

Feb. 16, 1960

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2,925,069

FUEL BURNING APPARATUS

Filed Dec. 29, 1954

3 Sheets-Sheet 1

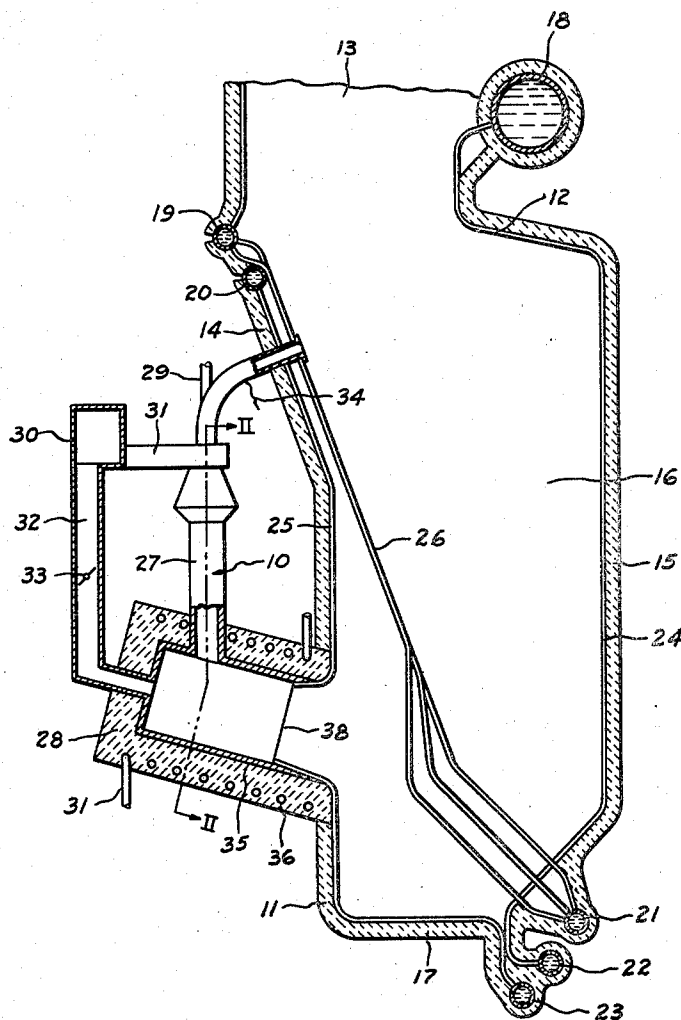


Fig. 1

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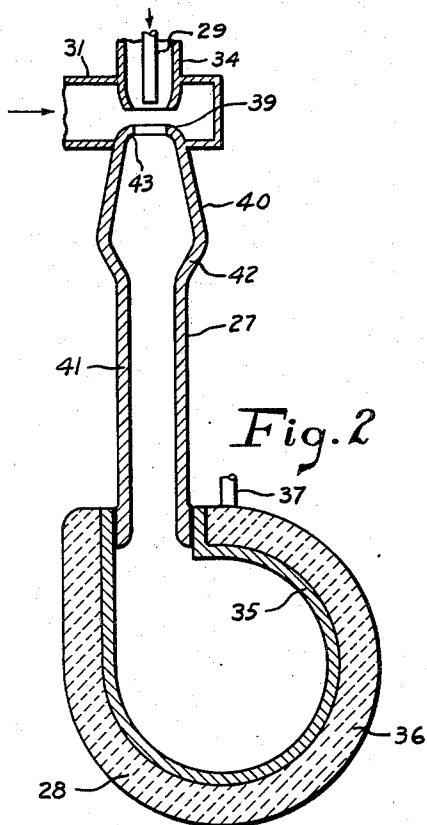


Fig. 2

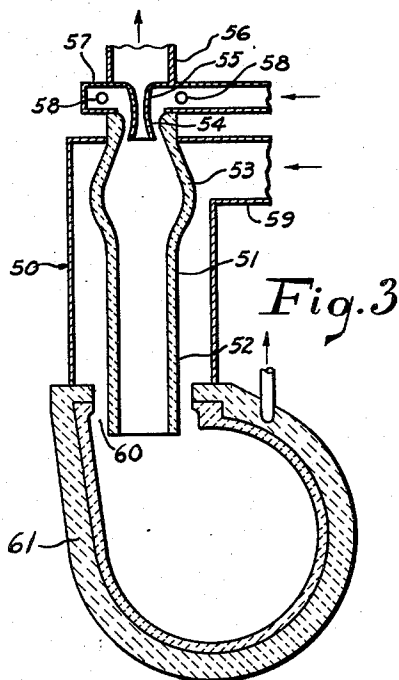


Fig. 3

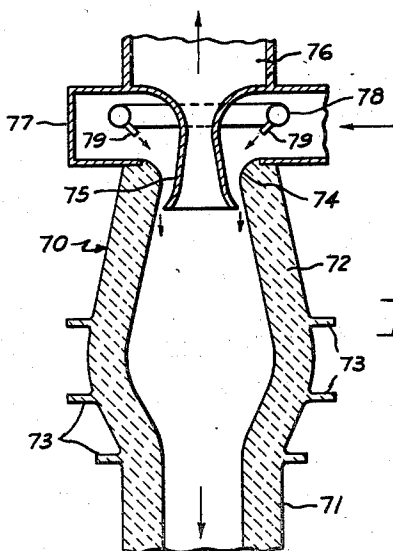


Fig. 4

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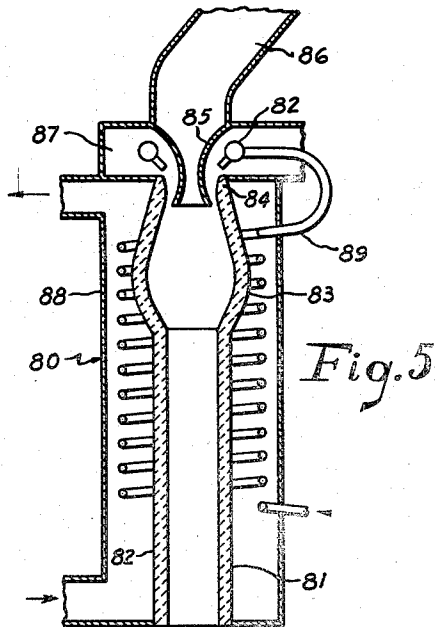
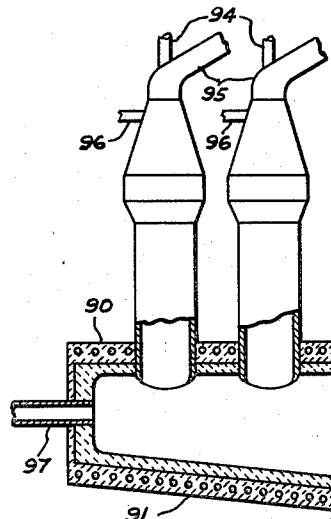
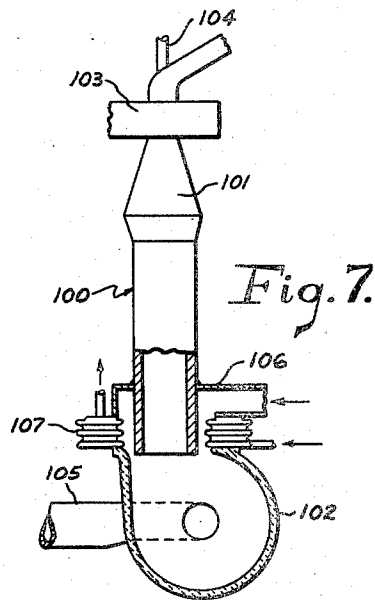
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3 Sheets-Sheet 3



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FUEL BURNING APPARATUS

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7 Claims. (Cl. 122—235)

This invention relates generally to fuel burning apparatus and more particularly to a construction making use of pulsating burning of fuel for use in generating steam.

In the past considerable work has been done in the development of the pulsating-type burner. However, it is apparent that the previously-known constructions do not entirely meet the requirements for use with steam generating units so far as ash removal, flue gas dust elimination and vibration are concerned. Also, in connection with the development of the cyclone burner, one of the outstanding drawbacks is the fact that a great deal of energy is required to force the fuel and air into the burner with sufficient energy to permit the apparatus to operate effectively. Since the work required must be subtracted from the output of the plant, the over-all efficiency is lowered by a considerable amount.

It is therefore an outstanding object of the invention to provide a fuel burning apparatus which will require a low auxiliary energy to establish combustion, which will use a minimum of excess air, which will promote more rapid and complete combustion by a thorough mixing of fuel and air and by high relative velocity between fuel particle and air, which will give a short, determined flame path, which will bring about maximum ash and fly-ash elimination, and which will be extremely versatile as regards the type of fuel used.

Another object of the invention is the provision of means for firing a cyclone-type burner wherein the energy of the combustion process is partially converted into kinetic energy to bring about the necessary turbulence for improved combustion and heat transfer and, in a pressurized furnace, to force the gases out of the burner into the furnace proper, so that the overall efficiency of the power plant in which it is used is increased.

With these and other objects in view, as will be apparent to those skilled in the art, the invention resides in the combination of parts set forth in the specification and covered by the claims appended thereto.

The character of the invention, however, may be best understood by reference to certain of its structural forms, as illustrated by the accompanying drawings in which:

Figure 1 is a longitudinal vertical sectional view of a steam generating apparatus using the apparatus of the invention,

Figure 2 is an enlarged sectional view of the apparatus taken on the line II—II of Figure 1,

Figure 3 is a sectional view of a modified form of the invention,

Figure 4 is a sectional view of a portion of still another form of the invention,

Figure 5 is a sectional view of a portion of still another form of the invention,

Figure 6 is a sectional view of another modification, and

Figure 7 is a partial sectional view of a still further form of the invention.

Referring first to Figure 1, wherein is best shown the

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general features of the invention, the fuel burning apparatus, designated by the reference numeral 10, is shown in conjunction with a furnace 11 and a boiler 12 of a steam generating unit 13. The furnace 11 is made up of a front wall 14, a rear wall 15, side walls 16, and a bottom 17. Only a portion of the boiler 12 is shown, this portion consisting of a large intermediate drum 18 and headers 19, 20, 21, 22 and 23. The drum and headers of the boiler are joined by water tubes in the usual manner, certain of the tubes 24, for instance, running between the drum 18 and the header 22 and covering the rear wall 15 of the furnace 11. Other tubes 25 join the header 20 with the header 23 and cover the front wall 14 and the bottom 17. Also, certain tubes 26 extend between the header 19 and the header 21 and form an inclined screen extending across the furnace, the tubes being arranged in a closely-spaced arrangement in the upper portion but being considerably spaced apart in the lower portion.

The fuel burning apparatus 10 is made up of an elongated tubular pulsating combustor 27 and a cyclone chamber 28. A fuel conduit 29 enters the upper portion of the combustor 27. A hot-air duct 30 is situated adjacent the apparatus and is joined to the upper portion of the combustor 27 by a duct 31; the duct 30 is also joined to the outer end of the cyclone chamber 28 by a duct 32 having a damper 33. A duct 34 of circular cross-section leaves the upper part of the combustor and passes through the front wall 14 into the upper part of the furnace. The cyclone chamber 28 is of generally tubular form with its axis inclined slightly upwardly away from the furnace and is provided with an inner shell 35 of hard, abrasion-resistant material and a thick outer jacket 36 containing a cooling tube 37 through which cooling water may be passed. The water wall tubes 25 which cover the front wall are formed into a lip 38 extending into the cyclone chamber. As is evident in Figure 1, the axis of the combustor 27 is approximately vertical, so that it resides at an angle to the axis of the cyclone chamber. In Figure 2 it can be seen that the lower end of the combustor extends through the outer jacket 36 and the inner shell 35 into the cyclone chamber. It enters the chamber in such a manner that the axis of the combustor is tangential to an imaginary circle having the same axis as the chamber and a diameter less than the diameter of the chamber by an amount equal to the diameter of the combustor. The conduit 34 is mounted with its lower end adjacent the upper end of the body of the combustor 27, so that a narrow annular opening 39 is defined. The duct 31 surrounds this opening and is connected by welding or otherwise to the duct 34 and the upper end of the combustor body. The fuel conduit 29 is coaxial with the duct 34 and terminates adjacent the opening 39. For the most part, the combustor 27 is formed of high-temperature ceramic material and is tubular. However, at the upper end the combustor changes from a straight tubular form to an enlarged hollow frusto-conical portion 40 which is joined at its larger end to the tubular lower portion 41 by a hollow conical transition portion 42. The junctions of the portions 40, 41 and 42 are smoothly formed, so that no abrupt changes occur in the inner surface of the combustor. At its upper end the portion 40 is provided with an inwardly-curving lip 43.

The operation of the apparatus will now be clearly understood in view of the above description. The fuel will enter the apparatus through the conduit 29, while the pre-heated air will enter through the duct 31. If the fuel is pulverized coal, the particles will be carried in primary air and the air entering from the duct 31 will be secondary air. Combustion will take place in the combustor 27 and, because of its nature, the combustion will take place in a pulsating manner. That is to say, combustion

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will take place explosively with an attendant high pressure in the combustor; this will force the products of combustion downwardly from the lower end and, to a lesser degree, upwardly into the duct 34 and, eventually, into the upper part of the furnace. The high pressure situation is followed by a very low pressure condition wherein air and fuel are drawn into the combustor for another explosion. The cycle repeats itself rather rapidly, producing the "pulsating" effect. Most of the gases are projected into the cyclone chamber 28 and swirl around the surface thereof. Tertiary air is introduced through the duct 32 axially through the outer end of the chamber and this air is picked up in the swirling gases which are progressing along the cyclone chamber into the furnace proper. Combustion will be substantially completed by the time the gases leave the combustor and enter the cyclone chamber, but the violent mixing in the chamber, due to the explosive burning in the combustor, will completely burn any combustible left in the gas stream. Furthermore, the temperature in the chamber will be well above the slagging temperature of the fuel, so that ash and fly-ash will be reduced to slag and will flow over the lip 38 into the bottom of the furnace where it may be removed by the usual means. The clean gases will then pass upwardly through the steam generating unit in the usual way.

In Figure 3 is shown another version of the invention. The fuel burning apparatus 50 consists of a combustor 51 and a cyclone chamber 61. The cyclone chamber is substantially like that described above in connection with Figure 2 and the combustor is connected to it tangentially in much the same way. The combustor 51 consists of an elongated tubular lower portion 52 and a pear-shaped upper portion 53. This shape of the upper portion 53 defines a narrow venturi opening 54 at the upper end and in this opening resides a venturi nozzle 55 having an open lower end residing in the upper portion 53 of the combustor and an upper end having joined to an exhaust duct 56 which leads to the upper portion of a furnace, not shown. A hood 57 to which pre-heated primary air is admitted surrounds the upper end of the combustor and the nozzle for causing air to pass through the annular space between the nozzle 55 and the opening 54. In the hood 57 resides a fuel conduit 58 which projects fuel, such as oil, into the primary air stream. Another hood 59 surrounds the combustor and part of the cyclone chamber and is connected to a source of secondary air. The combustor is mounted on the chamber in such a manner as to leave an annular space 60 therebetween for the admission of secondary air into the chamber from the hood 59. The operation of this form of the apparatus is very similar to that described above. Fuel from the conduit 58 mixes with the primary air from the hood 57 and the mixture passes into the combustor. The nature of the combustor is such as to produce extreme alternating compressions and rarefactions of pressure. The nozzle 55 and the associated portion of the combustor form an aerodynamic valve, so that, during conditions of high pressure, i.e., explosion, products of combustion are not only projected from the lower end of the combustor into the cyclone chamber but a certain amount passes upwardly through the nozzle 55 and the duct 56. During conditions of low pressure, a mixture of fuel and primary air is drawn into the combustor from the hood 57. Secondary air from the hood 59 mixes with the products of combustion entering the chamber and serves to assure complete combustion.

Figure 4 shows another combustor construction that may be used in the apparatus of the invention. Only the upper portion of a combustor 70 is shown. As is evident from the drawing the combustor consists of a tubular lower portion 71 and a pear-shaped upper portion 72. The upper portion 72 is provided with cooling fins 73. The upper end is formed with a venturi opening 74 in which resides a nozzle 75 of venturi configuration. An

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enlarged lower end of the nozzle extends downwardly into the combustor and an annular space is defined between it and the opening 74 of the combustor. The upper end of the nozzle is connected to a duct 76 leading to the upper portion of a furnace, not shown. A jacket 77 surrounds the nozzle and the upper end of the combustor and is connected to a source of pre-heated primary air. A fuel supply ring 78 extends around the nozzle and is provided with nozzles 79 which project fuel into the primary air stream. The combustor is lined with ceramic or other material capable of withstanding extremely high temperatures. It should be noted that, during the operation of the apparatus, the products of combustion which pass through the nozzle 75 to the duct 76 serve to heat the nozzle, so that, when the fuel-air mixture passes over the outer surface of the nozzle on its way to the combustor, it will in turn be preheated to bring about more rapid and more complete combustion.

Figure 5 shows another form of combustor for use in the apparatus of the invention. The combustor 80 consists of a main body 81 of ceramic or the like having an elongated tubular lower portion 82 and a pear-shaped upper portion 83. A venturi opening 84 at the upper end of the main body surrounds a venturi nozzle 85 to define therewith an annular passage. The nozzle 85 is connected at its upper end to a duct 86 and a hood 87 surrounds the annular passage and is connected to a source of primary air, not shown. A water jacket 88 surrounds the main body of the combustor and is connected to a source of cooling water, not shown. A tube 89 is coiled in the space between the water jacket 88 and the main body 81 of the combustor; fuel such as oil is passed through this coiled tube. The exit end of the tube is connected to a fuel ring 82. With the exception of the preheating of the fuel, this apparatus operates in a manner similar to the others described above.

In Figure 6 is shown a modification of the invention in which more than one combustor is used. The fuel burning apparatus 90 is shown as consisting of a cyclone chamber 91 served by two combustors 92 and 93. Each combustor is provided with a fuel conduit 94 and a duct 95 leading to the upper portion of a furnace, not shown. A duct 96 connected to each combustor supplies it with preheated air. A duct 97 connected to the outer end of the cyclone chamber provides an additional supply of preheated air. The action of the apparatus will be similar to that described above for the other species of the invention, with the exception that the amount of gas passing into the chamber and the degree of turbulence will be commensurate with the presence of more than one combustor. A plurality of combustors will tend to maintain turbulence at a high value throughout the length of the chamber instead of permitting it to die down as the gases approach the opening into the furnace and this will bring about more efficient operation. Furthermore, the degree of control over the combustion conditions in the cyclone chamber will be substantially improved.

Figure 7 shows a variation of the apparatus in which emphasis has been placed on the manner in which a combustor is connected to a cyclone chamber. The fuel burning apparatus 100 consists of a combustor 101 mounted on a cyclone chamber 102 which is shown in transverse cross-section. The combustor 101 includes a duct 103 for supplying secondary air, a fuel conduit 104, and a back-pressure duct 105 leading to the upper portion of a furnace, not shown. The lower end of the combustor is mounted to cause gases to enter the chamber tangentially. A tertiary air duct 105 is connected axially to the outer end of the chamber. A hood 106 is fastened to and surrounds the lower portion of the combustor and is connected to a source of air. A metallic annular bellows 107 is connected between the lower portion of the hood 106 and the outer surface of the cyclone chamber 102 to form a gas-tight joint; means is provided for passing water or other coolant through the bellows to permit

the presence of such a delicate structure in an area of intense heat. Also, air enters the hood 106 and passes downwardly into the chamber, passing between the bellows and the lower end of the main body of the combustor. The air entering the apparatus in this way serves to cool the inner surface of the bellows to an even greater degree.

It is to be understood that it may be desirable or necessary to direct the exhaust gases passing upwardly through the aerodynamic valve of any of the pulsating burners into auxiliary devices for the removal of ash therefrom before permitting the gases to enter the furnace. For instance, the two pulsating burners of Fig. 6 could be connected through their ducts 95 in a "push-pull" relationship.

It is obvious that minor changes may be made in the form and construction of the invention without departing from the material spirit thereof. It is not, however, desired to confine the invention to the exact form herein shown and described, but it is desired to include all such as properly come within the scope claimed.

The invention having thus been described, what is claimed as new and desired to secure by Letters Patent is:

1. A fuel burning apparatus for use in a steam generating unit, comprising a furnace, a cyclone chamber having an opening into the said furnace, the chamber being circular in cross-section, an elongated tubular combustor having a discharge opening at one end connected to an opening in the chamber to discharge products of combustion tangentially into the chamber at a position considerably removed from the opening thereof into the furnace, the combustor being of the pulsating type wherein burning takes place with alternating compressions and rarefactions of pressure, whereby the cyclone chamber is operated substantially without the necessity for auxiliary power, an inlet opening at the other end of the combustor, a back-pressure duct situated co-axially of the combustor and having an edge situated a short distance from the edge of the said inlet opening, an air hood surrounding the adjacent portions of the duct and the combustor, the passage between the edge of the duct and the edge of the combustor opening being small compared with the

cross sectional area of the duct whereby an aerodynamic valve may be formed, and a fuel conduit located adjacent the said passage.

2. A fuel burning apparatus as recited in claim 1 wherein the said duct constitutes a nozzle situated in the said inlet opening, the surface of the combustor at the opening and the surface of the nozzle being of venturi form.

3. A fuel burning apparatus as recited in claim 2 wherein the air hood surrounds the nozzle at the combustor opening and a fuel injection means is situated in the hood adjacent the said opening.

4. A fuel burning apparatus as recited in claim 1 comprising a jacket surrounding the combustor, means providing for the flow of coolant through the jacket, and a heat exchanger situated within the jacket and connected to preheat fuel flowing to the combustor for burning.

5. A fuel burning apparatus as recited in claim 1, comprising at least one more pulsation-type combustor connected to the cyclone chamber for discharging products of combustion tangentially therein, this last combustor being situated between the first-named combustor and the opening of the chamber into the furnace.

6. A fuel burning apparatus as recited in claim 1, comprising a flexible annular bellows connected in a gas-type manner between the combustor and the chamber, the bellows being substantially the only connection therebetween.

7. A fuel burning apparatus as recited in claim 6, wherein the bellows is double-walled and means is provided for passing coolant therethrough.

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