

[54] **BOILER**
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[58] Field of Search.....122/135, 136, 155,
122/152, 233, 367 R, 367 C

2,834,323	5/1958	Radford	122/367
1,642,600	9/1927	Burkman	122/155
2,452,852	11/1948	Hilkene	122/155
2,744,504	5/1956	Gellman	122/135

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[56] **References Cited**

UNITED STATES PATENTS			
2,674,981	4/1954	Clarkson	122/136
1,672,252	6/1928	Garvey	122/155
2,625,139	1/1953	Langen	122/155
571,208	11/1896	Wood	122/155
2,753,851	7/1956	Lemos, Jr. et al.	122/136

[57] **ABSTRACT**
A boiler is disclosed in which hot flue gases generated by combustion within a furnace tube mounted in a liquid filled boiler drum are directed back and forth over different portions of the outside of the drum by an arrangement of partitions and baffles located within a housing containing the boiler drum. The resulting multi-pass design provides for substantially uniformly high flue gas velocity over a plurality of fins helically disposed along the length of the boiler drum on the outside thereof, resulting in effective extraction of heat from the flue gases and high boiler efficiency. The helically disposed fins can be subjected to substantial temperature variations without undue stressing of the boiler drum.

20 Claims, 6 Drawing Figures

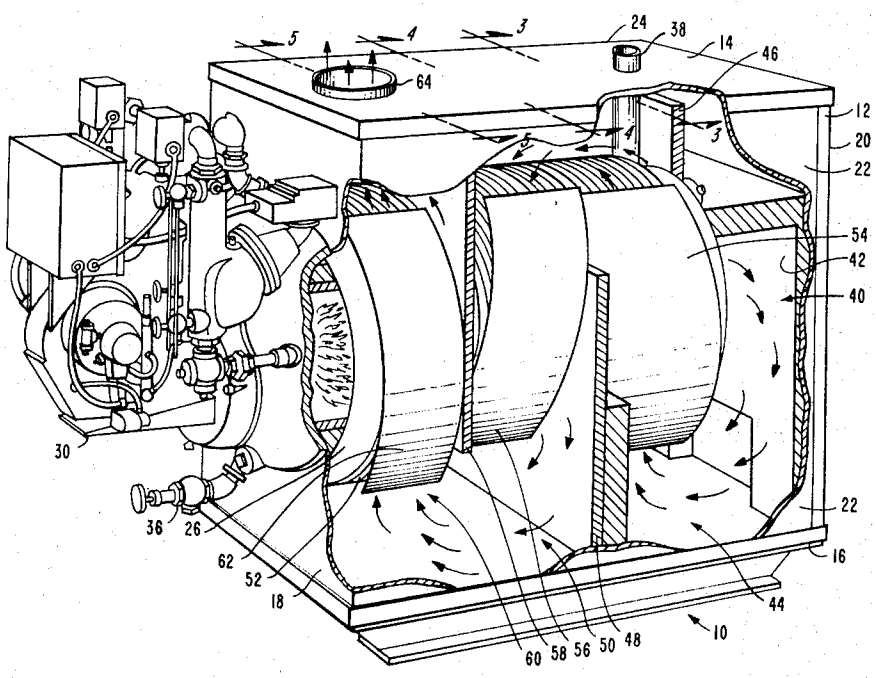
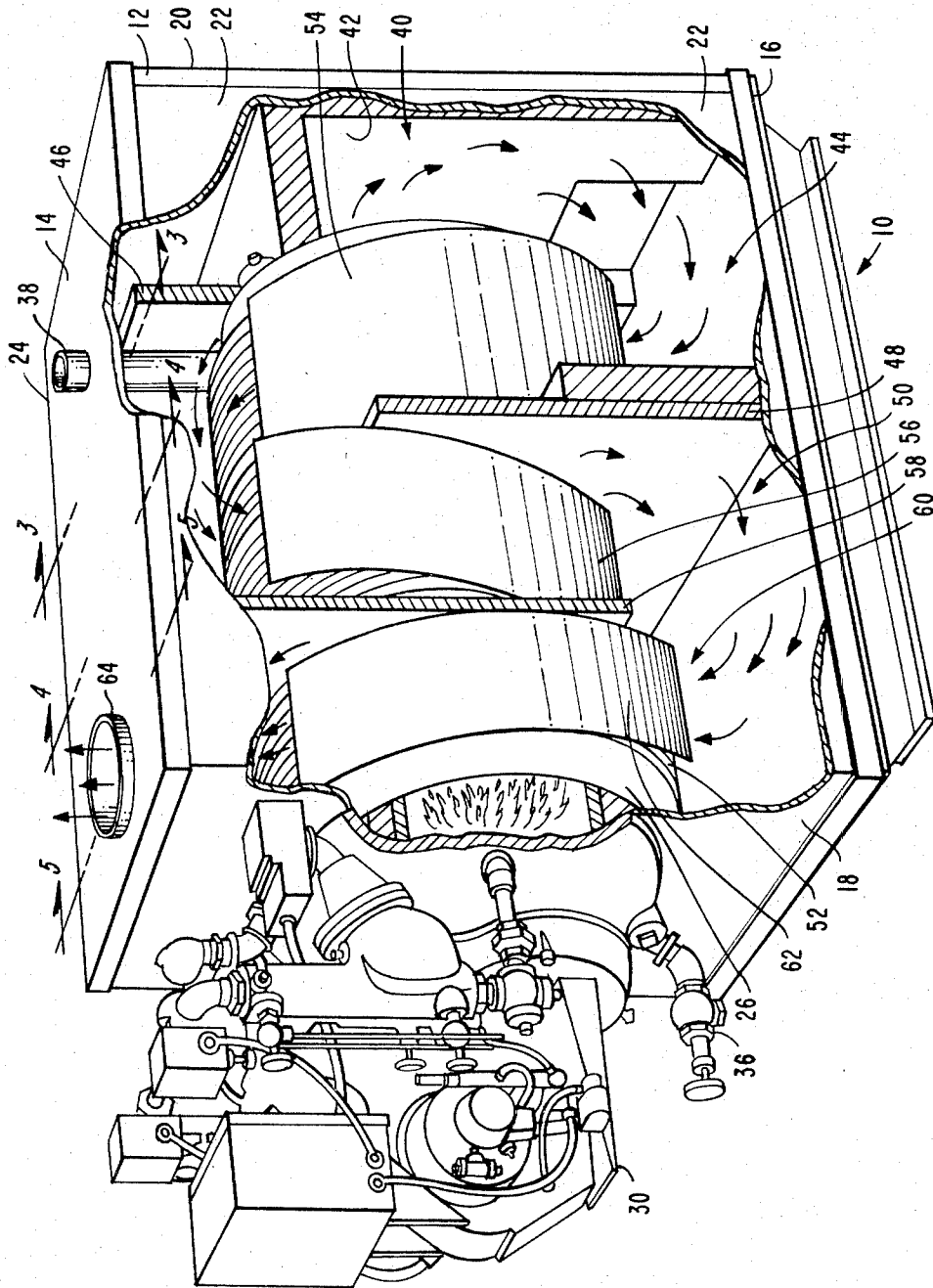


FIG.-1



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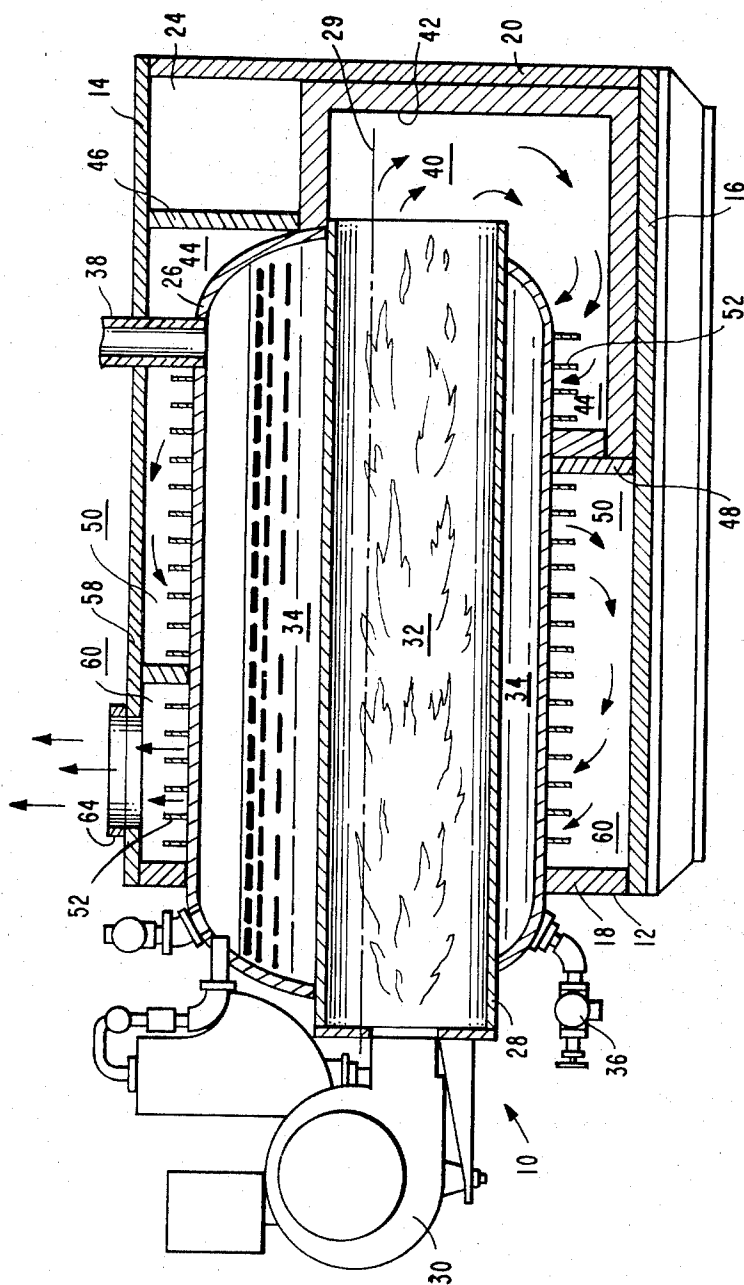


FIG. - 2

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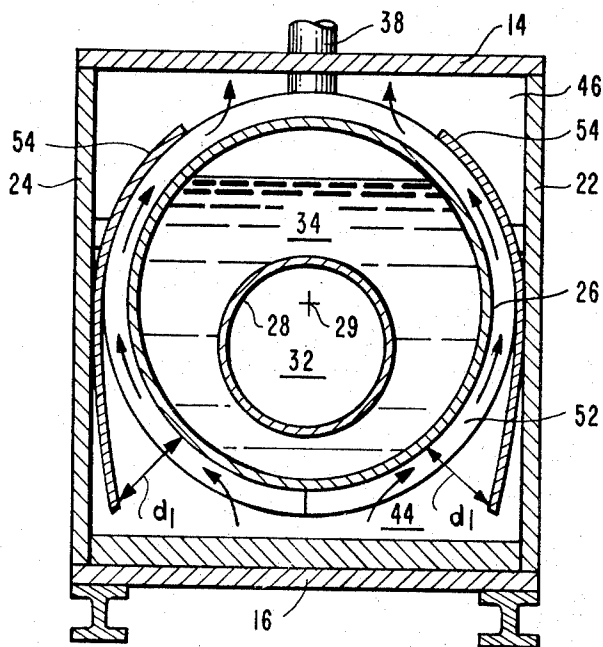


FIG. -3

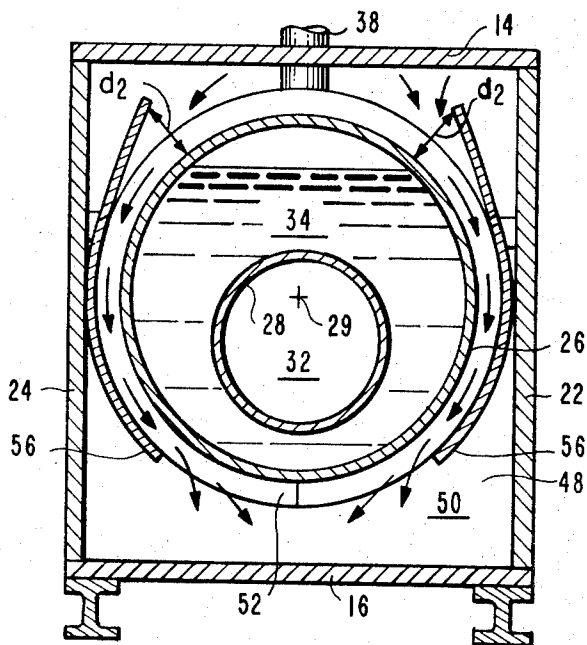


FIG. -4

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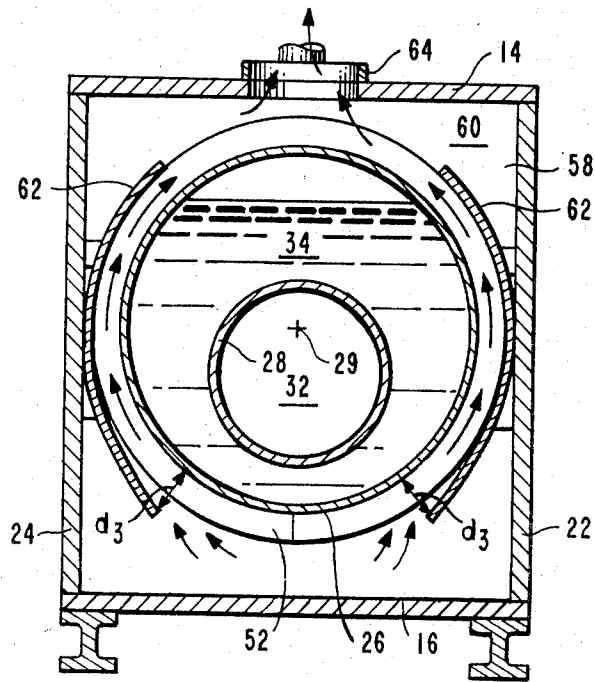


FIG. - 5

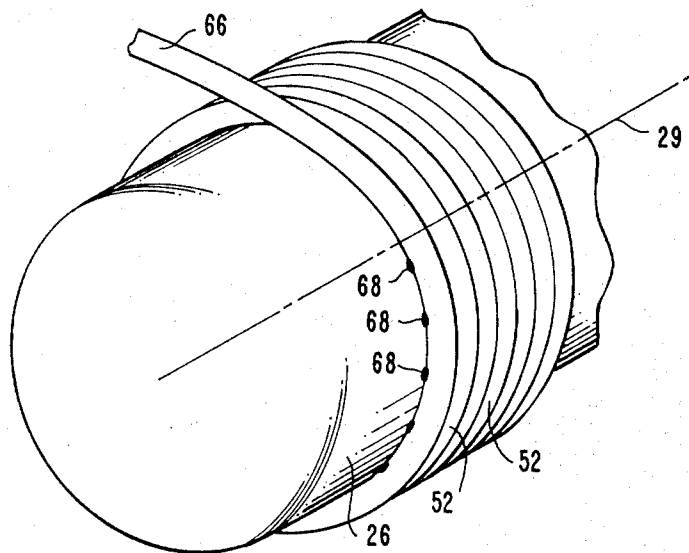


FIG. - 6

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BOILER

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to boilers for vaporizing or otherwise heating a liquid, and more particularly to boilers of the "Scotch Marine" type in which hot flue gases are generated within a combustion chamber located within a liquid containing boiler drum and are thereafter used to heat the liquid such as by directing them through a plurality of fire tubes extending through the drum or by directing them over the outside of the drum.

2. History of the Prior Art

Boilers are known in which hot flue gases are generated within a combustion chamber located within a drum, a separate firebox or other container for liquid to be heated, the hot flue gases providing some heating of the liquid by virtue of the combustion process and thereafter being utilized in appropriate fashion to create further heating of the liquid. In the well known "Scotch Marine" type boiler the flue gases are typically generated in a combustion chamber defined by the inside of a furnace tube, the furnace tube being disposed within and extending along the length of a liquid containing boiler drum. Combustion within the furnace tube is typically provided by a burner assembly which mixes natural gas, oil or other appropriate fuel with air and forces the resulting mixture past an ignitor and into the combustion chamber. The resulting combustion and generation of hot flue gases and which constitutes a first "pass" of the hot flue gases, relative to the liquid, provides heating of the liquid surrounding the furnace tube. Further heating of the liquid is provided by one or more additional passes of the flue gases relative to the liquid.

Such further heating is provided in one type of boiler by a plurality of fire tubes which are mounted within the boiler drum along with the furnace tube so as to extend along the length of the drum. The combustion gases may be directed through all of the fire tubes in the same direction, providing the second pass of a two-pass boiler. Alternatively the combustion gases may be directed through different fire tubes in opposing directions providing a boiler of the type having four passes or other numbers of passes greater than two. The number of fire tubes carrying hot flue gases is reduced in the third and subsequent passes of a boiler having more than two passes in order to obtain a reduction in cross-sectional area as a means to obtain, in each pass, the highest flue gas velocity for greater heat transfer efficiency. In a very few cases extremely expensive tapered fire tubes are used to maintain uniformly high flue gas velocities as the flue gases cool down in each pass.

As the hot flue gases pass along the fire tubes, heat is transferred therefrom to the liquid surrounding the fire tubes within the boiler drum. In the case of a water or liquid boiler the liquid is ultimately heated to a desired temperature or temperature range, whereupon it is transferred from the boiler drum to the location where it is to be used. In the case of a steam or vapor boiler the liquid within the drum is ultimately heated to the point where it vaporizes, the resulting vapors exiting through a pipe or other appropriate arrangement at the top of the boiler drum.

While boilers of the type described function in a reasonably effective and efficient manner for many appli-

cations, they suffer from a number of limitations which may limit their usefulness generally as well as for certain particular applications. As the boiler is used, lime becomes deposited on the water side and soot builds up on the flue gas side within the fire tubes requiring that the boiler be periodically shut down and opened up so that the fire tubes can be rodded out. The fire tubes, moreover, must generally be replaced one or more times during the natural life of the boiler; a process which may prove to be almost as expensive as the boiler itself. In those boilers of the type in which the hot flue gases are passed through different groups of fire tubes in more than one direction, significant differences in temperature occur at different locations along the lengths of the fire tubes. Such temperature variations may range from approximately 350° F. at one extreme to approximately 1,800° F. or higher at the other extreme; and as a result the ligaments which join the opposite ends of the fire tubes to tube sheets in time often crack due to thermal stresses causing the fire tubes to leak. The constant need to clean (rod out the fire tubes) and replace fire tubes in a boiler of this type makes it absolutely necessary that an additional service area equal to the space taken up by the boiler be provided in order to clean or replace the fire tubes. The fire tubes also take up space within the boiler drum which would otherwise be occupied by the liquid, and tend to inhibit circulation of the liquid, resulting in reduced heat transfer.

The Horizontal Return Tube (H.R.T.) boiler is of similar design as the "Scotch Marine" boiler except that the combustion takes place in a firebox under the boiler with the resulting flue gases travelling through fire tubes that are located in a boiler drum in a manner similar to the fire tubes in a "Scotch Marine" boiler. The H.R.T. boiler suffers the same deficiencies as the "Scotch Marine" type except that the thermal stress problem is reduced but the size and cost are increased.

In a further alternative form of prior art boiler which eliminates fire tubes within the boiler drum, the hot flue gases generated within the combustion chamber defined by the furnace tube are directed to the outside of the boiler drum where they are allowed to pass over the outside of the drum to effect further heating of the liquid. Boilers of this type while generally free from the problems posed by the presence of fire tubes nevertheless suffer from an overall reduction in efficiency. In an effort to increase their efficiency some boilers of this type are equipped with an arrangement of fins which extend longitudinally along the outside of the boiler drum. Such fins are typically continuously welded along their entire length. Boilers with longitudinal (straight) fins located around the periphery of a boiler drum of cylindrical shape do not lend themselves to multiple pass design or to a baffling arrangement, both of which are necessary for the efficient extraction of heat from the flue gases. Because of these fundamental design problems, finned boilers have never been accepted, except in small sizes as a low-cost boiler. Also, straight finned boiler designs are basically of a vertical design configuration which severely limits the size that can be built.

One key factor in achieving good heat transfer between the flue gases and the boiler drum or other liquid containing member is to maintain a uniformly high velocity of the gases relative to the drum or other member, thereby providing a turbulent flow rather than a

laminar flow of the gases. However, in boilers having a relatively long flow path for the gases such as those of the multi-pass type, uniformly high flue gas velocity is maintained over the entire flow path only if adequate compensation is provided for the decrease in the volume of the gases as they cool. For a given volume of flue gas, the velocity of the gas is a direct function of the cross-sectional flow area. Therefore as the volume of the flue gas decreases with cooling, the flow path must be tapered or otherwise reduced in cross-sectional area along the length thereof to obtain the highest flue gas velocity for greater heat transfer efficiency.

In boilers of the type having a plurality of fire tubes disposed within the drum, the flow area may be progressively reduced so as to maintain the flue gas velocity such as by using tapered tubes with a reducing diameter or by reducing the number of fire tubes with each succeeding pass. The practical result is a long and twisted flow path which presents considerable friction to the flue gases and therefore requires a relatively large blower in the burner assembly in order to force the combustion products through the furnace tube under considerable pressure.

In some boilers various devices are located within the fire tubes or other vessels for the flue gases in an attempt to spiral the gases or otherwise cause turbulence thereof so as to improve heat transfer. However the desired degree of turbulence is difficult or impossible to accomplish in many such systems where the fire tube or vessel may be as little as 1 inch in diameter and as much as 20 feet long.

Accordingly, the prior art would be significantly improved upon by a boiler which eliminates the need for fire tubes within the boiler drum while at the same time providing for optimum heat transfer and relatively high efficiency of the boiler. Such boiler should also be capable of multi-pass design in which the hot flue gases are caused to make a plurality of different passes relative to liquid within the drum while at the same time negotiating flow paths of minimum frictional resistance but of continuously decreasing size so as to maintain uniformly high flue gas velocity with resulting turbulence and increased heat transfer. In cases where fins are used on the outside of the boiler drum, such fins should be capable of optimizing heat transfer by controlling and directing the flow of hot flue gases so as to maximize the striping of heat from the flue gases and the transferring of said heat to the boiler liquids or fluids.

BRIEF SUMMARY OF THE INVENTION

Briefly, the present invention provides a boiler in which hot flue gases generated within a combustion chamber defined by the interior of a furnace tube located within an elongated, generally cylindrical boiler drum having opposite enclosed ends are allowed to pass to the outside of the boiler drum where they are directed by an arrangement of partitions and baffles to pass over selected portions of the finned exterior of the boiler drum in opposing directions. Such an arrangement avoids fire tubes and the problems which are inherent in the use of such tubes. At the same time, however, heat transfer and the ultimate efficiency of the boiler are optimized by the presence of the fins on the outside of the boiler drum and the repeated passing of the hot flue gases over the outside of the drum and the

included fins in opposite directions at a substantially uniformly high velocity. The partitions are arranged within a housing containing the boiler drum so as to divide the interior of the housing into a plurality of different chambers, with each chamber defining a different "pass" of the flue gases over the drum in a transverse direction generally normal to the axis of elongation of the drum. Contact between the flue gases and the drum is enhanced and the flue gas velocity is controlled by curved baffles within each chamber which extend from locations spaced apart from the drum near the upstream end of the chamber onto the outer edges of the fins at the downstream end of the chamber so as to cause the flue gases to converge on the fins and on the outside surface of the drum.

The chambers and included baffles are arranged in accordance with the invention to provide a flow path of decreasing area having minimal frictional resistance. As a result, the velocity of the flue gas is maintained at a uniformly high level providing turbulent flow and increased heat transfer; while at the same time the need for a large blower in the burner assembly in order to force the flue gas into the system under increased pressure is substantially reduced. Controlled decreases in the flow path area can be provided by decreasing the length of each succeeding chamber in the flow path for the gases. With the length of the chamber decreased, the length of the included baffles is also decreased providing a decrease in the width and area of the flow path between the baffles and the drum. The baffles themselves provide a gradual decrease in the flow area since they extend from locations spaced apart from the outside edges of the fins at their upstream ends into contact with the fins at their downstream ends. Where desired, the upstream ends of the baffles within each succeeding chamber may be spaced progressively closer to the drum and included fins to provide further uniform decreases in the flow area.

The fins on the outside of the boiler drum extend around the circumference of the drum so as to encircle the drum in a direction which is transverse relative to the axis of elongation of the drum and parallel to the passes of the flue gases, each individual fin which encircles the entire circumference of the drum being spaced apart from adjacent fins along the axis of elongation of the drum. Such arrangement effectively facilitates heat transfer to the boiler drum. The fins may comprise a plurality of individual fins with each fin extending around the entire circumference of the drum in spaced apart relation to the adjacent fins. Fabrication and mounting of the fins on the outside of the drum are facilitated however by an arrangement in which a single element is repeatedly wound around and mounted on the outside of the drum in helical fashion.

In one preferred arrangement of a four-pass boiler in accordance with the invention, a mixture of fuel from a burner assembly at one end of the furnace pipe is ignited within the combustion chamber to generate the hot flue gases and to provide the first pass of the gases relative to the liquid. The flue gases exit at the opposite end of the furnace tube from the burner assembly where they are directed downwardly to the underside of the drum within a second pass chamber. As the gases rise within the second pass chamber, they are directed onto the outside surface of the drum and included fins by curved baffles on the opposite sides of the drum within the chamber to complete a second pass relative

to the liquid. The gases rise to the top of the second pass chamber where they are directed to the top of an adjacent third pass chamber, the third pass chamber being separated from the second pass chamber by a partition which extends between the outside of the boiler drum and the boiler housing. The flue gases at the top of the third pass chamber are directed downwardly over both sides of the boiler drum by a pair of baffles to the bottom of the third pass chamber to complete a third pass. The gases at the bottom of the third pass chamber are directed into the bottom of an adjacent fourth pass chamber which is separated from the third pass chamber by a partition and which directs the flue gases upwardly around the opposite sides of the boiler drum to complete a fourth pass with the aid of opposite baffles. The flue gases at the top of the fourth pass chamber exit from the boiler through a stack at the top of the housing.

The invention facilitates the design of boilers using different arrangements by scientifically combining various alternative arrangements of fins, partitions and baffles to achieve desired design objectives such as efficiency, cost, size and the like.

BRIEF DESCRIPTION OF THE DRAWINGS

A better understanding of the present invention may be had from a consideration of the following detailed description, taken in consideration with the accompanying drawings, in which:

FIG. 1 is a perspective view, broken away, of a boiler in accordance with the invention;

FIG. 2 is a side sectional view of the boiler of FIG. 1;

FIG. 3 is an end sectional view of the boiler of FIG. 1 taken along the line 3—3 thereof;

FIG. 4 is an end sectional view of the boiler of FIG. 1 taken along the line 4—4 thereof;

FIG. 5 is an end sectional view of the boiler of FIG. 1 taken along the line 5—5 thereof; and

FIG. 6 is a perspective view of one end of the boiler drum of the boiler of FIG. 1 illustrating one preferred technique for mounting fins thereon.

DETAILED DESCRIPTION

Referring to FIGS. 1 and 2, one preferred embodiment of a boiler 10 in accordance with the invention has a generally rectangular housing 12 comprising a top 14, a bottom 16, opposite ends 18 and 20, and opposite sides 22 and 24. The housing 12 encloses an elongated, generally cylindrical boiler drum or vessel 26 having opposite semi-ellipsoidal closed ends, one of which is disposed within the housing adjacent the end 20 and the other of which extends through the housing end 18 to the outside of the housing 12. An elongated cylindrical furnace tube 28 of steel or other appropriate construction is disposed within the drum 26 so as to extend between the opposite ends of the drum, the axis of elongation of the furnace tube 28 being generally parallel to and located below the axis of elongation 29 of the drum 26. The furnace tube 28 is open at the end thereof adjacent the housing end 20. The other end of the furnace tube 28 is coupled to a burner assembly 30.

The burner assembly 30 which may assume any appropriate form functions in conventional fashion to provide combustion within a combustion chamber 32 defined by the inside of the furnace tube 28 and to thereby generate hot flue gases therein. The burner assembly 30 mixes oil, natural gas or other appropriate

fuel with air and forces the resulting mixture past an ignitor (not shown) to provide the desired combustion and generation of flue gases. Combustion within the chamber 32 results in the transfer of heat through the furnace tube 28 to a surrounding liquid 34.

The liquid 34 which may comprise water, Dowtherm (a registered trademark of Dow Chemical Co.) or other appropriate liquid to be heated is disposed on the outside of the furnace tube 28 and within the drum 26. The liquid 34 is introduced into the interior of the drum 26 by means of an entry valve 36 or other appropriate device. In the present example the boiler 10 comprises a steam or vapor boiler in which vapors rise from the surface of the liquid 34 as a result of the heating of the liquid and exit via an outlet pipe 38 extending from the top of the drum 26 through the top 14 of the boiler housing 12. It will be understood by those skilled in the art, however, that the present invention also encompasses water or liquid boilers in which the liquid is heated without necessarily being vaporized and is thereafter used in liquid form. Sensing devices (not shown) located in the vicinity of the burner assembly 30 monitor the level of the liquid 34 and provide for a continuous supply of liquid 34 into the drum 26 to maintain the liquid level within a desired range as vaporization occurs.

The combustion chamber 32 within the furnace tube 28 defines the first pass of the boiler 10. At the end of the furnace tube 28 opposite the burner assembly 30 the hot flue gases enter a chamber 40 which is generally rectangular in configuration and which is defined by walls which are preferably made of concrete, Firecrete (a registered trademark of Johns-Manville Sales Corporation) or a combination thereof. The back wall 42 of the chamber 40 adjacent the end 20 of the boiler housing is preferably made of Firecrete to provide further combustion of the hot flue gases and thereby prevent wasteful reduction in the temperature of the flue gases.

The hot flue gases within the chamber 40 are directed downwardly into the bottom of an adjoining second pass chamber 44 defined at one end by a partition 46 and at the other end by a partition 48. The partition 46 which extends between the opposite sides 22 and 24 of the boiler housing from the housing top 14 to the top of the chamber 40 prevents flue gases which rise to the top of the second pass chamber 44 from entering the space directly above the chamber 40. The partition 48 as best seen in FIG. 4 extends between the opposite sides 22 and 24 of the housing 12 and the outside of the drum 26 from the housing bottom 16 up to a level which is slightly higher than the axis of elongation 29 of the drum 26. The partition 48 which helps to support the drum 26 along with the end 18 prevents flue gases entering the second pass chamber 44 from flowing directly into a third pass chamber 50, and instead forces the gases in an upward direction generally normal to the axis of elongation 29 of the drum 26 through a second pass around the opposite sides of the drum 26.

Heat transfer between the flue gases and the drum 26 and included liquid 34 is enhanced by a plurality of fins 52 mounted on the outside of the drum 26 so as to encircle the circumference of the drum in directions transverse to the axis of elongation 29 of the drum 26. Heat transfer is also facilitated within the second pass chamber 44 by a pair of baffles 54 disposed on opposite sides of the drum 26. The baffles 54 which are curved,

generally rectangularly shaped elements extend from locations spaced apart from the drum 26 and included fins 52 at their upstream ends adjacent the upstream end of the chamber 44 into contact with the outer edges of circumferential portions of the fins 52 at their downstream ends adjacent the downstream end of the chamber 44. As best seen in FIG. 3, the baffles 54 are arranged to cause the flue gases to converge on the outside surface of the drum 26 between the included fins 52 to enhance the heat transfer during the second pass of the gases. The upstream ends of the baffles 54 are spaced a selected distance d_1 from the drum 26 to provide the flue gas flow paths defined by the space between the baffles 54 and the outside of the drum 26 with selectively decreasing cross-sectional areas. As more fully discussed hereafter, decreases in the areas of the flow paths within each succeeding chamber are also provided for by decreasing the length of each chamber and its included baffles.

The flue gases within the second pass chamber 44 are directed over the partition 48 and into the third pass chamber 50. As seen in the sectional view of FIG. 4 the flue gases within the third pass chamber 50 undergo a third pass in which they are directed generally downwardly in directions which are opposite those of the second pass and which are normal to the axis of elongation 29 of the drum 26. The gases are caused to converge on the outside of the drum 26 between the fins 52 by a pair of baffles 56 disposed on opposite sides of the drum 26. The baffles 56 are curved, rectangular shaped members which are similar to the baffles 54 in the second pass chamber 44 except that their lengths in the direction of the axis of elongation 29 of the drum 26 are shorter than the corresponding lengths of the baffles 54 and they are mounted so as to account for the fact that unlike the second pass chamber 44 the third pass chamber 50 has its upstream end at the top thereof and its downstream end at the bottom thereof. Accordingly the baffles 56 have upstream ends which are spaced a distance d_2 from the drum 26 and extend into contact with circumferential portions of the fins 52 at their downstream ends. As seen in FIG. 1 the lengths of the baffles 56 are less than the lengths of the baffles 54 within the chamber 44 to reduce the flow area. The flow area may be even further reduced in the chamber 50 as compared with the chamber 44 by making the distance d_2 less than the corresponding distance d_1 in FIG. 3.

Flue gases at the bottom of the third pass chamber 50 are directed under a partition 58 and into a fourth pass chamber 60 which extends between and is defined by the partition 58 and the end 18 of the boiler housing 12 and which is shown in detail in the sectional view of FIG. 5. The partition 58 extends between the opposite sides 22 and 24 of the housing 12 and the outside surface of the drum 26 from the top 14 of the housing to a level just below the axis of elongation 29 of the drum 26. The flue gases within the fourth pass chamber 60 are directed upwardly through a fourth pass in which they are caused to converge on the outside of the drum 26 and included fins 52 by a pair of baffles 62. The baffles 62 which are of like shape but shorter than the baffles 54 and 56, are mounted in a fashion similar to baffles 54 within the second pass chamber 44 in that they extend inwardly from positions spaced apart from the drum 26 a distance d_3 at their lower or upstream ends onto the outer edges of the fins 52 at their downstream

ends. Accordingly, as the gases undergo the fourth pass, they travel in directions which are opposite those of the third pass and the same as those of the second pass and which are normal to the axis of elongation 29 of the drum 26. The lengths of the baffles 62 in the direction of the axis of elongation 29 of the drum 26 are less than the corresponding lengths of the baffles 56 within the third pass chamber 50 to provide a further reduction in the flow area for the flue gases. Where desired the flow area can be even further reduced by making the distance d_3 less than the distance d_2 . The flue gases at the top of the fourth pass chamber 60 exit from the boiler 10 via a stack 64 in the top 14 of the boiler housing 12.

As previously noted, the flow path for the flue gases is gradually decreased in area without a significant increase in the frictional resistance of the path in a multi-pass system according to the invention. The various chambers 44, 50 and 66 and their included baffles define a flow path having a minimum of turns, constrictions and other friction producing items which generally require a larger and more powerful blower in the burner assembly 30. The cross-sectional area of the flow path may be selectively decreased by a number of factors including variation in the lengths of the chambers and included baffles and variation in the distances d_1 , d_2 and d_3 between the baffle upstream edges and the drum 26. With respect to the chamber lengths it has been found that satisfactory results are achieved if the lengths of the chambers 44, 50 and 60 respectively comprise 40, 35 and 25 percent of the length of the finned portion of the drum 26, although other proportions can of course be used. Where further reduction in flow path area is desired the baffles can be mounted such that d_2 is less than d_1 and d_3 is less than d_2 as previously discussed.

As previously noted, the fins 52 facilitate heat transfer between the hot flue gases and the liquid 34 in the inside of the drum 26. The circumferential disposition of the fins 52 relative to the drum 26 in accordance with the invention enables the fins to be subjected to substantial variations in temperature without excessively stressing or otherwise endangering the drum 26. The fins 52 can comprise individual fins, each of which encircles the circumference of the drum so that its opposite ends are joined together. For ease of manufacture, however, an arrangement shown in FIG. 6 is preferred in which the fins 52 are formed by helically winding a continuous strip of material 66 around the outside of the drum 26. As the strip 66 is wound about the drum 26 it is affixed thereto by appropriate means such as a plurality of spot welds 68 located at selected intervals around the circumference of the drum 26 or by a continuous weld such as at 70. Each "fin" which results from this technique extends around the circumference of the drum 26 with its opposite "ends" spaced apart from one another by the distance between adjacent fins and comprises a portion of the length of the strip 66.

The fins 52 may comprise any appropriate material which will provide good heat transfer and which is readily bonded to the steel or similar material typically comprising the drum 26. It has been found that the fins 52 may be fabricated from a strip of 12 gauge steel. The fins 52 may have any appropriate width, although it has been found that sufficient heat transfer is provided if fins at least 1 - 1 1/2 inches wide are used in relatively

small boilers and fins $2\frac{1}{2}$ – 3 inches wide are used for large boilers.

The various members such as the top 14, the bottom 16, the ends 18 and 20, and the sides 22 and 24 which comprise the housing 12, can be fabricated of any appropriate material such as a single sheet of steel or a sandwich of two sheets of steel with a layer of insulating material therebetween. For high temperature applications a metal-insulation-metal sandwich may be used with a further layer of insulating material being located on the inside thereof, and the inner sheet of metal may comprise a combination of aluminized steel at the upper portion thereof and stainless steel at the lower portion thereof, as desired.

It will be appreciated by those skilled in the art that boilers in accordance with the present invention eliminate many of the problems present in prior art boilers such as of the type in which fire tubes are mounted within the boiler drum. As already noted the use of circumferential fins on the outside of the boiler drum allows greatly improved heat transfer because of the greatly improved ability of this design concept to control uniformly the flue gas velocities. Heat transfer between the hot flue gases and the liquid inside the drum is further facilitated by the design of boilers in accordance with the invention wherein different chambers are defined by the use of partitions to provide a multi-pass system. The curved baffles within each chamber greatly aid in controlling the flue gas velocities and in directing the flue gases onto the outside of the drum. This type of multi-pass design also provides a low friction flow path of gradually decreasing area so as to maintain uniformly high flue gas velocity over the fins to more effectively extract heat from the flue gases. Heat transfer in accordance with the invention is even further improved by the absence of fire tubes and other obstructions within the drum which allows the liquid to freely circulate and to undergo turbulence at the inside surfaces of the drum.

Whereas prior art boilers of the "Scotch Marine" type and other similar types usually have a maximum efficiency on the order of 75 percent, it has been found that boilers in accordance with the invention have an efficiency more on the order of 80 or 81 percent with even higher values being attainable depending on design. Boilers of one particular design in accordance with the invention have been found to provide $5\frac{1}{2}$ – 6ft^2 of heating surface per boiler horsepower. The stack temperature where the flue gases exit from the boiler and which provides one measure of boiler efficiency must usually be no greater than about 600°F . if the boiler is to be considered reasonably efficient. In boilers in accordance with the invention the stack temperature is typically no greater than 450°F . and is frequently more on the order of 300° to 400°F .

The preferred embodiment of FIGS. 1–6 is shown and disclosed herein by way of example only, and it will be appreciated by those skilled in the art that modifications and variations thereof can occur within the scope of the invention. Boilers in accordance with the invention may comprise water or liquid boilers rather than a steam or vapor boiler of the type shown and described. The boilers need not be of the four-pass type but can include any number of passes desired. Also, the boiler need not necessarily be fired by a forced draft system using a furnace tube within the drum. Where available space or other design considerations dictate,

the boiler may be of the vertical type in which the axis of elongation of the drum is vertically rather than horizontally disposed.

What is claimed is:

1. In a boiler in which hot gases are generated by combustion within a liquid carrying drum, the hot gases being directed over the outside of the drum transversely in directions substantially perpendicular to the longitudinal axis of the drum, the improvement comprising a plurality of fins mounted on the outside of the drum, each of said fins extending around the entire circumference of the drum so as to form substantially a circle and comprising an elongated element of substantially uniform cross section mounted so as to be substantially perpendicular to the outer surface of the drum and having at least one flat edge in contact with the outer surface of the drum over substantially the entire length of the fin.

2. The invention defined in claim 1 above, wherein the fins comprise a strip which is helically disposed on the outside of the drum.

3. In a boiler in which hot gases are generated by combustion within a liquid carrying drum, the hot gases being directed onto the outside of the drum, the improvement comprising a plurality of fins mounted on the outside of the drum, each of said fins extending around the entire circumference of the drum, and baffle means having at least one curved element mounted on the outside of the fins at one end thereof and spaced apart from the fins at the other end thereof to cause the hot gases to converge on the fins and the outside of the drum.

4. A boiler comprising the combination of a generally cylindrical vessel having opposite enclosed ends and including means for receiving a liquid to be heated therein and means for allowing vapors formed within to pass out of the vessel, means for directing hot gases onto the outside of the vessel so as to flow over the outside surface of the vessel in directions generally normal to the direction of elongation of the vessel, and a plurality of fins mounted on the outside of the vessel, each fin encircling substantially the entire circumference of the generally cylindrical vessel so as to facilitate heat transfer between the hot gases and the inside of the vessel and comprising an elongated strip of uniform rectangular cross section defined by a pair of opposite broad surfaces and a pair of opposite narrow surfaces, each fin being mounted on the vessel so that the broad surfaces are perpendicular to the outside surface of the vessel and one of the narrow surfaces is in contact with the outside surface of the vessel over substantially the entire length of the fin.

5. A boiler comprising the combination of a generally cylindrical vessel having opposite enclosed ends and including means for receiving a liquid to be heated therein and means for allowing vapors formed within to pass out of the vessel, means for directing hot gases onto the outside of the vessel, a plurality of fins mounted on the outside of the vessel, each fin encircling substantially the entire circumference of the generally cylindrical vessel so as to facilitate heat transfer between the hot gases and the inside of the vessel, and at least one baffle comprising a flat element being curved so as to converge on the fins from locations spaced outwardly from the fins.

6. A boiler comprising the combination of a generally cylindrical vessel having opposite enclosed ends and

including means for receiving a liquid to be heated therein and means for allowing vapors formed within to pass out of the vessel, means for directing hot gases onto the outside of the vessel, a plurality of fins mounted on the outside of the vessel, each fin encircling substantially the entire circumference of the generally cylindrical vessel so as to facilitate heat transfer between the hot gases and the inside of the vessel, and means for directing the hot gases onto the outside of the vessel in at least two substantially opposite directions.

7. The invention defined in claim 6 above, wherein each of the at least two substantially opposite directions is generally normal to the axis of elongation of the generally cylindrical vessel.

8. The invention defined in claim 7 above, wherein the means for directing hot gases onto the outside of the vessel includes tube means disposed within the vessel for generating the hot gases from combustion therein and means coupled to the tube means for directing the hot gases onto the outside of the vessel in a first direction generally normal to the axis of elongation of the generally cylindrical vessel, and the means for directing the hot gases onto the outside of the vessel in at least two substantially opposite directions includes means for directing the hot gases onto the outside of the vessel in a second direction opposite the first direction and generally normal to the axis of elongation of the generally cylindrical vessel and means for directing the hot gases onto the outside of the vessel in a third direction the same as the first direction and generally normal to the axis of elongation of the generally cylindrical vessel.

9. In a boiler in which hot gases are directed onto the outside of an elongated drum to heat liquid contained within the drum, the improvement comprising means for directing the hot gases through successive different passes over the outside of the drum, each of said passes comprising simultaneous flow of the gases around opposite sides of the drum in directions generally perpendicular to the direction of elongation of the drum through substantially the entire transverse dimension of the drum.

10. The invention defined in claim 9 above, wherein the directions of each successive pair of passes are generally opposite one another.

11. The invention defined in claim 9 above, further including a plurality of fins mounted on the outside of and encircling the elongated drum in a generally transverse direction, the fins being generally parallel to the directions of the successive different passes.

12. The invention defined in claim 9 above, wherein the means for directing includes means for providing a flow path for the hot gases having an area which decreases with each successive different pass.

13. The invention defined in claim 9 above, wherein the means for directing includes means associated with each pass for decreasing the area of a flow path for the hot gases through the pass.

14. The invention defined in claim 10 above, further including a housing surrounding and enclosing at least a part of the elongated drum, and partition means extending between the inside of the housing and the outside of the elongated drum to define a plurality of chambers, each of the chambers being operative to receive and direct hot gases through one of said passes over the outside of the drum.

15. The invention defined in claim 14 above, wherein the lengths of the chambers decrease with each different succeeding pass contained therein so as to provide a flow path of continually decreasing area for the hot gases.

16. The invention defined in claim 15 above, further including baffle means disposed within each chamber, said baffle means extending from a location spaced outwardly from the drum and the fins at one end thereof adjacent one end of the associated chamber where hot flue gases enter the chamber to a location adjacent the drum and the fins at the other end thereof to provide a flow path of decreasing area for the hot gases and to cause the hot gases to converge on the outside of the drum.

17. The invention defined in claim 16 above, wherein the distance between said one end of each baffle means and the drum decreases with each succeeding chamber and the pass contained therein.

18. A boiler comprising the combination of:

an elongated, generally cylindrical drum having opposite closed ends;

a plurality of fins mounted on the outside of the drum so as to extend around the drum in a circumferential direction, the fins being spaced apart from one another along an axis of elongation of the drum;

a housing surrounding and enclosing at least a part of the drum;

a furnace tube mounted within and having opposite ends disposed adjacent the opposite closed ends of the drum;

burner means coupled to one of the opposite ends of the furnace tube for generating hot gases within the furnace tube, the path of the hot gases through the furnace tube defining a first pass of the hot gases relative to a liquid to be heated within the drum; and

partition means extending between the inside of the housing and the drum to define three separate chambers, a first such chamber receiving the hot gases from the other one of the opposite ends of the furnace tube and directing the hot gases over the outside of the drum in directions normal to the axis of elongation of the drum to define a second pass of the hot gases relative to a liquid to be heated within the drum, the second such chamber receiving the hot gases from the first chamber and directing them over the outside of the drum in directions normal to the axis of elongation of the drum but opposite the directions of the second pass to define a third pass of the hot gases relative to a liquid to be heated within the drum, and the third such chamber receiving the hot gases from the second chamber and directing them over the outside of the drum in directions normal to the axis of elongation of the drum and parallel to the directions of the first pass to define a fourth pass of the hot gases relative to a liquid to be heated within the drum.

19. The invention defined in claim 18 above, further including baffle means within at least one of the chambers, the baffle means comprising at least one curved element which extends from a location spaced apart from the drum onto the fins.

20. The invention defined in claim 19 above, wherein the drum is disposed with its axis of elongation generally horizontal, the first and third chambers direct the hot gases upwardly around opposite sides of the drum,

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the second chamber directs the hot gases downwardly around opposite sides of the drum, the lengths of the first, second and third chambers and included baffle means in the direction of the axis of elongation of the drum are such that the lengths of the first chamber and included baffle means are greater than the lengths of the second chamber and included baffle means which

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are greater than the lengths of the third chamber and included baffle means, and the distance between the curved element comprising the baffle means and the drum is greater within the first chamber than within the second chamber which is greater than within the third chamber.

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