This invention relates to improvements in fluid fuel fired water tube steam boilers.

An object of the invention is to provide a water tube steam boiler having improved efficiency of utilization of fluid fuels, such as fuel oil or gas.

A further object of the invention is to provide a fluid fuel fired water tube steam boiler in which, by improved form and arrangement of the components and, especially of the water tubes, an improved recovery of heat values from the products of combustion is obtained. More particularly, the fuel nozzle and fire box are formed and arranged to produce very rapid, thoroughly complete combustion and extreme turbulence of the gases in and discharging from the fire box. The water tubes and lower tube header are formed and arranged to receive the radiant heat emanating from within the fire box substantially completely except for a relatively small amount which is received by the bottom of the upper water and steam chamber. The formation and arrangement of the water tubes is also such as to greatly promote turbulence in the combustion products flowing past and around the tubes and such that the extremely turbulent hot gases violently scrub the relatively long water tubes throughout their entire length to transfer a maximum amount of heat from the products of combustion to the water and steam. Those and other hereinafter disclosed features of the invention combine to produce a water tube steam boiler of high efficiency and compact size.

In the accompanying drawings:

Fig. 1 is a vertical section through a preferred form of water tube boiler embodying the invention, with a schematic showing of the fuel supply means;

Fig. 2 is a vertical section through the fire box at right angles to the plane of Fig. 1 and looking in the direction of the arrows 2-2 in Fig. 1; and

Figs. 3 to 6 are horizontal sections on the lines 3-3 to 6-6 respectively in Fig. 1.

The illustrated boiler comprises an upper header and steam chamber 10 of circular section and having a larger upper portion 11 of larger diameter joined to a smaller lower portion 12 of smaller diameter through a horizontal annular wall portion 13. The upper ends of an outer ring of water tubes 14 are secured in tube openings in the annular wall portion 13 by welding or otherwise, and the upper ends of an inner ring of water tubes 15 are similarly secured in tube openings in and near the periphery of the bottom wall 16 of the upper header 10. A lower water header 17 has annular upper and lower walls joined with a preferably cylindrical outer wall 18 and an inner wall 19 which provides an upwardly narrowing passage of relatively large diameter for the combustion gases issuing from the fire box 20. The upper wall of the lower header has inner and outer circles of openings in which the lower ends of the water tubes 15 and 14 of the inner and outer rings, respectively, are secured, as by welding.

A shell 21 formed of inner and outer metal sheets 22 and 23 with an intermediate filling of heat insulating material 24 rests at its lower end on the outer edge portion of the upper wall of the lower header 17 and extends upwardly to form, about the water tubes, a chamber of approximately the same diameter as the upper portion 11 of the upper header and steam chamber 10. The upper portion of the shell 21 from the top of the upper header 10 to a level a little below the annular wall portion 13 has a little greater diameter so that between the header 10 and the shell there is formed a restricted annular passage having an abrupt jog adjacent the annular wall portion 13 of the header 10. The annular passage surrounding the header and steam chamber 10 discharges into a smoke chamber under a hood 25 which rests on the upper end of the shell 21 and in turn discharges into a smoke pipe or stack 26 provided with a suitable adjustable damper 27.

The water return pipes 28 and 29 are secured in and extending outwardly from openings in the side wall of the lower portion 12 of the upper header close to the bottom thereof extend downwardly between the inner and outer metal sheets 22 and 23 of the shell 21 and are secured at their lower ends in openings in the upper wall of the lower header 17.

The upper header and steam chamber 10 are supported by the tubes 14 and 15 and return pipes 28 and 29 which in turn are supported by the lower header 17. The latter is in turn supported on the fire box 20 which is shown as formed entirely of molded hard refractory material 30, though it may, alternatively, be formed of an outer steel shell which supports the lower header 17 and is provided with a refractory lining. At its upper end, the fire box has an annular wall portion 31 extending inwardly under the lower header 17 and having an opening registering with the central passage through the header 10. The upper portion, approximately one-third, of the interior of the fire box immediately below the annular top wall portion 31, is of circular cross section of substantially larger diameter than the passage through the lower header 10 and the lower re-
The fuel nozzle 34 is positioned in and closes the outer end of the opening 33 and is supplied with air and gas or liquid fuel under pressure by any known suitable means 35 as indicated schematically in Fig. 1, so that it delivers a relatively narrow jet of atomized liquid or gaseous fuel and air at substantial velocity into the fire box in the direction of the flame splitter 32. The latter splits the burning fuel and air mixture into two portions which spread outwardly in opposite directions around the walls of the fire box until they again come together in the vicinity of the incoming jet of fuel and air and creating two main rapidly swirling vortices of burning fuel and air and combustion products having therein numerous smaller high velocity turbulences which promote rapid and complete combustion. The different heights of the flame splitter 32 on opposite sides of the vertical median plane thereof greatly increases the turbulence of the burning gases and the rapidity of complete combustion by producing a condition of substantial inequality or unbalance between the two main vortices in the fire box. The upper and overhanging inner refractory surfaces of the fire box, by reflecting radiant heat toward the lower central region traversed by the incoming jet of fuel mixture appears to rapidly increase the temperature thereof to a high value and further promote rapid complete combustion.

The water tubes 15 of the inner ring are bent at an angle inwardly at 36 a short distance above the lower ends and at 37 a short distance below their lower ends and are again bent at 36 and 35 into vertical parallel relation so that the intermediate portions of the tubes 15 of the inner ring are very closely spaced around a central free passage of relatively small diameter. As will be apparent, the spacing of the tubes 15 increases gradually from the bends 36 and 35 to the bends 36 and 37, respectively. The tubes 14 of the outer ring are bent at an angle inwardly at 40 very near their lower ends and at 41 just below the bottom of the upper header 10 so that they extend into the spaces between the inner tubes 15 at the bends 36 and 37 where the outer tubes 14 are again bent into vertical parallel relation so that the intermediate portions of the tubes 14 of the outer ring are spaced by a little more than their own diameter around the outer side of a free space of annular section surrounding the cylindrical cases. The upper free space of annular section is thus also provided between the inner surface of the shell 21 and the cylindrical array of the intermediate portions of the tubes 14 of the inner ring. Another free space of annular section is thus also provided between the inner surface of the shell 21 and the cylindrical array of the intermediate portions of the tubes 14 of the outer ring. The above described formation and arrangement of the water tubes 14 and 15 greatly promotes turbulence in the hot gases passing from the fire box through the interior of the shell 21. Immediately above the upper wall of the lower header, the space between adjacent water tubes is substantial so that a substantial portion of the turbulent hot gases passes around and between the tubes 14 and 16 of the inner and outer rings and rises through the space surrounding the outer ring of tubes. Where the outer tube 14 are bent through the spaces between the bends 36 in inner tubes 15, the tubes are so close together that flow from the central space within the inner ring of tubes 15 to the space outwardly of the tubes is restricted. Likewise flow from the space between the inner and outer rings of tubes below the bends 35 to the space between the two rings of tubes above those bends is also restricted. Immediately above the bends 36, the spacing between the tubes 15 of the inner ring is sufficient to permit flow of a substantial amount of the hot gases from the central space into the space between the two rings of tubes but the spacing between the tubes 15 of the inner ring is reduced to a very small value at the bends 36 and remains at that small value from the bends 36 to the bends 35 so that flow outwardly between the tubes 15 is restricted from the level of the bends 35 to the level of the bends 36. Just below the bends 31 of the tubes 15, the spacing between the tubes 15 increases to a value to permit substantially greater flow through the spaces between those tubes but where the outer tubes 14 are bent through the spaces between the bends 37 of the inner tubes, the spaces between tubes are again so small as to restrict flow through those spaces. Above the bends 37, the spacing between tubes is again sufficient to permit substantially greater flow radially outward through both rings of tubes. It appears that the above described variations in the spacings between the tubes in different regions within the shell 21 cause variations in the directions and rates of flow of different portions of the hot gases which in turn greatly increases the turbulence in those gases so that, while the rate of overall linear travel upwardly within that portion of shell 21 which is below the bottom of the upper header 10 is relatively low, the turbulent hot gases are nevertheless continuously very efficiently scrubbing the surfaces of the tubes 14 and 15 as they turbulent swirl at high velocity over and around the tubes and effect a very rapid transfer of a high proportion of their heat to the tubes. Also, a portion of the turbulent hot gases from the fire box is caused to pass upward within the inner ring of tubes to impinge against the bottom wall of the upper header 10. Thus different portions of the very hot gases are also distributed in such manner that they are brought into heat exchanging relation to different areas of the heat absorbing surfaces while they are still very hot whereby there is obtained a more efficient transfer of heat than is obtainable in structures where substantially all of the gases, while still very hot, pass in heat exchanging relation to a relatively small portion of the heat absorbing surfaces and arrive in heat exchanging relation to the large remainder of the heat absorbing surfaces only after they have greatly cooled.

In the restricted annular passage between the shell 21 and the upper header and steam chamber 10, the upward flow of the gases, the temperature and rate of flow have been greatly reduced in the course of their flow through and around the tubes 14 and 15. Flow upwardly at high velocity and efficiently scrub the outer wall of the header 10 to transfer as much as possible
of the remaining heat of the gases to the header 10. Another very important feature of the arrangement of the water tubes 14 and 15 and the upper and lower headers 10 and 17 to the fire box is that substantially all of the radiant heat coming through the opening in the top of the fire box is intercepted by the inner wall of the lower header, by the water tubes and by the bottom wall of the upper header and practically none of the direct radiation reaches the shell 21. It will be seen from Fig. 1 that a very substantial part of the radier end portion joined through the stem top of the fire box falls upon the inner wall of the lower header 17. From Fig. 5, considered in conjunction with Fig. 1, it will be apparent that the radiation passing through the central opening in the lower header 17, the major portion is substantially completely intercepted by the tubes, mostly by the tubes 15 and to some extent by the tubes 14. That portion of the radiation which passes through the constricted portion of the central space within the inner ring of tubes 15 is intercepted completely by the bottom wall of the upper header 10. Such interception and absorption of the radiation from the fire box also contributes greatly to the high efficiency of the boiler of this invention not only by preventing any significant portion thereof from reaching the shell 21 but also by more extensively distributing the heat over the heat transferring walls of the boiler parts.

In summation, it may be stated that the present invention provides a fluid fuel fired water tube boiler in which the various components including the fire box, upper and lower headers, water tubes and shell are so formed and arranged in relation to each other as in combination to provide a very high and efficient recovery and utilization of the heat content of the consumed fuel. The fuel is burned very rapidly and completely at high temperature within the fire box, the radiation therefrom is substantially completely intercepted by large portions of the heat absorbing surfaces of the headers and tubes and with no significant portion of such radiation reaching the shell of the boiler, and the hot products of combustion are brought to and maintained in a condition of very great turbulence and are well distributed through and around the water tubes which they very efficiently scrub by reason of the very great turbulence of said gases as they pass at a relatively low rate of overall displacement along the tubes.

I claim:

1. In a fluid fuel fired water tube boiler comprising vertically spaced upper and lower headers, said lower header having an inner wall portion surrounding a central vertical passage of large diameter for passage of hot gases of combustion into the space between said headers from below the lower header, a shell having its lower end abutting said lower header, enclosing the space between said headers, and laterally surrounding said upper header with a relatively small space between the latter and said shell, for discharge of cooled gases of combustion from the space between said headers, water tubes extending through the space between and having their opposite ends joined to said headers and arranged in inner and outer rings, the tubes of the inner ring of tubes each having a substantially straight and vertical lower end portion joined through an obtuse bend to an inclined portion extending inwardly and upwardly in said space between the headers to a further bend joining said inclined portion to the lower end of a further substantially straight and vertical portion, the latter portions of said tubes of the inner ring being closely spaced around a central portion of said space through which to direct a portion of the hot gases of combustion entering through said passage through the lower headers against the bottom of the upper header, and the tubes of the outer ring each having an inwardly and upwardly included portion extending from a point closely adjacent its lower end to a point between said obtuse bends of a respective pair of adjacent tubes of the inner ring and there joined through an obtuse bend to the lower end of a substantially straight and vertical portion, so that said inclined portions of the tubes of the inner and outer rings extend across the path of the remainder of the hot gases of combustion and produce differing resistances to the flow thereof at different points across said path to promote turbulence in the hot gases flowing across them and rising outwardly in the inner ring of tubes and around the tubes of the outer ring.

2. A fluid fuel fired water tube boiler comprising vertically spaced upper and lower headers, said lower header having an inner wall portion surrounding a central vertical passage of large diameter for passage of hot gases of combustion into the space between said headers from below the lower header, a shell having its lower end abutting said lower header, enclosing the space between said headers, and laterally surrounding said upper header with a relatively small space between the latter and said shell, for discharge of cooled gases of combustion from the space between said headers, water tubes extending through the space between and having their opposite ends joined to said headers and arranged in inner and outer rings, the tubes of the inner ring of tubes each having a substantially straight and vertical lower end portion joined through an obtuse bend to an inclined portion extending inwardly and upwardly in said space between the headers to a further bend joining said inclined portion to the lower end of a further substantially straight and vertical portion, the latter portions of said tubes of the inner ring being closely spaced around a central portion of said space through which to direct a portion of the hot gases of combustion entering through said passage through the lower header against the bottom of the upper header, the tubes of the outer ring each having an inwardly and upwardly included portion extending from a point closely adjacent its lower end to a point between said obtuse bends of a respective pair of adjacent tubes of the inner ring and there joined through an obtuse bend to the lower end of a substantially straight and vertical portion, so that said inclined portions of the tubes of the inner and outer rings extend across the path of the remainder of the hot gases of combustion and produce differing resistances to the flow thereof at different points across said path to promote turbulence, said tubes being so arranged in relation to said upper and lower headers, to said central vertical passage through the lower header and to each other as to shield said shell substantially completely from radiant heat entering the space between said headers through said last-mentioned passage.

3. A fluid fuel fired water tube boiler comprising a fire box, means to produce a jet of fluid fuel
and air mixture directed across the lower portion thereof from one side across the center thereof, means in said fire box in the path of said jet to increase the turbulence of the burning fuel and air to a high value, said fire box having at its top a central discharge opening, a lower water header of annular horizontal section and having an inner wall portion defining an upwardly narrowing central passage through said header and conforming and registering at its lower end with said discharge opening, and an upper wall portion formed with inner and outer rings of tube openings, an upper water header and steam chamber spaced vertically above said fire box and lower header and having upper and lower substantially cylindrical portions of larger and smaller diameters and formed of upper and lower walls, a substantially upper cylindrical side wall portion of said larger diameter, a lower substantially cylindrical side wall portion of said smaller diameter and a substantially horizontal and annular wall portion joining the adjacent ends of said upper and lower side wall portions and formed with a ring of tube openings, a bottom wall portion formed with a ring of tube openings near its periphery, and a top wall portion, a substantially cylindrical shell surrounding the space between said upper and lower headers with its lower end abutting said lower header and its upper portion surrounding said upper header at a small distance from said side wall portions, an outer ring of water tubes having their lower ends secured to said upper wall portion in said outer ring of tube openings therein and their upper ends secured to said annular wall portion of said upper header in the tube openings therein, an inner ring of tubes having their lower ends secured to the upper wall portion of said lower header in the inner ring of tube openings therein and their upper ends secured to the upper header bottom wall in the tube openings therein, the tubes of the inner ring having substantially straight and vertical end portions, obtuse bends joining the latter with inwardly inclined portions and obtuse bends joining the inclined portions with substantially straight and vertical intermediate portions of substantially length, said intermediate portions of said inner tubes being very closely spaced to define a vertical hot gas passage of substantially less diameter than and centered above said fire box discharge opening to direct a portion of the hot gases from the latter to the bottom wall of the upper header, and the tubes of said outer ring having substantially straight upper end portions extending substantially vertically between said header and the upper header portion of smaller diameter, obtuse bends closely below the bottom wall of said upper header and close to the lower ends of the tubes and joining the end portions of said tubes to inclined portions extending into the spaces between the first-mentioned bends of the tubes of the inner ring, and obtuse bends in said last-mentioned spaces and joining said inclined portions to substantially straight and vertical intermediate portions arranged in a ring spaced from and surrounding the ring of intermediate portions of the tubes of the inner ring, said water tubes providing differing amounts of resistance to the flow of gases in different regions within said header, the greatest being the resistance to flow outwardly between the intermediate portions of adjacent tubes of the inner ring and between the first-mentioned bends of the tubes of the inner ring and the adjacent bends of the tubes of the outer ring, to distribute the hot gases from said fire box discharge opening in different directions and with differing velocities and to promote great turbulence in said gases as they flow through the space around the tubes within said header, the tubes and headers being so arranged that the radiant heat emanating from within the fire box is substantially completely intercepted by the bottom wall of the upper header, the inner wall of the lower header and by the water tubes.

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