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(54) **Fluidised-bed boilers and method of operating the same.**

(57) This invention relates to boilers and in particular to fluidised bed boilers and burners, and to a method of controlling such boilers and provides a base plate which is water cooled during operation by virtue of having the combustion chamber located within the water jacket of the boiler. The invention provides a method and apparatus for reconditioning the bed, thereby reducing the necessity of topping up the bed with new sand or a similar carrier material as well as an accurate system of controls for the boiler. A vertical and a horizontal boiler incorporating the above mentioned features are described.

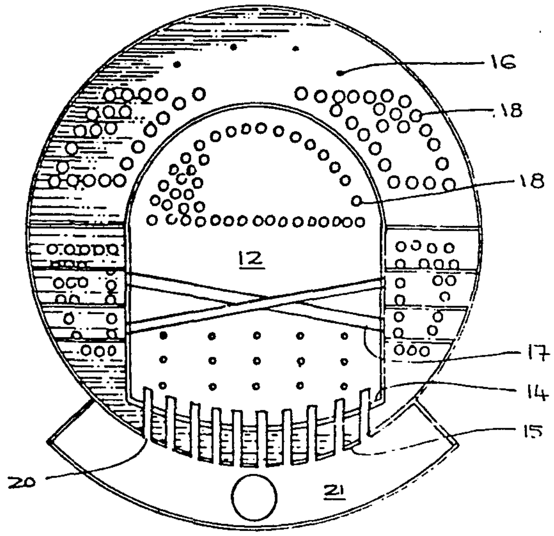

Fig. 2.

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FLUIDISED BED BOILERS

This invention relates to boilers and in particular to fluidised bed boilers and burners, and to a method of controlling such boilers. In fluidised bed boilers the bed is normally external to the water circuit when the fluidised bed burner is used for steam raising. At most, a shell boiler is used in which a recessed combustion chamber is formed in the wall which receives the base plate by means of high-temperature seals to prevent the flow of air around the outside edge of the base plate. The plenum is attached to the base plate by further high-temperature seals. Whilst the base plate can be shielded from the combustion temperature by a quiescent layer of the carrier to some extent, the base plate does become hot since it is only cooled by the flow of the primary combustion air and tends to distort putting stress on the seals.

It is an object of this invention to overcome this problem by providing a base plate which is cooled during operation. It is a further object of this invention to provide a method and apparatus for reconditioning the bed, thereby reducing the necessity of topping up the bed with new sand or a similar carrier material.

In fluidised bed burners which use solid fuels such as coal, a certain amount of ash and other particles which are larger than the carrier material particles are left behind after combustion. The ash, of course, is largely elutriated in the air stream, but it is necessary, from time to time, to remove the large particles from the bed in order to improve its characteristics since too great an amount of large particles will affect the heat transfer characteristics of the bed. In the past these particles have been removed by means of sieving, but it will be appreciated that the operation of sieving is accompanied by difficulties caused by the temperature of the bed itself and its propensity to flame during the sieving operation.

The use of a water-cooled base plate and the reconditioning of the bed allows the use of an accurate system of controls although it will be appreciated that the control system is not dependent on the use of either the cooled base plate or the reconditioned bed and may find application in conventional fluidised bed boilers or heaters.

It is a further object of this invention to provide a vertical and a horizontal boiler incorporating the above mentioned features.

It will be appreciated that, while this invention is described with the reference to the boilers suitable for producing steam, it will find equal application in heaters or burners for the production of hot water or for incineration and the provision of hot gas for drying purposes.

According to one aspect of the present invention, a boiler is provided with a combustion chamber base plate having an upper surface adapted to support a burning fuel bed and, spaced apart therefrom a lower surface to which a combustion air plenum is to be attached the base plate being at least partially hollow between its surfaces whereby water can flow therebetween and cool these surfaces.

The base plate can be a block containing a plurality of ducts through which the cooling water can be pumped; if the water is taken from, and returned to, the boiler no heat is wasted. However it is preferred that the surfaces are constituted by two spaced apart members so that the space between the members can form part of a water jacket completely surrounding the combustion chamber except for necessary openings such as those required for the introduction of fuel for instance. The water can circulate under convection in such a water jacket and in practice the water jacket could be the shell of a fire-tube boiler. The combustion chamber may further be penetrated by a plurality of thermosyphon tubes.

In fluidised bed burners, there is usually a quiescent layer of the carrier created by introducing the primary combustion/fluidising air into the bed above this quiescent layer through sparge pipes or stand pipes and another aspect of this invention provides a fluidised bed burner having a base plate with upstanding combustion air stand pipes in which at least some of the stand pipes include or have associated therewith air flow control devices, each device being individual to a stand pipe and at least some of the devices having a common operating means.

In a further aspect of the present invention the fluidised bed burner has an auxiliary fuel introduction means leading into the bed.

The auxiliary fuel introduction means may conveniently be for fuels which, because of their lightness or size would be rapidly elutriated by the combustion air flow, for example, waste straw,sawdust, or coal dust and for this purpose the auxiliary fuel introduction means may comprise a pipe extending into the fire bed preferably at the level of the upper surface of the quiescent layer, in which pipe the auxiliary fuel would be at least partially burnt. The normal fuel would be in the form of lumps of coal but all coals contain a certain amount of coal dust and this is elutriated and separated out from the combustion gases in exhaust cyclones along with the elutriated ash; the elutriated ash can be recycled so that the one or two percent elutriated coal dust therein can be reclaimed. The auxiliary fuel should preferably be injected along with air. The auxiliary fuel introduction means could alternatively be designed for the introduction of a liquid fuel which might otherwise be difficult to burn.

This fuel would be injected into the quiescent layer and wet it (the ash component in particular, would soak it up and act as a wick) and on reaching the upper surface of the quiescent layer some of the oil wetted ash would break away and enter the active fire region. The quiescent layer, although not agitated by the air flow, is in contact with the seething mass of the active fire and this, and a bombardment by falling fuel, ensures that the quiescent layer is not static. If the fuel is injected under pressure and is such as to degrade, forming a skin, the fuel pressure will break up the skin as it forms.

Quiescent layers are created in most fluidised bed burners by introducing the combustion air some way above the true base plate by means of stand pipes or sparge pipes. It is possible to introduce the air through a plain perforated plate but this loses the insulating effect of the quiescent carrier layer.

In yet a further aspect of the invention a fluidised bed burner comprises a combustion chamber and an air plenum separated by a plain perforated plate and a layer of coarse bodies resting on the plate.

The coarse bodies would be resistant to elutriation and could be dropped onto the plain plate along with an easily elutriated carrier such as sand and alumina and then separated into a lower layer of the coarse bodies supporting the finer carrier by blasting air through it. If the bodies are graded in size, possibly progressively, it should be possible to grade the layers of bodies and carrier by blasting air therethrough at an abnormally high rate so that as to get grading by elutriation.

According to another aspect of the invention a method of conditioning a fluidised bed includes the steps of transferring the bed to a crusher adapted to reduce the particle size of material other than carrier material (i.e. inert incombustible material) to a size approximating the particle size of the carrier material, and returning the crushed material to the bed.

The crushed material may be returned by any one of a number of known transport methods, but in a preferred form of the invention the crushed material is collected by way of a venturi and pneumatically transported to an inlet in the burner above the plate supporting the bed.

The invention includes a control method for fluidised bed heaters in which method at least a first parameter, being the pressure of the steam raised or the temperature of the water being heated, and a second parameter, being the bed temperature, are sensed and applied to regulate the fuel feed, the first parameter being applied in steps to limit the maximum range over which fuel may be fed and the second parameter being applied to regulate the feed in that range.

Also according to the invention a method of controlling combustion in a fluidised bed heater comprises the steps of:

sensing the first and second parameters and a third parameter, being the free-board gas pressure in the fluidised bed heater, at chosen number of stepped levels of the first parameter, allowing the fuel feed to the bed to operate over given ranges in steps with the first parameter steps;

at the chosen steps of the first parameter dampening the flow of exhaust gases in the same number of steps;

controlling the inlet for the fluidising air or gas to the bed also in steps which result from a pneumatic connection derived from the above bed combustion chamber gas pressure in response to the same number of chosen steps in the third parameter;

and controlling the fuel feed in the chosen range allowed at any time in response to the second parameter.

The invention also provides that on start-up a special start-up control circuit should override the control system outlined above until a predetermined bed temperature has been reached.

Embodiments of the invention are now described, by way of example, with reference to the accompanying drawings in which:

Figure 1 is a schematic vertical section of a horizontal boiler according to the invention;

Figure 2 is a section taken on line II-II of Figure 1;

Figure 3 is an enlarged detail showing a combined stay and primary air supply pipe;

Figure 4 is a similar detail showing a simple primary air supply pipe;

Figure 5 is a similar detail showing an air supply pipe which includes a flow control device;

Figures 6 and 7 illustrate auxiliary fuel introduction means;

Figure 8 illustrates a base plate structure;

Figure 9 is a flow diagram of an apparatus for a fluidised bed burner incorporating a crusher;

Figure 10 is a section in side elevation of a vertical boiler;

Figure 11 is a section taken on line II-II in Figure 10; and

Figure 12 is a diagrammatic illustration of a fluidised bed heater and its associated control circuits.

Figures 1 and 2 show a horizontal shell boiler enclosed by an outer shell 11 within which a fluidised bed reactor chamber 12 is wholly contained. The base plate 14 of the reactor chamber, on the upper surface of which rests the bed, is spaced apart from the lower part of the shell 11 by stays 15 leaving the space between the two plates 14, open to the water jacket surrounding the reactor chamber 12. Further stays 16 are used to locate the chamber 12 which is of considerable height so that the carrier or bed material of sand, alumina . or the like is not over-prone to elutriation (entrainment in the air stream). To avoid the large size of the chamber blanking off water circulation, a plurality of water tubes 17 cross through the chamber at an inclination to the horizontal and at various bearings to induce convective flows of water. If the boiler is used with a chimney generating an induced draught, an exhaust gas turbine can be installed. Banks of fire or smoke tubes 18 lead off from the combustion chamber to deliver heat from the combustion gases to water in the boiler. The banks can form a single or a multiple pass as shown in the drawings.

It will be seen that the chamber is surrounded by water. The base plate 14 is shaped so that any steam bubbles formed on its water side will float away and will not impair the heat transfer characteristics, and can be contoured for strength or other purposes. A series of primary air tubes 20 extend between the two members to conduct primary air from a forced draught plenum 21 attached on the outside of the shell into the combustion chamber 12, some of these air pipes can serve as stays 15, which pipes 20a are shown in Figure 3. Each air pipe has a bore 22 and receives a standpipe 23 which in Figure 3 is screwed directly into the air pipe and in Figure 4 which a non-structural standpipe 20b is shown, provided with a threaded collar which screws onto the air pipe. The standpipes are of heat-resistant material and varying lengths of standpipes can be fitted to suit the fuel to be burnt and other relevant factors. Each standpipe has its upper end blanked off and has holes in the sides. In Figures 3 and 4 the upper ends are blanked off by an umbrella plate 25 so that when the bed is slumped, without an air flow preventing the carrier entering the holes, the umbrella plate creates a clear space with the holes being in the clear space. The size of the umbrella plate will, of course, depend on the angle of repose of the particular carrier material used so that the clear space is in fact large enough to leave the holes free.

Figure 5 shows another design of standpipe which does not require the top closure to be in the form of an umbrella plate. This has a succession of air outlet holes 27 in an outer tube 28 which holes can be progressively blocked off by a valve device which comprises a tube 29 slidably located within the bore of the air pipe 21 associated with the standpipe. Upward movement of the inner tube 29 will block off the holes 27 which may be staggered to give an infinitely variable blocking off action. The end of the tube

29 may be cut on an incline to give the same effect. The lower end of the tube 29 is blanked off by a plate 30 above which there is a plurality of air inlet apertures 31. When the tube 29 is fully inserted, a seal on the plate 30 sealingly engages a seat on the lower end of the air pipe 28, thereby sealing off the aperture 31 within the air pipe 28. A common activating means for the tubes 29 comprises a regulator plate 32 within the plenum which can be displaced up and down by suitable means sealingly entering the plenum. This regulator plate can be perforated or otherwise adapted to balance out any unevenness of air pressure within the plenum or be connected adjustably to the various devices by flexible couplings 33 so as to allow each standpipe to take equal amounts of air.

It will be appreciated that use of the cooled base plate results in a number of advantages. Heat is delivered through the base plate itself from the fluidised bed so increasing the heat transfer surface area and owing to the cooling, the base plate is less liable to distort so that a relatively inexpensive material can be used. The shell is also water cooled so that the problems associated with the seal between the plenum and the prior art base plate no longer arises, and this enables the use of a higher forced draught pressure. In fact a higher pressure throughout the air flow path can be used. A higher combustion pressure with the resultant greater oxygen content concentration, leads to more intense combustion and thus a smaller boiler. The advantages are more pronounced in the so-called shallow bed versions of fluidised bed combustion.

To allow a higher combustion pressure to be used, a fuel inlet hatch 37 in the outer wall of the shell and the combustion chamber is fitted with a fuel feed device which limits blow-back of fuel on failure of combustion as well as limiting ingress of air additional to that required as secondary combustion air. (see Figure 1)

The use of flow controlling standpipes also gives many advantages. One advantage is the elimination of the need to have an umbrella plate on each standpipe which permits closer spacing of the standpipes for intensely active shallow bed burners. However the main advantage of regulating each standpipe instead of, or even as well as, using a common damper is that the air flow is more evenly shared between standpipes and regulating down the air flow does not change the balance of the air flow between standpipes.

It is thought that the life of the base plate 14 will be extremely long not only because of its cooling but also because the carrier or bed material will after initially polishing the upper face of the member tend to plate out giving a wear and heat resistant surface.

In Figure 6, a series of separators 39 are provided in the exhaust circuit for separating out any solids elutriated out of the reactor chamber 12, which solids will be either ash or unburnt fuel dust. The use of multiple separators such as cyclones would permit the various fractions such as the heavier fuel particles from the cyclone 39a, ash from the cyclone 39b and light fuel particles from the cyclone 39c, to be individually separated or at least for some fractions to be richer in unburnt fuel than others. At least the fuel rich fractions are fed back into a hopper 40 into which can also or alternatively be fed any light fuels likely to be elutriated such as straw, waste and sawdust. The contents of the hopper are allowed to fall or are fed into a stream of air which can be derived from the forced draught fan (not shown) for feeding the plenum 21. A tube or retort 41 leads into the active fire region preferably just above the quiescent layer and the stream of air with entrained fuel particles is directed into and through this tube which is of course hot,so that the particles are heated whilst they pass along the tube and are at least partially burnt therein. This fuel return system can be incorporated into the reconditioning system described below. (shown in dotted outline in Figure 9).

The auxiliary fuel introduction means of Figure 6 is suitable for burning solid light fuels and Figure 7 shows another auxiliary fuel introduction means suitable for liquid fuels, especially those which may be difficult to burn because of a high flash point or a tendency to clog normal nozzles. The fuel is introduced under pressure by means of a pump 42 with an outlet 43 leading into the quiescent layer of the fluidised bed that is below the level of the air outlets from the standpipes or sparge pipes. The ash component of the quiescent layer soaks up the liquid fuel acting similarly to a wick in distributing the liquid fuel throughout the quiescent layer. On reaching the turbulent upper surface of the quiescent layer some of the wet ash is broken off and burnt in the active fire region. If any skin tends to form due to degradation of the liquid fuel, the skin will be broken away by the fuel pressure whilst the skin is still forming.

Figure 8 shows an alternative base plate structure. In this structure, a quiescent layer is not formed by means of stand or sparge pipes but the base plate proper 44 is a plain perforated plate which is thermally insulated from the active fire region 45 by a layer of coarse refractory bodies 46 resistant to elutriation. Above this layer of bodies 46 there is the usual active fire region consisting of fuel and carrier. The carrier can be charged into the chamber along with the heavier bodies and the graded layers can be formed by elutriation by a high pressure air stream. Alternatively, the heavier bodies can be introduced first and then the carrier added with or without an air current.

The gaps between the coarser heavy bodies must be sufficiently small for the carrier to be unable to seep down through the gaps and through the perforations in the base plate proper. This can be done by judicious grading.

As is shown in Figure 8, the base plate 44 can be spaced from the shell 11 by the air pipes 20 which would be welded to the shell and the base plate 44, or alternatively, a unitary, prior art base plate may be used which relies solely on the refractory material 46 for cooling.

A bed reconditioning system is shown in Figure 9 to include a fuel inlet 60 to the reaction chamber 12. When the average particle size or density of the bed material is such as to interfere with the efficiency of the reaction, the bed material 54 is removed through the drop tube 62 into a crushing unit 64 where the final particle size of the material can be reduced to a predetermined value. The crushed material is then conveyed by a conduit 66 to be drawn off and entrained in an air stream by a venturi 68 which is fed with air from the forced draught fan in the direction of the arrow 70. The reconditioned carrier material is fed back through the fuel inlet 60 to the reaction chamber 12. Thus, partially burnt coal is returned to the bed and burnt to ash which is elutriated, and ground inert, incombustible material is introduced to the bed 54, which further reduces the necessity to top the bed up with fresh sand.

This embodiment permits substantially continuous operation of the fluidised bed burner and ensures that substantially all of the ash will be collected in the cyclones in the exhaust of the system.

In Figures 10 and 11 the plenum 110 of a vertical fluidised bed boiler is fed with air under pressure in the direction of arrow 112. The air rises through the base plate 114, on which rests a fluidised bed 113. The heat generated from the fluidised bed flows upwardly through the reaction chamber which rises high enough to constitute a vertical flue 115, as a first pass. The side walls 116 of the reaction chamber 115 are therefore heated by direct contact.

The heated gas then flows through a series 118 of smoke tubes which constitute a second pass, and then into a smoke box 120, from which the hot gases pass upwardly through a series 122 of smoke tubes constituting a third pass, terminating in a manifold 124, which is connected to suitable cyclones and chimneys (not shown).

A series of thermic siphon tubes 126 is provided, leading from the jacket 128, through the bed 113 and the vertical flue 115 in order to produce steam. This steam rises and is then allowed to enter the steam space 130 above the level 132 of water above the flue 115. Baffles 132 are provided to avoid instability of the steam space 130.

The working pressure inside the steam space in the boiler shown is 860 KPa.

Coal or other fuel is introduced through the inlet orifice 134 and water enters through inlet 136. An access door 138 is provided as well as a manhole ring 140. A series of stays 142 serve to ensure constructional strength and the smoke pipe 118 and 122 also serve as constructional units.

A microprocessor may be used which constantly monitors the various parameters and all of some mechanical factors. This microprocessor may be used with a number of boilers in conjunction with a modulator/de-modulator (MODEM) unit, which allows the microprocessor to receive and send messages along telephone wires to a central computer and/or to individual computers. Thus, the central control can send warning signals to customers' boilers in advance of catastrophe or damage or malfunction, thereby providing a preventative maintainance feature.

In Figure 12 a heater 210 is formed with an air distributor and plenum chamber 211 having an air inlet controlled by a damper 212. The inlet leads from the forced draught fan (not shown). Above the chamber 211 is a space occupied by the fluidised bed 213 of conventional design with its associated free-board 214. The steam space is indicated by the reference numeral 215. There is a gas outlet controlled by a damper 216. In this case a suction fan (not shown) is connected to the outlet.

The heater 210 is fitted with four transducers. There are two thermocouples 217 and 218 in the bed 213 serving as temperature transducers. There are two pressure transducers 219 and 220 serving to sense the steam pressure and free-board pressure respectively.

The heater 210 is also fitted with a bed preheating unit 221 of any conventional construction which is controlled by an ignition control unit 222 which in turn is controlled by a start up control unit 223. Once activated the unit 223 is controlled by a signal from the thermocouple 217. At a predetermined bed temperature, the unit 223 causes the ignition control unit 222 to switch off the preheating unit 221. At another and lower temperature the unit 223 is once more activated and causes the unit 222 to operate once more.

The other thermocouple 218 signals a temperature controller 224 to control the fuel feed in a manner described later on. The controller 224 functions through the unit 223 and as long as the unit 223 is activated, signals from the unit 224 are blocked and only signals from the unit 223 pass along the line 225 to a speed controller 226 which regulates the coal feed to the bed 213 of a coal feeder (not shown) so that only the quantity of coal required at start-up is fed to the bed 213.

The speed controller226 is arranged to be operative over one or more ranges each from zero to a predetermined maximum. This is done by means of a three step controller 227 which enforces a maximum speed setting on the controller 226 in response to signals from the transducer 219. At a predetermined maximum pressure the coal feed is stopped. At a predetermined high pressure the lowest speed setting becomes operative and at two lower pressures, high speed settings become operative.

The three step controller 227 operates the damper 216 in a similar manner among one or more positions. At the maximum pressure in the freeboard the damper 216 is at its smallest opening and at two lower pressures it is at an intermediate and at its fullest opening. The damper 216 should never be closed.

The setting of the damper 216 affects the pressure in the freeboard 214 so that the transducer 220 senses any changes in pressure as the aperture of the damper 216 is changed. The transducer 220 then signals a three term proportional controller 228 which controls the damper 212 causing the fluidising and combustion air to increase or decrease thus balancing the above bed pressure to a predetermined positive or negative pressure level. This change in combustion air also increases and decreases the heat transfer surfaces covered by the fluid bed, i.e. increase in fluidising and combustion air gives an increase in heat transfer surface. A decrease in fluidising and combustion air gives a decrease in heat transfer surface. In all uses of fluid combustion the greater the quantity of combustion air the greater the heat extraction from the bed and the lower the combustion air the lower the heat extraction becomes from the bed. This is because the air, as it passes through the bed absorbs heat while being involved in the combustion process. The air and combustion gases in the boiler situation remove a proportion of the heat from the bed, while in a fluidised bed incinerator and crop drier the combustion air and gases, remove nearly all of the heat from the combustion system. The rest of the heat becomes dissipated through losses in the system which, however, is a very small percentage.

The control therefore of damper 216 in relationship with damper 212 and the correct delivery of coal to the combustion system must be related correctly with the combustion air, this being done by the three step controller 227. The response time of the controller 228 and the damper 212 is shorter than the response time of the damper 216 to prevent pressurization of the space 214.

Note that when the unit 223 is activated it overrides the control by the transducer 214 to enforce the setting of the damper 212 to that required at start up. As soon as the unit 223 is deactivated, the transducer 214 takes over.

In addition to the above,conventional safety circuits may also be provided, but these do not affect the operation of the invention.

As an illustration take the case of a boiler designed to deliver steam at a pressure of about 960 kPa with a maximum allowable pressure of 1000 kPa. The controller 227 would then be set to select one of four boiler states:

1. High fire at 890 kPa
2. Medium fire at 930 kPa
3. Low fire at 960 kPa
4. Slump at 1000 kPa

Corresponding to the boiler states the controller 226 will have one or more maximum speed settings:

1. High speed
2. Second speed
3. Third speed
4. Stop

The damper 216 will also have four settings:

1. Wide open

2. Partially open
3. Partially closed
4. Almost closed

In response to this the controller 228 would place the damper 12 into four settings resulting from a pneumatic connection derived from the above bed combustion chamber gas pressure:

1. Wide open
2. Partially open
3. Partially closed
4. Closed.

For a coal fired furnace the average bed temperature should be about 950°C and the maximum allowable about 1000°C. In such a case the start up control unit 23 should become deactivated at A°C and come into operation again if the bed temperature drops to B°C, which is a temperature below that of A°C. In effect the temperature controller 224 will then send out signals over a range of A°C to 1000°C. At the latter temperature it would order the speed controller 226 to stop the coal feed while at A°C it would order the controller 226 to feed coal at the maximum rate permissible in terms of the setting allowed by the controller 227.

The effect is that once the steam pressure is up and steam is consumed, more air will pass through the bed tending to lower the temperature, so that the controller 224 will cause more fuel to be fed to the bed once more to raise the temperature and also to provide more heat to raise more steam. As the demand drops, air flow will first drop while the controller 226 will operate in a range which will cause the fuel feed to be diminshed in step with the decline in demand.

CLAIMS:

1.A boiler is provided with a combustion chamber base plate having an upper surface adapted to support a burning fuel bed and, spaced apart therefrom, a lower surface to which a combustion air plenum is to be attached, characterised in that the base plate is at least partially hollow between its surfaces whereby water can flow therebetweeen and cool those surfaces.

2.

A boiler according to claim 1 characterised in that the surfaces are constituted by two discrete members, the space between the members forming part of a water jacket completely surrounding the combustion chamber except for necessary openings such as for the introduction of fuels.

3.

A boiler according to claim 3 characterised in that the water jacket is the shell of a fire-tube boiler.

4.

A fluidised bed burner for a boiler which has a combustion chamber base plate with upstanding combustion air stand pipes characterised in that at least some of the stand pipes include or have associated therewith air flow control devices, each device being individual to a stand pipe and at least some of the devices having a common operating means.

5.

A boiler according to claim 1 in which auxiliary fuel introduction means is provided, characterised in that the auxiliary fuel introduction means is adapted to introduce fuels which, because of their lightness or size would tend to be rapidly elutriated by the combustion air flow, the auxiliary fuel introduction means comprising a pipe extending into the fire bed at the level of the upper surface of a quiescent layer in the bed.

6.

A boiler according to claim 5 characterised in that means is provided in the gas circuit of the boiler at least partially to separate from one another, elutriated, unburnt fuel dust, light combustible waste materials such as straw and sawdust, and elutriated ash and which includes means to return the combustible waste material and the unburnt fuel dust to the combustion chamber via the auxiliary fuel introduction.

7.

A boiler according to claim 6 characterised in that the means to return the fuel dust and combustible material comprises a container formed with an opening arranged to feed the contents of the container into a moving air stream.

8.

A boiler accorind to claim 1 in which auxiliary fuel introduction means is provided, characterised in that the auxiliary fuel introduction means is adapted to introduce a liquid fuel into the bed, the introduction means being arranged to inject the fuel under pressure into a quiescent zone of the bed.

9.

A fluidised bed burner comprising a combustion chamber and a primary combustion air plenum separated by a plane perforated plate characterised in that the bed comprises a layer of coarse elutriation-resistant refractory material bodies resting on the plate.

10.

A method of grading the bed of a fluidised bed burner into layers comprises the steps of dropping coarse elutriation resistant bodies onto a plane perforated plate separating a combustion chamber of the boiler from a combustion air plenum thereof along with an easily elutriated carrier characterised in that the bodies and the carrier are separated into a lower layer of the coarse bodies supporting a layer of the finer carrier by blasting air therethrough.

11.

A method of conditioning the bed of a fluidised bed burner characterised in that the bed material is transferred to a crusher adapted to reduce the particle size of material other than carrier material to a size approximating the particle size of the carrier material, and returning the crushed material to the bed.

12.

A method according to claim 11 characterised in that the crushed material is collected by way of a venturi and pneumatically transported to an inlet in the burner above the plate supporting the bed.

13.

A control method for fluidised bed heaters characterised in that at least a first parameter, being the pressure of the steam raised or the temperature of the water being heated, and a second parameter, being the bed temperature, are sensed and applied to regulate the fuel feed, the first parameter being applied in steps to limit the maximum range over which fuel may be fed and the second parameter being applied to regulate the feed in that range.

14.

A method according to claim 13 characterised in that the method comprises the additional steps of:

sensing the first and second parameters and a third parameter, being the free board-gas pressure in the fluidised bed heater, at a chosen number of stepped levels of the first parameter, allowing the fuel feed to the bed to be operated over given ranges in steps with the first parameter steps;

at the chosen steps of the first parameter dampening the flow of exhaust gases in the same number of steps;

controlling the inlet for the fluidising air or gas to the bed also in steps which result from a pneumatic connection derived from the above bed combustion chamber gas pressure in response to the same number of chosen steps in the third parameter;

and controlling the fuel feed in the chosen range allowed at any time in response to the second parameter.

15.

A method according to any one of claims 13 or 14 characterised in that a start-up control circuit is provided and adapted to override the control system until a predetermined bed temperature has been reached.

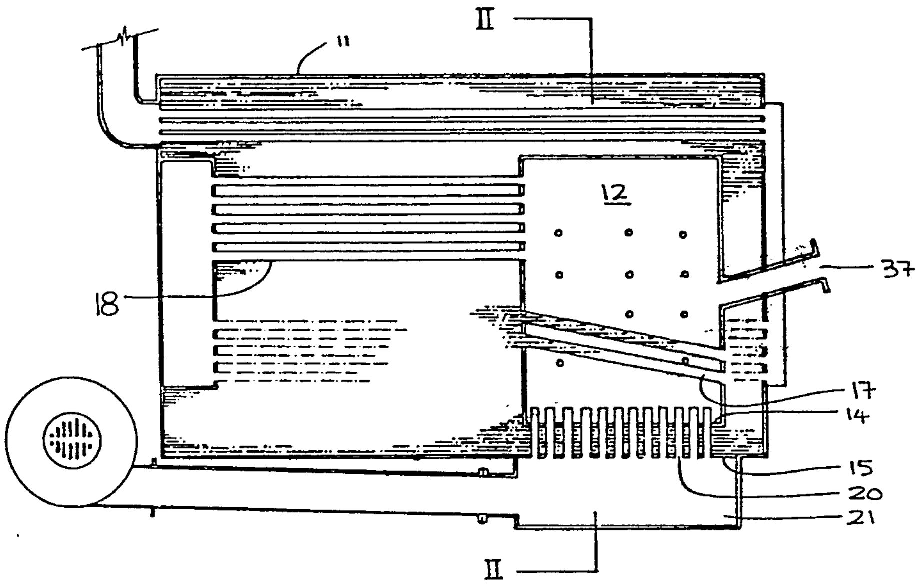


Fig. 1.

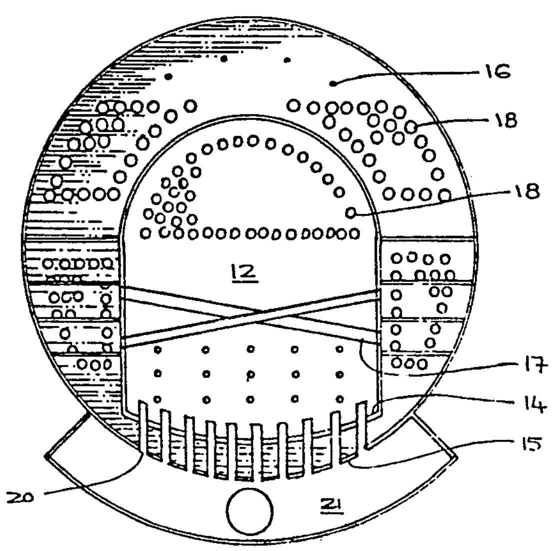


Fig. 2.

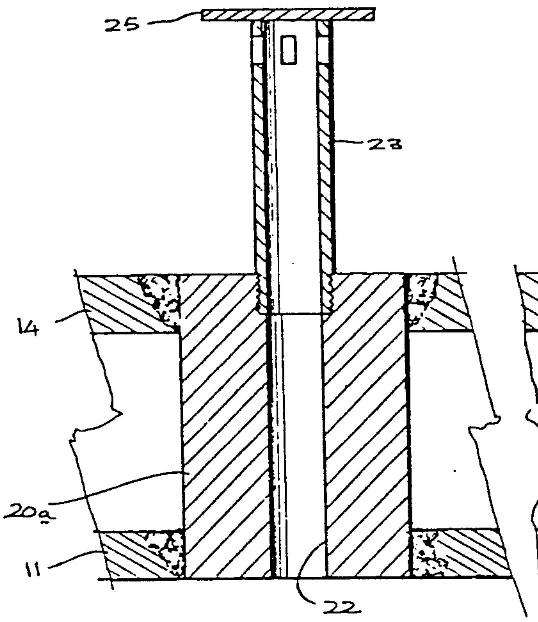
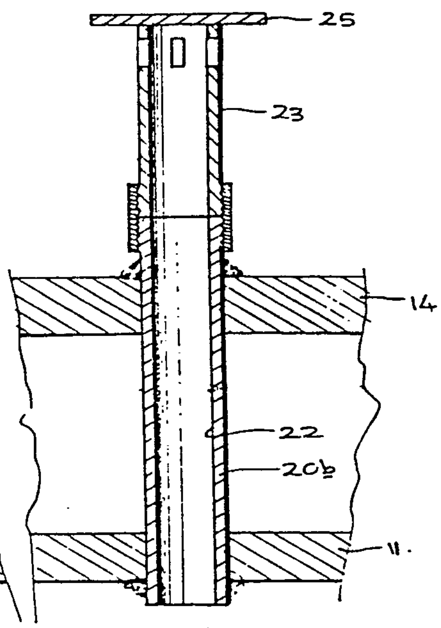


Fig. 3.



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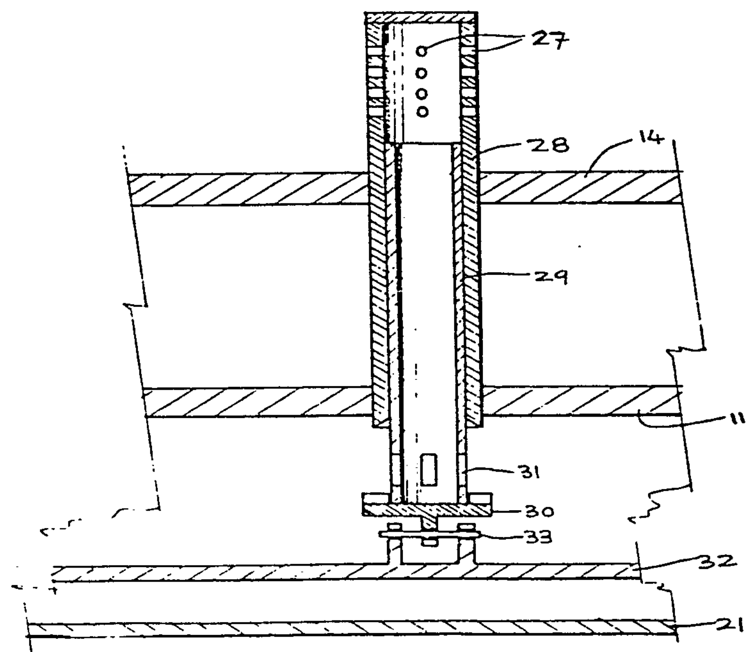

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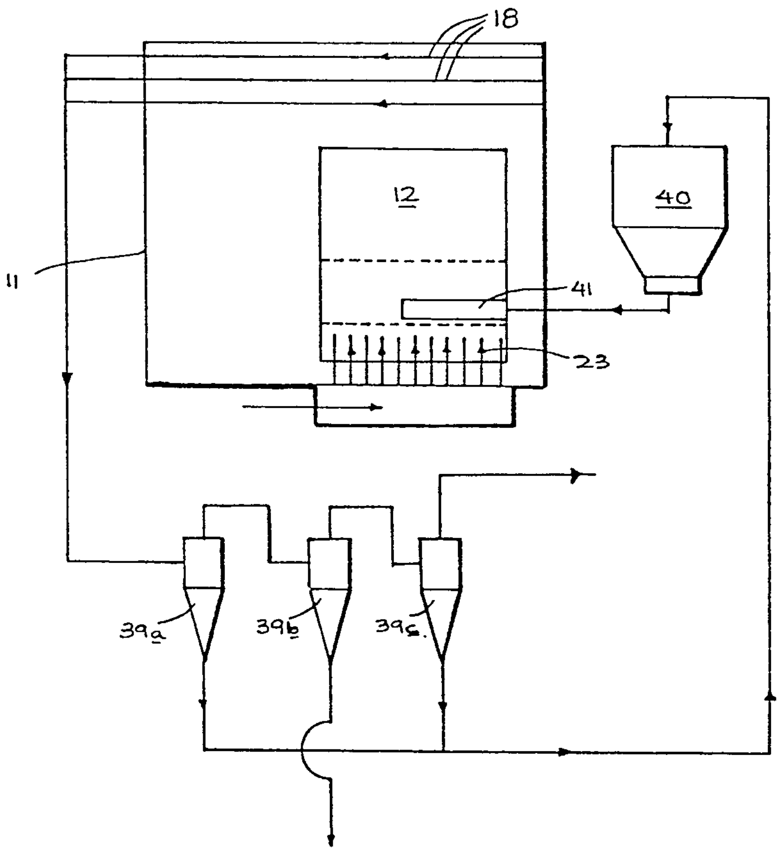

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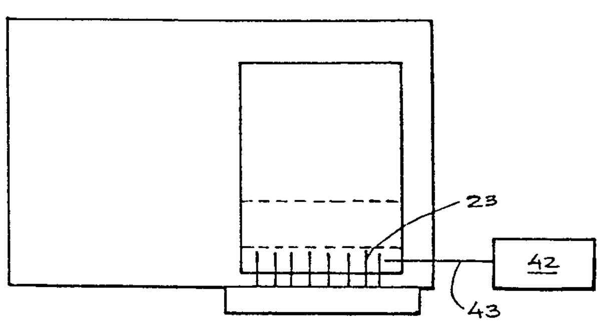

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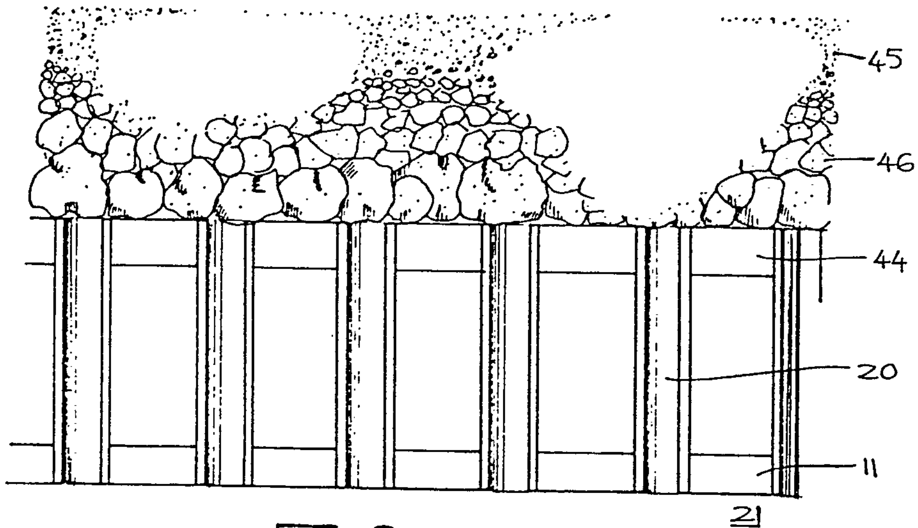

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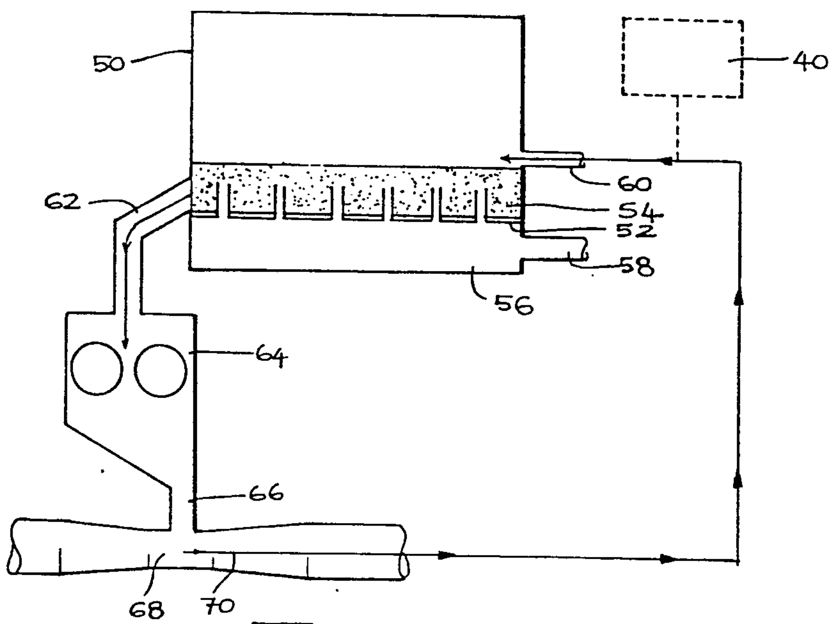

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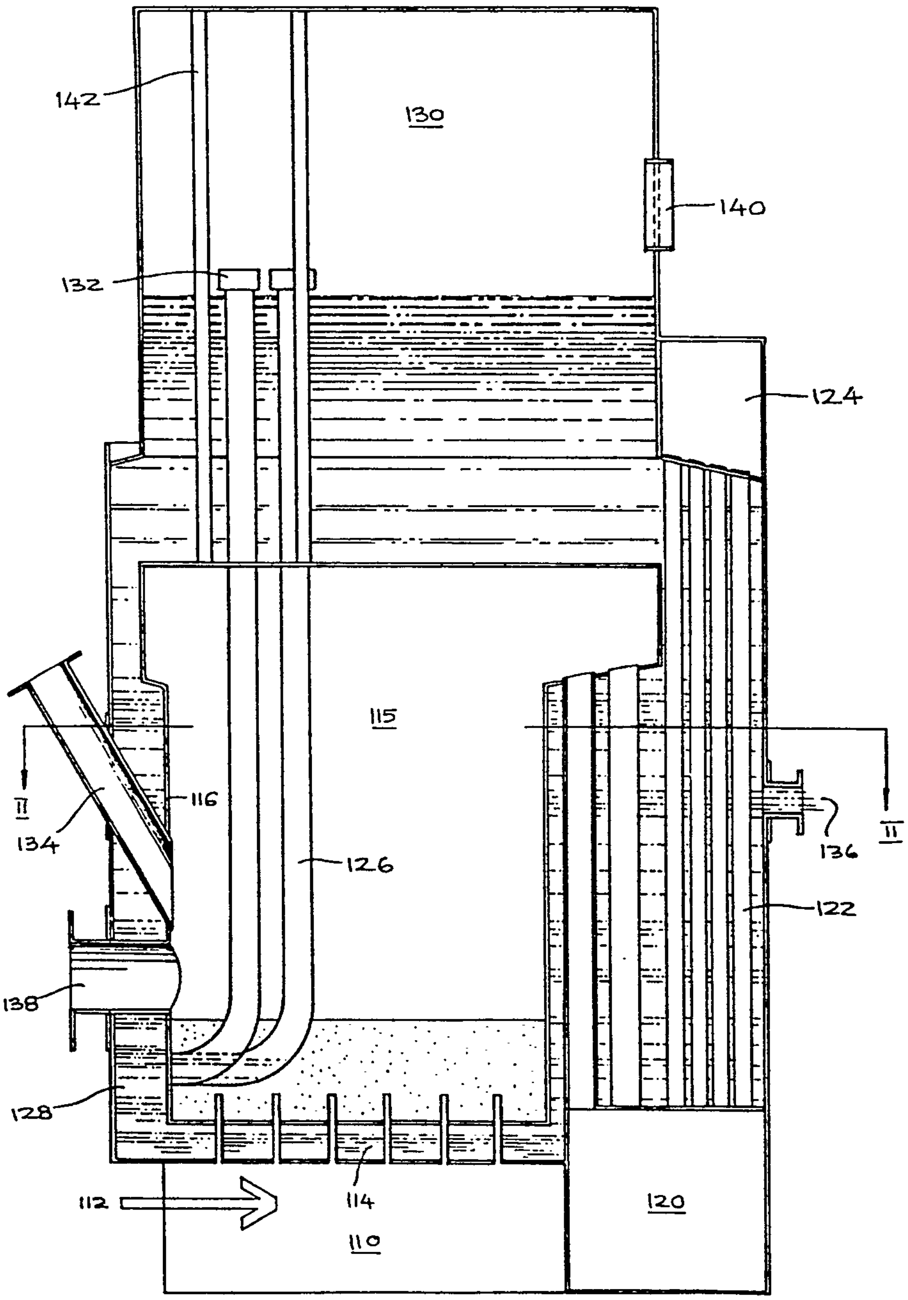
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Fig. 10.

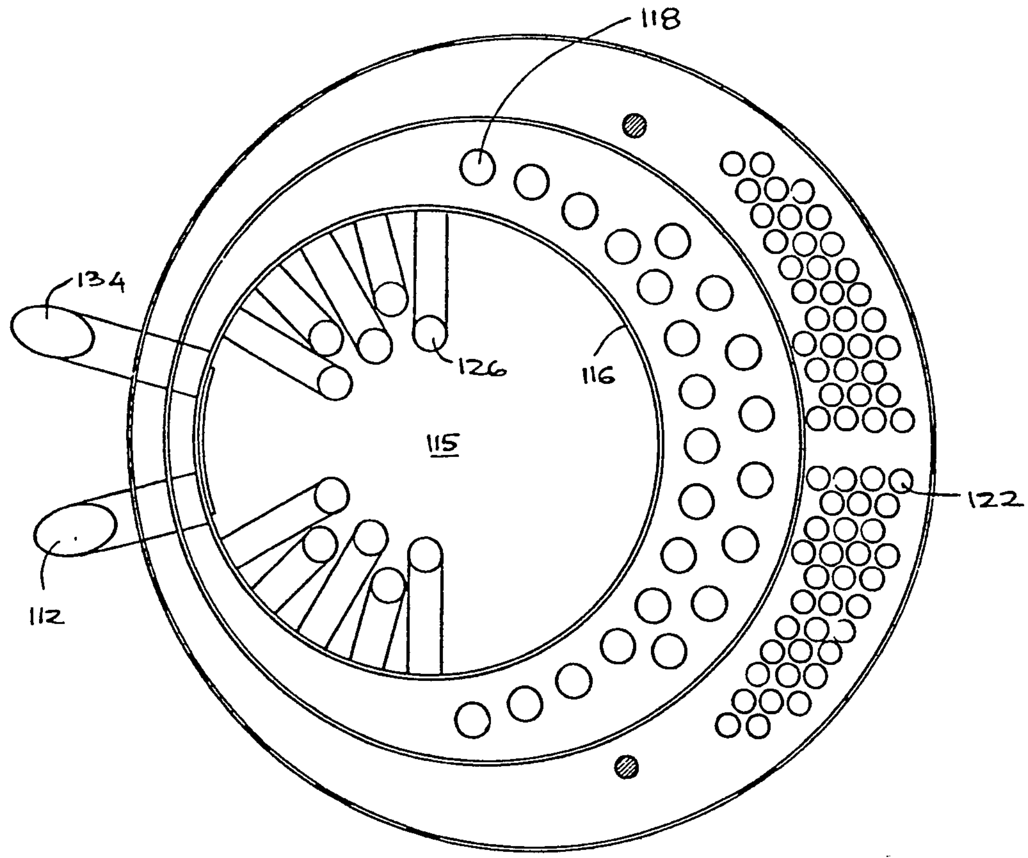
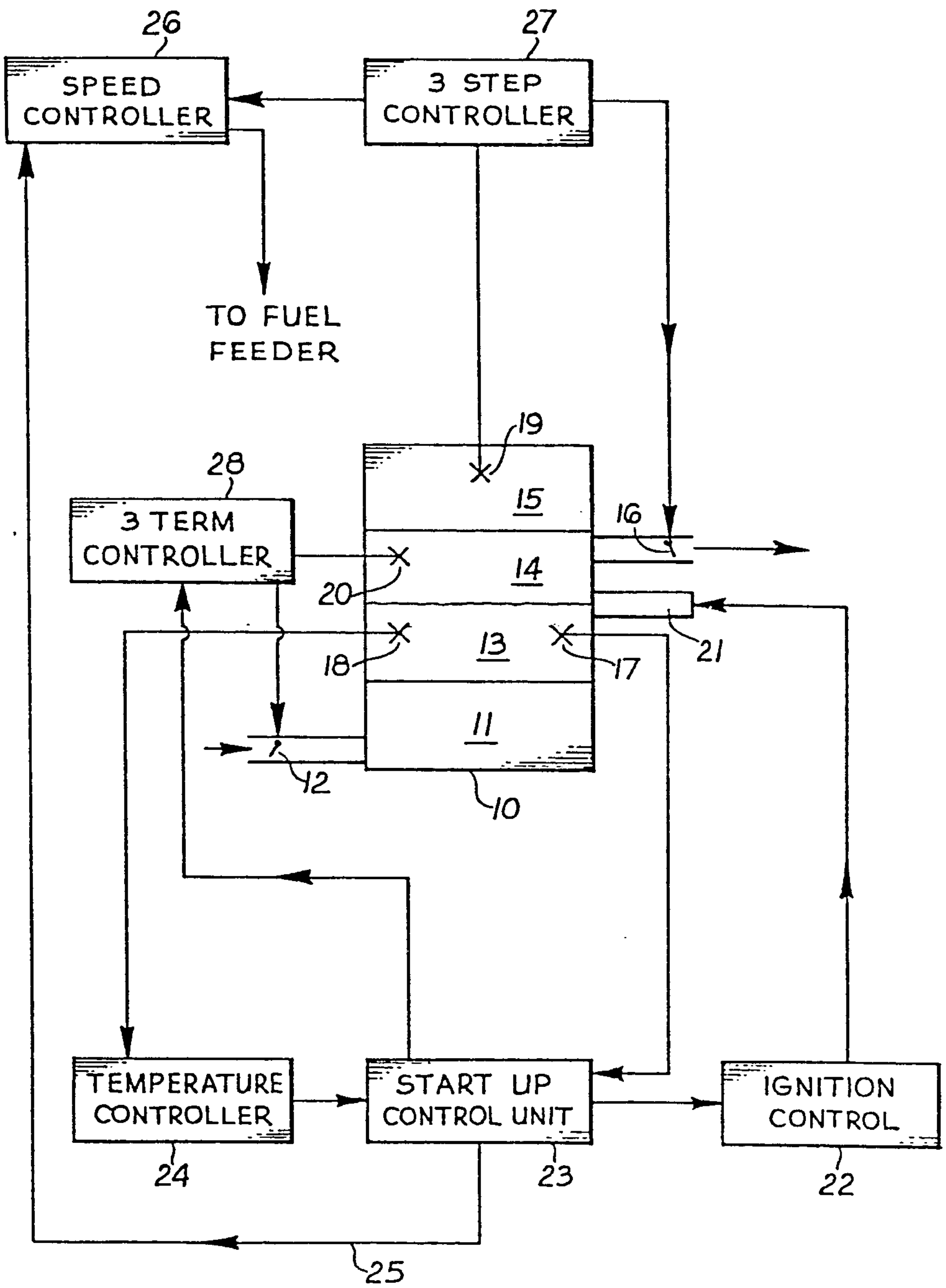


Fig. 11.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SPEED CONTROLLER
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3 STEP CONTROLLER
TO FUEL FEEDER
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15
28
3 TERM CONTROLLER
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14
20
13
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18
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11
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10
TEMPERATURE CONTROLLER
START UP CONTROL UNIT
IGNITION CONTROL
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Fig. 12.