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(54) **Fuel burner and fuel distribution device therefor.**

(57) A fuel burner capable of burning oil, gas or pulverised coal fuel is provided. The burner is particularly suitable for large scale installations such as for steam boilers for power generation plants.

The burner provides a single main airstream which may be supplemented by a secondary gas flow. The secondary flow may be of burnt gases so that flame temperature may be controlled to prevent production of pollutant nitrogen oxides.

-A novel burner fuel distribution nozzle is also provided.

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This invention relates to a fuel burner, particularly a burner for use with multiple fuel sources.

DESCRIPTION OF THE PRIOR ART

Traditional design of oil-gas or coal fired boiler-burners are designed on the basis that their individual performance in a multi-configuration firing can be measured by analysing the products of the combustion of all the burners as a whole, e.g. the measurement of O_2 and/or CO_2 in the flue gas passages.

This design basis is in fact false as the traditional designs do not provide for the control or measurement of the fuel-air ratio of the individual burner, at any particular load on the boiler; and, in particular, do not include control measurement or calibrations for fuel-air ratios or load changes on the boiler which is a common problem when the boiler is associated with an electrical-generation system.

By way of explanation the following are the facts:

(i) Multi-configuration boiler-burners are fitted with a common hot air duct which supplies hot "total" air in the case of oil and gas, and hot "secondary" air (e.g. usually 70% of "total" air) in the case of coal fired boilers.

(ii) The common duct surrounds all the configuration of burners with hot air at varying pressures according to where the individual burner is situated in relation to the flow of air and also according to the adjustment of the dampers (e.g. usually vane type) of each burner, and also in accordance with the wear on these dampers and the pressure at the outlet of the burner throat. This pressure can vary with the state of the firing of the individual burner in relation to the others in the configuration.

(iii) In traditional design there is no individual accurate metering of the individual fuel flow to an individual burner in the configuration. Such measuring as is done is normally done within the main fuel supply system to the boiler as a whole.

(iv) In the case of coal, further adjustment problems of the fuel-air ratio arise in the traditional designs over and above gas and oil. These are that the fuel is carried to the burner after grinding by the primary air flow (25-30% of the total combustion air). This causes the following problems in the fuel-air ratio: (a) the velocity of this primary air leaving the throat of the burner carrying the coal for combustion has a significant effect on the differential pressure between the burner throat and the air pressure in the burner box on the other side of the damper of the initial burner; (b) the primary air stream must be at a temperature so as not to cause combustion of the fuel that it is carrying, e.g. around 170^{o}F. Whereas, the secondary air in the burner box is at full air heater temperature e.g. 500-540^{o}F. Any variations in these temperatures or the volumes of the primary or secondary air significantly upset the air-fuel ratio at the burner. Additionally the differential temperature of primary and secondary air causes stratification within the boiler, which then can significantly affect the overall fuel-air ratio of the total boiler.

(v) In understanding the problems of multi-burner firing, it must be considered as a number of burners receiving unequal amounts of fuel and all according to their pressure differential, striving to obtain the one source of air from the burner box. Any variation in the load on the boiler or the burning efficiency of an individual burner, will alter the pressure of the gas, fuel and air at the burner throat. This effect is amplified because it is easily absorbed in the large volume of primary and secondary air in the case of coal; and secondary air only in case of oil and gas. This huge volume of air, in each case, that can absorb pressure differentials occurs because the source of energy to move the air e.g. forced draught fans for secondary air, and exhausters for primary air are situated far removed from the burner box and indeed the burner boxes are in general of such massive design that the volume of air between the burner throat and source of energy is huge.

(vi) Therefore, it can be said about conventional designs that when fuel was extremely cheap such designs, though inefficient, were practical as the boiler could operate on sufficient excess secondary air as to reasonably ensure that sufficient air was available to ensure that the fuel at each burner was burnt. However, this created two major problems which have become extremely important with the increase in fuel prices and new environmental air pollution standards. These problems are as follows: (a) the excess air will collect a proportion of the heat energy available and carry that heat through the boiler and out of the stack. Therefore making the boiler inefficient through fuel usage and cost; and (b) the oversupply of O_2 and N_2 in the excess air makes available an excess of free O_2 which normally, if carbon was available, would have a preference to unite with the carbon atom. However, as no such carbon is available at the temperatures of combustion, particularly when such combustion is inefficient, therefore the free O_2 will tend to readily unite with the free N_2 and thereby generate NO, NO_2 and NO_3 and other nitrogen and oxygen combinations which are major sources of pollution.

SUMMARY OF THE INVENTION

Thus this invention provides a device to burn a gas, liquid, or coal fuel particularly for use in steam boilers. The device can be constructed to replace existing burners or boilers already in use. The device will burn any one of the three fuels mentioned above without modification or even two or three fuels at the one time.

In its broadest form this invention comprises a fuel burner comprising an air inlet, air flow control means to control the quantity and velocity of air to a primary air channel, said primary air channel being adapted to feed a primary air stream past fuel distribution means to mix fuel to be burnt and the air; said fuel distribution means being disposed within said primary air stream and having means to distribute fuel into the primary air stream; and means to supply and control the fuel flow to said nozzle such that said burner can be operated at the minimum air:fuel ratio required for combustion of the fuel.

In its broadest form the invention can be designed to distribute only one fuel such as oil, coal or gas.

In a preferred form there is provided a secondary air flow channel concurrent and surrounding the primary air flow channel, said secondary air flow channel being adapted to receive air from the same air flow control means which forces the primary air past said fuel distribution means, said secondary air flow channel being arranged such that air velocity and quantity directed therethrough is related to the primary air in such a manner that as the velocity of the primary air is increased, the velocity of the secondary air flow is increased by a greater amount.

The invention also provides a fuel burner nozzle mounted on an axial shaft and comprises a ceramic forward end having an opening therein, said opening being adapted to provide a fuel-oil outlet, said forward end having a first tubular member extending behind said outlet and in communication therewith; a gas distribution section annularly surrounding said tubular member and having peripheral openings therein adapted to provide outlets for gas radially from said nozzle and a second tubular member outwardly concentric with said first tubular member and adapted to feed gaseous fuel to said gas distribution section; and a coal distribution section disposed behind said gas distribution section, and having an outer circular wall having openings therein adapted to radially outwardly distribute fine coal particles on axial rotation of said nozzle and having means to receive fine particulate coal into said coal distribution section.

Where a burner is used with low moisture high grade coals the flame temperature will normally become excessive as more oxygen is present than necessary. This is because low moisture high grade (energy) coals require less oxygen for combustion per unit weight of coal due to the low ash and moisture contents.

Excessive flame temperatures produce pollutants such as various nitrogen oxides. To overcome this problem the invention provides for the secondary air channel to feed pre-combusted gases instead of air to the fuel combustion zone to keep the flame temperature sufficiently low to prevent production of nitrogen oxides. Preferably the pre-combusted gas is a cleaned flue gas from the furnace. There is no substantial loss of heat energy by using the flue gases which in effect are re-heated as the gases pass through economizers and superheaters in the normal manner following the combustion zone to give up their heat energy.

The use of a variable speed blower (fan) to drive the air along the channels has a number of advantages over the prior art. It allows more accurate control of the air flow than a damper system. Faster flow responses are possible than with a damper system. Less windbox pressure is necessary than is required for a damper system, which also results in greater uniformity of air pressure throughout the system. The fan power drive is less than required for a normal system and flame flash-back is prevented.

DESCRIPTION OF THE DRAWINGS

The invention will now be described by way of example only with reference to the accompanying drawing wherein there is shown a longitudinal cross-section of burner and nozzle in accordance with the preferred form of the invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

A furnace such as a boiler furnace normally is fired by a series of burners suitably spaced on one wall of the furnace, preferably furthest from the boiler. Surrounding the furnace is a hot air box 60 which encloses the ambient air surrounding the furnace and captures the heat passing through the furnace wall to the surrounding environment. The furnace wall 10 has passing through it a number of boiler tubes 11 which remove heat from the wall to generate steam and to reduce heat losses from the furnace. Each burner 14 passes through an opening 12 in the furnace wall 10 so that only the actual flame 36 (apart from the tip of the ceramic burner nozzle 20) from the burner 14 is within the furnace 61, whilst the operating apparatus of the burner 14 is external to the furnace wall 10. The burner 14 in accordance with the preferred form of the invention, comprises an outer shell 15 mounted upon a set of wheels 16 which are adapted to ride upon a rail 17. The rail 17 is mounted within the hot air box and allows the burner 14 to be easily and accurately inserted into the hot air box 60 and the opening 12 in the furnace wall 10 by simply pushing the burner 14 along the rail 17 after inserting it through an opening 18 in the outer wall of the hot air box. The arrows 19 illustrate the reciprocable movement of the burner 14.

The burner 14 has a ceramic flame nozzle 20 which is able to withstand the high temperatures generated in the furnace. The nozzle 20 has surrounding it a seal 21 such as a steel ring with asbestos wool which seals the hot air box 60 from the furnace 61. The burner has within its outer shell 15 an inner concentric shell 22 which divides the burner into primary and secondary air flow channels 24 and 23 respectively, as indicated by the arrows. Air from the hot air box 60 is drawn into the nozzle 14 through an entry duct 25 and if it is not sufficiently hot, it may be preheated by means of a heating element 26 located in the entry duct 25. The air is drawn from the hot air box and passes into a blower 27 preferably a multi-stage blower which forces air through the flow paths 23 and 24. The fan means 27 is preferably mounted on a shaft 28 driven in a rotary motion by suitable means 30 such as a V-belt or direct drive motor. The rotation is shown by the arrow 29. The shaft 28 passes through the hot air box and has at its furnace end a fuel distribution nozzle 31. The nozzle 31 comprises an outer ceramic facing 32 which is adapted to withstand the radiant heat from the furnace, thus, to protect the nozzle 31. The shaft 28 comprises concentric tubes 33 and 34. The inner 34 of these concentric tubes carries oil through the shaft 28 to an oil distribution nozzle 35. This oil distribution nozzle allows the oil to be finally atomised before being carried into the burning zone 36 of the furnace by the air flow for combustion. The outer 33 of the concentric tubes of the shaft 28 carries fuel gas to a gas distribution section 37 of the nozzle 31. The gas distribution section 37 has a series of slots 38 around the periphery thereof so that when the shaft 38 is rotated, the gas being forced into the gas distribution section 37 leaves that section 37 through slots 38 and is mixed with hot air passing through the channel 34 before being carried into a flame zone 36.

The nozzle 31 also comprises a coal distribution section 39 which is attached to the gas distribution section 37. The coal distribution section 39 is a frusto-conical shell having slots 40 which operate in a similar manner to the slots 38 except they obviously act as coal distribution slots. Coal in a fine powdered form is fed to the burner 14 by means of a feeding device 41 comprising a tubular member 44 having a feed screw 43 driven by a motor 42 mounted therein. The feeding device 41 passes through the outer wall of the hot air box and sealingly engages a coal inlet 45 of the burner. The coal inlet 45 directs pulverized coal down to the shaft 48 and along to the coal distribution section 39 of the nozzle 31. The shaft 28 passes through the coal feeder 46 and is sealed by means of an asbestos wall type seal 47 against leakage of the coal. The shaft 28 has screw members 48 mounted thereon which serve to advance the coal into the coal distribution section 39 of the nozzle 31. The coal distribution section additionally has a small gap between its end 49 and the coal feeder 46. This gap allows a small amount of air to pass from the channel 24 into the coal distribution section 39 to aid in a slight fluidisation and expansion of the coal to assist its distribution through the slots 40. As the coal leaves the slots 40 in a ribbon type form, it is picked up by the air flow through the passage 24 and carried to the flame burning zone 36 of the furnace wherein combustion takes place. Rotatable baffles 50 mounted within the passage 24 serve to provide, if necessary, a swirling motion of the air flowing through the passage 24. This swirling motion increases the mixing and effects the flame angle α emanating from the burner nozzle 20 and also permits adjustment of flame angle α for burner flare as desired. The rotatable baffles 50 are rotatable about their axis 51 as shown by the dashed line. Air passing through the outer passage 23 serves to keep the surfaces of the nozzle 20 cool and clean and to also effect the flame length by changes in the flow rate of the air passing through passage 23. As mentioned above the flame characteristics are critical to the operation of the furnace and to adjust the flame characteristics by means of the baffles and air flowing through passages 23 and 24, pressure and/or flow measurements are taken within the passages at the points represented by metering devices 52 and 53.

If it is desired to increase the flow through the inner passages 24, or the outer passages 23, the speed of rotation of the shaft 28 is suitably varied to drive the fan 27 at a higher speed. Additionally damper means may be provided to regulate the flow of air into the passages 23 and 24. Increasing the shaft 28 speed will also increase the nozzle

31 speed of rotation directly so that the two operate in unison. Furthermore, monitoring of the coal fuel oil or fuel gas flow rates relative to the air flows is essential to deliver the fuel at the required rate relative to the air being supplied. To ignite the fuel, a fuel ignition means 55 such as a spark gap igniter is removably inserted into the burner 14 for ignition.

The shaft 28 is mounted on a series of bearings 54 which support it throughout its length. The inner shaft 34 of the concentric shaft 28 is suitably held in spaced position to the outer shaft 33 by means of spaces 56. It is to be noted that the shaft 28 may be actually split into two sections (not shown). The first section driving only the fan means 27 whilst the second section drives the nozzle 31 only. This allows independent adjustment of the fan and the nozzle in accordance with the required operating conditions.

The parameters in the hot air box are infinitely variable, e.g. load changes and air changes etc. affect performance of the burner.

Thus, the fan which is preferably a multiple stage unit, has to take a set proportion of combustion air regardless of the temperature and pressure in the hot air box and feed the air through high pressure and low pressure volume control channels (secondary and primary passages, respectively). This proportion is predetermined by the speed of the coal feed screw, by the flow of gas or oil into the burner or any combination of the three, as laid down by the calorific value of each fuel and the amount of air required to ensure complete combustion.

The speed of the fan drive is minutely controlled as the result of the measurement of pressure and temperature in the high and low pressure volume control (secondary and primary air) channels which have been calibrated in accordance with the total air flow across the burner throat, in relation to the fuel supplied even for fuel combinations.

This control of the total combustion air must be compensated by a velocity measurement taken in both the secondary and primary air flow channels 23 and 24.

The pressure readings can be altered in relation to flow by the position of the air rotation dampers (not shown) and the pressure in the furnace.

The flow of the fuel(s) is metered individually and then the preset ratio of fuel and combustion air in each case is arrived at so that when the signal is given to the fan motor speed control it is in fact at all times supplying the exact quantity of air regardless of temperature as to ensure full combustion of the fuel.

It should be noted that when the air temperature is below 500°F or other predetermined combustion temperature, then the control signal to the fan speed motor will automatically bias up to supply excess air to compensate for the low temperature which will slow combustion.

The high volume (secondary) control air is necessary for two reasons: (i) it passes directly over the surface of the ceramic burner ring thereby keeping it cool and has such velocity as to sweep any solid and particles of fuel through the burner throat, ensuring that it does not come into contact with the surface of the ceramic burner ring 10 which would otherwise cause coking and scale; and (ii) to extend the length of the flame from the burner throat as may be desired to increase the velocity of burnt gas through the boiler.

The air rotation dampers provided in the primary air flow 24 comprise a series of dampers which are designed to change the direction of the flow in order to form a rotation of this low pressure combustion (primary) air. This rotation has two advantages: (i) the spiral effect of the rotation lengthens the path taken by the combustion air between the time it first comes in contact with the fuel and the time it leaves the burner throat. This permits greater mixing of the fuel air before and during combustion; and (ii) the rotation of the stream of air-fuel mixture has its centrifugal force contained by the shape of the burner throat until such time as this mixture leaves the burner throat when the centrifugal force flares the shape of the flame in proportion to the rotation imparted by the air rotation dampers.

Where a burner is used with low moisture high grade coals the flame temperature will normally become excessive as more oxygen is present than necessary. This is because low moisture high grade (energy) coals require less oxygen for combustion per unit weight of coal due to the low ash and moisture contents.

Excessive flame temperatures produce pollutants such as various nitrogen oxides. To overcome this problem the invention provides for the secondary air channel 23 to alternately feed pre-combusted gases instead of air to the fuel combustion zone to keep the flame temperature sufficiently low to prevent production of nitrogen oxides. Preferably the pre-combusted gas is a cleaned flue gas from the furnace.

The flue gas is introduced to the secondary air channel 23 by means of a manifold 62 which receives gas from duct 63. Duct 63 passes down through the windbox 60 to the manifold 62.

The manifold 62 is adapted to inject flue gas through openings (not shown) when flue gas if forced into said manifold. When flue gas is to be fed to the secondary channel 23 the entry of air from fan 27 to the channel 23 is prevented by means of an iris diaphragm 64 shown in its open position in the drawing.

The iris diaphragm 64 is similar to that of a camera or microscope and thus can be rotated into a close position to shut off the air flow to channel 23, or to partially shut off the air flow to channel 23 thus allowing a mixed air-flue gas flow if desired.

The flue gas flow into channel 23 is controlled by conventional means.

The fuel distribution nozzle 31 is designed to work in the following manner. The nature of fine powdered coal or gas is such that they cannot be easily atomised as in the case of oil. Therefore to obtain maximum mixing of air-fuel, in the case of coal and gas, the fuel is extruded in strip or ribbon form through the slots in the nozzle. These strips present the greatest possible surface to the primary combustion air flowing over the nozzle.

The oil is sprayed from the centre of the nozzle with a rotation caused by the nozzle flaring the atomised fuel which is taken uniformly into the air stream due to the centrifugal force imparted by the nozzle.

The face of the nozzle is adequately protected by the ceramic shield from the radiant heat from the burner. The configuration of the design of the burner ring, the nozzle, ceramic shield and the flow of high pressure (secondary) air protect all components from radiant heat damage or overheating and pre-combustion.

Preheated oil and also gas will maintain combustion at ambient air temperature. Due to the fact that the coal particle takes more preheat before ignition temperature due to its high heat capacity, the time cycle of ignition for coal is greater. Therefore to have stable ignition of coal the combustion air must be preheated to ensure the particle reaches ignition temperature. The time to reach the ignition temperature for coal is proportional to the size of the coal particle and how much moisture is present.

Finally it is pointed out that as the burner brings into association very readily and efficiently the oxygen and the combustible materials, it is not critical to use a high grade coal as in normal coal burning plant. Furthermore, less total oxygen or air fuel is required as the efficiency of combustion is greater. This also virtually eliminates pollutants which occur due to excess oxygen.

CLAIMS :

1. A fuel burner comprising an air inlet, air flow control means to control the quantity and velocity of air to a primary air channel, said primary air channel being adapted to feed a primary air stream past fuel distribution means to mix fuel to be burnt and the air; said fuel distribution means being disposed within said primary air stream and having means to distribute fuel into the primary air stream; and means to supply and control the fuel flow to said nozzle such that said burner can be operated at the minimum air:fuel ratio required for combustion of the fuel.

2. The burner of claim 1 wherein said means to distribute fuel comprises a nozzle adapted to rotate about an axial drive shaft.

3. The burner of claim 1 wherein there is further provided a secondary air flow channel concurrent and surrounding the primary air flow channel, said secondary air flow channel being adapted to receive air from the same air flow control means which forces primary air past said fuel distribution means, said secondary air flow channel being arranged such that air velocity and quantity directed therethrough is related to the primary air in such a manner that as the velocity of the primary air is increased, the velocity of the secondary air flow is increased by a greater amount.

4. The burner of claim 3 wherein said secondary air flow channel may have its air inlet shut to prevent entry of combustion air and said channel may be placed in communication with a source of pre-combusted gas.

5. The burner of claim 1 further including adjustable vane means in said primary air channel to rotate the air flow.

6. The burner of claim 1, 3, 4 or 5 wherein said means to distribute fuel comprises a rotatable nozzle adapted to receive and distribute individually or in combination liquid, gaseous or solids fuel.

7. The burner of claim 6 wherein said nozzle is mounted on an axial shaft and comprises a ceramic forward end having an opening therein, said opening being adapted to provide a fuel-oil outlet, said forward end having a first tubular member extending behind said outlet and in communication therewith; a gas distribution section annularly surrounding said tubular member and having peripheral openings therein adapted to provide outlets for gas radially from said nozzle and a second tubular member outwardly concentric with said first tubular member and adapted to feed gaseous fuel to said gas distribution section; and a coal distribution section disposed behind said gas distribution section, and having an outer circular wall having openings therein adapted to radially outwardly distribute fine coal particles on axial rotation of said nozzle and having means to receive fine particulate coal into said coal distribution section.

8. A fuel distribution device for a gas-liquid-solids fuel burner comprising a nozzle mounted on an axial shaft and comprising a ceramic forward end having an opening therein, said opening being adapted to provide a fuel-oil outlet, said forward end having a first tubular member extending behind said outlet and in communication therewith; a gas distribution section annularly surrounding said tubular member and having peripheral openings therein adapted to provide outlets for gas

radially from said nozzle and a second tubular member outwardly concentric with said first tubular member and adapted to feed gaseous fuel to said gas distribution section; and a coal distribution section disposed behind said gas distribution section, and having an outer circular wall having openings therein adapted to radially outwardly distribute fine coal particles on axial rotation of said nozzle and having means to receive fine particulate coal into said coal distribution section.

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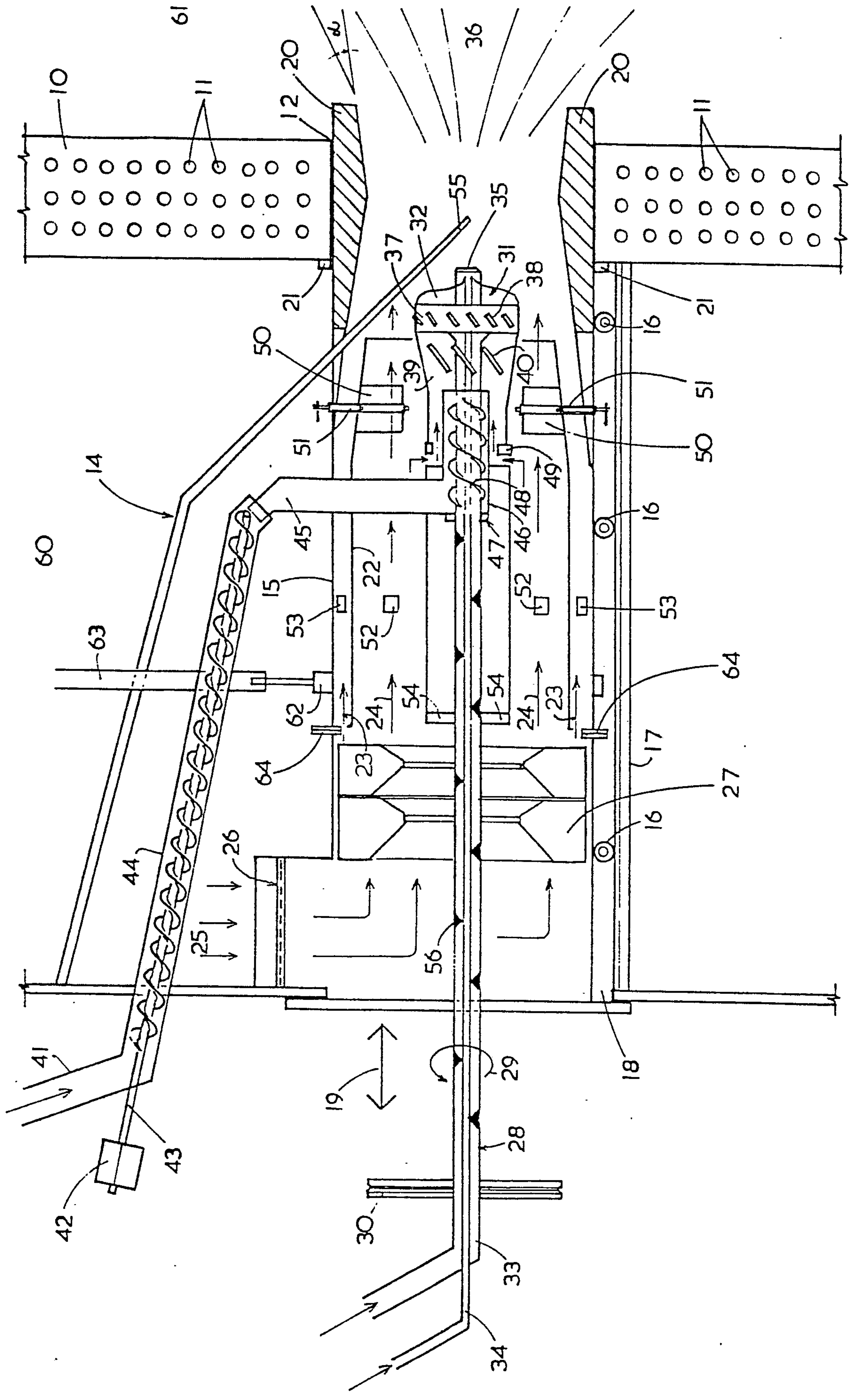
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