

### [54] WATER HEATER

[72] Inventor: **Robert B. Black**, 2925 Denver Street, Corpus Christi, Tex. 78404

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[58] Field of Search.....122/24, 115, 130, 136, 156,  
122/266, 267, 271, 348

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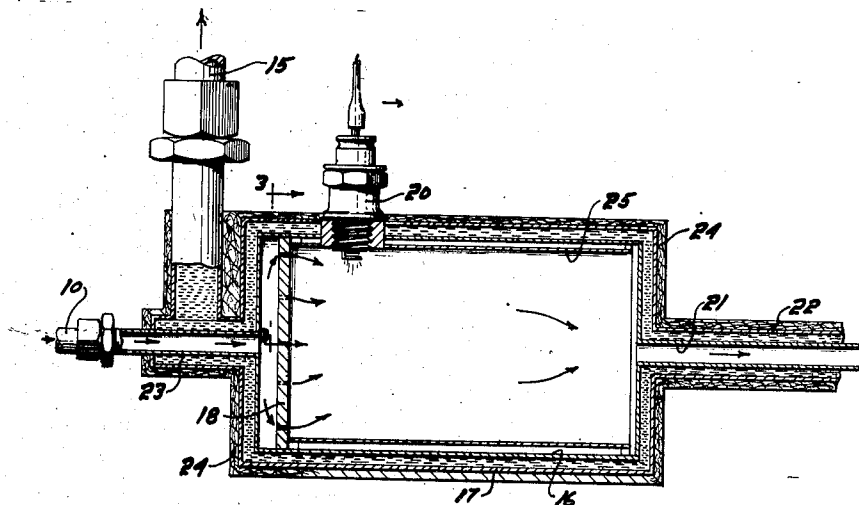
Primary Examiner—Kenneth W. Sprague

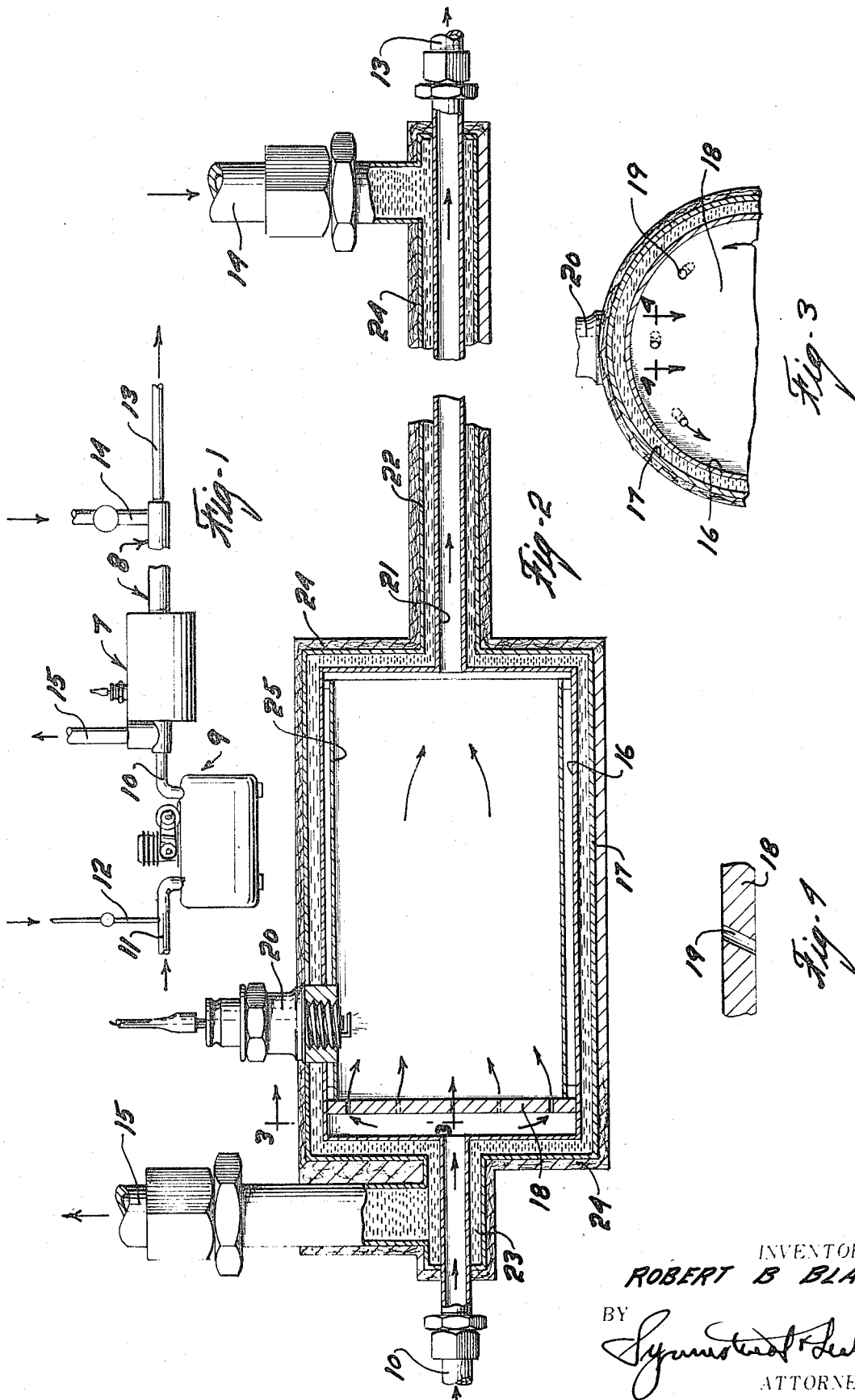
Attorney—Synnestvedt & Lechner

### [57] ABSTRACT

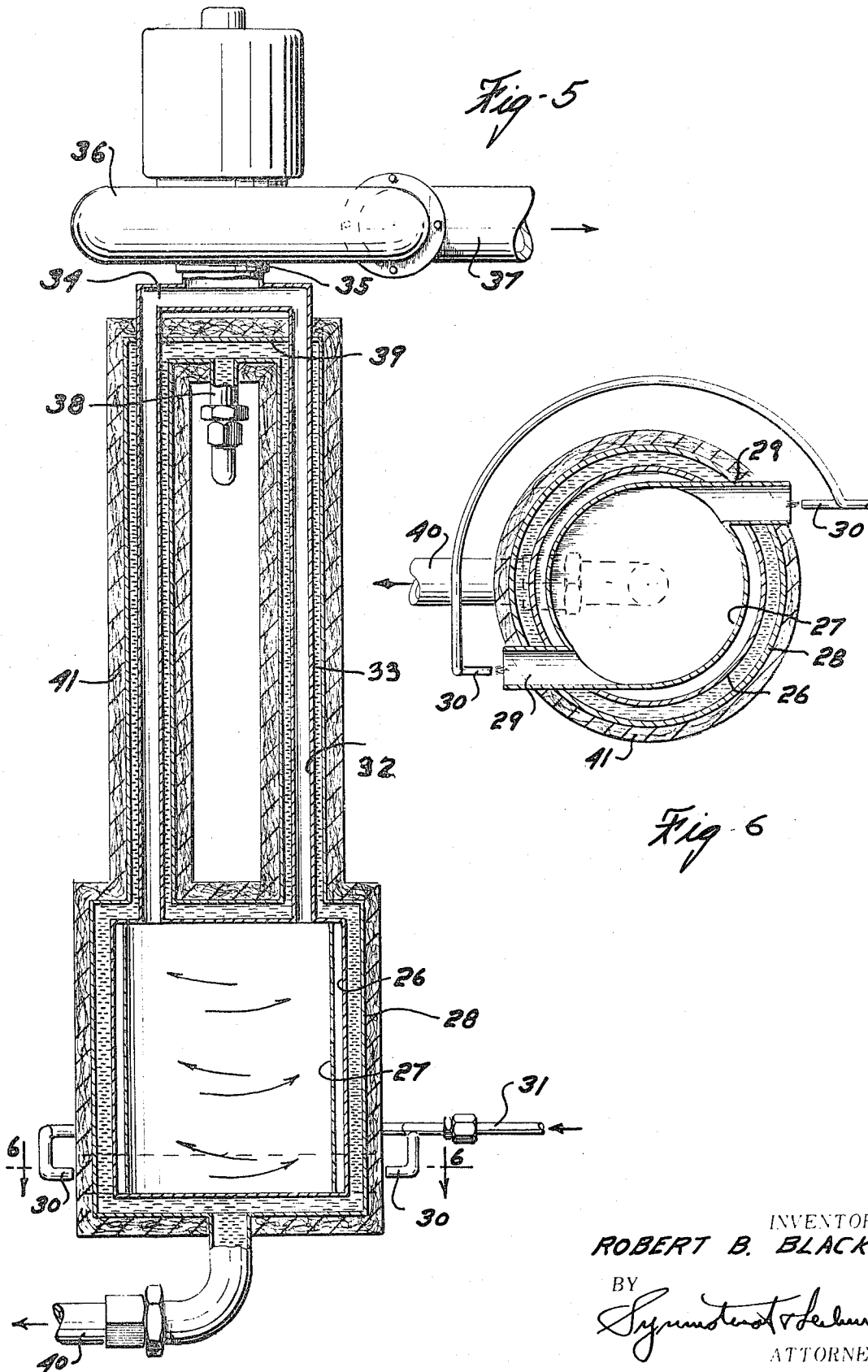
Water heaters having a combustion chamber with a water jacket and having flue tubes extended from the combustion chamber with surrounding water tubes, the water tubes being connected with the water jacket and the circulation being arranged to provide for passage of the water through the water tubes surrounding the flue tubes and through the water jacket in counterflow relation to the flow of products of combustion through the combustion chamber and through the flue tubes.

**12 Claims, 12 Drawing Figures**

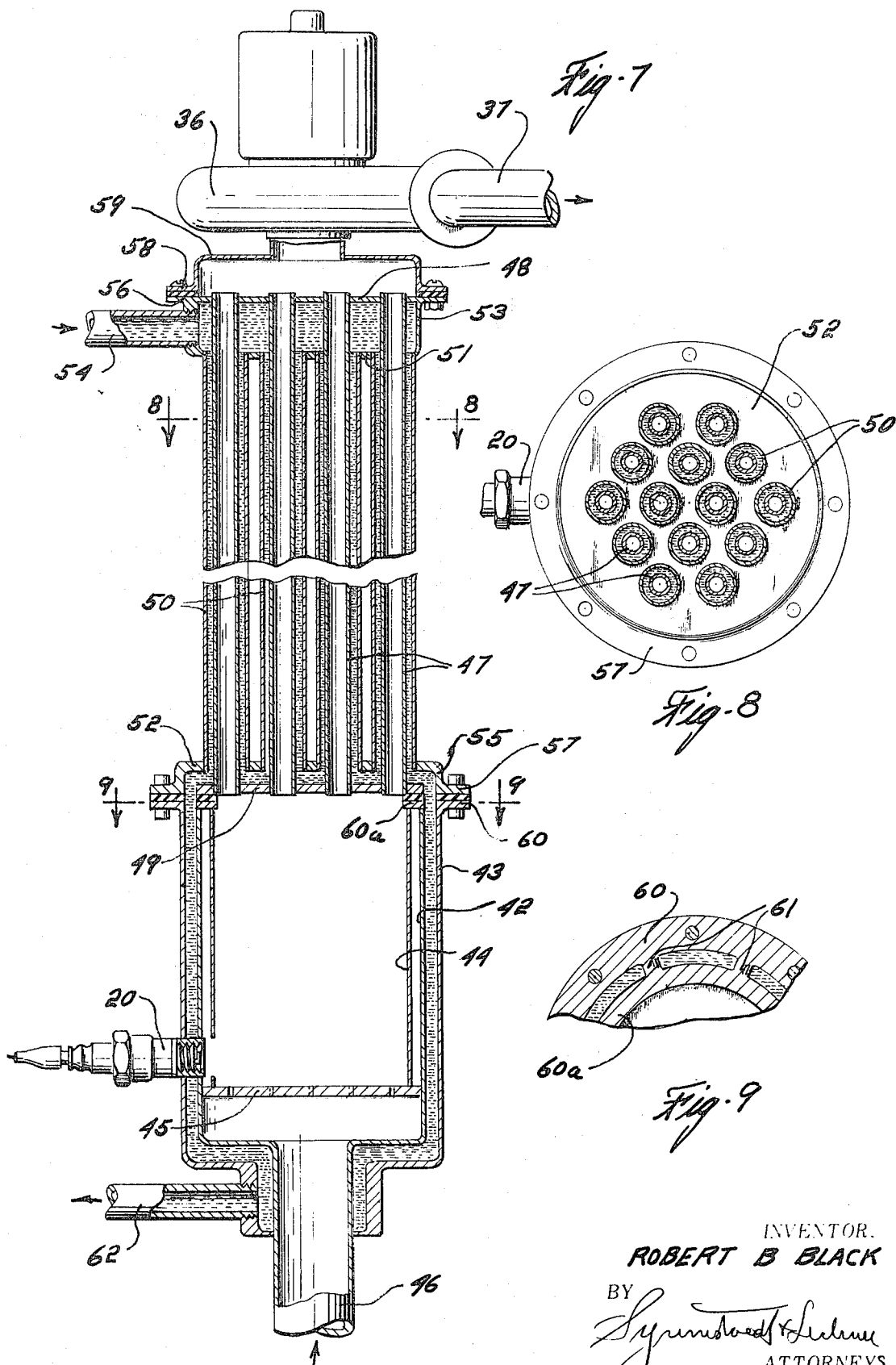




INVENTOR.  
**ROBERT B BLACK**  
 BY *Lyman W. Perkins*  
 ATTORNEYS



INVENTOR.  
**ROBERT B. BLACK**  
 BY  
*Symon & Leber*  
 ATTORNEYS

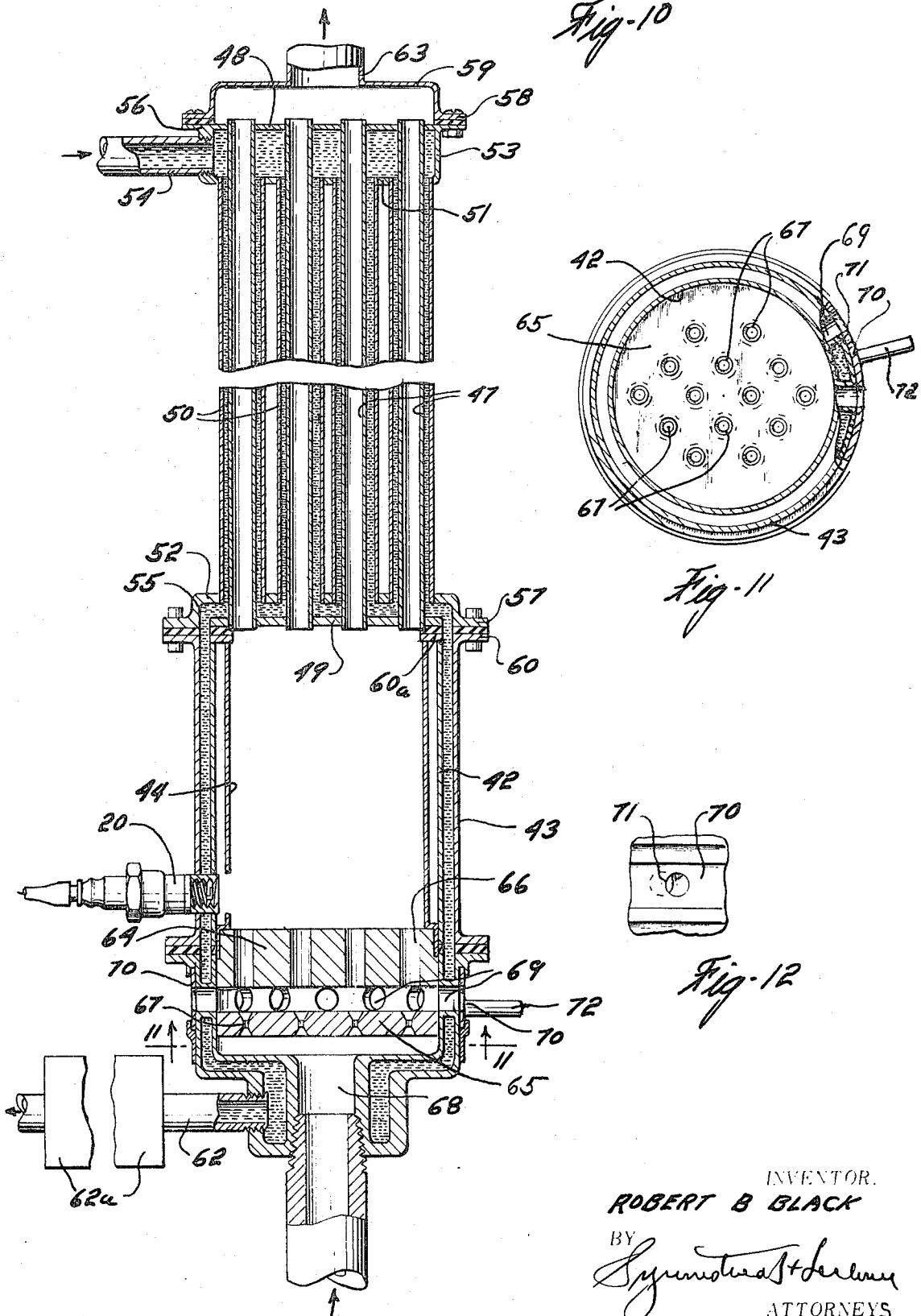


INVENTOR.

ROBERT B BLACK

BY

*Symons & Schme*  
ATTORNEYS



INVENTOR.  
**ROBERT B GLACK**  
 BY  
*Symon & Berline*  
 ATTORNEYS

## WATER HEATER

This invention relates to water heaters and is concerned with very high efficiency water heater equipment in which the efficiency of use of the fuel approaches to within a couple of per cent of the theoretical maximum.

Water heaters of the prior art are in general of two known types. Perhaps the most common type of water heater now in use is one in which a water tank is provided with a combustion chamber at the bottom and has a flue extended upwardly through the tank for indirect heat transfer to the water and for discharge of products of combustion at the top. In this form of heater, commonly referred to as a "storage heater", the products of combustion are commonly discharged at quite high temperatures, so that the overall efficiency is not more than about 80 percent. In another well known type of water heater, a water coil is positioned in a combustion chamber or passage for hot products of combustion, and while this form of heater is effective for rapidly increasing the water temperature, it also discharges products of combustion at relatively high temperatures and has an efficiency which at the maximum reaches about 80 percent.

It is a major objective of the present invention to provide a water heater having an exceptionally high efficiency rate. In accordance with the invention, the gases or products of combustion released from the heater are not more than a few degrees higher, even as low as 1° F., than the temperature of the incoming cold water. This represents a thermal performance which no conventional water heaters now known are capable of approaching. Indeed it is not unusual for conventional water heaters to release their products of combustion well above the boiling point of water, in many cases running even as high as 500°-700° F.

The foregoing striking improvement is achieved according to the present invention by utilizing certain novel combinations of elements or devices and by observing certain operating conditions, all of which will be fully explained hereinafter.

One of the important structural features used according to the present invention is a tube-within-a-tube heat transfer element in which the products of combustion are delivered through the interior of the inner or flue tube and in which the water to be heated is fed through the outer or water tube in the annular space surrounding the inner tube in a direction in counterflow to the direction of flow of the products of combustion in the inner tube. This structural feature is used in combination with a combustion chamber having a water jacket, the water jacket being connected in series with the water tube.

Provision is also made for effecting combustion of the fuel in the combustion chamber at a high temperature so that the combustion of the fuel is virtually complete before entry of the products of combustion into the flue tube. This is accomplished in part by utilizing a liner within the combustion chamber providing a dead air space between the water jacket and the interior region of the combustion chamber where the fuel is burned. Still further, conditions of pressure in the combustion chamber and flue tube, feed rates and proportions of the equipment are established so that the temperature of the products of combustion being discharged are very close to the temperature of the inlet or feed water into the heater. All of these factors cooperate in achieving the high degree of efficiency obtainable in accordance with the present invention.

Still another object of the invention is to provide a tube bundle incorporating a plurality of flue tubes each with a surrounding water tube, which bundle is arranged as a unitary structure and provided with separable connection means by which the bundle may readily be removed from and reassembled with the system, either for the purpose of cleaning the tubes or for the purpose of replacing the used bundle with a new one.

How the foregoing and other objects and advantages are attained will appear more fully from the following description referring to the accompanying drawings illustrating several preferred embodiments of the invention and, in which:

FIG. 1 is a somewhat diagrammatic outline view of a water heater system according to one embodiment of the present invention;

FIG. 2 is a sectional view through the combustion chamber, water jacket, and tube-within-a-tube heat transfer element arranged according to the embodiment of FIG. 1;

FIG. 3 is a partial transverse sectional view taken as indicated by the section line 3-3 on FIG. 2;

FIG. 4 is an enlarged sectional view of a detail taken as indicated by the section line 4-4 on FIG. 3;

FIG. 5 is a sectional view through a combustion chamber and multiple tube-within-a-tube heat transfer system, arranged according to a second embodiment and illustrating certain parts in elevation;

FIG. 6 is a transverse sectional view taken as indicated by the section line 6-6 on FIG. 5;

FIG. 7 is a sectional view through the combustion chamber and a tube bundle of a third embodiment of the invention;

FIG. 8 is a transverse sectional view taken as indicated by the section line 8-8 on FIG. 7;

FIG. 9 is a partial transverse sectional view taken as indicated by the line 9-9 on FIG. 7;

FIG. 10 is a view similar to FIG. 7 but illustrating still another embodiment of the invention;

FIG. 11 is a sectional view taken as indicated by the line 11-11 on FIG. 10; and

FIG. 12 is an elevational view illustrating the arrangement of air inlet passages and control damper employed in the embodiment of FIG. 10.

Although any embodiment of the equipment may be positioned with the major components such as the combustion chamber and heat transfer tubes extended either horizontally or vertically, the arrangement shown in FIGS. 1 to 4 is advantageously arranged horizontally, whereas the arrangements shown in FIGS. 5 to 12 are most desirably arranged vertically, for reasons which will further appear.

Considering first the somewhat diagrammatic outline view of FIG. 1, the equipment includes several components which are designated in that figure in a general manner. Thus, the equipment includes a combustion chamber indicated at 7 having a tube-within-a-tube heat transfer device 8 extended from the combustion chamber. A compressor unit diagrammatically indicated at 9 serves to deliver fuel and air under pressure through the inlet connection 10 into the combustion chamber 7, the air being supplied to the compressor through the connection 11 and the fuel through the connection 12. The flue tube of the heat transfer device 8 is extended as indicated at 13 for discharging the products of combustion to atmosphere. Water enters the system through the connection 14 and flows through the device 8 and also through the jacket for the combustion chamber as described more fully hereinafter, the hot water being discharged through the pipe 15.

As seen in FIGS. 2, 3 and 4, the combustion chamber has a wall 16, in this case a cylindrical wall which is surrounded by another cylindrical wall 17 spaced therefrom so as to provide a water jacket between the two walls. The fuel and air inlet or supply line 10 enters the left hand end of the combustion chamber behind the distributor plate 18 which extends transversely across the combustion chamber and which is provided with ports 19 (see particularly FIGS. 3 and 4) through which the fuel and air passes into the main part of the combustion chamber. The ports 19 are inclined in the manner indicated in order to cause the entering fuel and air to partake of a swirling motion as they enter the region where combustion occurs. Combustion may be initiated by an electric spark plug such as indicated at 20 which ordinarily need only be employed at the commencement of operation, the continuance of the combustion being normally maintained under the influence of the generated heat as the fuel and air are forced into the combustion zone.

At the end of the combustion chamber opposite to the inlet 10, a flue tube 21 is extended for ultimate discharge through the connection 13 already referred to. This flue tube is sur-

rounded by a water tube 22, the water tube being spaced from the flue tube to provide an annular water flow passage between the two tubes. This annular passage is connected with the water jacket space as is plainly shown in FIG. 2. The water inlet 14 is connected with the annular water flow passage at the end thereof remote from the combustion chamber so that the water being heated flows through the annular passage toward the combustion chamber and then through the water jacket surrounding the combustion chamber to the passage 23 from which the discharge line 15 is extended. Copper tubing is desirably employed for the tubes 21 and 22.

For maximum conservation of heat, it is preferred to provide an insulative coating or lagging such as indicated at 24 covering the combustion chamber and heat transfer tube units.

From the foregoing it will be observed that the water passes in counterflow heat transfer relation to the combustion gases and products of combustion within the flue tube 21 and the combustion chamber 16, this counterflow relationship being maintained all the way from the cold or feed water inlet 14 to the hot water outlet 15.

For the purpose of assisting maintenance of high combustion temperature within the interior of the combustion chamber and consequent substantially complete combustion of the fuel within that chamber, a liner 25 is provided within the combustion chamber, this liner, in the embodiment shown in FIGS. 1 to 4 being of cylindrical form but of smaller diameter than the combustion chamber 16 itself so as to provide a dead air space between the liner and the inside surface of the combustion chamber wall 16. The liner is advantageously made of some special alloy steel having high heat resistance, such as the so-called No. 321 stainless steel which is not only highly temperature resistant, but which also possesses high resistance to oxidation. This arrangement of liner 25, dead air space, combustion chamber wall 16 and the surrounding water jacket allow sufficient radiation from the combustion chamber to prevent the refractory liner from disintegrating while at the same time providing for relatively high liner temperature, for instance of the order of 1,300°–1,800° F.

In the system illustrated in FIGS. 1 to 4, it is contemplated that a combustion chamber pressure be established which is substantially elevated as compared with atmospheric pressure, for instance a pressure running anywhere from about 4 PSI up to about 80 PSI. As an example of other factors usable in a system of the kind shown in FIGS. 1 to 4, it may be noted that inner and outer tubes having outside diameters of the order of three-eighths and three-fourths inch respectively are suitable where a single tube-within-a-tube unit 21–22 is employed. In such an installation it would also be contemplated to employ a tube unit of considerable length, for instance of the order of 25 feet. Such a unit may either be straight or coiled. In an installation of these proportions, considerable pressure is desirable in order to effect feed of the products of combustion through the flue tube, and this is advantageously achieved by the use of a compressor such as indicated at 9 in FIG. 1 to which both the fuel and air are admitted, so that the fuel and air mixture are introduced into the combustion chamber under a pressure such as referred to above. The fuel employed may be gas or may alternatively be atomized fuel oil or the like.

During operation of a system of this kind, the pressure results in relatively high velocity flow through the flue tube and this contributes two important results. First, the high velocity maintains such a condition of turbulence at the surface of the flue tube that there is no opportunity for a stagnant boundary layer to form, thereby aiding in maintaining the high efficiency of heat transfer through the wall of the flue tube. Second, the high velocity and turbulence of the flow through the flue tube prevents the accumulation of scale or other deposits within the flue tube, thereby maintaining the high efficiency of heat transfer for long periods of time without the necessity for any cleaning or replacement of the flue tube.

With flue and water tubes of diameters such as those referred to above, the velocity of flow of water may also be relatively high, thereby helping to reduce deposits of scale or the like on the water side of the system.

With equipment of the kind just described, a very high rate of water heating is practical, even with a combustion chamber and tube unit having a total weight of the order of 20 pounds. For instance in one installation of this kind, it was found that 120 gallons of water per hour were delivered at 125° F., with a water input temperature of 75° F., and that the products of combustion were discharged at 76° F., only 1° F. higher than the input water.

Similar results are also obtainable with the modified system now to be described with reference to FIGS. 5 and 6.

Here a combustion chamber 26 is positioned at the bottom of the equipment, this chamber having an inner liner 27 of the kind described above and having an outer wall 28 providing a water jacket, as before.

Tangential inlet pipes 29–29 (see FIG. 6) are provided for introduction of air and fuel into the combustion chamber. These pipes 29 are open to atmosphere to receive the ambient air, and fuel may be injected or otherwise delivered through the nozzles 30–30 which are supplied by means of the supply pipe 31. It will be noted that the inlet pipes 29 are arranged at the bottom of the combustion chamber and provide for introduction of fuel and air with a swirling motion.

One of the principal differences between the arrangement of FIGS. 1 to 4 and the arrangement of FIGS. 5 and 6 lies in the use in the latter embodiment of a plurality of tube-within-a-tube units, two such units being here shown and each comprising an inner flue tube 32 and an outer water tube 33. The flue tubes are extended upwardly for communication with the common chamber 34 with which the inlet 35 of the exhaust blower 36 is connected. The discharge from this blower is indicated at 37. In the system of FIGS. 5 and 6, therefore, instead of compressing the fuel and air in advance of entry into the combustion chamber, the air is admitted to the combustion chamber at ambient pressure, accompanied by injection of fuel, so that combustion will occur in this instance substantially at atmospheric pressure. Because of this pressure condition, an ordinary pilot light may be utilized for initiating the combustion, it being unnecessary to resort to an ignition system, such as a spark plug, capable of operating under pressurized combustion conditions.

In the system of FIGS. 5 and 6, the inlet or feed water enters through the supply line 38 into a header 39 with which the annular flow passages within the water tubes 33 communicate, the discharge ends of those flow passages again being connected with the water jacket surrounding the combustion chamber as in the first embodiment. The hot water is discharged from the bottom end of the water jacket through the connection 40. As in the first embodiment the combustion chamber and tube units are here also provided with a lagging 41 which insulates those parts and reduces heat losses.

It will be understood that an arrangement such as shown in FIGS. 5 and 6 may utilize any desired number of tube-within-a-tube units. The provision of more than one such unit has distinctive advantages, including the fact that the overall length of the tube units need not be as great. Indeed for a production capacity of the general order of magnitude above referred to, whereas a single tube about 25 feet long was required, with a multiple tube arrangement four tubes of about 4–6 feet in length would suffice. The employment of a plurality of the tube units also has another important advantage, namely the fact that combustion need not take place at substantially elevated pressures, and in view of this, it is not necessary to employ a compressor in the air and fuel supply line. Instead, it becomes a practical to employ an exhaust blower such as indicated at 36 connected to receive the products of combustion being discharged, or even to eliminate the blower entirely, as is contemplated in one of the embodiments hereinafter described.

It is to be kept in mind that the high efficiency of heat transfer and the relatively low exhaust gas temperature are factors which make possible the use of a simple exhaust blower such as shown in FIG. 5 connected in the exhaust side of the system, the employment of a blower at the exhaust side of a water heater system not being practical where relatively high exhaust gas temperatures are encountered.

Although the velocity of the products of combustion is not as high in the multiple tube arrangement of FIGS. 5 and 6, as in the single tube arrangement of FIGS. 1 to 4, nevertheless the system of FIGS. 5 and 6 has many of the advantages of the arrangement of FIGS. 1 to 4. With either system the arrangement of the present invention provides much greater water heating capacity in proportion to bulk and weight than is possible with conventional water heaters, such as those referred to above.

Turning now to the embodiment of FIGS. 7, 8 and 9, it is first pointed out that the arrangement here shown, like the arrangement of FIGS. 5 and 6, is a multiple tube arrangement, certain features of which are of special importance in providing ease of maintenance and replacement of the tube bundle.

As shown in FIG. 7, the combustion chamber is defined by the wall 42, this being surrounded by the spaced wall 43 providing a water jacket. A liner 44 is provided within the chamber, in the general manner described above with reference to the liners 25 and 27 of FIGS. 2 and 5. An ignition plug 20 is here also used in the manner of the first embodiment. An apertured plate 45 is positioned in the entrance end of the combustion chamber, being arranged in the general manner of the plate 18 of the first embodiment, the apertures serving to distribute the fuel and air entering the combustion chamber from the fuel and air supply connection 46.

A plurality of flue tubes 47 are here employed, these tubes being provided with upper and lower tube plates 48 and 49. Each flue tube 47 is surrounded by a water tube 50 which are also provided at their upper and lower ends with tube plates 51 and 52.

The tube plates 48 and 51 at the upper end of the tube bundle are spaced from each other and the tube plate 51 is provided with a generally cylindrical wall portion 53 cooperating with the plates to define an inlet water header with which the water supply line 54 is connected.

Similarly at the lower end of the tube bundle, the tube plate 52 is provided with a cylindrical portion 55 which cooperates with the plates 49 and 52 to provide an outlet water header the edges of which communicate with the water jacket lying between the inner and outer combustion chamber walls 42 and 43.

At the upper and lower ends of the tube bundle, the header structures are provided with bolting flanges 56 and 57. The flange 56 is adapted to be separably connected with the flange 58 formed peripherally of the gas manifold 59 which receives the gases discharging from the upper ends of the flue tubes 47. The flange 57 is adapted to be separably connected with the flange 60 formed on the outer combustion chamber wall 43. This provides for separation of the tube bundle with respect to the combustion chamber.

The tube bundle arrangement as described just above provides for convenient handling of the entire tube bundle as a unit, which is of importance for purposes of maintenance and also for replacement purposes. Indeed, the tube bundle may be of such simple form and construction that it may even be considered almost in the category of a disposable unit. Therefore in a water heater installation of the kind here described, instead of discarding an entire water heater when either flue or water tubes become clogged or surface coated with deposits or impurities, the tube bundle may merely be replaced, the remainder of the equipment being retained and continued in use.

As seen in FIGS. 7 and 9, the flange 60 includes not only the annular portion thereof projecting radially outwardly from the combustion chamber wall 43, but also the annular portion indicated at 60a which projects inwardly of the inner com-

bustion chamber wall 42, these two portions of this flange being interconnected by means of spoke-like parts 61 which are circumferentially spaced from each other so as to provide free flow of water from the lower header of the tube bundle into the upper edge of the water jacket surrounding the combustion chamber. The tube plate 49 and the mounting flange 57 at the lower end of the tube bundle may similarly be interconnected by spoke-like parts circumferentially spaced from each other so as not to interfere with water flow from the header into the jacket. This form of construction thus assures proper interpositioning of the lower ends of the flue tubes within the water tubes while at the same time providing adequate cross sectional water flow area from the lower header into the jacket.

The water offtake from the heater is indicated at 62 toward the bottom of FIG. 7.

At the top of FIG. 7 an offtake blower 36 having a discharge connection 37 is shown as being connected with the gas manifold 59 in the same general manner as described above with reference to FIG. 5.

Turning now to the embodiment illustrated in FIGS. 10, 11 and 12, it is first to be noted that the tube bundle, comprising parts 47-53 and 55-57 may be identical with those described above with reference to FIGS. 7 to 9. The embodiment of FIGS. 10 to 12 thus also contemplates the use of a unitary tube bundle providing ease of maintenance and replacement. Certain other parts of the arrangement of FIGS. 10 to 12 are also similar to FIGS. 7 to 9, including the provision of a water supply connection 54 associated with the upper water header, the gas manifold 59 with its bolting flange 58 adapted for cooperation with the flange 56.

In the embodiment of FIGS. 10 to 12, however, it will be noted that no blower 36 is associated with the upper end of the system, the discharge connection 63 being arranged to discharge to atmosphere.

The arrangement of FIG. 10 also utilizes a combustion chamber formed by inside and outside walls 42 and 43, with an inner liner 44 and having a bolting flange 60 projecting radially outwardly, as well as a flange 60a projecting radially inwardly. An ignition plug 20 is also provided in FIG. 10.

The fuel and air inlet arrangements of FIGS. 10 to 12, however, are different from those provided in any of the other arrangements described. Thus, as seen in FIG. 10, two spaced plates 64 and 65 are provided at the lower end of the combustion chamber, the two plates being positioned in spaced relation. The upper plate 64 is provided with venturi apertures 66, and the lower plate with fuel jet nozzles 67, a nozzle 67 being aligned with each venturi passage 66. The fuel nozzles are supplied with fuel under pressure, for instance gas, through the fuel supply line 68.

An annular series of air inlet openings 69 are provided through the walls 42 and 43 of the combustion chamber in registry with the space lying between the venturi plate 64 and the nozzle plate 65, so that the fuel jet nozzles and the venturi passages serve to induce inflow of air required for combustion. An annular damper 70 (see FIGS. 10 and 12) having a series of openings 71 surrounds the combustion chamber in the region of the air inlet opening 69 and provides for control of the cross sectional flow area for admission of air. An operating handle such as indicated at 72 may be provided for regulating the damper.

The water jacket lying between the inner and outer combustion chamber walls 42 and 43 is continued down to the bottom of the equipment, at which point the hot water discharge connection 62 is arranged, in the general manner already described with reference to some of the other figures.

The plan pattern of fuel jet nozzles and also of the venturi passages is clearly shown in FIG. 11. Advantageously this plan pattern may be similar to the plan pattern of the flue and water tube units, the latter of which is shown in FIG. 8 in relation to the embodiment of FIGS. 7 to 9.

With respect to the embodiments of both FIGS. 7 to 9 and FIGS. 10 to 12, it will be understood that if desired heat insu-



lation or lagging may also be applied surrounding the tube bundle and the combustion chamber, for instance in the general manner indicated at 24 in FIG. 1 and at 41 in FIG. 5.

With respect to all of the embodiments illustrated and described, it will be understood that many specific details of structure have not been shown in the drawings, these being unnecessary to an understanding of the nature of the invention. For example, many portions of the walls surrounding the combustion chamber may desirably be formed of a multiplicity of parts assembled and welded together in any desired manner. For the sake of simplicity and clarity in illustration and description, only those portions of the structure having a significant bearing upon the features of novelty have been illustrated and described.

In considering the operation of all of the embodiments disclosed in this application, it is to be noted that while any of the water heaters illustrated and described may be used to deliver heated water to a storage tank, it is preferred to completely dispense with the storage of heated water, because hot water storage necessarily involves loss of heat and this in turn reduces the overall efficiency of the system. It is therefore contemplated according to the present invention that the water heater be operated only in accordance with the demand for hot water, rather than in accordance with the water temperature, as in the prior art storage heater systems. In most situations this necessarily involves intermittent operation, and with this in mind it is contemplated that the equipment of the invention be employed with an automatic control system for initiating and terminating the feed of fuel and air in response to the demand for hot water. For example in a domestic or home installation, it is contemplated to utilize a control system responsive to the flow of water from the heater, for instance resulting from the opening of a hot water valve or spigot. Such a flow responsive control device is indicated diagrammatically at 62a in FIG. 10.

Automatic controls of the kind just referred to are known and are not disclosed herein as the details thereof form no part of the present invention per se. Such controls have been known heretofore in connection with the type of prior art water heater hereinabove referred to in which a water coil is positioned within a combustion chamber or combustion products passage. However, in contrast to such prior known water heaters, all embodiments of the heater of the present invention contemplate the use of flue tubes surrounded by water tubes which, in a sense, represents an inversion of the heat transfer system, as compared with the prior water coil type of heater referred to. By employing flue tubes of relatively small cross sectional flow area surrounded by water tubes defining a water flow passage of relatively small cross sectional area, much greater thermal efficiencies are obtainable, than is possible by placing a water coil in a gas or other combustion chamber, as has been done heretofore.

All embodiments of the heater according to the present invention are also clearly distinguishable from the other well known type of water heater above described (commonly referred to as a storage heater) for a number of reasons, including the following. First, the prior storage type of heater has a combustion chamber at the bottom and a flue extended upwardly through the water storage tank. Because of the necessity for relying upon this water tank for storage purposes, it is necessarily of very large volume in relation to the hot water discharge pipe and also in relation to the flue channel for the hot gases leaving the combustion chamber. These relationships do not admit of highly efficient heat transfer conditions, in consequence of which a very high BTU loss occurs because of the discharge of the gases at a relatively high temperature in relation to the input temperature of the water. Preferably the cross sectional water flow area of the water tubes is not substantially greater than the cross sectional flow area of the hot water delivery line extended from the heater. In a case where the cross sectional water flow area approximates the cross sectional flow area of the hot water delivery line, the rate of flow through the heater will substantially cor-

respond to the rate of flow of water through the delivery line. While it is not necessary to maintain the water flow area through the heater approximately the same as the water flow area through the connected delivery pipe, nevertheless it is preferred to keep the water flow area through the heater within a limit of several times the water flow area of the pipe, for instance within two or three times the water flow area of the pipe.

Thus, the system of the present invention is clearly distinguishable from the prior art so-called "storage" systems in that the present invention deliberately avoids the storage function with a view to eliminating the heat losses which are incident both to the storage function itself and also to the low efficiency imposed upon the system as a result of the attempt to effect heat transfer from the hot gases to the large bulk or volume of water necessarily contained in a storage tank.

The arrangements of the invention are thus capable of achieving almost perfect combustion efficiencies and extremely high thermal efficiencies, going far beyond the capabilities of the conventional types of water heaters. These efficiencies are due to several factors, some of which have already been mentioned and further including the use of the counter-flow principle in the tube-within-a-tube units, the use of counterflow not only within those tube units but also within the jacket surrounding the combustion chamber, the water flow path being extended serially through the tube units and then through the water jacket. Still another factor of importance in achieving the efficiencies referred to is the high temperature established in the combustion chamber and the consequent virtually complete combustion, before the products of combustion enter the flue tubes. The establishment of operating conditions providing for discharging of combustion products at a temperature within a couple of degrees of the temperature of input of the water is also of importance in achieving the efficiencies referred to.

As above noted, although the velocities of water and products of combustion in the systems of FIGS. 5 to 12 are not as high as in the system of FIGS. 1 to 4, nevertheless even in the system of FIGS. 10 to 12, one or the other or both of those velocities are relatively high as compared with conventional water heaters of the kinds referred to above. Therefore, even in the arrangement of FIGS. 10 to 12, there is a minimization of soot and mineral deposits in the gas and water sides of the system, as compared with prior water heaters.

Although in all of the embodiments described and illustrated, the fuel and air both enter through the same inlet or inlets into the combustion chamber, it will be understood that the fuel and air may be introduced through separate inlets either in a system in which combustion is established under pressure, or in a system in which combustion occurs at substantially ambient pressure.

From the foregoing it will be seen that various important features of the present invention may be utilized in systems of a wide variety of types, especially with respect to the introduction of the fuel and air. Thus, a relatively high pressure type of system may be employed, as in FIGS. 1 to 4, or a relatively low pressure blower type of system, as in FIGS. 5 and 6 or 7 to 9, FIGS. 5 and 6 illustrating the application of the blower to the input side of the system, and FIGS. 7 to 9 illustrating the application of the blower to the output side. In FIGS. 10 to 12 various features of the invention are shown as applied to a system in which no blower or compressor is used for the air, the introduction of the fuel and air and the flow of the gases through the system being effected only by virtue of the fuel feed or supply line, such as the normal pressure available in gas supply tanks or mains.

From the foregoing it will also be seen that water heaters according to the present invention are well adapted to a variety of uses, including both domestic and commercial. For example, the heaters of the present invention are well adapted for use in supplying the hot water used in homes.

Water heaters according to the present invention are also especially well adapted to use in a situation where a large

volume of water is to be heated on a "once-through" basis, i.e., without storage, for instance the heating of water for a swimming pool. In such an installation the heater may be used for long periods of time without accumulation of mineral deposits, because high water temperatures are not needed.

I claim:

1. A water heater comprising a combustion chamber, inlet means for introducing fuel and air into one end of the combustion chamber, a flue tube for discharging products of combustion from the other end of the combustion chamber, a water jacket surrounding the combustion chamber and having an inlet in a region remote from the fuel and air inlet and having an outlet in a region adjacent to the fuel and air inlet, a liner in the combustion chamber spaced from the chamber wall to provide a dead air space between the water jacket and the interior of the combustion chamber where the fuel and air is burned, and a water tube surrounding the flue tube and providing an annular water flow passage surrounding the flue tube, the water tube having a water inlet at its end remote from the combustion chamber and being connected with the water inlet to the water jacket surrounding the combustion chamber and thereby provide for counterflow of combustion products through the combustion chamber and flue tube in relation to the flow of water through the annular passage surrounding the flue tube and through the water jacket surrounding the combustion chamber.

2. A water heater as defined in claim 1 and further including a compressor for introducing the fuel and air under compression through the fuel and air inlet into the combustion chamber.

3. A water heater as defined in claim 1 and further including a blower in the discharge from the flue tube providing for drawing of the fuel and air through the inlet into the combustion chamber.

4. A water heater as defined in claim 1 in which the fuel and air inlet means comprises a fuel jet, a venturi passage through which the fuel jet delivers fuel into the combustion chamber, and an inlet for combustion air communicating with the inlet end of the venturi passage.

5. A water heater comprising a combustion chamber, inlet means for introducing fuel and air into one end of the combustion chamber, a flue tube for discharging products of combustion from the other end of the combustion chamber, a water jacket surrounding the combustion chamber and having an inlet in a region remote from the fuel and air inlet and having an outlet in a region adjacent to the fuel and air inlet, a water tube surrounding the flue tube and providing an annular water flow passage surrounding the flue tube, the water tube having a water inlet at its end remote from the combustion chamber and being connected with the water inlet to the water jacket surrounding the combustion chamber and thereby provide for counterflow of combustion products through the combustion chamber and flue tube in relation to the flow of water through the annular passage surrounding the flue tube and through the water jacket, and pump means for establishing combustion under pressure and forced circulation of combustion products from the combustion chamber through the flue tube.

6. A water heater comprising a combustion chamber, inlet means for introducing fuel and air into the combustion chamber, a plurality of flue tubes for discharging products of combustion from the combustion chamber, a common chamber into which the flue tubes discharge, a blower having its inlet connected with said common chamber providing for drawing of the combustion products through the flue tubes, a water tube surrounding each flue tube and providing an annular water flow passage surrounding the flue tube, and an inlet header for feeding water into the water tubes at the ends thereof remote from the combustion chamber and thereby provide for counterflow of the water through the annular flow passage in relation to the flow of combustion products through

the flue tubes.

7. A water heater comprising a combustion chamber, inlet means for introducing fuel and air into the bottom of the combustion chamber, a flue tube extended upwardly from the combustion chamber for discharging products of combustion from the top of the combustion chamber, a water jacket surrounding the combustion chamber and having an inlet in the region of the top of the combustion chamber and having an outlet in the region of the bottom of the combustion chamber, and a water tube surrounding the flue tube and providing an annular water flow passage surrounding the flue tube, the water tube having a water inlet at its upper end and being connected with the water inlet to the water jacket surrounding the combustion chamber and thereby provide for upward counterflow of combustion products through the combustion chamber and flue tube in relation to the downward flow of water through the annular passage surrounding the flue tube and through the water jacket.

8. A water heater as defined in claim 7 and further including a blower connected with the upper end of the flue tube providing for drawing of the fuel and air through the inlet into the bottom of the combustion chamber.

9. A water heater as defined in claim 7 in which a plurality of flue tubes and surrounding water tubes are provided and further including a common flue tube discharge chamber, and an exhaust blower connected with said common chamber and providing for flow of combustion products through the flue tubes.

10. A water heater comprising a combustion chamber, inlet means for introducing fuel and air into the combustion chamber, a tube bundle including a plurality of flue tubes for discharging products of combustion from the combustion chamber and further including a plurality of water tubes surrounding the flue tubes and each providing an annular water flow passage surrounding a flue tube, the tube bundle having flue sheets and tube sheets at each end spaced from each other to provide inlet and outlet water headers, and separable connection means between the tube bundle and the combustion chamber providing for removal and replacement of the tube bundle with respect to the combustion chamber.

11. A water heater comprising a combustion chamber, a water jacket surrounding the combustion chamber, inlet means for introducing fuel and air into the combustion chamber, a plurality of flue tubes for discharging products of combustion from the combustion chamber, a common chamber into which the flue tubes discharge, a water tube surrounding each flue tube and providing an annular water flow passage surrounding the flue tube, and inlet and outlet headers for feeding water through the water tubes, the water inlet header having water supply means and the water outlet header having connection means for delivering water from the outlet header into the water jacket surrounding the combustion chamber, said connection means being separable to provide for removal and replacement of the water tubes.

12. A water heater comprising a combustion chamber, inlet means for introducing fuel and air into the combustion chamber, a flue tube for discharging products of combustion from the combustion chamber, a water jacket surrounding the combustion chamber, and a water tube surrounding the flue tube and providing an annular water flow passage surrounding the flue tube, the water tube having a water inlet at its end remote from the combustion chamber and being connected with the water jacket surrounding the combustion chamber and thereby provide for flow of water serially through the annular passage surrounding the flue tube and through the water jacket, the fuel and air inlet means comprising a pair of spaced plates one having fuel jet nozzles extended therethrough and the other having venturi passages extended therethrough in alignment with the fuel jet nozzles, the space between said plates comprising an air chamber for supplying air to the venturi passages.

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