ABSTRACT: A steam boiler or analogous heat exchanger is provided with a gas-fired burner comprising a plenum chamber from which a combustible gas-air mixture escapes through an inexpensive and readily replaceable burner member formed of foraminous ceramic material. The porosity and thermal conductivity of the burner member are such as to produce substantially flameless combustion toward the outer surface of the burner member, which causes that surface to incandescce and to radiate heat directly to water-filled boiler elements facing the burner member.
FIG. 3.

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1 GAS-FIRED BOILERS OR THE LIKE

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to gas-fired steam boilers or analogous heat exchangers and more particularly to such devices employing surface combustion radiant burners.

2. Description of the Prior Art

In gas-fired steam generating units at least four principal heat transfer mechanisms occur simultaneously; namely, non-luminous radiation from the products of combustion, luminous radiation from burning particles of suspended solids carried by the combustion gases, convection from the combustion gasses and conduction between the boiler surfaces and hot particles deposited thereon during combustion. In most types of boilers, radiation is the most significant of these mechanisms, particularly in those portions of the boiler where the highest rate of steam generation takes place. Accordingly, it has long been recognized that boiler efficiency can be improved by increasing the amount of available heat energy which is transferred to the boiler surfaces by radiation; which is most commonly accomplished by employing refractory firebrick furnace and boiler wall linings which radiate energy to the boiler surfaces when they become heated to incandescent temperatures. Due to the weight and relatively low strength of such refractory firebrick materials, however, it is generally impracticable to employ such a construction to a meaningful extent in high output portable boilers, e.g., of the type employed in steam automobiles.

If a combustible mixture of air and gas is forced through a porous refractory material and ignited at the outer surface thereof while a sufficient flow velocity is maintained to prevent combustion from flashing back through such material, the outer surface of the material adjacent the combustion is rapidly heated to an incandescent temperature. Thereafter, the incandescent refractory material promotes the combustion to the extent that the mixture burns with almost no visible flame but with high radiant energy output. Although such so-called surface combustion can be produced by means of a porous mass of almost any type of refractory substance, a particularly desirable material for that purpose comprises a molded composition of ceramic fibers bonded together to provide a relatively light and self-supporting rigid structure of predetermined permeability and low thermal conductivity. Specific details of such materials and techniques for the production thereof are disclosed in U.S. Pat. No. 3,179,156, which also illustrates and describes the use of that type of material as a burner element in a reflective-type gas-fired radiant space heater. An example of a commercially available material particularly suitable for such surface combustion applications in the product sold by the Babcock and Wilcox Co. of Augusta, Ga., under the trademark KAOWOOL.

At least 50 years ago, experimental attempts were made to improve steam boiler performance by the employment of surface combustion firing. Briefly, these experiments involved filling the firetubes of firetube-type boilers with loosely packed lumps or particles of a refractory material such as firebrick and effecting combustion of an air-gas mixture introduced into the refractory mass through central jet openings in annular fireclay plugs partially closing the inlet ends of the tubes adjacent the tube sheet. While those experiments conclusively demonstrated improved heat transfer performance, and thereby potential reduction in boiler flue lengths, this technique apparently enjoyed little or not practical application, presumably because of the obvious attendant difficulties and inconvenience involved in boiler cleaning, inspection and maintenance.

SUMMARY OF THE INVENTION

The present invention contemplates improving heat transfer rates in gas-fired steam boilers by the employment of surface combustion firing without involving any of the complications or inconveniences inherent in the above-described previously known means for achieving such combustion. Briefly, these objectives are accomplished in accordance with the invention by providing a boiler, preferably of the water tube-type, with a gas-fired burner comprising a plenum chamber from which a combustible gas-air mixture escapes through a burner member formed of molded ceramic material of the general type described above. When the combustible mixture is ignited at the outside surface of the burner member, the resulting previously described incandescent surface combustion phenomena imparts a high proportion of radiant energy to the burner member or analogous water-filled elements spaced from but facing the burner member. Due to the low thermal conductivity of the burner member material and the homogeneous porosity thereof, the burner material adjacent the plenum chamber is kept at a temperature well below the ignition temperature of the combustible mixture by the passage of unignited air and gas therethrough. Consequently, since the burner member is devoid of any sizeable individual passages between its inner and outer surfaces, the possibility of flashback into the plenum chamber is positively avoided regardless of the flow velocity through the burner member. Additionally, this relatively cool condition of the portion of the burner member beyond its outer combustion surface allows it to be sealed in gas-tight cooperation with the plenum chamber structure without compensating for large differences in thermal expansion and without subjecting the joint surfaces to high temperatures. In accordance with a preferred embodiment of the invention, this feature allows a gas-tight joint to be provided between the burner member and the mating surface of the plenum chamber structure by means of a conventional resilient O-ring gasket. Preferably, the burner element is adapted to be removed and replaced in a simple straightforward manner without recourse to any major disassembly of the boiler or any significant interruption in its operation.

The configuration of the burner member is such as to present a maximum incandescent area thereof to the adjacent water-filled elements of the boiler. For example, the burner member may be in the form of a relatively flat disc confronting a spiral boiler tube or in the form of a tube having spiral extension along the axis of a helical boiler tube. Additionally, the incandescent burner surface may define a corresponding spiral or helical recess partially surrounding the adjacent boiler tube to thereby further increase the impingement of radiant energy on that tube. In various embodiments of the invention a plurality of such burner elements of either similar or different configurations may be employed in a single boiler, in which case each of such burner members can be replaced individually whenever necessary.

Although the foregoing description refers to steam boilers, it will be apparent that the invention is equally applicable to water heaters or other analogous structures in which heat is imparted to a confined gas or liquid. Accordingly, it will be understood that the term "boiler," as used herein, is intended to be confined strictly to conventional steam producing boilers but is intended also to encompass such related devices for heating various confined liquids or gases.

Various means for practicing the invention and other advantages and novel features thereof will be apparent from the following detailed description of illustrative preferred embodiments of the invention, reference being made to the accompanying drawings in which like reference numerals identify like elements.

BRIEF DESCRIPTION OF THE DRAWINGS

In the drawings:

FIG. 1 is an exploded perspective view of a compact boiler according to a preferred embodiment of the present invention, comprising two relatively flat burner members confronting corresponding spirally disposed boiler water tubes;

FIG. 2 is a cross-sectional side elevational view of the boiler construction depicted in FIG. 1; and
FIG. 3 is a cross-sectional elevational view of a boiler in accordance with an alternate preferred embodiment of the invention comprising a tubular cylindrical burner member surrounded by a helically disposed boiler water tube.

DESCRIPTION OF THE ILLUSTRATIVE PREFERRED EMBODIMENT

The illustrative embodiment of the invention depicted in FIGS. 1 and 2 of the accompanying drawings is a very compact gas-fired water tube boiler particularly suitable for steam automobiles or other related applications. The boiler housing, identified by numeral 12, is generally symmetrical above and below its horizontal center plane and comprises a central cylindrical wall member 13 from which tapered burner seating cones 14 extend outwardly to peripheral flanges 15. An annular channel-shaped manifold member 16 surrounds the central portion of the boiler and is welded to the outer surfaces of cones 14 to define an annular exhaust chamber 17 provided with outlet tubes 18, which can also serve to support the boiler unit.

In the assembled boiler, a combustion chamber liner ring 19 fits snugly into the cylindrical wall member of the boiler housing and includes radial holes 21 aligned with corresponding holes 22 in the burner member. The burner ring is made of a refractory material, preferably of the same type of molded ceramic fiber composition mentioned previously, which is also the material of which the hereinafter described burner elements are formed. Shallow slots 23 are located in the upper and lower surfaces of the liner ring to receive and position the laterally projecting rods 24 of boiler tube support members 25 and 26.

The three boiler tubes of the illustrative boiler are identified by numerals 27, 28 and 29 and are all of flat spiral configuration. The primary boiler tubes 27 and 28 are supported respectively by support members 25 and 26 above and below the planes defined by the upper and lower faces of the liner ring. The secondary boiler tube 29 is supported between the primary tubes in generally parallel relation thereto. In FIG. 1, both ends of all three tubes are shown extending outwardly through the boiler housing so that they can be connected externally to one another, as well as to a feedwater pump and control valve unit and to a steam manifold or the like. However, it will be apparent that the three boiler tubes could be connected within the boiler housing in any desired fashion so that one single and single steam outlet would emerge through the housing. Preferably, the three tubes are connected in series to provide a so-called monotube-type boiler in which the secondary tube functions as a superheater or economizer.

Burner elements 31 are in the form of generally flat discs with tapered edge surfaces 32 which conform to the conical configuration of the internal surfaces of the boiler seating cones 14. The smaller diameter faces of the burner elements are provided with spiral grooves 33 conforming to the spiral form of the adjacent primary boiler tubes. As previously described, the burner elements are made of a gas-permeable composition of bonded refractory fibers. Preferably, the burner elements are produced in finished form by molding techniques, but it is also possible to machine such elements from blocks or slabs of the above-identified KAWSOOL material or some other analogous material.

In the assembled boiler, burner elements 31 are supported by the mating engagement of their tapered edge surfaces with the tapered internal surfaces of the burner seating cones and are oriented such that the primary boiler tubes are partially received in the corresponding burner elements. The internal surfaces of those grooves in spaced confronting relation to the adjacent external tube surfaces. Peripheral flanges 34 of closure members 35 are attached to the corresponding flanges 15 by bolts 36 extending through gaskets 37. Flanges 34 overlap the adjacent surfaces of the outer faces of the corresponding burner elements and thereby hold the tapered edge surfaces of those elements tightly against the mating surfaces of the burner seating cones. To further insure the existence of a gastight seal between the edges of the burner elements and the respective burner seating cones, a heat-resistant resilient O-ring 38 is located in an annular depression 39 in each of the two cones and is slightly flattened and squeezed into the adjacent burner element when the latter is pressed into place by the corresponding closure member. Accordingly, it will be seen that the closure members cooperate with the burner members to define plenum chambers 41 into which combustible mixtures of air and gas are admitted through mixing valves 42 removably attached to the two closure members.

During the operation of the boiler, the combustible air-gas mixture introduced into the plenum chambers permeates through the uniformly permeable burner elements into combustion chamber 43 and also eliminates the exposure of burner elements and by liner ring 19. When the boiler is first put in operation, this combustible mixture is ignited in the combustion chamber by a conventional spark plug or the like projecting into the combustion chamber through a radial tube in the exhaust chamber, as depicted at numeral 44.

As previously mentioned, the ignited mixture initially burns within a flame adjacent to the inner surfaces of the burner elements. Under the influence of the heat thus produced adjacent the inner burner surfaces, those surfaces soon become incandescent, whereas the resulting promotion of the combustion process causes the air and gas mixture to burn near the burner surfaces with little or no visible flame but with a high level of radiant energy emission. By virtue of the relatively uniform porosity and low thermal conductivity of the burner element material, however, those portions of the burner elements beyond the regions of surface combustion are maintained at a relatively cool temperature, well below the ignition temperature of the combustible gas mixture, by the cooling influence of the unignited gases constantly permeating therethrough. Consequently, this mode of burner construction positively avoids the danger of combustion flashback through the burner elements and also eliminates the potential for the burner sealing rings to potentially destructive temperatures.

Due to the configuration of the combustion surfaces of the burner elements with the configuration of the corresponding boiler tubes, it will be apparent that radiant energy is impinged upon approximately half the total surface area of those tubes facing the closely adjacent burner surfaces generally parallel thereto. Additionally, the remaining portions of the tubes are of course also exposed to less concentrated but nevertheless very intense radiation, both directly from the burner elements and also by reflection from the refractory liner ring. Accordingly, very high rates of heat transfer are achieved, resulting in a correspondingly high level of boiler efficiency as compared to previously known boilers of comparable simplicity and compactness. By way of example, a single small scale experimental boiler comprising a single flat spiral water tube heated by a flat gas-fired surface combustion burner according to the present invention was found to produce at least 30 percent more power in terms of steam output compared to its corresponding power output when heated with a similarly located conventional multiple orifice burner burning gas at the same rate of consumption.

To further improve the thermal efficiency of the boiler illustrated in FIGS. 1, 2, a feedwater tube, not shown, can surround manifold member 16, whereby some of the heat energy of the exhaust gases within chamber 17 is devoted to preheating the boiler feedwater. Similarly, if the boiler is fired by a vaporized liquid fuel such as gasoline, a vaporizer or preheater tube can also be provided within the annular exhaust chamber. Appropriate insulating lagging may also be provided about the outer periphery of the boiler, but in automotive applications it may be preferable to surround the manifold member 16 with an air duct from which hot air can be obtained to supply heat to the interior of the automobile.
If it should be necessary to replace one of the burner elements of the boiler, this can be accomplished simply by shutting off the flow of combustible gases to the boiler, disconnecting the mixing valve from the corresponding closure member, and then unbolting and removing that closure member from the boiler housing. Therefore, if the boiler is mounted in such a manner as to provide suitable access to both of its closure members, such replacement of the burner elements can be accomplished rapidly and conveniently without removing the boiler from its mountings or disconnecting steam or water lines.

The monutube boiler shown in FIG. 2 to illustrate an alternate embodiment of the invention comprises a generally cylindrical housing member 45 provided with an upper exhaust stack 46 and with a peripheral lower flange 47. A tubular combustion chamber liner 48, similar to the previously described liner ring 19, fits into the boiler housing and is held in place by disc member 49; the latter being provided with appropriate annular gaskets and sandwiched tightly between flange 47 and the conical flange 51 of plenum chamber member 52 by bolts 53. Beyond bolts 53, holes 54 are provided through the two flanges and the disc member for the purpose of mounting the boiler in a stationary support frame, not shown.

In accordance with this embodiment of the invention, burner element 55 is formed of the same type of bonded fibrous ceramic material previously described and is in the form of a cylindrical tube closed at its upper end 56 and provided with a conical lower flange 57. A metal support tube 58, closed at its top end, extends upwardly with the upper face 59 of its enlarged base portion 61 seated against the lower face 62 of the flanged lower end of the burner element. The portion of the support tube within the burner element is uniformly perforated with a pattern of narrow vertical slots 63, or the equivalent, whereas the larger base portion of the support tube is provided with a plurality of larger radial holes 64.

When the burner element is installed in the boiler it is positioned in coaxial relation with the helical boiler tube 65 by the mating engagement of the conical burner element flange 57 with a correspondingly tapered lip 66 defining a central opening in disc member 49 and by the reception of the base portion of the support tube in a central opening 67 in the bottom wall 68 of plenum chamber member 52. A removable cover plate 69 is attached to the bottom wall of the plenum chamber with a gastight gasket by means of nuts 71 threaded onto studs 72. When this cover plate is in place, it engages the lower end of support tube 58 so that the latter rests on the conical flange of the burner element into tight engagement with the mating tapered surface of disc member 49 and with O-ring 73, corresponding to the previously mentioned O-ring 38. Accordingly, when a combustible gaseous mixture is introduced into the plenum chamber member through a mixing valve connected to inlet tube 74, it passes into the support tube through radial holes 64 and then permeates outwardly through the perforated upper portion of the support tube and through the adjacent cylindrical wall of the burner element. Upon being ignited in the combustion chamber 75, the gaseous fuel mixture therefore burns at the surface of the burner element in the same manner described above, thereby imparting heat energy to the boiler tube both by direct and reflected radiation.

Although the boiler depicted in FIG. 3 is somewhat less compact and efficient than the one illustrated in FIGS. 1 and 2, its very simple construction may offset those comparative disadvantages in various applications; for example, in domestic steam or water heating units. Additionally, it will be apparent that maintenance of this unit is even more straightforward than in the case of the previously described unit inasmuch as only one element, namely cover plate 69, need be removed to provide access to the removable burner element and support tube.

The invention has been described in detail with particular reference to illustrative preferred embodiments thereof, but it will be understood that variations and modifications can be effected within the spirit and scope of the invention as described hereinabove and as defined in the appended claims.

1. A boiler comprising:
   a. a housing;
   b. a water tube coil of generally flat spiral configuration supported in said housing;
   c. a disc-shaped burner element made of porous refractory material of such porosity and relatively low thermal conductivity that a combustible gas mixture supplied to one surface of said burner element will permeate through said element to the opposite surface thereof and when ignited adjacent said opposite surface will produce substantially flameless surface combustion of high radiant energy output at said opposite surface;
   d. means for supplying a combustible gas mixture to said one surface of said burner element; and
   e. support means supporting said burner element in said housing with said opposite surface thereof generally parallel to and in direct confronting relation to adjacent external surface areas of said water tube coil.

2. A boiler according to claim 1 in which said burner element includes a peripheral conical surface, said housing including means defining a plenum chamber and a conical support surface adapted to mate with the conical peripheral surface of said burner to support said burner element in communication with said plenum chamber so that a combustible gas mixture within said plenum chamber is supplied to said one surface of said burner element and permeates through said burner element to said opposite surface thereof.

3. A boiler according to claim 2 including a burner seating member engageable with said burner element adjacent said conical surface thereof to seat said conical surface of said burner element firmly in mating contact with said conical support surface.

4. A boiler according to claim 3 including an annular O-ring seal adapted to be compressed between said mating conical surfaces of said burner element and said support member.

5. A boiler according to claim 1 in which said opposite surface of said burner element is provided with a generally semicylindrical groove conforming to the configuration of said coil, said coil being partially received in said groove out of contact with said burner element.

6. A boiler comprising:
   a. a boiler tube element including a pair of generally flat tubular coils substantially parallel to one another,
   b. a housing laterally surrounding said boiler tube element,
   c. a pair of generally flat surface combustion burner elements supported in said housing at opposite sides of said boiler tube element in parallel confronting relation to the adjacent ones of said tubular coils,
   d. plenum chamber means defining plenum chambers in communication with the outwardly facing surfaces of said burner elements, and
   e. means for introducing into said plenum chambers a combustible mixture of gases which permeates through said burner elements and after being ignited adjacent the outwardly facing surfaces of said burner elements produces surface combustion at those surfaces.

7. A boiler comprising:
   a. a housing including opposed conical housing sections tapering outwardly from each end of a generally cylindrical central housing section,
   b. a boiler tube element including a pair of opposed generally flat tubular coils substantially parallel to one another,
   c. means supporting said boiler tube element within said central housing section in substantially normal relation to the axis of said housing,
   d. a pair of generally flat round surface combustion burner elements having tapered peripheral surfaces adapted to mate with said conical sections of said housing to support said burner elements respectively in parallel confronting...
relation to the corresponding ones of said tubular coils located between said burner elements, e. cover members peripherally engageable with the outwardly facing surfaces of said burner elements to urge said burner elements into tight supported mating engagement with said corresponding conical housing sections and to define respective plenum chambers in communication with the outwardly facing surfaces of said burner elements.
f. means for introducing into said plenum chambers a combustible mixture of gases which permeates through said burner elements and after being ignited at the inwardly facing surfaces of said burner elements produces surface combustion at those surfaces, and
g. exhaust means for conducting exhaust gases out of the boiler combustion chamber defined within said central housing section between said burner elements and occupied by said boiler tube element.