CORRESPONDENCE TUITION SCHEME

COURSE FOR POWER PLANT OPERATORS

LESSON 4 - THE DEVELOPMENT OF THE MODERN BOILER

Contents

List of Figures

1 INTRODUCTION

1.1 History

Twenty years or so ago, most of what was then modern boiler plant in this country was stoker-fired, operating at a pressure of 450 to 650 p.s.i. and a final steam temperature 343°C. (650°F.) to 454°C. (850°F.). Output capacities were generally in the region of 150,000 to 180,000 lb/hr. and steam from such units discharged into a common main or to steam receivers from which the steam required for the turbines was drawn.

During the second World War little development took place and no major advancement in steam conditions was considered. Additions to existing plant were made only to fulfill the immediate need.

In the years directly after the war, however, there was a rapid increase in the demand for electrical power. Since the manufacturers were not at that time able to supply plant sufficiently quickly to meet this increase, load demands which exceeded the capabilities of existing plant could not be met and load shedding resulted, the most memorable example of which is probably the winter of 1947.

Conditions such as these and the continued rate of rise in demand in the years which followed provided an excellent opportunity for the development of larger units operating at higher steam conditions than had previously been experienced. The increased reliability of boilers and turbines, moreover, enabled greater confidence to be placed in these plants so that future design was based on the unit boiler and turbine principle, thereby achieving some economy in initial cost by the omission of the "spare" boiler and much interconnecting steam and feed piping.

The early 1950's, therefore, saw the installation of the first 30 MW unit boiler/turbine plant operating under steam pressure and temperature conditions corresponding to those of the immediate pre-war period - 625 p.s.i, and 463°C. (865°F.).

This was followed within a short space of time by the 60 MW unit boiler and turbine operating at 950 p.s.i, pressure and 496°C. (925°F.) temperature - steam conditions which had not, up to that time, been in use to any. great extent in this country.

Since then the continued rise in demand for electrical power and the higher overall efficiency offered by higher steam conditions and the use of reheated steam has resulted in still further advances in outputs so that, at the present day, units having a duty of 550 MW have now been commissioned. Furthermore, the increased thermal efficiency Offered by very high pressures in the supercritical region will be used to advantage in plant now being installed. (See Table 1)

In this lesson some of the features which have had to be considered in the development of boiler plant from those immediate post war years will be examined.

2 SELECTION OF STEAM CONDITIONS

2.1 General

In Lesson 3 the Steam Cycle was explained and elementary thermodynamics discussed. In this section of the lesson the reasons for choosing the various steam cycles will be considered.

2.2 The Straight Cycle

The straight cycle is that in which the steam produced by the boiler at a given temperature and pressure, passes straight to the turbine and thence to the condenser.

As indicated in Table 1 the plant having the smaller output, that is, say, 30 MW, has for its steam conditions at the boiler outlet a pressure of 625 p.s.i. and a temperature of 463°C. (865°F.).

If, however, it is decided to design plant much in excess of this output (say, 60 MW) there are two main factors which must be considered.

(i) If the pressure and temperature conditions selected are too low, there will be too much "wet" steam formed at the L.P. end of the turbine.

(ii) A gain in overall efficiency will result if higher steam conditions are selected.

Consideration of these two factors has, therefore, led to a choice of a pressure of 950 p.s.i, and a temperature of 496°C. (925°F.) for the boiler associated with the 60 MW turbine.

Similarly, further advances in turbine size (which necessitates higher boiler outputs, as shown in Table 11) have led to higher pressures and temperature until an economic limit is reached for the straight cycle and the reheat cycle must be considered.

Size MW	Boiler Evaporation lb/hr.	Steam Conditions at Turbine Stop Valve			Reheat Temperature		Stations Existing and Projected
		Pressure p.s.i.	Temperature °C	Temperature °F	°C	°F	
30	300,000	600	454	850	-	-	Hackney 'B', Westwood, Walsall and others
60	550,000	900	482	900	-	-	Tilbury 'A', Skelton Grange 'A' and others
100	830,000	1,500	566	1,050	-	-	Castle Donington, Willington 'A'
100	760,000	1,500	524	975	510	950	Ferrybridge 'B', Aberthaw 'A'
120	860,000	1,500	538	1,000	538	1,000	Agecroft 'C', Blyth 'A', Drakelow 'B' and others
200	1,350,000	2,350	566	1,050	538	1,000	High Marnham, West Thurrock (part)
275	1,900,000	2,300	566	1,050	566	1,050	Blyth 'B' (part)
300	2,240,000	2,300	566	1,050	566	1,050	West Thurrock (part)
350	2,350,000	2,400	566	1,050	566	1,050	Blyth 'B' (part) Tilbury 'B', Drakelow 'C' (part)
375	2,500,000	3,500	593	1,100	566	1,050	Drakelow 'C' (part)
500	3,350,000	2,300	566	1,050	566	1,050	Eggborough, Aberthaw 'B', Ironbridge 'B'
500	3,400,000	2,300	566	1,050	566	1,050	Cottam
500	3,450,000	2,300	566	1,050	566	1,050	West Burton 'A', Ferrybridge 'C', Fidlers Ferry, Ratcliffe
500	3,550,000	2,300	566	1,050	566	1,050	Fawley, Kingsnorth
550	3,900,000	2,300	566	1,050	566	1,050	Thorpe Marsh

Table 1:

2.3 The Reheat Cycle

This cycle may be regarded as a development of the straight cycle. Steam passes into the turbine in the usual way, but after passing through the H.P. cylinder it flows back to the boiler where it is reheated and passed into the I.P. cylinder. This helps to reduce wetness at the exhaust end of the L.Po turbine. The overall efficiency of the reheat cycle is higher than that of the corresponding straight cycle.

It will be seen from Table 1 that units of 100 MW are in operation both on the straight and reheat cycle, but for units in excess of this size the reheat cycle is always adopted.

In order to achieve a further increase in overall efficiency it is possible to return the steam to the boiler a second time for reheating (i.e. "double reheat")° This practice has been carried out to some extent in the U.S.A. but not in this country. The gain in efficiency does not always warrant the extra complication and cost.

2.4 The Supercritical Cycle

It will be seen by reference to Table 1 that a smaller boiler is required for a 100 MW reheat cycle installation than for a 100 MW straight cycle unit.

A further reduction in boiler size could be achieved if a pressure in the supercritical region were chosen (i.e. a pressure in excess of 3,208 p.s.i.). That this is not done for outputs in the region of 100 MW or so is one of economics. The supercritical pressures demand very thick walled tubes for instance, which may mean the use of special metals and, therefore, involve greater initial cost. This may only be justifiable for larger units, say, in the region of 350 MW or over and it is for this reason that the development of the supercritical cycle in this country has been slow.

3 SELECTION AND DEVELOPMENT OF FIRING METHODS

3.1 General

The selection and development of the various firing methods will be considered in this section. It is not proposed to describe these methods in detail as this will be considered in Lesson 11.

3.2 Stoker Firing

The maximum practical size of a travelling grate stoker or a spreader stoker is sufficient to provide an evaporation of 270,000 to 280,000 lb/hr. in a boiler. There are many plants in this country where stoker firing is employed, some of which were installed in the immediate post war years but with the advancement in boiler size and the establishment of the unit boiler and turbine arrangement, the stoker has had to give way to other forms of firing.

Development work in this field has, therefore, been confined to the modification of existing stokers, where necessary, to handle fuels for which they were never designed but which they are now being called upon to burn. The development of the modern boiler is, therefore, based on the use of pulverised fuel in the majority of instances.

3.3 Pulverised Fuel Firing

with very few exceptions plant in the last ten years has been designed to burn pulverised coal.

In all cases the milling technique is known as the "unit" system, that is, the coal is fed direct to the mill, is ground and passed direct to the boiler furnace.

Some earlier schemes included a separate pulverised coal storage but this practice is now discontinued, mainly on account of explosion or fire risk and dust nuisance.

Generally speaking, the advancement in boiler size has had little effect on mill design until recent years. After all, it has only been necessary to increase the number of mills in order to achieve the output required from the larger units.

In the early days of pulverised fuel firing the periodic maintenance and adjustment required on a mill necessitated load reduction when the mill was withdrawn from service. With the deterioration in coal quality in post war years and the increase in the number of mills on these large units, it was envisaged that mill outages for this purpose may be frequent. This could lead to loss of load and to overcome this a spare mill is essential.

Current practice is to install sufficient mills to give full boiler output with one mill out of service and on the poorest coal anticipated.

It is expected, however, that where the tube ball mill is in service (that is the Foster Wheeler, John Thompson or Mitchell type) continuous operation without the need for adjustment can be expected between overhaul periods and the requirement in these cases is that the exhauster fans associated with such mills may be capable of giving the full duty with one fan out of service for, say, blade renewal.

Where pressure mills are used the exhauster fan is replaced by the primary air fan and this condition is no longer required.

In recent years, where units have advanced to 200 MW and over, the number of mills was becoming a serious embarrassment to the layout of the boiler plant as well as the increase in time required for maintenance.

On such units, therefore, larger redesigned mills have been developed. An International Combustion type L M mill has, for instance, been developed to include a three-roller arrangement. Furthermore, the relatively large power requirements of exhauster fans on suction mills has led the manufacturers of that type of mill towards the use of pressure mills thereby reducing the overall power consumption of the milling plant. It is easier to design a highly efficient primary air fan than an exhauster fan.

The tube ball mill, mentioned earlier, has undergone little change apart from a scaling up of its size to meet higher output requirements. The number in use has increased considerably in recent years, however, due mainly to its improved reliability compared with those of the pre-war years.

3.4 Oil Firing

Oil firing could be used on any boiler, whatever the size, but until the last few years the price of oil compared with that of coal has made oil firing an unattractive proposition on account of higher running costs.

In the last few years, however, increased coal costs, especially high transportation costs to stations situated in the South of the country have made oil more competitive but the advancement in size of the modern boiler has brought with it the problem of production and supply of large quantities of residual low grade oils. The use of oil firing is still limited, therefore, to those boilers converted from coal to oil burning to cover an anticipated coal shortage some years ago, together with a few stations where the boilers were designed for oil firing.

Its development in connection with the ignition of the pulverised fuel burner has, however, been extensive. In the early days of pulverised fuel firing, ignition of the coal was obtained by a paraffin torch. Later came the mariually operated oil torch.

As boiler sizes increased, greater quantities of oil were used for pressure raising, due to the inability of the large P.F. burners to operate alone at very low outputs without becoming unstable in operation. It became common practice to keep the oil burner ignited until the P.F. flame was established and its ignition maintained by the help of a warm furnace. The older type oil burner was not designed for this however and inefficient combustion of the oil had adverse effects on heating surfaces and brickwork. It became essential, therefore, to improve the design to give efficient combustion and today the oil burners for P.F. ignition are capable also of carrying load. On a modern design this load amounts to approximately 10% of the full boiler output.

The increase in the use of automatic control of the boiler plant has also resulted in a further improvement, in that the majority of burners are now automatically inserted ignited and retracted and flame failure detection is provided.

4 THE BOILER UNIT

4.1 General

The development of the boiler unit itself, i e. from the furnace to the air-heater will be considered in this section.

4.2 The Furnace

It is unfortunate that the advancement in boiler size has been accompanied by a deterioration in the quality of coal received by British power stations. High ash quantities and properties of the ash which cause heavy slagging in a furnace and superheater have meant that furnaces must, nowadays, be more easily rated than those in the past. This means that an amount of heating surface must be installed in the furnace sufficient to reduce the furnace gas exit temperature to a level low enough to prevent slagging in the superheater.

This easier rating has been achieved, not only by making furnaces bigger, but also by making the tube surface more effective in absorbing the heat given up by the hot gases in the furnace. In modern designs, therefore, the Bailey Wall, a characteristic of the Babcock and Wilcox furnace designs and the finned tube, a characteristic of the International Combustion furnace, have been discontinued in favour of the tangent tube furnace arrangement with furnace tubes touching each other.

There are a number of examples of the Bailey or the finned tube furnace in boilers serving 30 MW sets but for boilers in excess of about 550,000 lb/hr, evaporation, the furnaces are in tangent tube construction, with a few exceptions.

In cases where the coal is known to have such characteristics that the temperature at which the ash melts is particularly low it has been the practice to introduce into the furnace a centre wall, or part centre wall, between the front and rear of the furnace. This has the effect of providing more tube surface in a given volume of furnace and by its inclusion provides a greater area into which heat from the gases can be absorbed. The result is a lower furnace gas exit temperature, A good design is one in which this temperature is below the temperature at which the ash is known to soften. It is, therefore, essential to know the characteristics of the coal to be burned when the boiler is being designed.

It will have been realised by now that the use of refractory materials in the furnace of ,the modern boiler is very limited. It is, in the main, confined to the burner zone and its purpose here is to avoid the cooling effect of the wall tubes which may hinder ignition, chiefly in a boiler in which low volatile coals are to be burned.

In the development of the modern boiler up to the present large sizes, there have been no revolutionary changes in the firing and burning of pulverised coal. For bituminous coals, the front or side wall firing as practised by many of the boiler manufacturers and the tangential corner firing of the International Combustion and other companies, still remain the standard methods, with only minor modifications by way of improving combustion.

The cyclone furnace (Figs. 1 and 2) has now made its appearance in this country but its use is limited, so far, on account of doubts as to its suitability to burn certain coals. In the furnace the coal, which is only coarsely ground, is burned in a zone of high heat intensity before passing to a secondary furnace. One of the advantages of this type of furnace is that of an overall reduction in total furnace size for a given output compared with a conventional furnace.

As boiler outputs have increased, the increase in furnace size has been met, in the main, by an increase in furnace width and height. Table 2 gives some idea how these dimensions have increased with unit size where front wall firing is employed. In these cases the furnace depth is 24 to 26 feet. In a corner-fired furnace, however, it is necessary to retain a roughly square cross section and since the maximum permissible size is of the order of 33 feet by 33 feet, it has been necessary to split the furnace into two separate units each of a roughly square cross section. Examples of this type are the 200 MW installations at High Marnham.

For still larger sizes, such as the first boiler for the 550 MW unit at Thorpe Marsh, four such furnaces are required. A corresponding front-fired boiler will have a furnace width of 120 feet.

	60 MW	100 MW	200 MW	300 MW	500 MW	550 MW
Furnace width (ft)	30	38	52	64	96	120

Table 2:

4.3 The Superheater

In the advancement to larger unit size it is the superheater which has probably undergone more change than any other single component.

In earlier days, when steam temperatures were low, the typical superheater was of a horizontal self-draining type, preceded in the gas

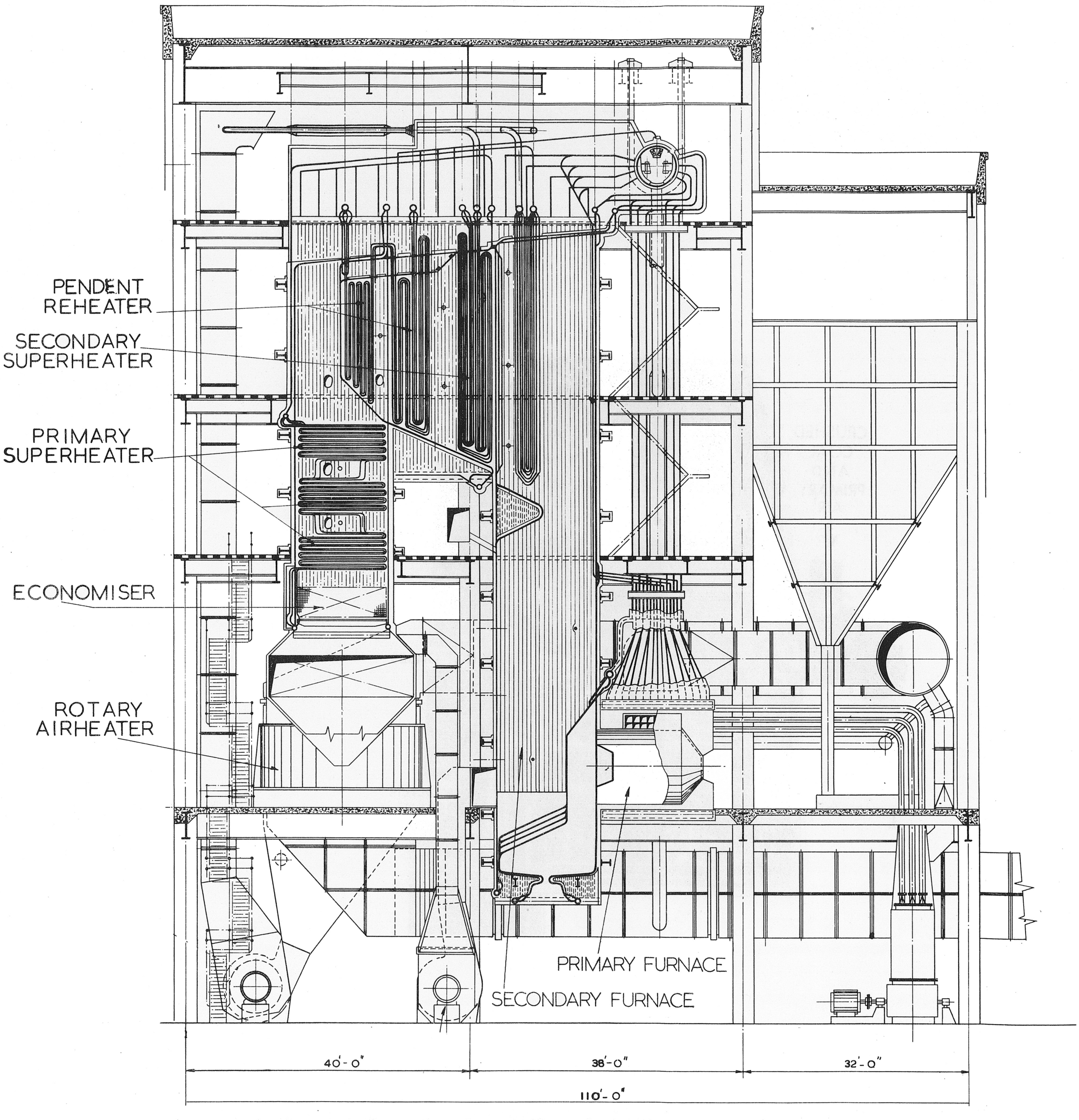

Figure 1: A TYPICAL CYCLONE FURNACE BOILER

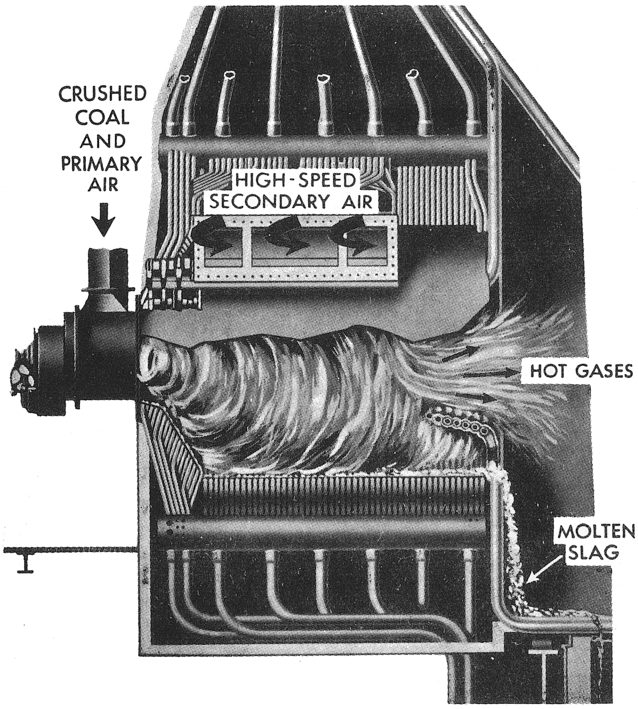

Figure 2: THE BABCOCK CYCLONE FURNACE

stream by a water-cooled tube bank (the screen or convection bank)+ Examples of this are still quite common in units of 300,000 lb/hr. evaporation (30 MW) in which the steam temperature is 463°C. (865°F.) or so (Fig 3).

At that time the self-draining superheater had become established in preference to the "pendent" superheater, since the latter caused much difficulty during start-up due to the inability to drain the water away from its lower loops. Some of the water could be evaporated off during pressure raising but where the superheater was preceded by a large tube screen the gases leaving the furnace were cooled too much to provide enough heat for this evaporation during pressure raising.

The 60 MW boiler, however, was designed to produce steam at 496°C. (925°F.) and in order to achieve this higher temperature, it was necessary to bring the superheater nearer to the furnace in order to make use of the high furnace gas exit temperature+

It became necessary to reduce the amount of tube screen surface in order to achieve the higher steam temperatures and it was considered that the superheater sections nearest to the furnace could be in pendent form since the greater amount of heat entering the superheater would give the water lodged in the elements a better chance to evaporate off.

Boilers designed for these temperatures are, therefore, characterised by a great reduction in, or, in some cases, the complete elimination of the tube screen before the superheater. Gases, therefore, enter the superheater zone at temperatures corresponding almost to the temperature of the gases leaving the furnace instead of a temperature some lll°C. (200°F.) lower, such as that obtained where an extensive tube screen is installed (Fig 4).

The next step in the steam temperature "ladder" was from 496°C.(925°F.) to 530°C. (985°F.) and 543°C. (1,010°F.) and although in a number of installations these temperatures have been achieved by the complete elimination of the screen tubes, there are instances, such as at Blyth 'A' and Ferrybridge 'B', where it has been necessary to construct the upper front wall in the form of superheater surface so that these surfaces receive direct radiation from the intensely hot zone of the furnace. They are known as the radiant sections of the superheater (Fig. 5).

As the temperature advanced to 569°C. (1,055°F.) in boilers serving 200 MW sets and over, more surface still had to be brought to the furnace. This had led to the introduction of a hitherto unknown type of superheater section the platen section. A section of this type is, in effect, a pendent section hanging down into the furnace through the furnace roof. It is subjected to the full furnace radiation and is, therefore, another form of radiant surface. It differs from the conventional superheater pendent section in that the tubes are very closely pitched, so that each section forms almost a tangent tube wall (See Fig. 6). It will also be noted that some of the upper side wall surface is in the form of radiant superheater surface.

In the preceding paragraphs am attempt has been made to show the general trend in superheater design and layout, as steam temperatures have advanced but exceptions to this trend do exist. For instance, it is not always necessary to install radiant wall surface for steam temperatures of 569°C. (1,055°F.) in some designs, of Which Castle Donington is an example.

No mention yet has been made of the quality of the steels for these high temperature conditions.

Where temperatures are of the order of 463°C. (865°F.) ordinary carbon steels may be used, but as temperatures have risen it has become necessary to use steels containing chromium and molybdenum since they give greater strength under high temperature conditions. For the very high steam temperatures it is necessary to go to the stainless steels in order to obtain the necessary strength.

In view of the poor quality of the coals burnt in power stations today, it has been necessary to space the superheater sections on a very wide pitch in order to avoid bridging over of the slag. The pitching of the superheater sections is anything from 8" for those in the cooler zone of the pendent section to 24" for the platen sections in the furnace itself. The horizontal self-draining sections (the primary sections) are usually on a pitch of 4" but, in any case, the pitch is such that there is a minimum gap of 2" between the tubes, even in this relatively cool zone.

4.4 The Reheater

The purpose of reheating has already been explained. It is used in some boilers serving 100 MW sets, but in all boilers serving 120 MW sets and over.

The reheater is, to all intents and purposes, a re-superheater in which the steam is raised in temperature by some 167 to. 222°C. (300 to 400°F.). The pressures associated with these temperatures, however, are only about one quarter of those in the main superheater.

In the design of a reheat boiler,, care must be taken as to where the reheater is to-be located. In view of what has already been said with regard to superheaters and the necessity for locating them near to the furnace when high steam temperatures are required some would think the same should apply to the reheater. It does up to a point. The difference between the two is that, unlike the superheater, the reheater will have no steam flowing through it during pressure raising. If allowance were to be made in the design for steam to flow through the reheater during pressure raising a system of bypassing round the turbine would be necessary so that during pressure raising steam could be brought back to the reheater. The cost of large bore piping and high pressure valves and the difficulties of making provision for expansion render this an unattractive feature, especially since it is possible to design the boiler so that with no steam flow through the reheater during pressure raising, overheating of the tubes can be avoided.

By careful arrangement of surface (which probably means more superheater in the furnace than for the equivalent "straight" cycle) the reheater is located, in some cases, between the secondary and primary superheater surfaces, as shown in Fig. 7 or, in others side by side with the primary surface. The latter usually applies where the reheat temperature is not very high (e.g. Ferrybridge 'B' where it is 513°C. (955°F.).

Where the two-furnace design has been adopted (e.g. the International Combustion boilers for High Marnham) the secondary superheater has been placed in the conventional position in one furnace and the reheater in a corresponding position in the other furnace, the primary superheater being common to both furnaces later in the gas pass. Overheating of the reheater is avoided in spite of its locality since, during start-up, the amount of firing done in the "reheater" furnace can be controlled to a degree corresponding to that which the tube metal will withstand.

Tube materials for reheaters follow the lines of those for the superheater and vary in accordance with temperature. Since the pressure is not so great as that of the superheater, tube thicknesses are correspondingly less.

4.5 The Economiser

Advances towards higher pressures have seen the elimination of the design of economiser in which handhole caps were provided to enable tube inspection to be made.

The economiser for high pressure conditions is of the ”continuous loop” all welded type and as the name implies, intermediate headers and flanged bends are eliminated. The economiser is divided up into a number of banks sufficiently shallow to simplify cleaning and sufficiently far apart to enable access to be made between basis (Fig. 8).

The gilled tube surface has not fallen into disfavour in spite of the possibilities of an increase in fouling from the burning of inferior coals with this type of surface. On pulverised fuel fired boilers up to 250-300 k.lbs. per hour, it was not necessary to install soot blowers. On the present large boilers, over 120 MW capacity, soot blowers of the lance or rake type have to be fitted for cleaning purposes.

4.6 The Air-heater

Ten years ago there were three principal types of air-heater in common use:-

(i) the plate type

(ii) the tubular type

(iii) the rotary or regenerative type

Each has its good points.

The plate and tubular types are simple and robust in construction and since there are no moving parts, the leakage of air to the gas side is virtually nil.

The rotary type, although not having these virtues is much smaller in size for a given duty than the other two and it is this feature which has brought the rotary type into prominence on the more advanced designs (Fig. 9).

When tenders are invited for boiler plant for a modern installation, it is the practice of the board to call for alternative boiler schemes, one to include a design and layout in which a plate or tubular air-heater has been incorporated and another in which a rotary air-heater has been included.

As unit size has increased, it has invariably been found that the design in which rotary air-heaters are included is the less costly of the two, mainly on account of the saving in building volume. The rotary air-heater is, then, accepted as almost inevitable om the advance design stations. The question now arises, how many? For years the manufacturers of this type of air heater have been able to keep abreast with development. In the majority of cases, two air-heaters are provided and even for boilers having an output corresponding to 275 MW, no more than two air-heaters are required. For the 550 MW boiler, four such air-heaters are included. A difficulty has arisen, however, where the boiler serves a 350 MW turbine, in that the size is just on the limit of the maximum size of air-heater for a two-air-heater arrangement and it has, in some cases, been necessary to consider three air-heaters.

The well known difficulties of sealing on this type of air-heater are still with us, although this equipment is much improved. The difficulties in designing an efficient seal is one of the reasons for the inability to go much further in air-heater size at the moment.

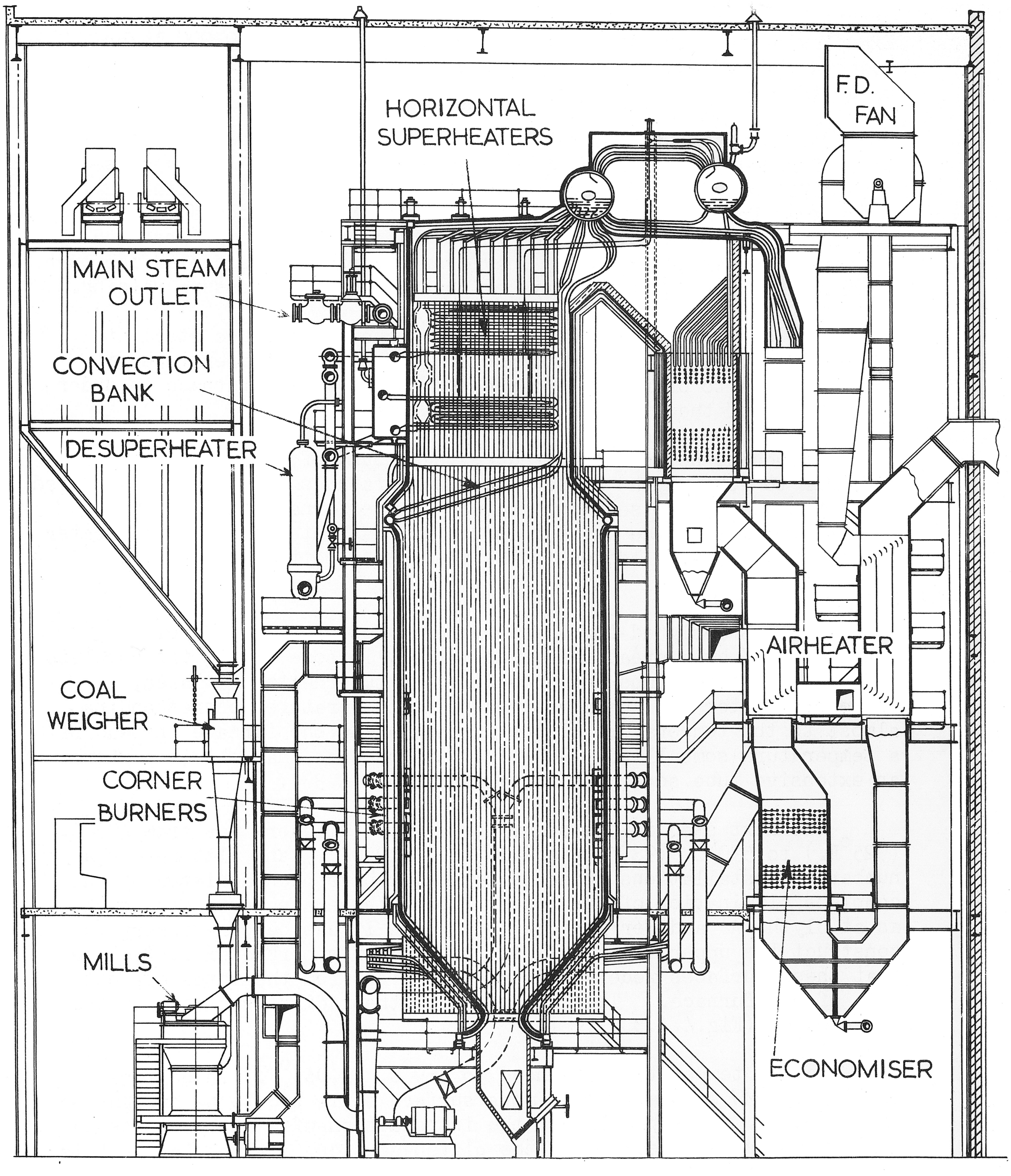

Figure 3: TYPICAL ARRANGEMENT OF 300,000 LB/HR P.F. FIRED BOILER

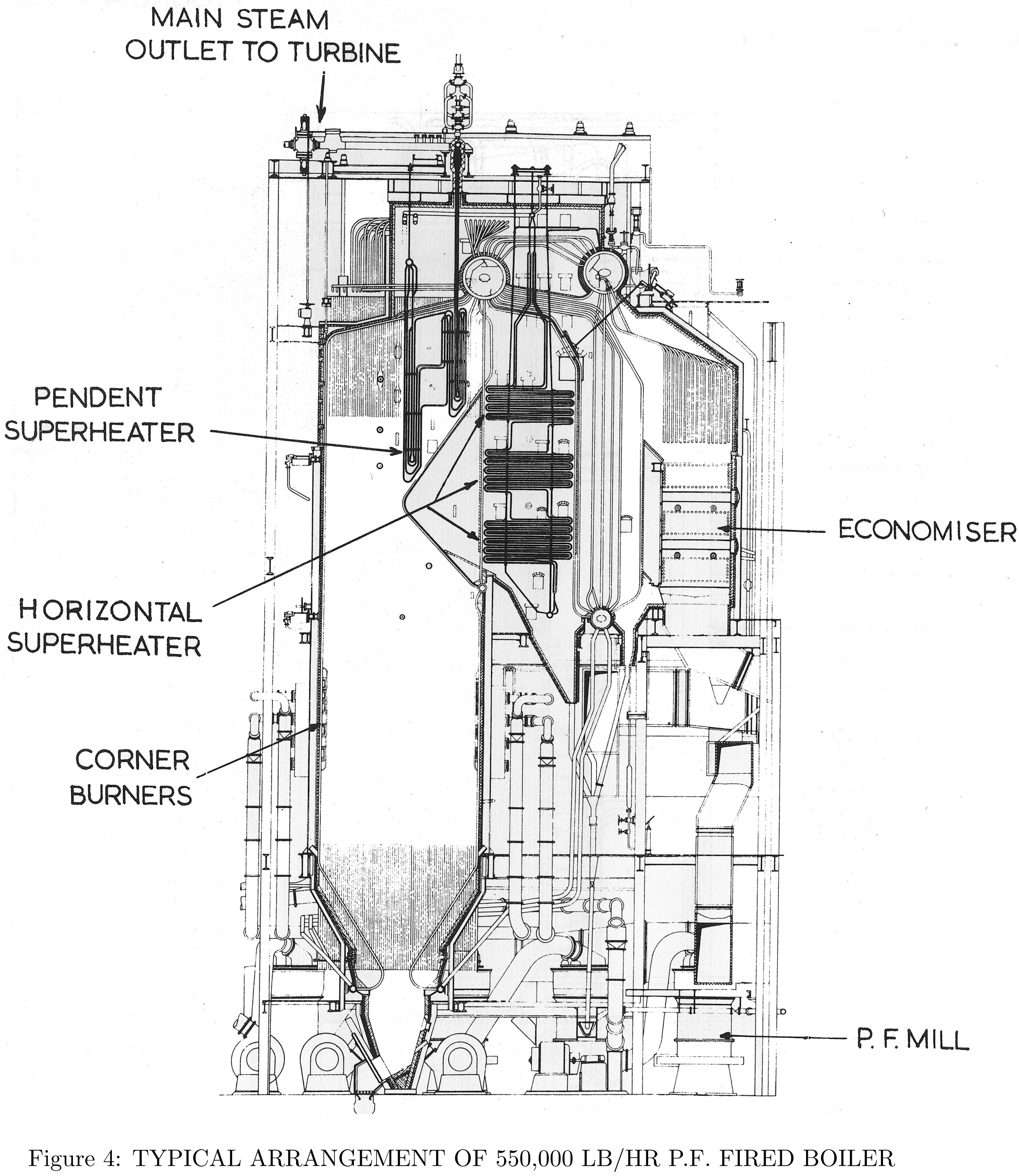

Figure 4: TYPICAL ARRANGEMENT OF 550,000 LB/HR P.F. FIRED BOILER

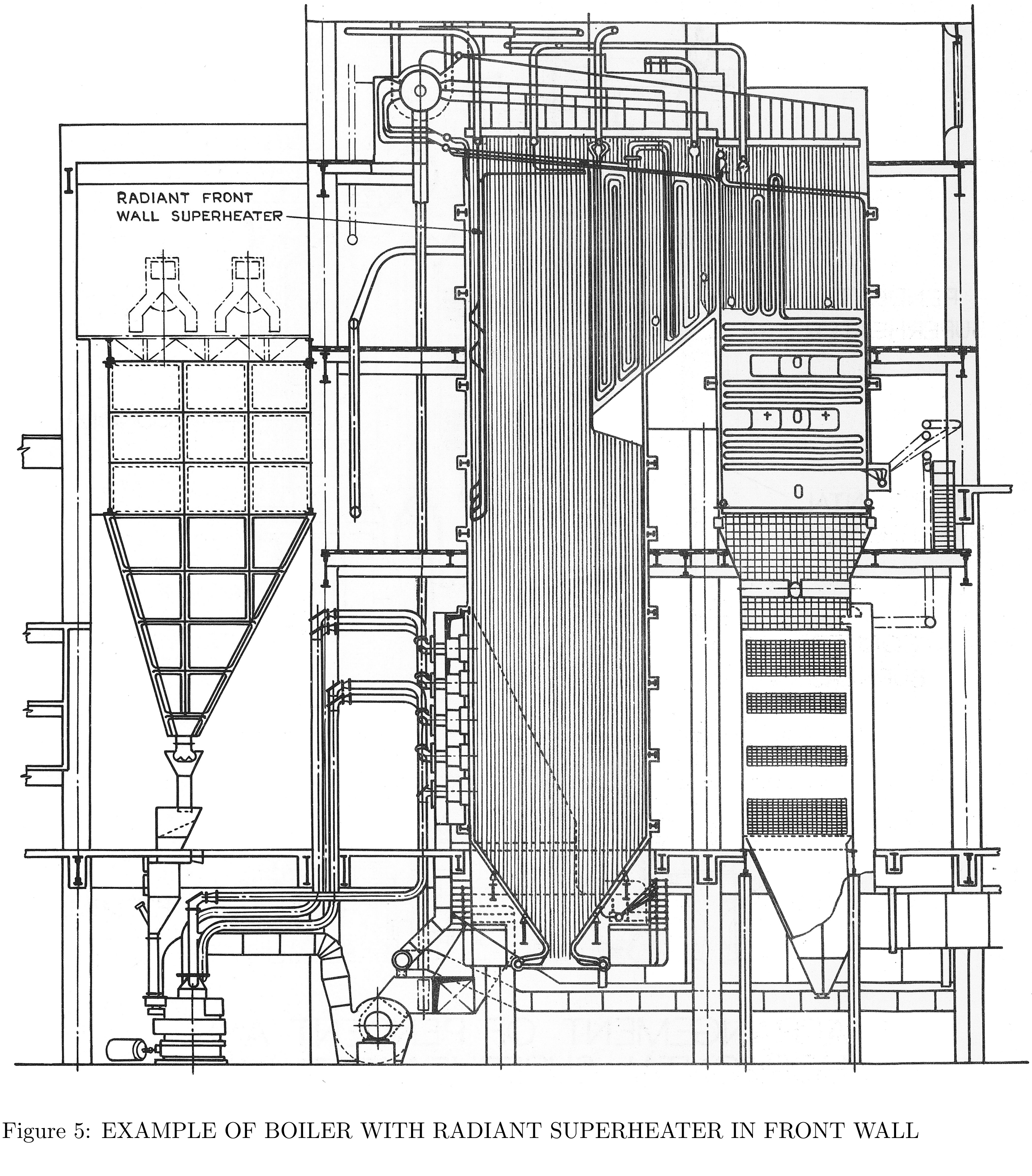

Figure 5: EXAMPLE OF BOILER WITH RADIANT SUPERHEATER IN FRONT WALL

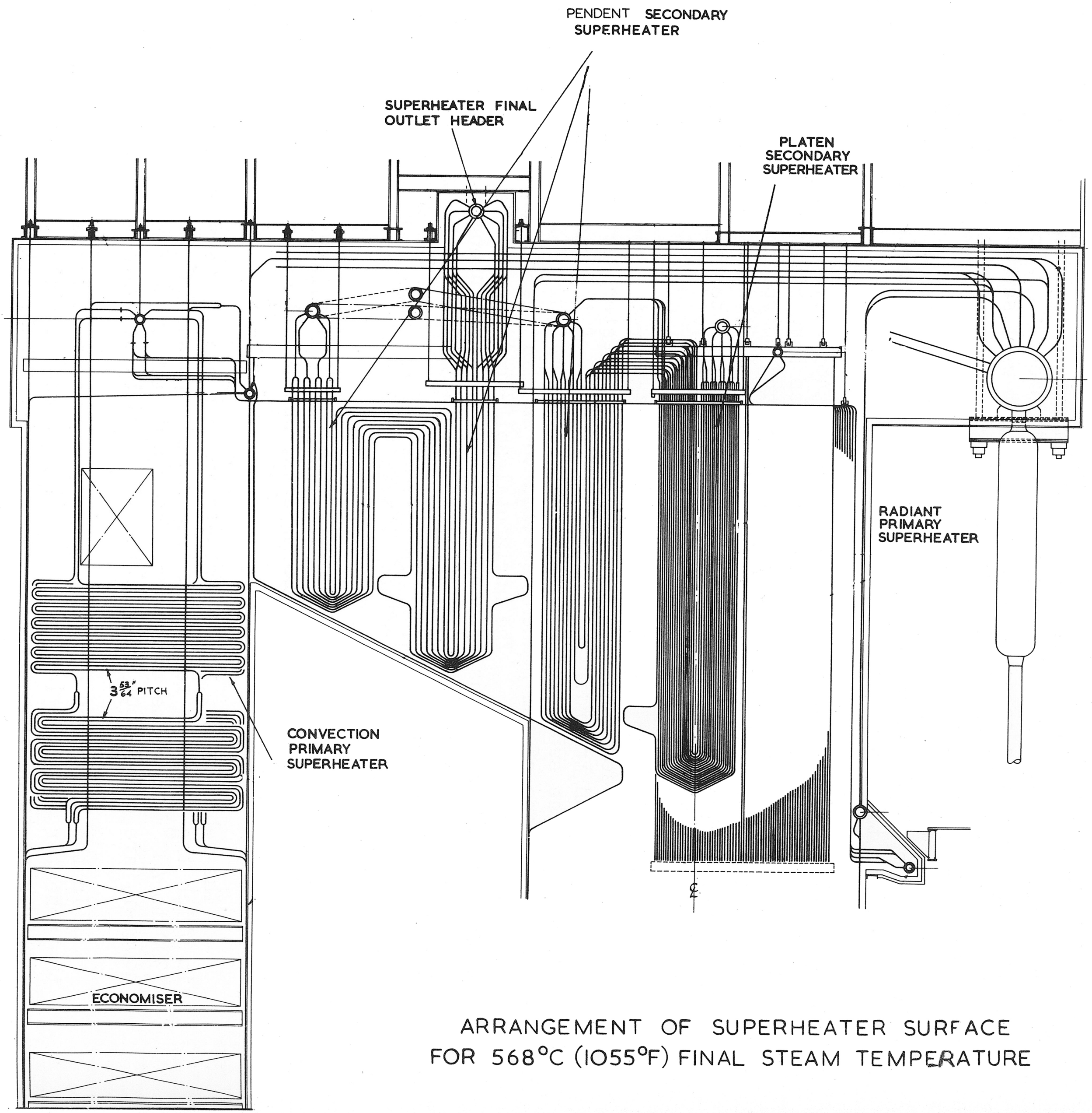

Figure 6: BOILER UNIT WITH PLATEN SUPERHEATER SURFACE

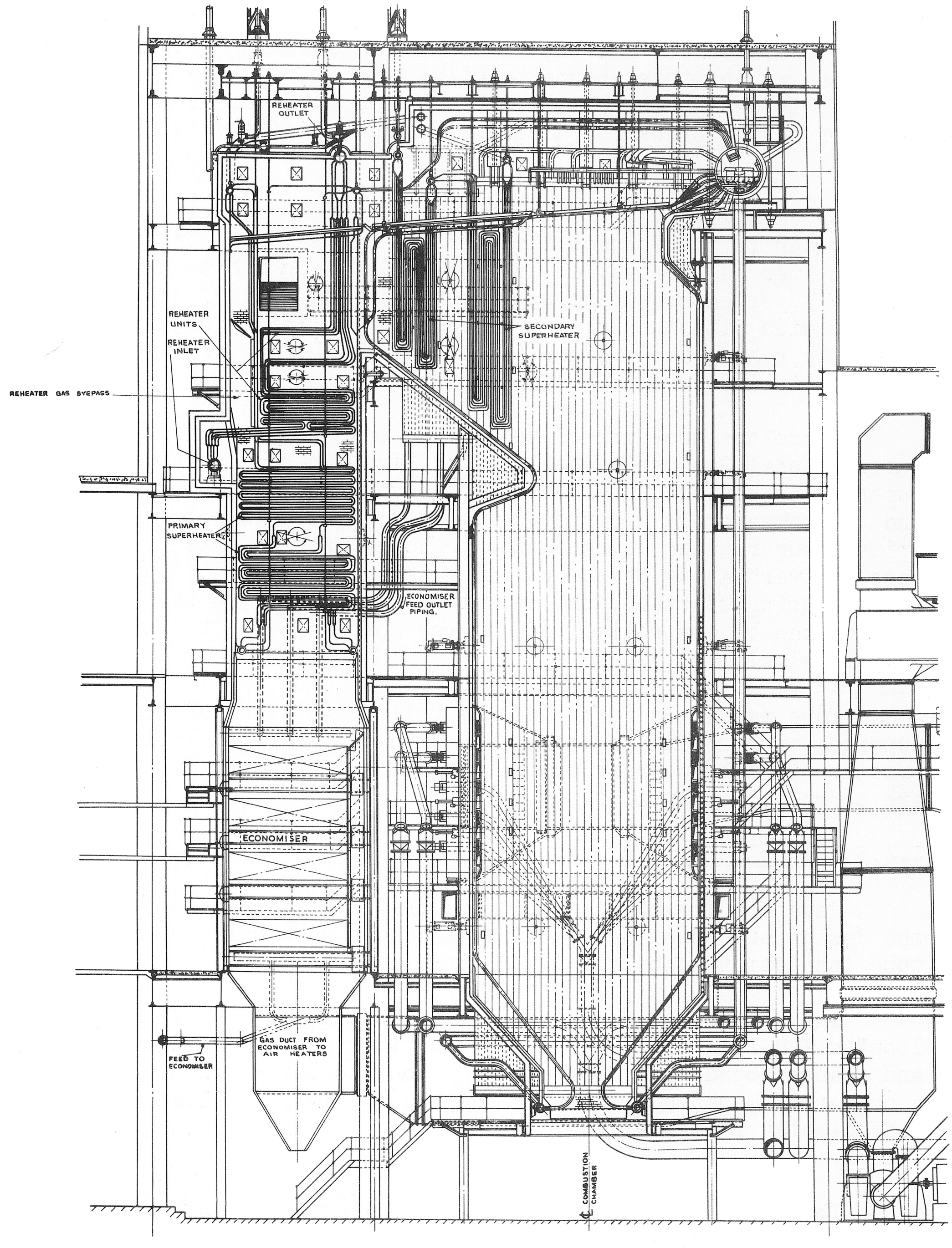

Figure 7: EXAMPLE OF REHEATER LOCATION BETWEEN SECONDARY AND PRIMARY SUPERHEATER SECTIONS.

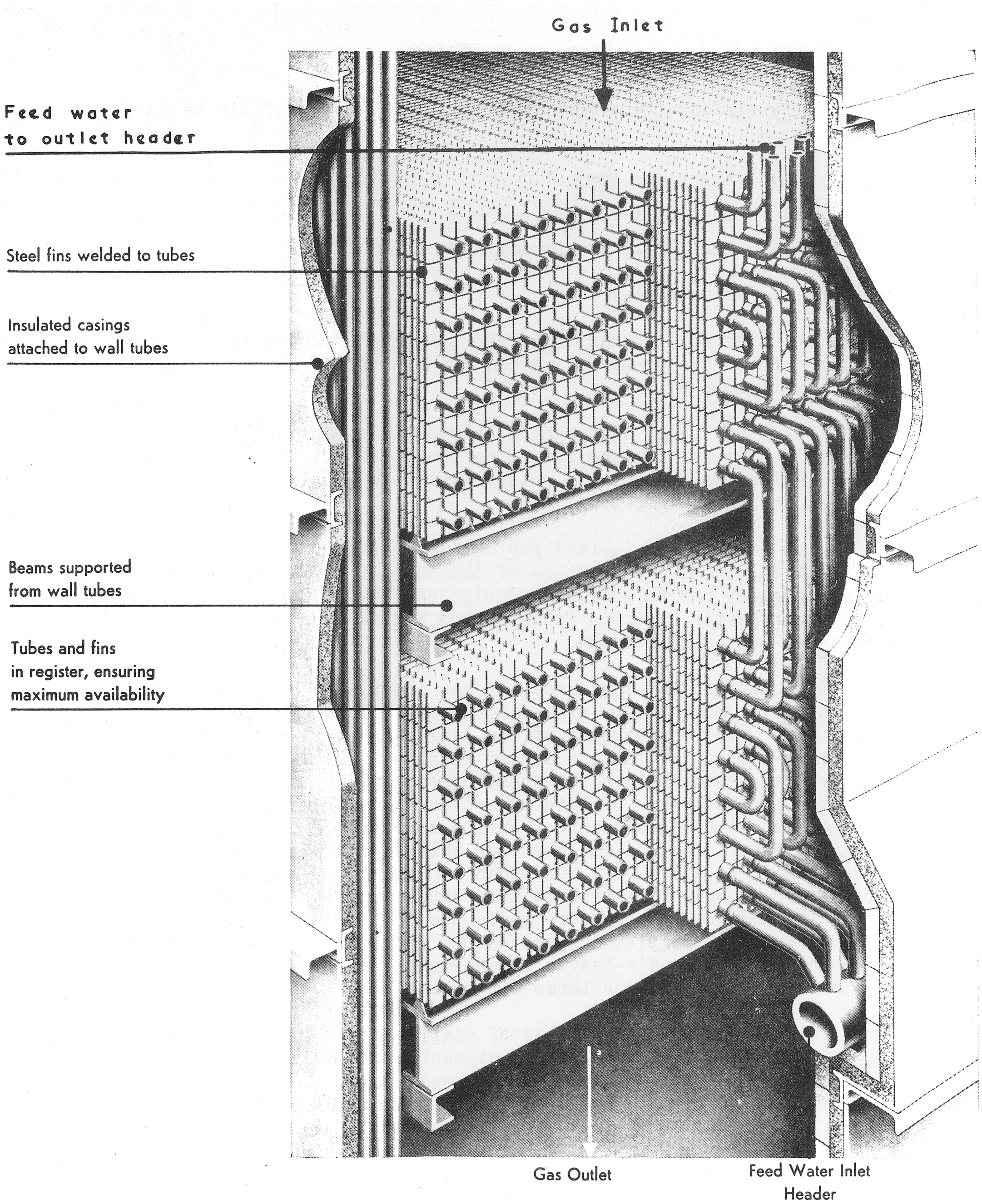

Figure 8: MODERN FINED TUBE ECONOMISER.

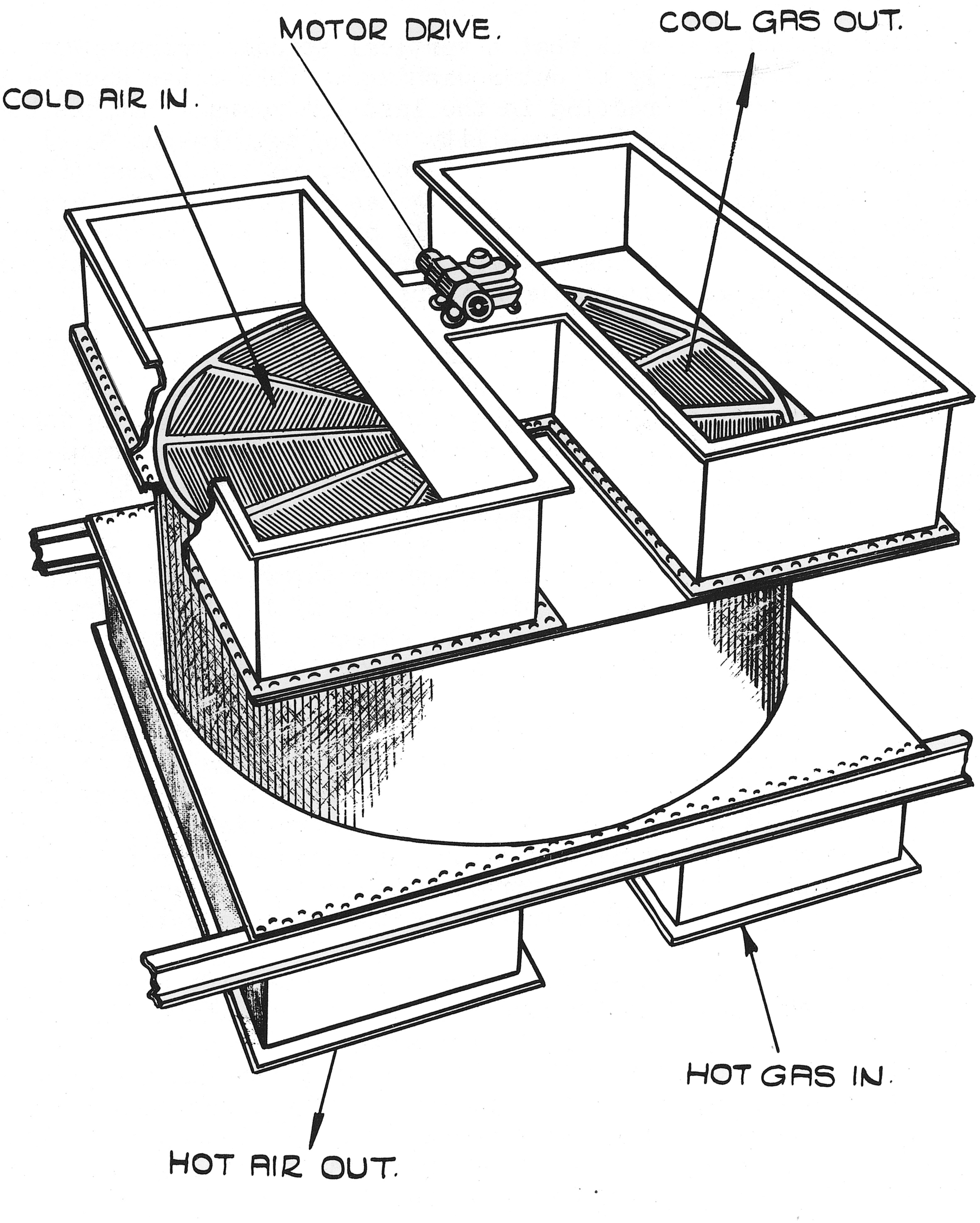

Figure 9: REGENERATIVE OR ROTARY TYPE AIR HEATER.

In all cases in the last ten years where rotary air-heaters have been installed, they have been of the vertical spindle type. There are two main reasons for this. With the horizontal spindle type, the rotation of the air-heater tends to cause the elements to "pack", thereby leaving gaps local to the hub through which gas or air can bypass, although this has been reduced to a large extent by the installation of the elements in self-contained bundles.

The second reason is that a vertical spindle arrangement lends itself much more readily to water washing. This water washing has become a very common practice in the last ten years. It has become necessary partly due to the inability of the sootblowers to clean completely the air-heater or, in some cases, the fact that the moisture from the steam in sootblowing has aggravated the formation of air-heater deposits which could only be removed by dissolving during washing. It is customary, therefore, to fit connections for water washing on all modern air-heaters.

In the immediate post war years, a number of new installations included what were called "primary" and "secondary" air-heaters. In such an arrangement an economiser was interposed between these two air-heater sections. The purpose of such an arrangement was to provide a high air temperature for coal drying in the mill where it was known that high moisture coals would be handled.

In most recent times, the high steam temperatures required have made 'this feature impossible, since so much of the heat from the gases is taken up in superheating the steam. Where it is essential to provide high temperature air for coal drying in the mill, it is now common practice to install, in parallel with the economiser, a "mill air-heater", i.e. a small air-heater, usually of the tubular type which handles only that air which passes to the mill (about 15 to 20% of the total). By locating it parallel to the economiser one is assured of a gas inlet temperature approximating Very closely to the economiser inlet temperature, Furthermore, since the quantity of gas passing to it can be controlled by damper, the required air temperature canbe readily adjusted to suit requirements.

Since all plant today is designed for two-shift operation, it has become necessary to make special arrangements at the "cold end" of the air-heater if corrosion of the metal surfaces is to be avoided. In the tubular heater this has been done in many cases by making the "cold end" bank of shorter tubes which can be more readily managed when replacement becomes necessary. In the case of the rotary air-heater, a special corrosion-resisting steel, known as "corten", has been used at the cold end.

5 BOILER AUXILIARIES

This section will aim to show how boiler auxiliaries, such as fans, sootblowers and boiler mountings, have changed over the years as unit size has increased.

5.1 Fans

It has been the aim of the Board to reduce to a minimum the ancillary power requirements of the modern boiler, that is the power taken by such items as fans, milling plant, feed-pumps and other auxiliary drives.

In the case of fans, it became evident that the use of the two speed induced draught fan would reduce this loss considerably and to gain maximum benefit, it would be necessary to choose the change speed point carefully.

Induced draught fans are, therefore, designed so that Under normal operating conditions the fan is giving somewhere near its full output at the lower speed. The upper speed is held in reserve for abnormal conditions such as operation at low CO_2 or under heavy slagging conditions which reduce the area of the gas space between the boiler and superheater tubes, thereby requiring more power to draw the gases through.

By the selection of this method of operation, the fan is normally operating at its maximum efficiency and therefore, its minimum power consumption per cubic foot of gas handled.

Other methods for varying the output, such as the use of a hydraulic coupling between motor and fan, the use of a variable speed motor thereby varying the speed (and, therefore, the output) of the fan are in use but economically the two-speed vane-controlled I.D. fan is now established as being the most suitable for the Board's operating requirements.

The forced draught fan has not the same exacting requirement and it is customary to install a single-speed fan with vane control, because economies dictate that this is the most suitable for the Board's operating requirements.

An advancement has been made in the design of fan blades in that the last few years have seen the introduction of the "aerofoil" section. This blade section, by careful design, minimises the development of eddies within the fan and this enables a higher fan efficiency to be obtained than with the more conventional straight bladed fan. Whereas in the earlier days, fan efficiencies of 60 to 70% were typical, it is now possible to achieve 80 to 85%, thereby giving a further saving in power consumption.

5.2 Sootblowers

Throughout the years the use of steam for sootblowing has maintained its popularity. This is due mainly to the greater cost with doubtful improvement in effectiveness of the only other alternative considered to date - air blowing. Air blowing has been used extensively in America, but in this country no economic case can yet be made, mainly on account of the cost of the air compressor.

Advances in the mechanical side of the sootblower have been necessary, however, in order to keep abreast of modern development. This has been directed mainly in the provision of the long retractable rack blower.

In the furnace the short retractable wall blower is used, but where extensive superheater surface must be cleaned it is necessary to have a sootblower which will reach almost to the centre of the boiler. Thus, the long retractable blower which can be made to reach some 35 feet makes possible the adoption of the 70 ft. wide furnace. It is a fact that a limitation is imposed upon the width of a boiler having a single furnace due to the limitation in reach of the retractable blower. 35 feet is, up to now, the practical limit, but work is being done on the development of a 38 foot and even longer retractable blower.

5.3 Boiler Mountings

5.3.1 Safety Valves

As pressures have increased, two significant changes have taken place in the approach to safety valve design.

In the first place, the torsion bar (Fig. 10) has, in a number of cases, replaced the coil spring. The main reason for this is that a torsion bar is of simpler construction than the heavy coil spring required for the very high pressures and therefore, more easy to accommodate.

Secondly, more recent years have seen the introduction of the electrically assisted valve. A safety valve which operates to overcome the resistance of a spring, be it coil or torsion bar, is known to "simmer" or "feather". A stage is reached as the pressure rises, when the valve is just opening but there is insufficient steam behind it to ensure a clear lift. This simmering very often results in a damaged valve seat through the cutting action of the steam. The electrically assisted valve achieves a positive lift from the seat at a pre-determined pressure and avoids this simmering and the consequent scoring of the valve seat.

5.3.2 Drum Level Gauges

It has been necessary to consider a new type of drum water level gauge for pressures above 1,600 p.s.i, and it has resulted in the "bull's eye" type of gauge (Fig. 11). In this the long sight glass with the mica backing has been replaced by a series of small circular sight glasses with mica, each of which can be replaced individually. A difficulty in the past has been to get a large area of mica of sufficiently good quality to withstand increasing pressures and temperatures. With the bull's eye type, only small discs of mica, approximately one inch in diameter, are required and these are much easier to obtain in good quality.

The importance of drum water level indication has become vital in latter years since the modern boiler has a relatively small water storage capacity. Efforts to ensure a satisfactory indication at all times have included the use of drum level recorders and television viewers at the control panel.

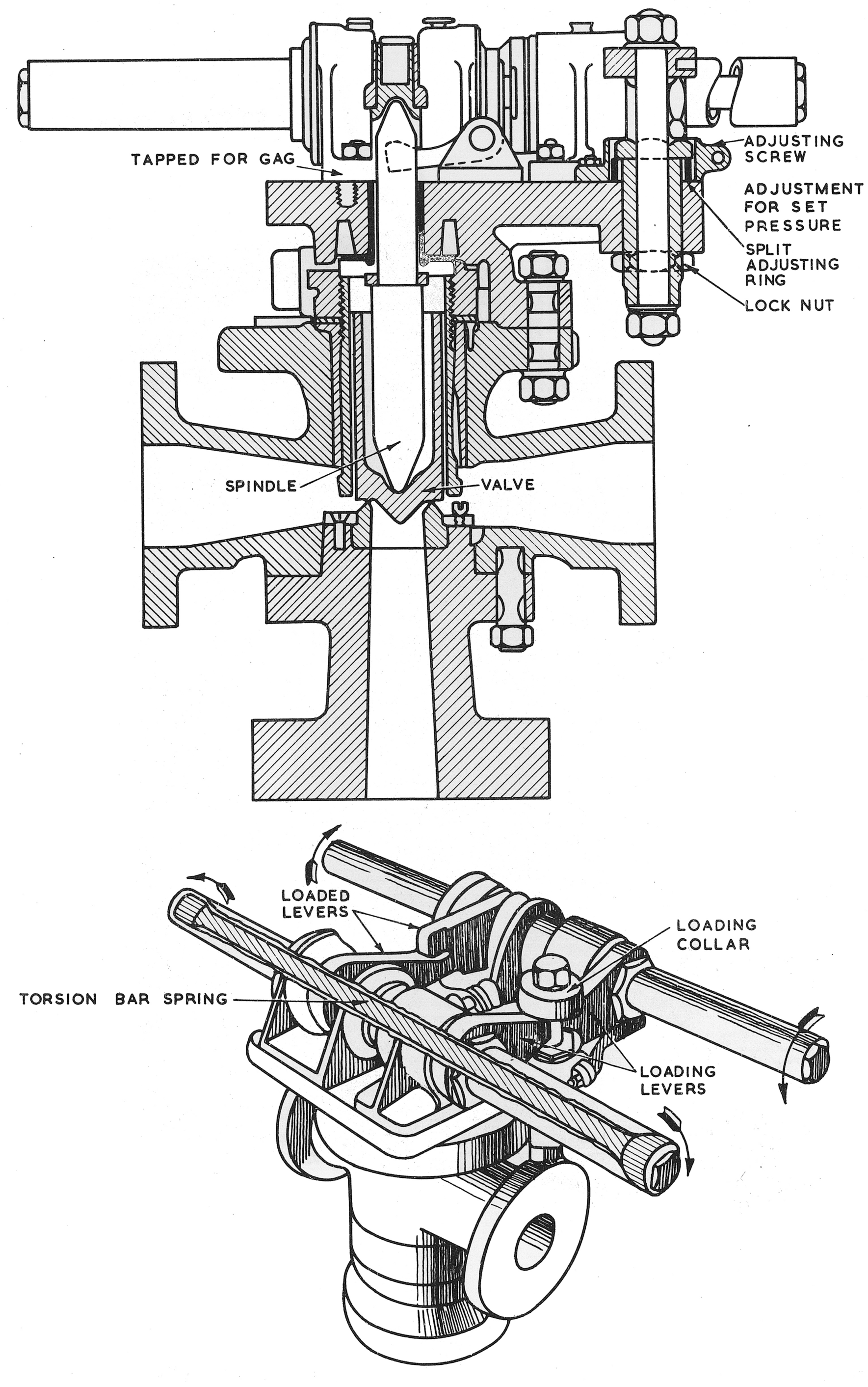

Figure 10: TORSION BAR TYPE SAFETY VALVE

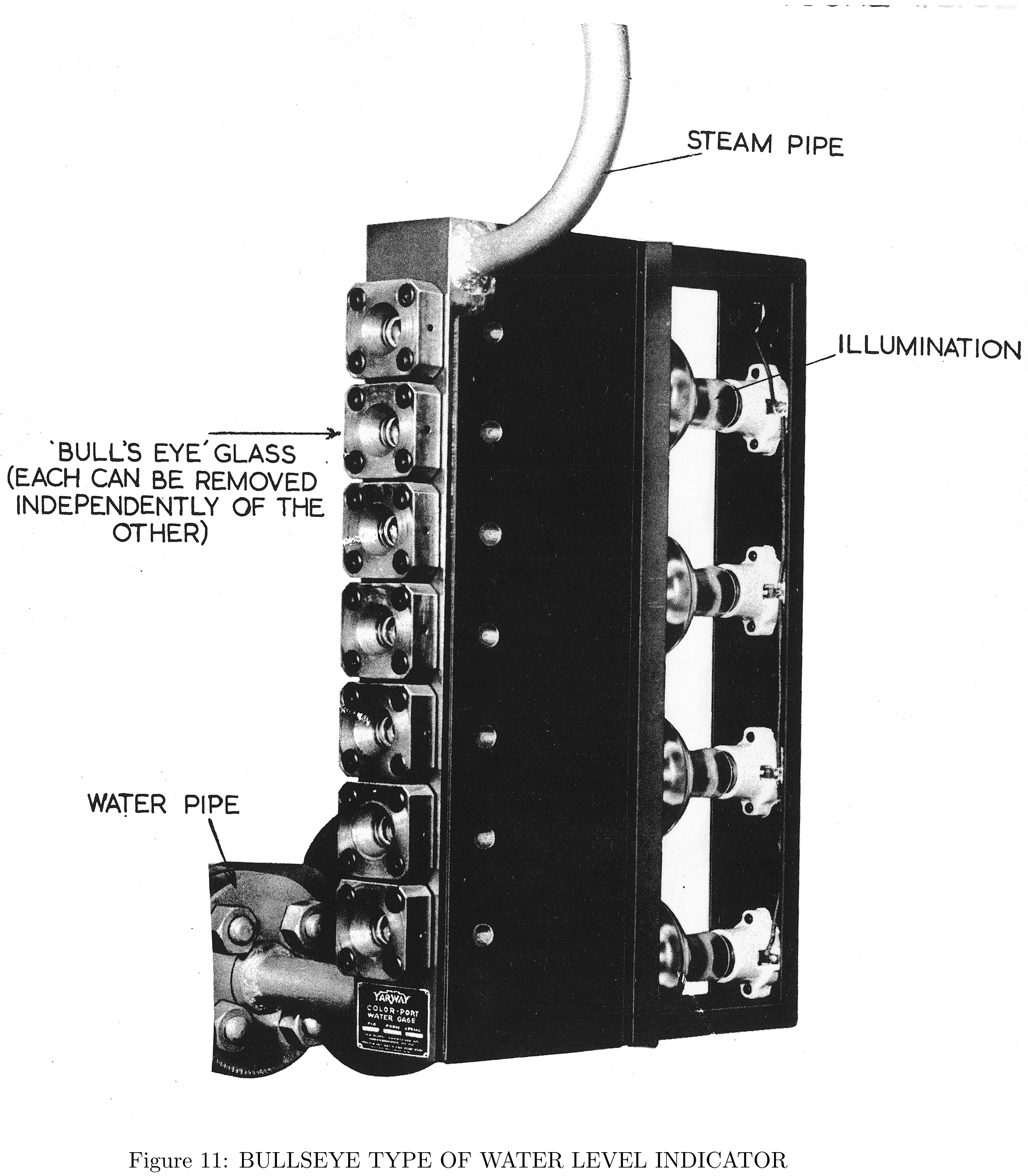

Figure 11: BULLSEYE TYPE OF WATER LEVEL INDICATOR

6 CONSTRUCTIONAL FEATURES

Some of the more outstanding constructional details which have accompanied the development of the modern boiler, will be considered in this section.

6.1 The Drum

The solid forged, or the fusion welded drum, is now universal.

It is obvious that as operating pressures have increased so the drum thickness has had to be increased. In the modern 2,400 p.s.i. pressure boiler, a drum thickness of 5 to 5 ½ ins. is quite typical.

Furthermore, as boiler outputs have increased, so boiler drums have increased in length. This is, of course, more noticeable on the single furnace unit where the drum length is roughly the width of the furnace. Transport difficulties, however, impose a limit on the length and on the weight of a drum shell which can be transported as a single unit. In some instances the excessive length is overcome by the installation of two drums instead of one, but this is more costly than using a single drum and is to be avoided if possible.

Serious consideration must now be given to the building of the drum in two halves, the final joining being done on site. Special techniques are obviously required for such work, but similar developments in the nuclear field will be of great assistance. In a few years time, therefore, the site welding of drums may be quite a common feature on the very large units.

6.2 Tube Wielding

Although the butt welding of one tube to another for such things as superheaters, economisers or furnace tubes is by no means new, the fitting of these tubes to headers or the drum has undergone some changes.

Reliance is no longer placed on the expansion of the tube into the header, but it is now welded at the joint to ensure tightness. It is, of course, impossible to weld, say, a complete bank of superheater tubes to its header in this fashion before despatch from the makers' works so the practice now is to weld to the header short "stub" tubes to which the superheater elements are butt welded at site.

The use of flanged joints has been reduced to a minimum and on modern high pressure boilers all piping, whether it is large bore steam or feed piping or small bore drain piping is butt welded; mostly on site.

Hand hole fittings in headers have been abandoned. Hand holes, in the first place, are reduced to a minimum (the avoidance of tubes expanded within the header has enabled this to be done) and where they are necessary for, say, internal inspection, a welded on cap is fitted. When inspection is necessary the weld must be ground away before the cap can be removed and re-welded when refitted.

6.3 Unit Suspension

In order to avoid the use of heavy boiler supporting steelwork it is now the practice of most manufacturers to suspend the boiler from the building steelwork. The main supporting beams, therefore, are of great depth and from these are suspended the drum, the furnace and boiler tubes, the superheater, reheater and economisero The airheater is not included in the equipment suspended, but rests on its own steelwork. A typical example of this can be seen in Fig. 6 or Fig. 1.

As the unit heats up during pressure raising it expands and since it is suspended from the top, considerable downward movement takes place. Allowance is made for this expansion by fitting some form of expansion joint between the moving part and the fixed part, i.e. the air-heater and the ash receiving hopper.

6.4 Building Space

In order to keep down the cost of the modern boiler, it is obviously necessary to reduce to a minimum the space it occupies. At the same time, access must be available for maintenance work. Modern plant is, therefore, designed with this in mind, but there are a number of factors which limit the reduction of building size.

The use of long retractable sootblowers, mentioned earlier, limits the distance between boiler units, for instance. If a boiler has a 35 ft. retractable blower, it has to be withdrawn 35 ft. so that there must be a minimum distance of approximately 35 ft. between the casings of neighbouring boilers or wing boilers and the wall.

It is not uncommon to see the milling plant or the precipitator plant governing the distance between boilers, but in the case of the former it is sometimes possible to arrange the mills in two rows instead of one, although such an arrangement also takes up space. In the case of the precipitators it is not unusual to see the banks arranged one above the other if a side by side arrangement is prohibitive in space.

The necessity to go to a tall furnace on the modern boiler and the introduction of more superheater surface into the hotter furnace zone has enabled an arrangement to be made whereby the air-heater is located immediately below the economiser, thus saving considerably on the "front to back" distance of the boiler house.

Another form of saving in building cost is to arrange the unit partly out of doors, but very often the saving made by such an arrangement is largely offset by the weather protection necessary for equipment and personnel.

Questions on Lesson 4 - The Development of the Modern Boiler

Please answer any four of the following questions

1. What is the difference between the straight cycle and the reheat cycle? Give two reasons for the adoption of the reheat cycle on larger units.

2. The stoker-fired boiler is seldom seen in the modern power station. Why is this? What has limited the use of oil-firing in this country?

3. What effect has the deterioration in coal quality had upon furnace design in recent years? What is the advantage of the cyclone furnace and why has its use not been more extensive in this country?

4. What are the three types of air-heater found in boiler plant within the last ten years? One of these three types has become more acceptable than the other two. Which air-heater is this and why is it so?

5. What advantages has the two-speed ID fan over other types of fan and of what significance is the change speed point?

6. What is the object of keeping the building volume to a minimum and what are the usual features which limit this reduction?