United States Patent

Hoch

[15] **3,635,284**

[45] **Jan. 18, 1972**

[54] **FLASH BOILER**

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[22] Filed: **May 21, 1970**

[21] Appl. No.: **39,265**

[52] **U.S. Cl.** ....**165/39,** 165/165, 237/12.3 B

[51] **Int. Cl.** **B60h 1/00**

[58] **Field of Search** ....165/39, 22, 165; 237/12.3 B

[56] **References Cited**

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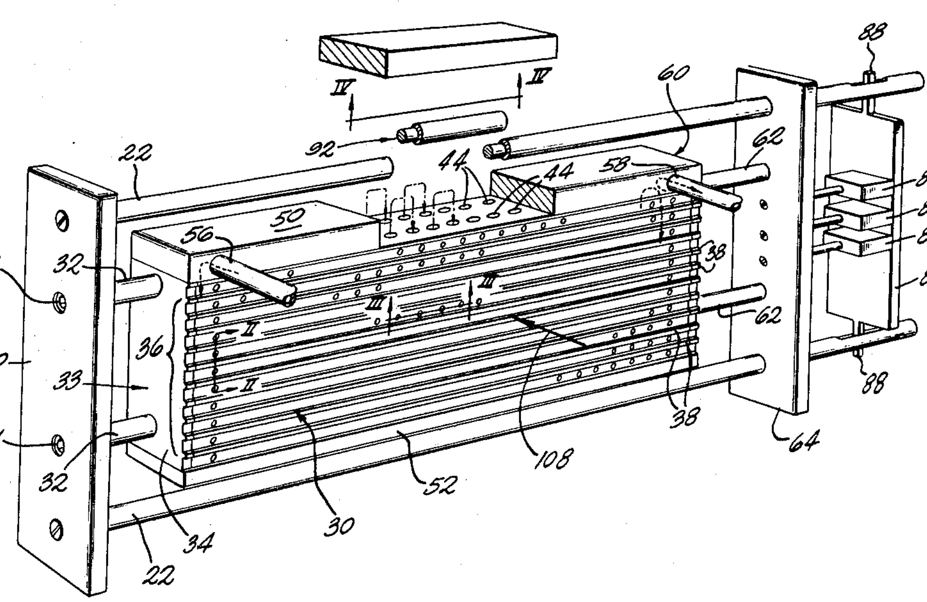
[57] **ABSTRACT**

A flash steam boiler utilizing a solid metallic core wherein the heat exchange passageways are drilled, the hot gas openings extending perpendicularly through the core with the water passages winding in a dual serpentine path through the core so as to contact both sides of the metal surfaces surrounding each gas passageway. The cores can be stacked so as to exchange heat between the gas flow and the serpentine path at a plurality of discreet levels. Because the cores are metallic, the ends of at least one core in each boiler is provided with a sensing plate which is caused to move by thermal expansion of the entire core toward a plurality of microswitches controlling the operation of the boiler, each of the microswitches being activated at a different amount of thermal expansion of the core.

35 Claims, 17 Drawing Figures



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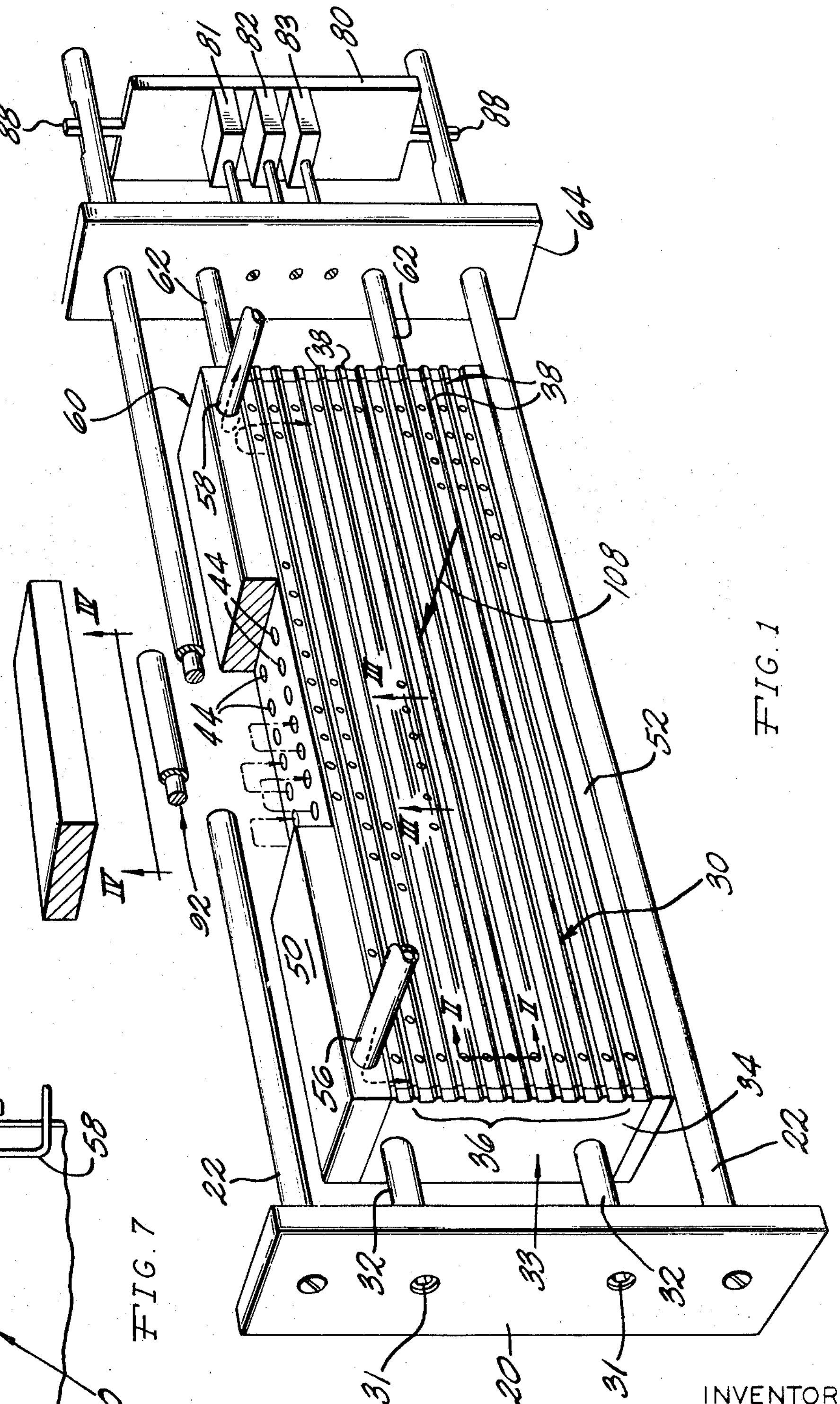

FIG. 1

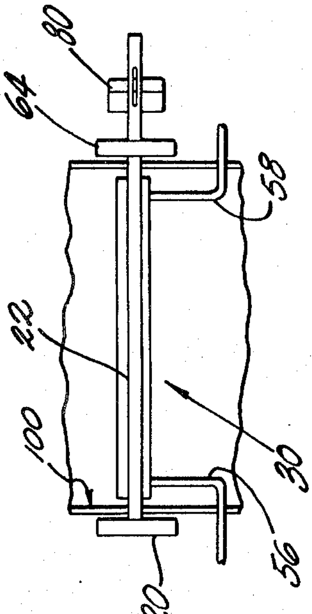

FIG. 7

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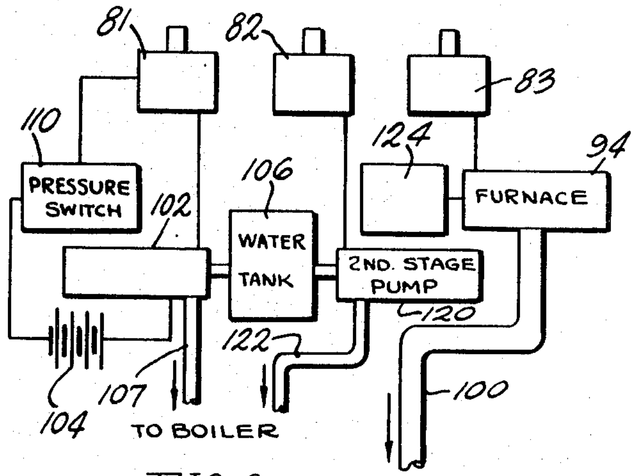

FIG. 8

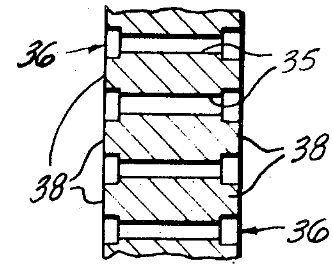

FIG. 2

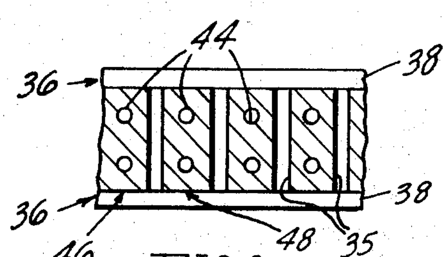

FIG. 3

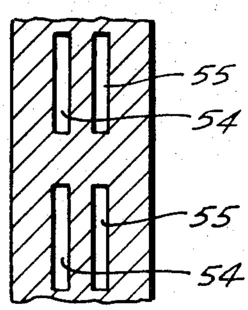

FIG. 4

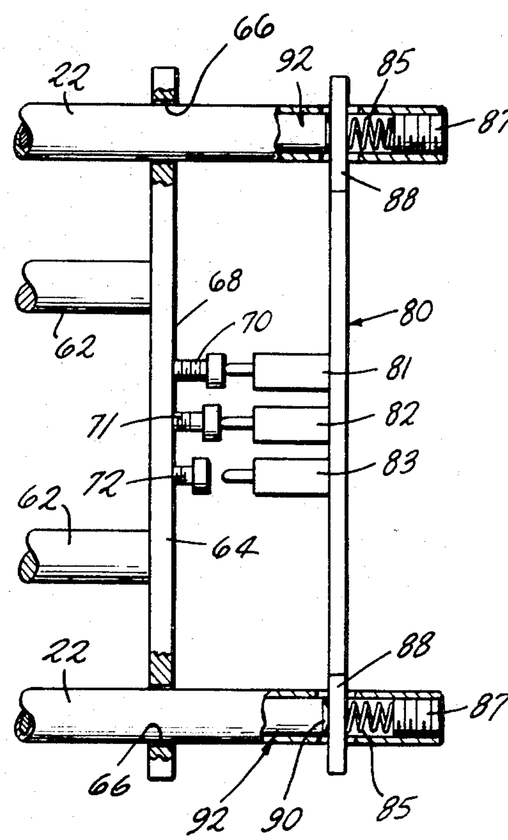

FIG. 6

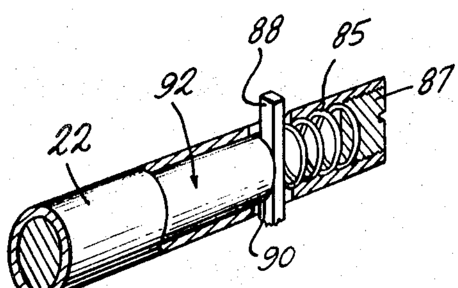

FIG. 5

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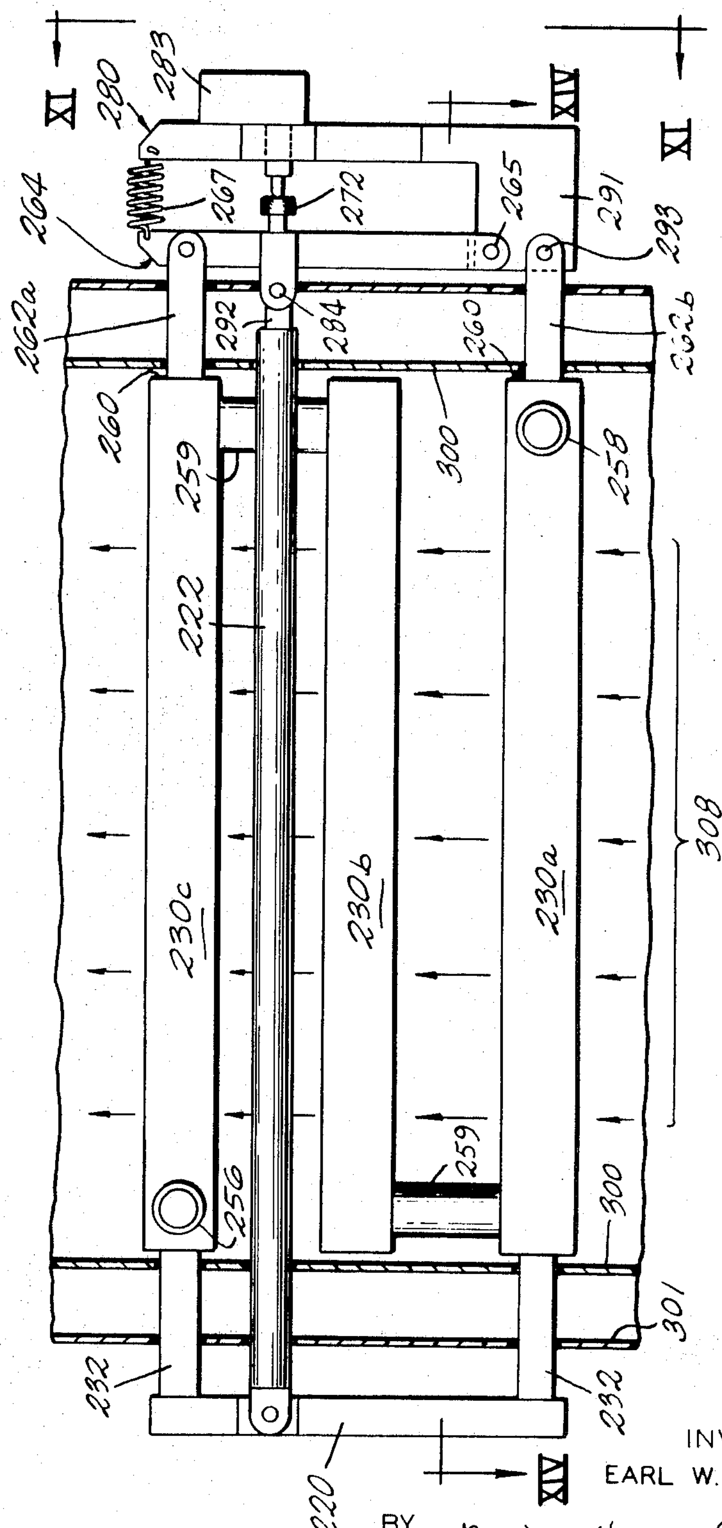

FIG. 9

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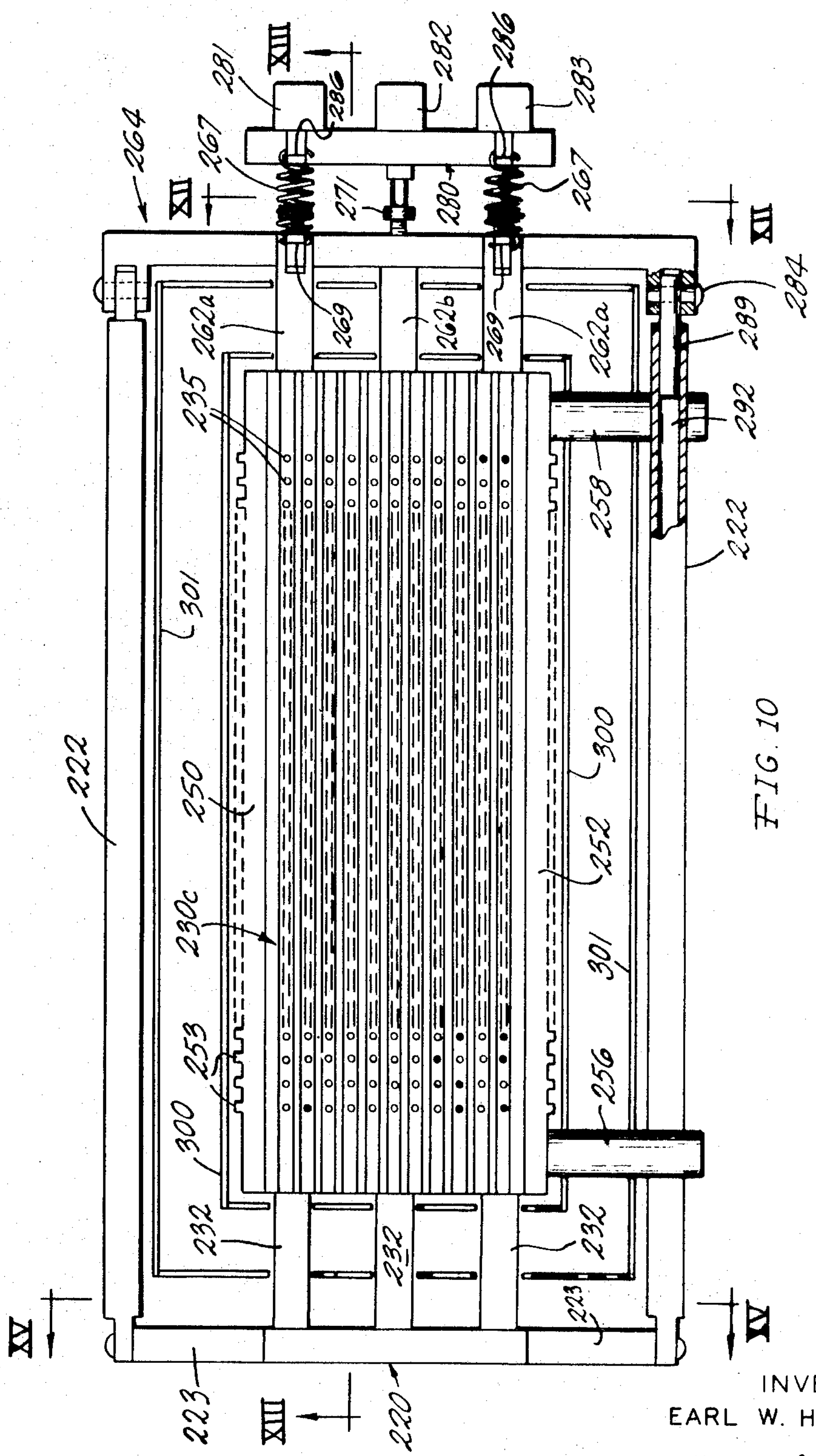

FIG. 10

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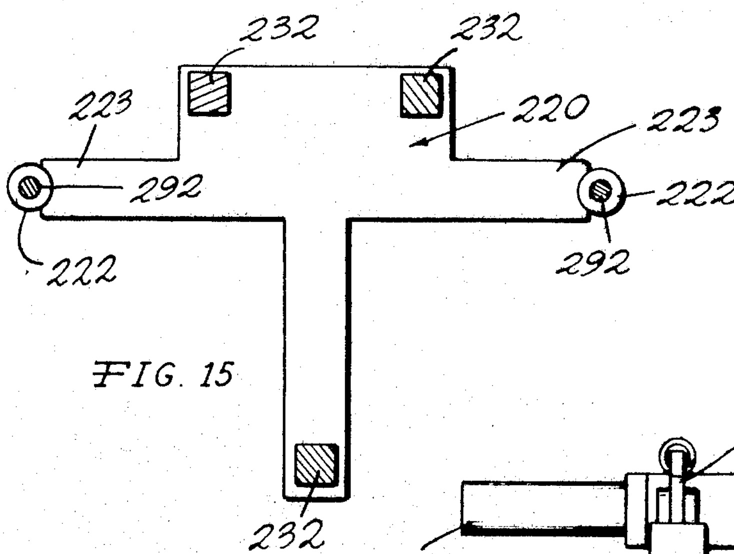

FIG. 15

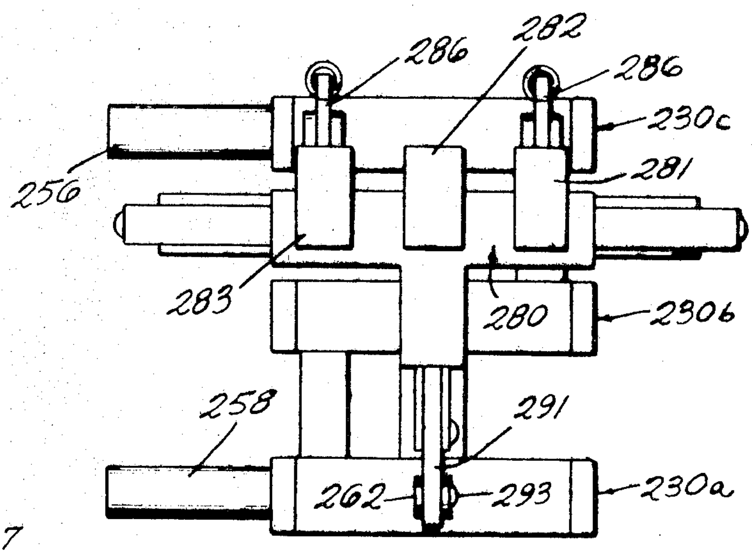

FIG. 11

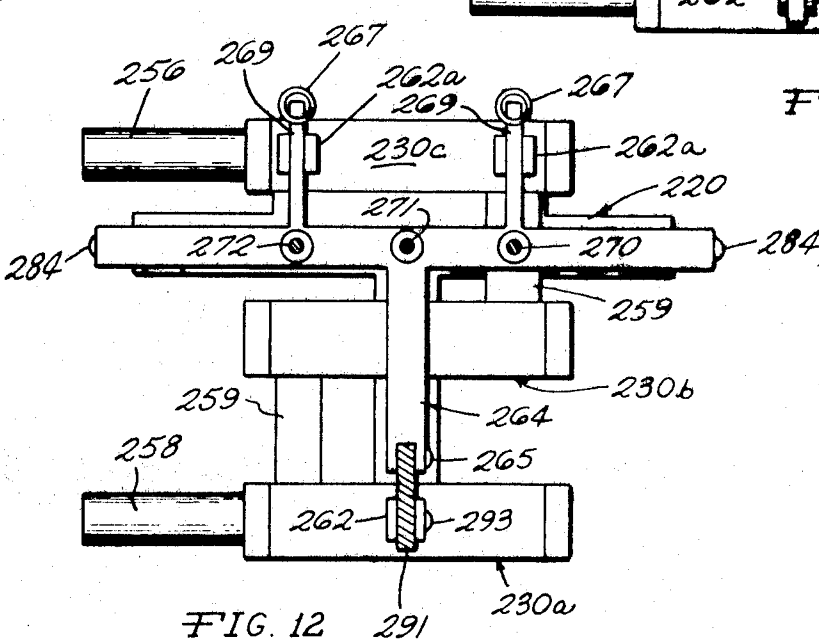

FIG. 12

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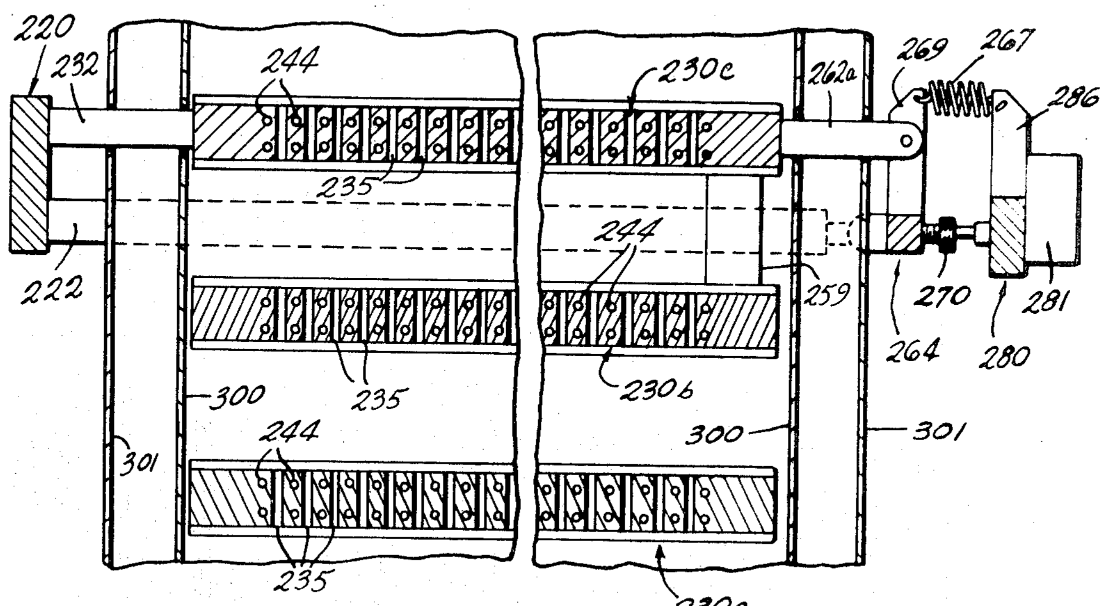

FIG. 13

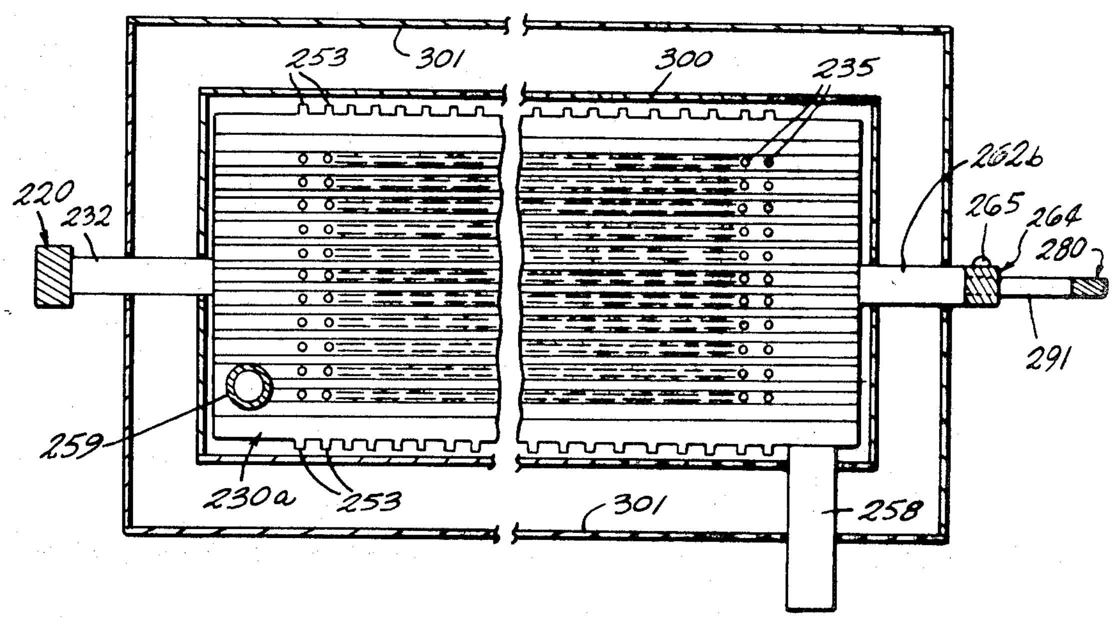

FIG. 14

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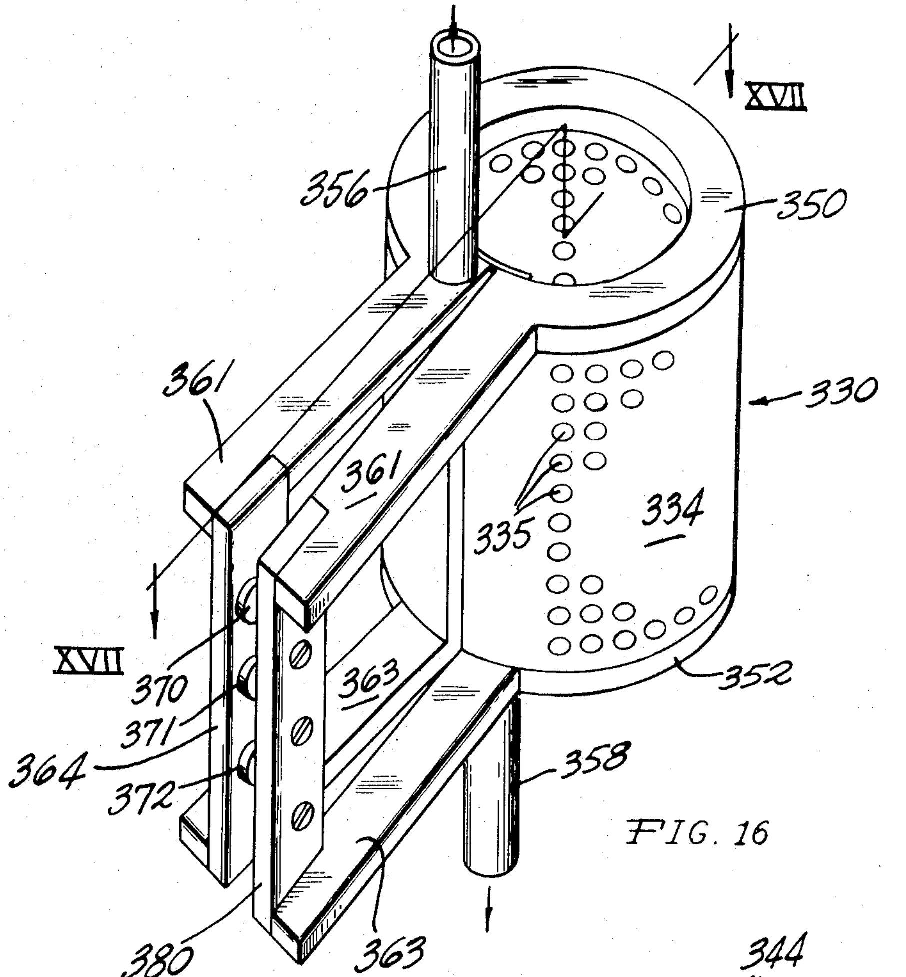

FIG. 16

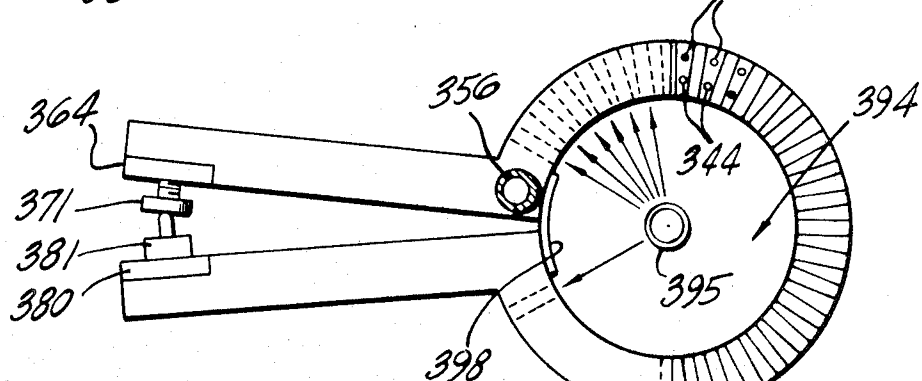

FIG. 17

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FLASH BOILER

BACKGROUND OF THE INVENTION

To convert water into steam, it is customary to utilize a boiler wherein the heat from gases of combustion is transferred to the water. A problem with boilers today and particularly when used with automobiles is to construct them so as to operate efficiently, at the same time occupying a minimum amount of space, and yet be controlled automatically. The use of a boiler to drive an automobile requires that the water be converted to steam at the proper pressure as soon as possible. This is best accomplished, for purposes of efficiency, by extracting as soon as possible as much heat as possible from the hot gases of combustion. The further use of a boiler in an automobile requires that no manual switching of the boiler be necessary other than turning it "on" and "off."

It will be apparent then that one problem is to provide maximum contact between the water and the surfaces of the pipes or other conductors carrying the hot flue gases, at the same time minimizing the amount of space such construction requires, in such a way as to allow the boiler to be automatically operated.

Other problems particularly pertinent to flash boilers is the presence of hot spots due to uneven heating, and the high pressure necessarily generated by the boiler under the best of conditions. Both of these problems have required very meticulous manufacturing standards, thus increasing the cost of flash boilers.

SUMMARY OF THE INVENTION

This invention relates to a flash boiler and the heat exchanger utilized in the flash boiler which achieves a maximum efficiency with a minimum of space and cost and with automatic controls. Specifically, the invention provides improvements in a heat exchanger utilizing passageways for carrying both a hot and cold medium for the exchange of heat therebetween, one improvement including the passageways for one of the mediums being positioned to confine the flow of that medium to a nonlinear path which contacts the exchanging surfaces of substantially all of the passageways for the other of the mediums on at least two opposite sides thereof. The contact on the two opposite surfaces of each of the passageways for the other of the mediums provides maximum contact, particularly when the passageways of the heat exchanger are confined to a planar core. This improvement also includes the use of a plurality of cores stacked together, the planar nature of the cores allowing them to be stacked parallel to each other with a minimum of space therebetween. With such a construction, the confinement of the flow of the one medium to a nonlinear path can contact the aforesaid surfaces of each of the passageways for the other of the mediums at a plurality of points discontinuously spaced along the length of each of the aforesaid surfaces. To this end, the nonlinear path representing the confinement of the one medium is a serpentine path which contacts all of the passageways for the other of the mediums in each of the cores, one core at a time, moving in a direction to maintain a maximum temperature differential between the two mediums.

A further improvement comprises the use of positive direct sensing of the core of the exchanger to determine the temperature limitations of operation of the core. This is accomplished by positioning sensing means adjacent to the end of the core for sensing dimensional changes of the same due to the operation of the exchanger, and providing controlling means operatively connected to the sensing means for controlling the amounts of hot and cold mediums to be supplied to the passageways of the core in response to the sensed dimensional changes of the core.

Still another improvement utilizes the wrapping of the core about itself in a cylindrical manner so as to confine the combustion chamber within the core.

Accordingly, it is an object of the invention to provide a heat exchanger in a flash boiler which, by drastically increased contact between the heat-exchanging surfaces of both mediums, a maximum efficiency utilizing a minimum of space is obtained.

It is another object of the invention to provide a heat exchanger of the above character wherein a maximum amount of heat is extracted from the heat source by repeated contact with the heat sink in a minimum amount of space necessary for this end.

It is a related object of the invention to provide a heat exchanger of the above character wherein a positive and direct control is obtained over the operations by sensing the dimensional changes in the core of the exchanger.

It is further object of the invention to provide a heat exchanger of the above character wherein the heating is uniform, without requiring expensive manufacturing techniques.

Other objects and advantages will become apparent upon reference to the following drawings and detailed discussion.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a partially exploded perspective view of a flash boiler constructed in accordance with the invention;

FIG. 2 is a fragmentary sectional view taken along the line II—II of FIG. 1;

FIG. 3 is a fragmentary sectional view taken along the line III—III of FIG. 1;

FIG. 4 is a fragmentary bottom view taken along the line IV—IV of FIG. 1;

FIG. 5 is a fragmentary perspective view with portions broken away, showing the details of the supporting rod illustrated in FIG. 1;

FIG. 6 is a fragmentary, partially sectioned and broken away, elevational view of the control end of the boiler illustrated in FIG. 1;

FIG. 7 is a partially schematic plan view of the boiler of FIG. 1, illustrating its position in the flue pipe;

FIG. 8 is a schematic diagrammatic view illustrating the control of the boiler;

FIG. 9 is a front elevational view of a plurality of flash boilers similar to that shown in FIG. 1 through 7 positioned in a stacked arrangement;

FIG. 10 is a plan view of the arrangement shown in FIG. 9;

FIG. 11 is an end elevational view with the insulating wall removed for clarity, of the arrangement shown in FIG. 9, taken generally along the line XI—XI;

FIG. 12 is a sectional view taken along the line XII—XII of FIG. 10, the insulating wall having been removed for clarity;

FIG. 13 is a sectional view taken along the line XIII—XIII of FIG. 10;

FIG. 14 is a sectional view taken along the line XIV—XIV of FIG. 9;

FIG. 15 is a sectional view taken along the line XV—XV of FIG. 10;

FIG. 16 is a perspective view of an alternate embodiment of the flash boiler of the invention; and

FIG. 17 is a sectional view taken generally along the line XVII—XVII of FIG. 16.

DESCRIPTION OF THE PREFERRED EMBODIMENT

As used throughout this application, the words "horizonal" and "vertical" are not absolute terms but are to be construed on the basis of the relationships depicted in the figures illustrating the described embodiment.

The invention relates to heat exchangers and specifically to a flash boiler specifically designed for use with an automobile engine or boat engine. The flash boiler is thus designed to exchange heat from hot gases of combustion to water so as to turn the latter into steam, the steam being utilized to drive the automobile or boat engine.

Referring to FIGS. 1 through 7, the embodiment illustrated therein includes a frame 20 and two stabilizing tubes 22 bolted at opposite ends of the frame 20. A core 30 is held by bolts 31 to the frame 20 between the bolts holding the tubes 22, the bolts 31 passing through standoff spacer tubes 32 which extend from the frame 20 to one end 33 of the core 30. By "-core," it is meant a solid platelike member, preferably of metal such as stainless steel. It is within the core that the heat exchanging takes place.

At the opposite end 60 of the core 30, rods 62 project therefrom and mount a sensing plate 64, which plate is provided with openings 66 (FIG. 6) for sliding over the stabilizing tubes 22. The sensing plate or member 64 cooperates with a control plate or member 80 positioned at the end of the stabilizing tubes 22 opposite to the ends joined to the frame 20.

The entire arrangement is then positioned within a flue pipe 100 as shown in FIG. 7, the stabilizing tubes 22, the spacer tubes 32, the rods 62, and the water inlet and outlet tubes 56 and 58 projecting through bushings located in the walls of the pipe 100.

THE CORE

Referring to FIGS. 1 through 4, the core 30 comprises a platelike member 34 of stainless steel having a plurality of generally circular passageways or openings 35 extending perpendicularly through the plate. In addition, heat exchanging passageways 44 extend through the member 34 in the plane of the member and perpendicularly to the direction of the passageways 35. The portion of the core member 34 between the openings 35 and 44 is the heat exchanging media of the core, the surfaces of the passageways 44 being the primary heat exchanging surfaces in that the heat generated by gases flowing through the openings 35 is released through these surfaces 44.

Each of the openings 35 is uniformly drilled so as to form a plurality of horizontal rows 36 and vertical columns one of which is partially shown in FIG. 2. Thus, the openings 35 are nonconnecting. Each of the rows 36 is recessed on both sides of the plate 34 so as to form a plurality of fins 38 between the rows.

Referring now to the passageways 44 and particularly as shown in FIGS. 1 and 3, these passageways are formed by drilling two holes between each column of openings 35, the two holes drilled between each column being parallel so as to establish a plane which is parallel to and between two columns of openings 35. Thus, the plane 46 defined by two openings 44 provides a parallel passage for the heat exchanging medium forced therethrough in an upward direction as shown in FIG. 1, whereas the plane 48 defined by two openings 44 provides parallel passage for the heat exchanging medium in a downward direction as viewed in FIG. 1.

It will be readily appreciated that the uniformly spaced drilling of the passageways 35 and 44 into a solid core greatly facilitates the manufacturing of the boiler, and provides a core which provides uniform heat expansion while retaining its strength.

Header plates 50 and 52 are welded to the edges of the core 34 representing the end of the passageways 44. The headers have provided therein on the underside thereof (FIG. 4) pairs of parallel slots 54 and 55, each pair comprising one slot 54 and one slot 55 and lining up with four openings 44. Each slot in the pair extends perpendicular to the plane of parallel openings defining one direction of travel of the heat exchanging medium. Thus, one pair of slots 54 and 55 are positioned so as to extend transversely to the planes 46 and 48, thereby linking up two of the passageways 44 by each of the slots. In this way, a turnaround is provided for the heat exchanging medium.

At one end of the header 50, a water inlet tube 56 is attached thereto, and at the other end of that header a water outlet tube 58 is similarly attached.

THERMAL EXPANSION CONTROL

Turning to FIGS. 5 and 6, the sensing plate 64 has mounted at the side 68 opposite to the side mounting the support rod 62 a plurality of abutments 70 through 72. Each of the abutments comprises an adjusting screw which can be turned into the plate 64 a prescribed distance. The positions of the adjusting screws 70 through 72 are such as to be aligned with the appropriate parts of the control plate 80. Those parts of the control plate are microswitches 81, 82 and 83 which control various functions and operations of the boiler as hereinafter described. The plate 80 is fixedly mounted with respect to the flue pipe 100 inasmuch as it is floatingly mounted within the stabilizing tubes 22 by means of a spring 85 held in place in each tube 22 by a threaded slug 87. The springs 85 press against one side of ears 88 extending from the control plate 80. The opposite side of the ears 88 is pressed against the end 90 of a carbon rod 92. Thus, whereas the stabilizing tube 22 undergoes thermal expansion, the carbon rod 92 undergoes very little expansion so as to maintain the position of the control plate fixed with respect to its original orientation. In contrast, the rods 62 expand outwardly due to the expansion of the core and of the rods themselves as the core is heated, thereby pushing the sensing plate 64 outwardly so as to bring the adjusting screws 70 through 72 into contact with their respective microswitches. The plate 64 is mounted via openings 66 for relative movement upon the stabilizing tubes 22 because the rods 62 tend to expand outwardly at a rate which exceeds the expansion of the stabilizing tubes 22.

OPERATION

As indicated previously, the heat exchanger is specifically designed as a flash boiler for driving a steam engine. Accordingly, referring to FIG. 8, when an ignition switch (not shown) is turned on, the furnace or combustion chamber 94 is activated and the hot flue gases flow through the pipe 100 and through the core 30 (FIG. 7). This continues until the temperature of the boiler rises to between 400° and 500° Fahrenheit at which time the core 30 and the rods 62 have expanded sufficiently so as to move the sensing plate 64 outwardly to the point where adjusting screw 70 abuts the microswitch 81. This closes the circuit to a first stage feed water pump 102 which operates from a battery 104, the pump supplying a relatively low volume of water from a water tank 106 to the boiler through a line 107 emptying into the inlet tube 56. The water then flows through the serpentine path defined by the passageways or openings 44, the water dividing up into the paired passageways and flowing first downwardly as viewed in FIG. 1 and then upwardly on the opposite side of the first column of flue openings 35. The serpentine path continues flowing in a direction perpendicular to the direction of flow of combustion gases through the flue openings 35, the latter being designated by the arrow 108, FIG. 1. The water flow thus contacts the portion of the core surrounding each of the openings 35 on two opposite sides thereof, thereby increasing the heat exchange efficiency. By the time the water flow reaches the outlet 58, at least a portion of it has turned to steam and the pumping by the pump 102 continues until the steam pressure rises to between 700 and 800 pounds. At this point, a pressure switch 110 opens the circuit to the pump 102 so as to cut off the flow of water to the flash boiler, thus causing the temperature of the boiler to increase to between 700° and 800° F. This increase of temperature causes an increase in expansion in the core 30 and the rods 62 so as to move the sensing plate 64 out further until the adjusting screw 71 abuts the microswitch 82. A second stage pump 120 is continuously driven by the engine (not shown), which in turn is driven by the steam produced by the boiler. However, until the microswitch 82 is activated, the pump empties all of its water back into the water tank 106 by a bypass line (not shown). When the microswitch 82 is activated, a solenoid valve switches the flow of the water delivered by the second stage pump 120 to a line 122 which joins the line 107 coming from the pump 102. The second stage pump 120 then supplies a larger volume to the water inlet tube 56. The larger volume of flow delivered by the second stage pump 120 provides a steam pressure between 1,000 and 1,200 p.s.i.

A second stage pressure switch 124, which could be an additional stage in switch 110, is included to shut off the furnace or combustion chamber 94 in the event of pressure delivered by the boiler exceeds 1,200 p.s.i. Also, the furnace or chamber 94 is shut down by the actuation of the microswitch 83 which is set to occur if for any reason the temperature of the boiler exceeds between 1,000° and 1,100° F. That is, the adjusting screw 72 is positioned so as to trigger the microswitch 83 when the core 30 and the supporting rods 62 have expanded to the point which represents a core temperature of between 1,000° and 1,100° F.

Each of the aforedescribed operations is reversible so that when the temperature or pressure drops, the switches which were closed when the temperature or pressure rose are reversed so as to reverse the effect that these switches had.

STACKED CORE EMBODIMENT

Referring now to FIGS. 9 through 15, there is illustrated an alternate embodiment wherein a plurality of cores similar to that described in FIGS. 1 through 7 are stacked and utilized together to increase the heat exchange between the water flowing through the serpentine path and the hot combustion gases flowing perpendicularly thereto. To clearly identify those portions which perform a function similar to the parts described in connection with the previous embodiment, the same reference numeral is utilized with the addition of the number 200.

Thus, a plurality of cores 230*a*, 230*b* and 230*c* are stacked one above the other within a flue pipe 300, the latter being provided with a double wall formed by the exterior wall 301 to insulate the flue pipe 300 from the exterior. A frame 220 mounts the cores 230*a* and 230*c* by means of standoff spacers 232 which may be integrally formed therewith. The opposite end 260 of the cores 230*a* and 230*c* are provided with rods 262*a* and 262*b*. The rods 262*a* (FIGS. 9 and 12) are hingedly connected to a sensing member 264, whereas the rod 202*b* is hingedly connected to a control member 280. As further hereinafter described, the sensing member 264 is also connected with a stabilizing tube 222, the opposite end of the tube 222 being hingedly connected to the ends of arms 223 of the frame 220 (FIG. 15).

The flow of the combustion gases is conveyed by the flue pipe 300 in the direction of arrows 308 through the openings 235 perpendicular to the three levels established by the parallel cores 230*a*, *b* and *c*.

The cores 230*a*, 230*b* and 230*c* are identical with the core 30 described in the previous embodiment with the following exceptions: the headers 250 and 252 are each provided (FIG. 10) on the external edges thereof with fins 253, these fins extending to but not touching the walls of the flue pipe 300. The gaps between the fins 253 and the pipe 300 allow thermal expansion in the transverse direction of the core. Only the header 252 for core 230*c* has a water inlet tube 256, and only the header 252 for the core 230*a* has a steam outlet tube 258 (FIG. 9). The remaining connection from each core to the adjacent core is via connecting pipes 259. The connecting pipe 259 joining the serpentine path of core 230*a* to that of core 230*b* joins the latter at the lower left-hand corner of the core as shown in FIG. 14. On the other hand, the pipe 259 joins the serpentine path core 230*c* with that of 230*b* by attaching to the latter at the opposite end of the core 230*b* (FIG. 13), preferably at the diagonally opposite corner, to prevent short circuiting of the water flow.

Thus, the flow of water either as a liquid form or as steam proceeds from the inlet tube 256 through the passages 244 in a serpentine path in and out of the plane of the page as viewed in FIG. 13 until the end of the core 230*c* is reached at which point the pipe 259 is connected. The water then flows down the pipe 259 and into the next core 230*b* wherein it traces a serpentine path to the opposite end of that core at the point at which pipe 259 connects core 230*b* to core 230*a*. The water then flows into the core 230*a* to follow the serpentine path in that core. The water in the form of steam exits out through tube 258. Thus, the water flowing in the passageways 244 touches the heat transferring surfaces of the openings 235 at a plurality of points discontinuously spaced along the length of the passageway for the flue gas through the pipe 300. By "-points discontinuously spaced along the length," it is meant a spacing distinguished from a continual spacing along the entire length of the passageway, so as to indicate instead at discreet locations or levels only. It is this repeated exchange of heat by repeated passes of the serpentine path between the passageways of the flue gases which allows maximum efficiency of heat exchange. Also, a counterflow for the water with respect to the direction of flow for the hot combustion gases provides a maximum temperature differential between the two mediums and thereby a maximum heat transfer.

The control of the boiler of this embodiment is accomplished by the sensing member 264 and the control member 280, which in turn are generally flat, cantilevered T-members. The sensing member 264 is hingedly connected by a hinge pin 265 to the control member 280, but it also pivots about a pivot pin 284 which is connected to a stud or plunger 289 that extends into the stabilizing tube 222 to contact a carbon rod 292. This causes the pin 284 to remain in a fixed position during boiler operation. The end of the sensing member 264 opposite to the hinged pin 265 has upstanding lugs 269 (FIG. 12) provided with two tension springs 267 which bias the control member 280 and the sensing member 264 together (FIG. 10). As in the previous embodiment, adjusting screws 270, 271 and 272 are spaced along the sensing member 264, but in this case, they are positioned horizontally rather than vertically. The control member 280 is also a flat "T" member having upstanding lugs 286 (FIGS. 10 and 11) similar to the lugs 269 on the sensing member 264, and mounting the opposite end of the springs 267. The control member 280 mounts the microswitches 281, 282 and 283 as in the previous embodiment, the positions of the microswitches being opposite to the adjusting screws 270, 271 and 272. The base 291 of the control member 280 extends toward the core 230*a* from the plane defining the support surface for the microswitches, and is joined to the sensing member 264 by the hinge pin 265 (FIG. 12). Below the hinge pin 265, the base 291 is joined to the rod 262*b* by a hinge pin 293.

The operation of this embodiment is identical to the first embodiment described insofar as the basic steps of operation are concerned. Thus, the microswitch 281 is triggered by its abutment with screw 270 when the temperature reaches between 400° and 500° F., the microswitch 282 is triggered by its abutment with screw 271 when the temperature increases to between 700° and 800° F., and the microswitch 283 is triggered by its abutment with 272 when the temperature of the boiler rises to a point between 1,000° and 1,100° F. However, the operation is somewhat different insofar as the relative positions of the control member and the sensing member are concerned. That is, the fixed point for the sensing member 264 is the pivot pin 284. The first of the three cores to expand is the core 230*a*, which pushes out on the base 291 to cause the control member 280 to pivot inwardly about pin 265 to bring the microswitches toward the adjusting screws rather than vice versa. The only movement of the sensing member 264 with respect to its original position occurs to a slight extend when the core 230*c* expands as it begins to heat up, this expansion causing the sensing member 264 to pivot about the pin 284 to only a very slight extent in a clockwise direction as shown in FIG. 9. Thus, the lever formed by the member 264 can be considered to be relatively fixed. The minor movement which it does experience further enhances the bringing together of the microswitches and their respective abutments with the adjusting screws. Because of the leverage of the connection between the control member 280 and the sensing member 264, a small expansion of the cores provides a large relative movement between the microswitches and their abutments with the adjusting screws.

Since the last of the cores 230*c* to receive the flue gases does so at a reduced temperature, that core can be formed from aluminum.

THE CYLINDRICAL CORE EMBODIMENT

FIGS. 16 and 17 illustrate yet another embodiment wherein the core is wrapped around itself to form a cylindrical tube. Parts performing a function similar to those described in the first embodiment are indicated by the same reference numeral to which the number 300 has been added.

Thus, the core 330 comprises a cylindrical tubular plate 334 through which flue gas passageways 335 extend on lines radiating from the center axis of the core 334. Water passageways 344, of which only several are shown, extend between the columns of passageways 335 and parallel to the center axis of the cylindrical tube. The headers 350 and 352 are similarly cylindrically bent so as to fit upon the edges of the core 334, the water entering into the core through the inlet tube 356 and exiting as steam through the outlet tube 358. The opposite ends of the header 350 radiate outwardly as arms 361 while the opposite ends of header 352 radiate outward as arms 363. Each of the arms 361 parallels an opposite arm 363, so as to mount either the sensing plate or member 364 or the control plate or member 380. The sensing plate member 364 has mounted thereon adjusting screws 370, 371 and 372, while the control plate has mounted thereon the respective microswitches of which only microswitch 381 is shown.

Because the core 330 is cylindrical, it is possible to incorporate the combustion chamber 394 within the core. In that case, the pipe 395 is the firing gun for the combustion chamber and is positioned near one end of the cylindrical core so as to allow the combustion to occur substantially along the entire length of the core. Or, the combustion chamber can be removed from the core and in that case, the pipe 395 is a portion of the fuel pipe coming from the combustion chamber. In either case, the end opposite to the pipe 395 is closed off and the combustion gases are carried away from the exterior of the core 330 by flue pipes not shown.

Because of the slight gap between the ends of the core plate 334 provided for thermal expansion, it is necessary to provide a sealing plate 398 (FIG. 17) which is fixed to at most only one of the two ends of the core 334.

The operation of the cylindrical core embodiment is exactly that of the first embodiment, except that as the core 330 expands, the cylindrical tube formed thereby tends to open upon itself, thereby causing the sensing plate 364 and the control plate 380 to depart each other so as to activate the microswitches at different points in the approach as controlled by the thermal expansion and the different settings of the adjustment screws. If desired, one of the plates 364 and 380 may be fixed, so as to cause the other to move during thermal expansion. The water flow through passageways 344 turns around in the headers 350 and 352 in the same manner as the previous embodiments.

It will be readily recognized that one advantage of the cylindrical embodiment is that it does away with the need for a frame such as frame 20 or 220 and for the stabilizing tubes 22 or 222.

Although the invention has been described in connection with several preferred embodiments, it will be readily appreciated that modifications can be made within the scope of this invention. For example, if stacked cores are to be utilized, any number of cores can be so stacked. Also, where a stack has been shown to be vertical so that the flow of the water through any one core is horizontal, the entire arrangement can be rotated 90° so as to arrange the stack horizontally. Furthermore, any orientation of the cores can be utilized inasmuch as the orientation with respect to the steam engine driven by the boiler is not important. Finally, it is not necessary that the microswitches be relatively positioned so that the next to be activated as the combustion chamber and core heat up is the next adjacent switch. Thus, with reference to the first embodiment, the microswitch 83 could be the switch which activates the second stage pump whereas the microswitch 82 when activated shuts down the combustion chamber. In that case, the adjusting screws are positioned so as to be the proper distance

from the microswitch. Also, additional microswitches can be added to the control plate or member along with appropriate abutting adjusting screws to perform other control functions, if desired. With respect to the microswitches and their respective adjustment screws, the controlling requirement is that each adjustment screw abuts one of the microswitches at a point in the thermal expansion of the core which is different from the point at which any other microswitch is abutted by its adjusting screw.

Thus, it is intended that the invention include as well alternate equivalent embodiments unless expressly stated otherwise in the following claims.

The embodiments of the invention in which an exclusive property or privilege is claimed are defined as follows.

1. In a heat exchanger for transferring heat from a first medium to a second medium, the exchanger including a set of passageways having external heat-exchanging surfaces and confining the flow of the first and second mediums in the vicinity of each other; the improvement comprising said passageways for one of the mediums each being positioned to confine the flow of said one medium to a nonlinear path which contacts said surfaces of substantially all of said passageways for the other of said mediums on at least two opposite sides, said passageways for said one medium forming a serpentine path for the flow of said one medium, and said passageways for said other medium comprising a plurality of nonconnecting openings in a core.

2. The improved heat exchanger as defined in claim 1, wherein said each of said openings extend approximately perpendicular to the direction of flow of said path at any point of said path which is in the heat exchanging vicinity of said each opening.

3. The improved heat exchanger as defined in claim 2, wherein said core is planar and otherwise solid, said passageways for said one medium and said serpentine path are both drilled into said core, and said openings are parallel to each other.

4. The improved heat exchanger as defined in claim 2, wherein said passageways for said one medium and said serpentine path are both confined to said core, said core is a cylindrical tube, and said pipes pass therethrough along radial lines radiating from the axis of said core.

5. The improved heat exchanger as defined in claim 1, wherein said path is confined within a solid metallic core one end of which is especially adapted to move away from its original position when said core is heated, and further including means for controlling the operation of the exchanger, said controlling means including sensing means positioned to sense said core end in its moved state.

6. The improved heat exchanger as defined in claim 5, and further including means for mounting said controlling means and said core on the same frame.

7. The improved heat exchanger as defined in claim 6, wherein said mounting means includes a rod in contact with said sensing means and having a coefficient of thermal expansion which is as low as that of carbon.

8. The improved heat exchanger as defined in claim 5, wherein said controlling means includes a generally planar member and at least two microswitches on said member, and said sensing means includes adjustable abutments for contacting said switches, each of said abutments being adjusted so as to abut its respective microswitch at a point in said movement of said end which is different from the point at which another of said microswitches is abutted.

9. The improved heat exchanger as defined in claim 8, wherein the exchanger is a flash boiler, said one medium is water and steam, said other medium is hot flue or combustion gases supplied by a combustion chamber, and said abutments are so adjusted that the first to contact its respective microswitch activates a source of supply of the water while the last to contact its microswitch deactivates the combustion chamber.

10. In a heat exchanger for transferring heat from a first medium to a second medium, the exchanger including a set of passageways having external heat-exchanging surfaces and confining the flow of the first and second mediums in the vicinity of each other; the improvement comprising said passageways for one of the mediums each being positioned to confine the flow of said one medium to a nonlinear path which contacts said surfaces of substantially all of said passageways for the other of said mediums on at least two opposite sides, said nonlinear path of said passageways of said one medium forming a plurality of connected, stacked levels, and said passageways for the other of said mediums penetrating all of said levels, whereby said one medium flows through said path sequentially from one level to the next so as to repeat its heat exchange with said other medium on each level.

11. The improved heat exchanger as defined in claim 10, wherein the flow of said one medium through said path proceeds from the first of said levels to the last, while the flow of said other medium through said passageways passes first through said last of said levels and lastly through said first of said levels.

12. The improved heat exchanger as defined in claim 10, wherein said levels are planar cores.

13. The improved heat exchanger as defined in claim 12, wherein the planes of said cores are parallel.

14. The improved heat exchanger as defined in claim 12, wherein at least one of said cores is metallic and has one end of which is especially adapted to move outwardly away from its original position when said one core is heated, and further including means for controlling the flow of the mediums through said passageways, said controlling means being operatively connected to said end of at least said one core.

15. The improved heat exchanger as defined in claim 14, and further including means for sensing certain predetermined outward movements of said core end, said sensing means including a first cantilevered member hingedly connected to at least one of said cores.

16. The improved heat exchanger as defined in claim 15, wherein said sensing means further includes a second cantilevered member hingedly connected at one end to said first member, a spring biasing said cantilevered members together at their ends opposite to said hingedly connected end, and mounting means for fixedly mounting one of said members so as to provide a reference surface for sensing said predetermined movement.

17. The improved heat exchanger as defined in claim 16, wherein said one member includes at least two adjustable abutments and said controlling means includes at least two microswitches mounted on the other of said members, each of said abutments being adjusted so as to abut one of said microswitches at a point in said movement which is different from the point at which another of said microswitches is abutted.

18. The improved heat exchanger as defined in claim 17, wherein the exchanger is a flash boiler, said one medium is water and steam, said other medium is hot flue or combustion gases supplied by a combustion chamber, and said abutments are so adjusted that the first to contact its respective microswitch activates a source of supply of the water while the last to contact its microswitch deactivates the combustion chamber.

19. The improved heat exchanger as defined in claim 16, wherein said mounting means includes a stud hingedly connected to said one member, and a rod in contact with said stud and having a coefficient of thermal expansion which is as low as that of carbon.

20. In a flash boiler, a plurality of heat exchanger passageways having external heat-transferring surfaces, one set of which conducts a first medium and the remainder of which conducts a second medium, one of said mediums being water, said one set being positioned to form a nonlinear, nonplanar path which contacts said surfaces of each of said passageways of said second set at a plurality of points continuously spaced along the length of each of said second set of passageways, the direction of flow of said mediums being adapted to maintain a maximum temperature differential between the two, whereby heat is transferred from one of said mediums to the water; and sensing means for sensing the amount of thermal expansion of said surfaces due to the heat of the other of said mediums which has not been absorbed by the water in forming steam.

21. The boiler as defined in claim 20, wherein said one set of passageways traces a serpentine path through a plurality of stacked cores each of which defines a plane, and said remainder of said passageways includes a plurality of openings extending approximately perpendicularly through said each core, said path contacting at least once said surfaces surrounding each of said openings in said each core; a connecting pipe between each adjacent pair of said cores and in communication with said path in said pair of cores; a passageway connecting said openings in said each core with said openings in each adjacent core, whereby hot gases flowing approximately perpendicularly through a first of said cores will generally flow through each adjacent of said cores in turn; and wherein said sensing means is mounted on said first core.

22. The boiler as defined in claim 21, wherein said sensing means includes a rod projecting from one end of said first core and a lever hingedly connected to said rod, said lever being hinged also to a relatively fixed reference point.

23. The boiler as defined in claim 22, wherein said lever is hingedly connected to said rod near one of its ends, and to said reference point between said rod connection ad the opposite end of said lever.

24. The boiler as defined in claim 22, and further including a plurality of microswitches mounted on said lever, each of which is especially adapted to be triggered by predetermined movement of said lever as measured from a reference position, the triggering movement for each microswitch differing from that of the others.

25. The boiler as defined in claim 21, wherein said path passes the core portions surrounding each of said openings in said each core on two opposite sides thereof.

26. In a heat exchanger including a core having a plurality of passageways for conducting both a hot medium and a cold medium for the exchange of heat between the two, the improvement comprising sensing means positioned adjacent to the end of said core for sensing dimensional changes of the same due to the operation of the exchanger, controlling means operatively connected to said sensing means for controlling the amount of the hot and cold mediums to be supplied to said passageways in response to said changes; said sensing means including two generally flat members, one of which includes means for relatively fixedly mounting the same and the other of which is operatively connected to said core end for movement with respect to said one member.

27. The improved heat exchanger as defined in claim 26, wherein said controlling means includes at least two microswitches on said other member and said sensing means includes at least two adjustable abutments on said one member, each of which is adjusted so as to abut one of said microswitches at a point in said movement of said other member which is different from the point at which another of said microswitches is abutted.

28. The improved heat exchanger as defined in claim 27, wherein said two members are hingedly connected together near one end and connected at their opposite ends by a spring.

29. The improved heat exchanger as defined in claim 28, wherein said connection of said other member to said core is positioned so that said hinged connection is between said core connection and said spring connection.

30. The improved heat exchanger as defined in claim 27, wherein the exchanger is a flash boiler, said cold medium is water, said hot medium is flue or combustion gases supplied by a combustion chamber, and said abutments are so adjusted that the first to contact its respective microswitch activates a source of supply of the water while the last to contact its microswitch deactivates the combustion chamber.

31. The improved heat exchanger as defined in claim 26, wherein said core is generally cylindrical and said members extend outwardly therefrom in planes radiating from the axis of said core.

32. The improved heat exchanger as defined in claim 31, wherein said one member is attached to the opposite end of said core.

33. In a heat exchanger including a core having a plurality of passageways for conducting both a hot medium and a cold medium for the exchange of heat between the two, the improvement comprising sensing means positioned adjacent to the end of said core for sensing dimensional changes of the same due to the operation of the exchanger, controlling means operatively connected to said sensing means for controlling the amount of the hot and cold mediums to be supplied to said passageways in response to said changes; said sensing means including a rod projecting from one end of said core and a lever hingedly connected to said rod, said lever being hinged also to a relatively fixed reference point.

34. The improved heat exchanger as defined in claim 33, wherein said lever is hingedly connected to said rod near one of its ends, and to said reference point between said rod connection and the opposite end of said lever.

35. The improved heat exchanger as defined in claim 33, and further including a plurality of microswitches mounted on said lever, each of which is especially adapted to be triggered by predetermined movement of said lever as measured from a reference position, the triggering movement for each microswitch differing from that of the others.

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