally dealt with by the firebrick or insulating-brick lining. The lining does become contaminated with acid, but as it is consumable it can be replaced without damage occurring to the shell of the chimney. It is, of course, impossible to replace the lining if the bore is too small to admit a man. The minimum bore within which a man can work is normally 2½ ft diameter and even so working conditions are extremely cramped.

On low-temperature chimneys where a great deal of condensation may be expected, or where there is a gas-washing plant, acid-resisting linings are often fitted. These will only stand temperatures up to about 400°F; so they can only be used in cold chimneys.

Plastics chimneys

These can be attacked by acid condensate but are not normally fitted with a lining. The durability of a plastics chimney depends upon the resin used in its construction; these resins vary considerably, so it is essential that the correct grade of resin is selected for the problem in hand. As far as I know, there is at present no commercial-quality resin which is both acid and heat resistant and of adequate structural strength to replace the conventional self-supporting type of chimney, but no doubt a suitable resin will be developed if there is sufficient demand.

Steel chimneys

The attack of acid condensate in a steel chimney can be combated in two ways, either by a barrier to prevent the acid attacking the steel, or by preventing the condensate forming. The barrier can take one of several forms.

Paint can be used. This is not very effective and can only be regarded as a short-term measure. It depends very much on the quality and type of paint and on the way in which it is applied, on the temperature involved and on the strength of the condensate, but its life is normally measured in months rather than in years.

The metal can be shot blasted, hot metallic sprayed, and then treated with a silicone sealer as with the exterior treatment. The life of this type of barrier varies greatly according to conditions, but it can normally be expected to last for between three and ten years according to the severity of the attack.

A firebrick or insulating-brick lining can be used as in brick chimneys. A plastics coating can be applied. This is only suitable for very-low-temperature chimneys, say not more than 250°F, and it is often very brittle and can be damaged by thermal or mechanical shock. A rubber lining can be applied, but, once again, heat is the limiting factor; rubber will not normally stand temperatures anywhere near as hot as will plastics, but it is far more resilient to shock.

A gunned lining can be used. This can be one of a number of types, which are described in the new BS 4207. It can only be used on larger chimneys, say 4 ft diameter or over, but is very effective. It is consumable but it can be patched, and if the correct type is selected it has a long life so that this would appear to be the best of barriers.

On small-diameter chimneys a refractory lining can be cast. This has similar results to a gunned lining, but is, of course, not replaceable because of the access problems.

The second method of combating acid condensate is of course to prevent it from forming. This is done by insulation; if the temperature of the shell can be kept above the dewpoint of the flue gases condensation will not occur. It is obvious that some condensation must occur when cooling down, but the latter, particularly, is negligible, as when the boiler goes offload the acidic flue gases purge quite quickly. As mentioned above, it is no use trying to insulate a chimney if the temperature of the flue gases is so low that despite any insulation the temperature falls below dewpoint level. If this is the case it is essential that a barrier be used.

5 General design

It must be appreciated that some corrosion, and consequently deterioration, will take place on all types of chimney, but this can be kept to a minimum by proper design.

Far too often a chimney is outlined by the architect so that it will harmonise with his design for the building, and little or no consideration is given to its operational design. Fortunately, the Clean Air Act has forced architects to keep to minimum heights for chimneys, but even so the average architect has little or no knowledge of detailed chimney design from an operational point of view.

I would submit that the operational design of a chimney is a complex subject with many variables which have to be taken into account, so that the chimney must be designed operationally before it can be designed structurally, let alone aesthetically. The architect, with the vast field he has to cover, cannot spend the time to become a specialist in all the facets of his profession, but must generalise and rely upon specialist advice for detailed design.

If a chimney is not designed to be operationally correct it will be a constant source of trouble and will require heavy maintenance. Sometimes this may cause periods of outage which cannot be accommodated without disruption of production. It will have a far shorter lifespan than is necessary, and it will cause the works engineer unlimited worry and trouble.

As a steeplejack I am preaching against my own creed, but as a businessman I abhor waste, especially unnecessary waste, if it is caused by a professional man who will not accept advice given freely by a specialist who has spent many years actively dealing with the multitude of problems affecting chimney life and design.

Conversion of prewar kitchen

by D. W. Foster, M.A., A.H.A.*

The Stellex tray system was introduced at Wythenshawe Hospital in June this year. It took six weeks to phase in the service to 14 wards, including children's, geriatric, medical and surgical, totalling approximately 300 patients.

The kitchen itself was a prewar building and many old army facilities were still in use. The cooking and serving area measures only 59 x 24 ft (Fig. 1) and the trolley bay and central wash-up area is 36 x 24 ft (Fig. 2). The entire system has been installed within this space; resiting of certain pieces of existing equipment and slight alterations to the structure within the area have been necessary, but ample space has proved to be available.

The existing kitchen-staff establishment has not been increased with the introduction of this system, and the standard of cooking, portion control and presentation has improved tremendously owing to the fact that the catering staff have a closer liaison with the patients.

Every day a menu card is issued to each patient from which he can select the next day's meals. A choice of soup, two hot and one cold main dish, and three choices of sweet including cheese and biscuits are offered at lunch time, and similar choices are available at other meals. The patient is also given a choice of portion size, and therapeutic diets are similarly catered for.

Fewer initial problems have occurred than expected as the system has proved to be very adaptable to the hospital's particular requirements. The appreciation of the patients, who are now able to select their meals and have them served on a tray, has been very well received.

Fig. 1 Heated bain-marie counter with meals being prepared and loaded into the tray trolleys

Fig. 2 Trolley parking bay and Stellex automatic time sequencer which will progressively switch on and off one or more trolleys at fixed intervals to reduce the electrical load

*Deputy Group Secretary, Baguley and Wythenshawe Hospitals

★ Market News ★

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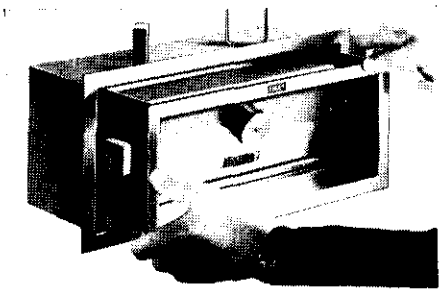
Evacuation valve

The new Power Utilities Ltd. air-evacuation valve, the 'W' type, is made in two sizes: the 1W valve handles 200 ft^3/min and the 2W valve 500 ft^3/min at a pressure of 0·1 in w.g. The valves can be easily adjusted onsite after installation so that they operate at any pressure in the range 0·02–0·12 in w.g. They are therefore ideally suited to installation in operating theatres and other clean areas.

The 'W' Valve has been designed specifically for use on internal walls where cascade systems control the air flow and Aercon X-type valves are used on external walls.



All parts in contact with the air flow are made of stainless steel; the valves are easily cleaned and are resistant to mild detergents and antiseptics.

If required, these 'W' Type valves can be supplied with mild-steel wall sleeves, complete with metal tongues for building into brickwork. **HE 102**

Power Utilities Ltd., Lombard House, Great Charles Street, Birmingham 3

'Gas in hospitals'

A new brochure available from the Gas Council sets out the case for choosing gas to fuel new and converted hospital equipment.

Appliances ranging from a 20m Btu central boiler to individual gas fires are described, and the brochure goes on to cover catering, incineration and sterilisation.

The total-energy concept is described, in which gas turbines provide generated electricity, the waste heat from which can provide hot water, space heating or air-conditioning. **HE 103**

Gas Council Commercial Gas Centre, Tottenham Court Road, London W1

'All risks' fire extinguisher

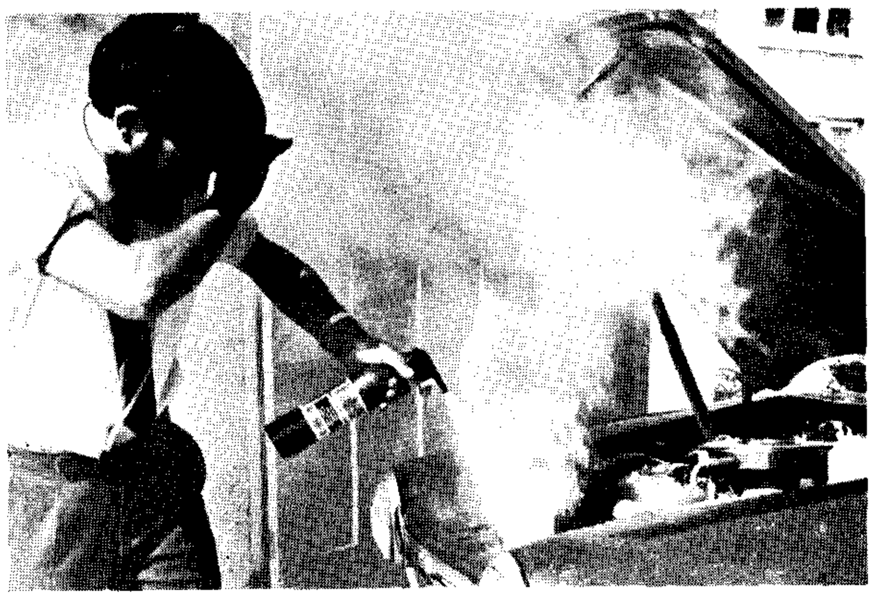
A new extinguisher which utilises low-toxicity BCF (bromochlorodifluoromethane) as the extinguishing medium is now available. The extinguisher has a completely new modern design; there is no safety clip or cap to remove and the instructions are limited to 'Hold upright, aim at base of fire, squeeze trigger'. Operation automatically breaks a small tab seal to reveal an 'empty' sign.

BCF is a vaporising-liquid extinguishant of very low toxicity. It is efficient and safe for use on class A, class B and, because it is electrically nonconductive, class C fires. The small size, neat appearance and simplicity of the extinguisher make it ideal protection for commercial vehicles, laboratories, garages, switch rooms and all locations where mixed risks are encountered. A mounting bracket is provided.

Recharging is effected by unscrewing the head, replacing the spent body with a new factory-sealed charge and inserting a new sealing tab.

The extinguisher is manufactured in two capacities to contain 1½ lb or 3 lb of extinguishant. The extinguisher head, containing the simple trigger mechanism and the nozzle, which emits a flat finely divided spray, screws directly onto the seamless red-anodised body. **HE 104**

George Angus & Co. Ltd., Angus House, Westgate Road, Newcastle upon Tyne



Computer data-acquisition systems

Hewlett-Packard Ltd. have announced medical-computing systems designed for cardiovascular and biomedical research and intensive-care patient monitoring. These new medical-data systems use a computer to control measurements and to process data. They can display trends, decide when to sound alarms, standardise readings, compute averages and deviations, and perform other related functions. The systems are intended to let users spend time on medical rather than computer-operating problems.

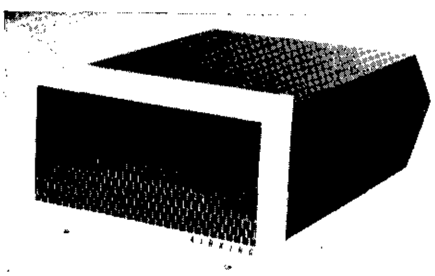
The user controls the computer either through switch registers and a teletypewriter or through a marked-card reader using IBM-type cards marked with a lead pencil. Online physiological data, such as e.c.g., pressures and temperature, are derived from a variety of signal amplifiers. Offline information, relating to the administration of drugs, or clinical notes, is routed through a teletypewriter and marked-card reader. Output is through the teletypewriter or a cathode-ray-tube display. **HE 105**

Hewlett Packard, 224 Bath Road, Slough, Bucks.

Filtered-air units

A range of air-filtration units is being manufactured by Stewart King Industries. Full air-conditioning systems are not always possible, but Airking air-filtration units are relatively inexpensive and can be installed for one-fifth of the cost of the most economical air conditioning.

By providing filtered fresh air with the windows closed, they reduce the amount of pollen, bacteria, smoke and dirt admitted into a room. By keeping the windows closed, of course, noise levels are also minimised.



Rooms fitted with this equipment can be pressurised, so that any air leakage is out of the room and when doors are opened less contamination is admitted.

A heater inside the unit, coupled to a thermostat, prevents cold spots during winter operation. Acoustic insulation of the fan ensures quietness.

Stewart King make units to two standards, both containing filters tested in accordance with BS 2831. The two standards are 95% at 5 μm for general ward work and 95% at 0·5 μm for more critical operations.

HE 106

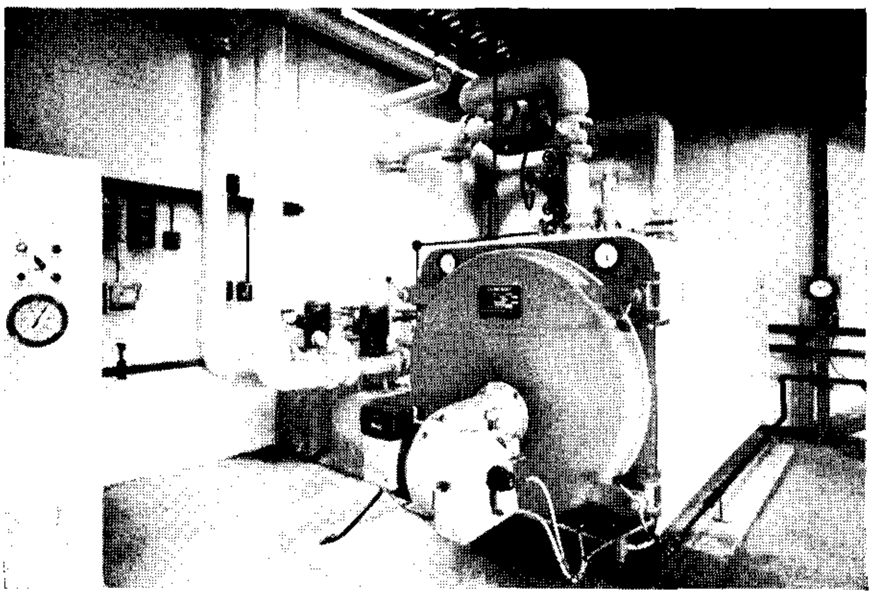
Stewart King Industries, Aysgarth Road, Waterlooville, Hants.

Kubomat boilers

IDC Thermodynamics was formed in October 1968 for the purpose of designing and manufacturing boilers and thermal-process equipment. To this end the British manufacturing licence for SHG plant was acquired. SHG of Kassel, Germany, are known throughout the world for their waste-heat boilers, and the experience gained in this field has contributed towards the development of a range of package boilers.

IDC Thermodynamics undertook to develop the package hot-water and steam boilers for the requirements of the UK market. These boilers are known as the Kubomat and the range is now complete for sizes from 1·6 to 16 million Btu/h for hot water and from 1750 to 23000 lb/h for steam. Kubomat boilers are suitable for firing with oil, towns gas, natural gas or l.p.g. The manufacture of these boilers is now well under way, and the first units are already in operation. **HE 107**

The IDC Group Ltd., Industrial House, Stratford upon Avon



Steel protection scheme

Metalife Ltd. have recently developed an organic anodic-metal system, System 202, to provide economical long-term protection in high-humidity, nonchemical environments such as in catering kitchens. This system combines blast cleaning, cathodic protection and an environmental barrier, and can be utilised for protecting new steel projects or for the planned maintenance of existing steelwork.

It is claimed that, when used in conjunction with System 202, blast cleaning is a one-off operation whereby the costs are never repeated. Immediately after blast cleaning Metalife Clad is applied by spray; this is a quick-drying anodic-metal coating which does not interfere with the speed of production or work flow. This is followed by the application of Metalife EB2. This part of the system is regarded as a direct alternative to galvanising or metal spraying and is more economical and versatile. The system is concluded by a coat of Metalife AS3 which acts as a self-sealing environmental barrier. This provides an attractive matt grey finish.

Metalife operates a free corrosion-engineering service which can monitor each step through regular visits by technical engineers to all the contractors. This procedure is to ensure that the predetermined standards of cleanliness and application are met.

HE 108

Metalife International Ltd., Claro Road, Harrogate, Yorks.

Smoke detector

New from Photain Controls Ltd. is a smoke detector for use with warm-air central-heating systems. It consists of a light probe and optoelectronic detector which are mounted in a cast aluminium housing on the return-air duct to the central boiler. The light-activated switch is set to switch off the boiler as soon as a certain level of smoke density is detected; this level can be set onsite, allowing for varying expected conditions.

The unit is suitable for gas or oil-fired systems, and has completely fail-safe circuitry. The complete system is retailed at £16. **HE 109**

Photain Controls Ltd., Randalls Road, Leatherhead, Surrey

Clippings

The UKAEA, Harwell, has just taken delivery of a giant electron microscope which has been successfully tested at a potential of one million volts. Supplied by AEI Scientific Apparatus Ltd., the EM7 microscope is the first commercial million-volt microscope to be built in Europe. The Harwell instrument is one of five ordered from AEI to a total value of £1 m.

The microscope is to be used to investigate thicker metal sections than has hitherto been possible with conventional high-resolution equipment. However, one of the most exciting possibilities is that the very high penetrating power of the electron beam may enable biologists to study not only cell structure but also maybe actual living material in special protective surroundings in the microscope.

The EM7 microscope design has been evolved in very close collaboration with prospective users, and this has led to the inclusion of particularly novel operational features. For example, the generator and beam accelerator are each housed in sulpher-hexafluoride-filled pressure vessels, giving flexible operation in the range 0·1–1 MV and the possibility of future extension to 1·2 MV. The control system for moving the specimen under examination is also particularly simple, consisting simply of a single 'joystick', which allows for movement in any direction with a wide range of speeds.

The microscope weighs 22 ton, of which the electromagnetic lenses provide about $\frac{1}{4}$ ton each. Magnification ranges from $1{\cdot}6 \times 10^6$ times right down to 63 times, and the resolution is put at 10^{-7} m, though this is expected to be improved in the coming months.

In 1895 a warm-air ventilation plant was installed at Sunnyside Royal Hospital, Montrose. Now it has just been demolished to make way for new plant, after heating the ground-floor rooms through a series of under floor ducts for over 70 years. In an unprecedented spate of modernisation, almost all of the electrical wiring in the hospital has also been replaced and it is now on a.c. supply throughout. The steam-driven d.c. generators that have been used up to now will be scrapped shortly.

The Wessex RHB has awarded the £3·4 m. second-phase contract for Basingstoke's new 600-bed district general hospital to W. E. Chivers & Sons Ltd. Work begins on the 17th November, and is due for final completion in April 1973. The new unit will be the town's first all-purpose hospital, many acute cases having previously been sent to Alton or Winchester hospitals. The present hospital-bed capacity in Basingstoke is 182.

The ward units will be housed in a five-storey tower block, consisting of four floors of general wards, each taking 120 beds, and one floor of special wards for children, geriatrics etc. On first-floor level will be seven operating theatres and an intensive-therapy unit, and the remaining facilities will be on the ground floor and basement levels.

Reinforced concrete frames with brick infills will be used throughout, except in certain cases where steel framing is to be used. The total area of the new project, including landscaped grounds and car parks, will be approximately 30 acres.

Britain's 12th International Mechanical-Handling Exhibition will take place at Earls Court, London, from the 5th 15th May 1970. The exhibition is held on alternate years; the last exhibition, in 1968, featured products from more than 300 British and foreign firms and attracted visitors from over 80 countries.

In 1970 more than 550 000 ft² of exhibition space will be available, showing, for example, industrial trucks, conveyors of all kinds, bulk-handling plant, elevators, hoists and winches, and storage equipment.

British Insulated Callender's Cables Ltd. has anticipated problems of the changeover to the metric system by training a number of its regional sales staff as metrication officers, so that they can help customers.

They will be able to advise not only the supplier, but also the user, installer and distributor.

★ Postbox ★

Dear Sir,

I have just finished reading 'all' of the new Journal, and feel I must congratulate you and the Council on the new approaches and outlook in this which can be so informative. May I, as a member, express my thanks for giving all of us what will be a highly respected voice in our complicated field.

T. B. James

7 Ellwood Path, St Dials
Cwmbran, Monmouthshire

* Members Diary *

SCOTTISH BRANCHES SEVENTH JOINT AUTUMN CONFERENCE

A most successful Conference was held at the Aberdeen Royal Infirmary on the 16th–18th October.

The President of the Institute, G. A. Rooley, acted as chairman at the opening and introduced Professor R. Ireland, LL.B., M.A., Q.C., Chairman of the Board of Management for Aberdeen General Hospitals, who officially opened the Conference. The first session, which followed, was chaired by the President, and was given over to a paper on 'Modern heat exchangers' by F. Hicks, of The British Steam Specialties Ltd.*

Mr. K. W. Wilson, Regional Engineer, Western Regional Hospital Board, was the chairman in the afternoon, when a paper on 'Bioengineering' was given by John Hughes, B.Sc., of the University of Strathclyde. This was followed by a paper on 'Internal automated transportation in hospitals' given by Mr. G. J. Belt of Drayton Castle Ltd.

On the Friday morning Mr. C. W. King, Hospital Secretary, gave an invigorating talk on the history and development of the Foresterhill Site, upon which the Aberdeen Royal Infirmary stands. This was followed by a film on the 'Finessa' food distribution system in hospitals. Mr. E. L. Taylor, Regional Engineer, Eastern Regional Hospital Board, was the chairman for the session.

The afternoon was taken up with a visit to the new laundry and c.s.s.d. and the Phase I development of the Aberdeen Royal Infirmary.

The final session on the Saturday morning was chaired by Mr. C. H. Harris, Regional Engineer, North Eastern Regional Hospital Board, and took the shape of an open forum. Members of the forum were G. A. Rooley, J. E. Furness, the Institute Secretary, Mr. Duncan MacMillan, Group Engineer, Inverness Hospitals Board of Management, and Mr. F. R. Potter, Group Engineer, Edinburgh Southern Hospitals Board of Management. Various subjects were dealt with by the forum and a lively general discussion ensued.

The Conference Organising Committee is to be congratulated on all the effort that went into planning and carrying through a most interesting programme.

The Institute is extremely indebted to the Board of Management for Aberdeen General Hospitals for all the facilities that were made available, and would particularly like to extend gratitude to W. Caie, Group Secretary and Treasurer, C. W. King, Hospital Secretary, Miss Anderson, Group Catering Officer, and Miss Steele, the Home Sister, for the contributions they made towards making the conference a success. Finally, mention must be made of the considerable contribution of W. Runcie, the Group Engineer.

*This paper will be published in the January 1970 issue

* Among the Branches *

EAST MIDLANDS BRANCH

At their meeting on 10th October, at the Royal Hospital, Chesterfield, members heard Mr. V. Machin, of the Sheffield RHB, talk on welding techniques. With the help of visual aids he pointed out where troubles were to be found in welded joints, such as lack of root penetration in butt welds and of heel penetration in fillet welds. He advocated that on steam lines all welds be checked by gamma radiography, and that any lines above 6 in should be automatically tested (this being detailed in all welding specifications).

SOUTHERN BRANCH

'Electronics in the field of medicine' was the subject chosen by Mr. A. Newton, M.I.E.E., M.I.E.E.E., Main Grade Engineer to the Wessex RHB, for his talk at Knowle Hospital on 20th September.

Mr. Newton opened by giving a brief résumé of the principles of electronics. He went on to say that although the therapeutic value of electricity had been known for centuries it was not until about 1800 that it first started to be harnessed and put into general use for the treatment of certain types of physical disorders. Over the years improvements have continued, and machines now do an infinite variety of jobs in the medical field. Owing to the miniaturisation of component parts, the use of such items as pacemakers has become possible. Mr. Newton illustrated this part of his talk with a sketch of a human heart and its work, and members were fascinated as he explained the various parts.

Electronics and its relationship to present-day computers was next discussed. The first computer was made about the year 1700 by Babbage; it was a hand-cranked affair with gear wheels–it was not until approximately 1947 that computers as we now know them came into being.

It was a talk which was interesting enough to have been continued well beyond the time allocated, but a halt had to be called for questions, which Mr. Newton answered.

LONDON BRANCH

On Friday, 10th October, 120 members and guests gathered at the Rembrandt Hotel, Knightsbridge, on the occasion of the 1969 Ladies' Festival of the London Branch.

During the dinner, Mr. E. Peck, Branch Chairman, made presentations on behalf of members of the Branch to Mr. and Mrs. P. C. Vedast, who both addressed the assembly. The presentations followed the retiring from office of Mr. Vedast, after completing seventeen years on the branch committee and as Branch Honorary Secretary. The value of Mr. Vedast's contribution has been referred to before in these columns but, typically, he was the first to say that he could not have sustained his role over the years without the willing support and assistance of his wife.

Among those attending the dinner, with their wives, were the Institute's President, Mr. G. A. Rooley, the Immediate Past President, Mr. L. G. Northcroft, and the Secretary, Mr. J. E. Furness.

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First class experience and training for young engineer seeking advancement. ONC (O2) engineering desirable and good practical training in maintenance of mechanical and electrical services. Salary (under review) £975 rising to £1270, plus London weighting. Consideration will be given to the appointment, on an abated scale, of persons without these qualifications.

Information available from Deputy Group Engineer, King's College Hospital. Telephone: 01-274 6222, extension 2213.

Applications, to be received not later than 24th December, giving full details of training, qualifications and experience, naming two referees, to Hospital Secretary, St. Francis' Hospital, St. Francis' Road, London SE22

ASSISTANT ENGINEER required at ORPINGTON HOSPITAL.

Post vacant February 1970. Salary scale £1065 – £1360 per annum. Candidates should have completed an apprenticeship in mechanical or electrical engineering or otherwise acquired a suitable practical training, and possess an ONC in Engineering or an equivalent qualification.

Consideration will be given to applications from Engineers who do not possess the above qualifications but for such applicants there would be an abatement in the above salary. Apply, naming two referees, to The Group Engineer, Cray Valley and Sevenoaks Hospital Management Committee, Orpington Hospital, Kent.

WESSEX REGIONAL HOSPITAL BOARD

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The post will be based in Winchester.

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Candidates must be either Chartered Mechanical Engineers or Corporate Members of the Institute of Heating & Ventilating Engineers with several years' experience in engineering services in buildings, including site practice.

Applications giving full details of age, experience, qualifications and the names and addresses of two referees (preferably employers) to the Secretary, Highcroft, Romsey Road, Winchester, Hants., by the 1st January, 1970.

SENIOR SUPERINTENDENT (ELECTRICAL)

Required by the GOVERNMENT OF KENYA, Ministry of Works, on contract for one tour of 24 months in first instance. Salary according to experience in scale (Kenya shillings) 29 880–33 420 (approximately £Stg.1743–£1949) plus an inducement allowance of £926–£956 per annum paid direct to the officer's bank in the UK. Gratuity 25% of total salary drawn inclusive of generous leave, or 45% without leave. Free passages. Education allowances. Quarters at reasonable rental. Contributory pension scheme available in certain circumstances.

Candidates, not over 50 years of age, must possess City & Guilds Full Technological Certificate or equivalent, and must have had at least 12 years' experience (including a comprehensive engineering apprenticeship followed by at least seven years in a supervisory position) in (a) the maintenance of electrical and mechanical equipment and services and medical equipment in large modern hospitals, preferably a teaching *hospital, (b) the operation and maintenance* of diesel-engine-driven alternators and L.T. and *11KV.* distribution systems. Officer appointed will be responsible for the maintenance of building structure and finish, hospital grounds and roads, hospital vehicles, electrical and mechanical engineering, building services and medical equipment at the Kenyatta National Teaching Hospital, Nairobi.

Apply to CROWN AGENTS, 'M' Division, 4 Millbank, London SW1, for application form and further particulars stating name, age, brief details of qualifications and experience, and quoting reference number M2T/681110/H.R.

LEWISHAM GROUP HOSPITAL MANAGEMENT COMMITTEE

DEPUTY GROUP ENGINEER required. A new post in busy acute hospital group. *Salary £1610 – £1845* p.a. *including* London Weighting and special responsibility allowances. Applicants must be experienced in accordance with P.T.B. 191 (or equivalent, approved by Department of Health). Job description and application form, (returnable by the 2nd January 1970), from Group Secretary, Lewisham Hospital, High Street, London S.E. 13. Telephone 01-690 4311.

APPOINTMENTS AND SITUATIONS VACANT

HULL (A) GROUP HOSPITAL MANAGEMENT COMMITTEE

hospital engineer

Responsible to the Group Engineer for the maintenance of the mechanical and electrical services of the Hull Royal Infirmary, a new acute general hospital of 780 beds. The hospital complex includes new ward block with full outpatient facilities, operating-theatre suite (7 theatres), central sterile-supplies department, pharmacy, nurse-training school, postgraduate medical centre, X ray department, staff residencies, steam boiler house with automatic coal firing.
Applicants must possess HNC or HND in either electrical or mechanical engineering with appropriate endorsements, or City & Guilds mechanical engineering technicians full technological certificate (Part III) which must include plant maintenance and works service.

Salary scale: £1370–£1650 per annum (increase pending) plus £100 responsibility allowance.

Application forms and further details obtainable from the Group Secretary, Victoria House, Park Street, Hull

BOARD OF MANAGEMENT FOR INVERNESS HOSPITALS

Applications are invited for the newly created post of HOSPITAL ENGINEER. The successful candidate will be directly responsible to the Group Engineer for the engineering services, both mechanical and electrical, in the Inverness group of hospitals, where a major development is approaching completion.

Applicants must hold one of the following qualifications, or an equivalent qualification approved by the Secretary of State for Scotland:

(i) HNC or HND in mechanical engineering, with endorsements in industrial organisation and management, and principles of electricity or electrotechnology, if this was not taken as a subject of the course

(ii) HNC or HND in electrical engineering, with endorsements in industrial organisation and management, and including (at S III or 02 level), or with endorsement in, Applied heat and applied mechanics, provided that he has suitable practical experience in mechanical engineering

(iii) City & Guilds mechanical engineering technicians full technological certificate (Part III) which must include plant maintenance and works service.

The salary scale is £1514–£1774 per annum, plus £100 special-responsibility allowance.

Application forms may be obtained from the Secretary and Treasurer, 14 Ardross Street, Inverness. Closing date for applications 30th December 1969.

SOUTH WEST LONDON HOSPITAL GROUP

DEPUTY GROUP ENGINEER

Required for this new post in a busy acute Group of 7 hospitals. Salary scale £1,610 to £1,845 per annum, inclusive of responsibility allowance and London Weighting.

Applicants should hold a Higher National Certificate or Diploma in Electrical Engineering, including Applied Heat and Applied Mechanics or an approved equivalent qualification. (i.e. H.N.C. Mechanical).

Application forms and Job Description from Group Secretary, South West London Hospital Group, St. James' Hospital, 72 St. James's Drive, London S.W.17. to be returned by 20th December, 1969.

THE ROYAL MASONIC HOSPITAL

DEPUTY CHIEF ENGINEER

Applications are invited for the post of Deputy to the Chief Engineer of this 270-bed hospital–the largest private hospital in the UK. This hospital is shortly to be extensively modernised.

Qualifications: An accredited apprenticeship in mechanical engineering, a Higher National Certificate in mechanical engineering with endorsements in industrial organisation and management and in principles of electricity or electrotechnology, or equivalent qualifications. Wide experience of engineering plant and services and of modern methods of planned maintenance. Ability to supervise general maintenance of buildings will be considered important and applicants are therefore asked to state any previous experience in this field.

Duties: applicants will be expected to carry out the entire range of duties of the Chief Engineer who is approaching retirement age.

Salary: commencing salary will depend on qualifications and experience, within the range £1600–£1800 plus 10% of basic salary for long hours gratuity. Residential accommodation will either be available or an allowance made in lieu.

Applications stating age and full details of education, training and experience, with names and addresses of not less than two referees, should be sent to the Secretary, Royal Masonic Hospital, Ravenscourt Park, London W6, marked 'Private and Confidential'.

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EDGWARE, MIDDLESEX

ASSISTANT ENGINEER

This is an excellent opportunity for a young man, preferably with ONC in engineering. He will be responsible to the hospital engineer for the operation and maintenance of engineering services which include a new oil-fired central steam-raising boiler house. Opportunities for day release for further study will be given.

Salary scale £975 p.a. rising by seven increments to £1270 p.a. plus £90 London weighting.

Applicants to Group Personnel Officer, Edgware General Hospital, Edgware, Middx. Telephone 01-952 2381.

continued overleaf

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continued from previous page

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HOSPITAL ENGINEER

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Further particulars and job description can be obtained from the Group Engineer (Telephone: Denbigh 2871).

Apply, giving full particulars and experience, with names of two referees, to Group Secretary, Rhianfa, Russell Road, Rhyl, by the 31st December

---

ASSISTANT HOSPITAL ENGINEER

For Saxondale Hospital, Radcliffe-on-Trent, Nottingham. This is a large psychiatric hospital with steam-raising and water-heating plant, which should prove an ideal training ground for future Hospital and Group Engineers.

Salary scale £975–1270 per annum.

House available on hospital estate at reasonable rental.

The Group Engineer, Mr. T. S. Elstub, will be glad to answer any enquiries. Applications, giving age, qualifications, experience and names and addresses of two referees to Group Secretary, Saxondale Hospital, Radcliffe-on-Trent, Nottingham, by the 30th November, 1969.

HOSPITAL ENGINEER for SUMMERFIELD HOSPITAL BIRMINGHAM 18

Salary scale £1370 – £1605, plus £75 per annum responsibility allowance. House available at reasonable rent.

Applications are invited from suitably qualified Engineers.

A person with a keen inquiring turn of mind, as well as independence and initiative, is sought.

Application forms and job description are available from:

Group Engineer, Dudley Road (Birmingham) Hospital Management Committee, Dudley Road Hospital, Birmingham 18

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