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Seitz

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(54) **THERMO-PLASTIC HEAT EXCHANGER**

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This patent is subject to a terminal dis-
claimer.

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Primary Examiner—Thor S Campbell

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Related U.S. Application Data

(57) **ABSTRACT**

(63) Continuation of application No. 07/521,541, filed on
May 10, 1990, now Pat. No. 5,216,743.

A flow-through instantaneous fluid heater system is designed
to satisfy the need for a heater not limited by being connected
to a storage tank and which can be made using a plastic
casing, incorporating cool-down when out of service and with
features of venting and simplified flushing and draining. The
system incorporates the use of one or more compartments,
usually assembled in two compartment modules connected in
series. Each compartment includes a casing having a hollow
cylindrical interior region. An inlet aperture is located at one
end of the casing and an outlet aperture is located at the other
end of the casing. The lower end of each casing is closed by a
removable base and the upper end of the casing is closed by a
top plate and a heating element. The heating element is posi-
tioned axially in the interior region of the compartment. The
heating element is activated by a control system which senses
and compares temperatures of the water at the compartment
outlets. The control system uses temperature comparisons to
detect flow through the system to determine whether the
heating elements should be activated to maintain the fluid at a
stand-by temperature or at an operational temperature.

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F24H 1/10 (2006.01)

(52) **U.S. Cl.** **392/490; 392/486; 219/497**

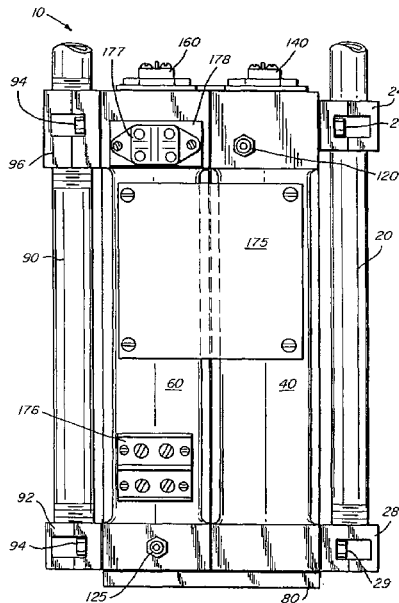
(58) **Field of Classification Search** 392/490,
392/488, 489, 485-487; 219/497, 505, 486;
73/204.15, 204.16, 204.23; 340/606; 364/510;
122/14, 19, 448.3, 13.2, DIG. 13, 4 A
See application file for complete search history.

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23 Claims, 5 Drawing Sheets



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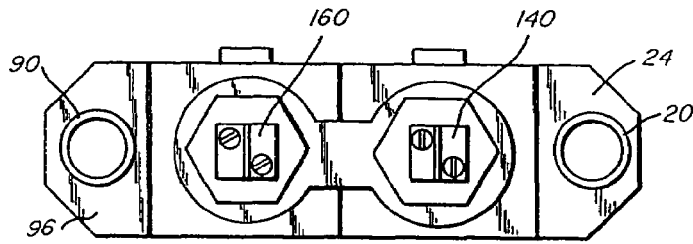


FIG. 3

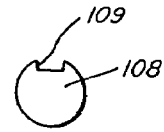


FIG. 6

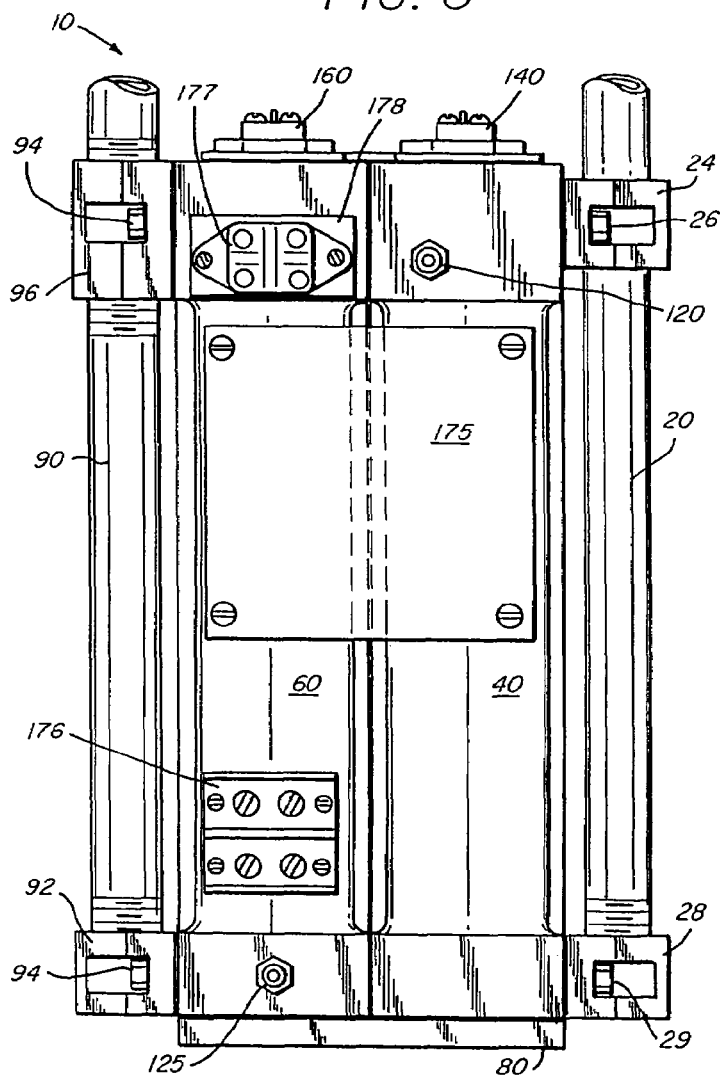


FIG. 1

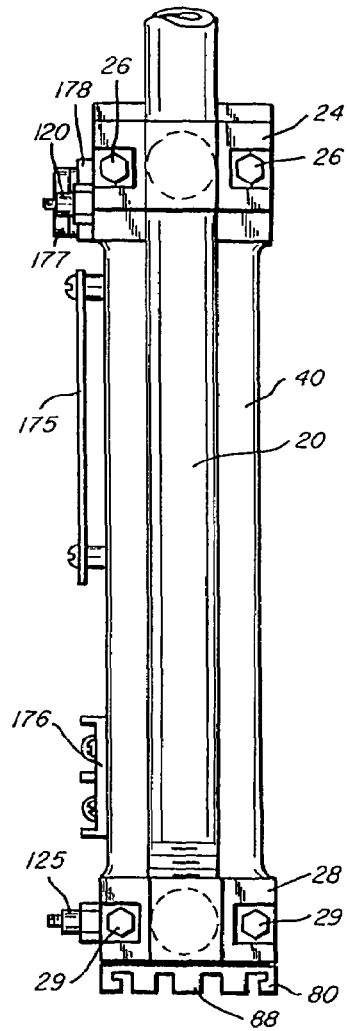


FIG. 2

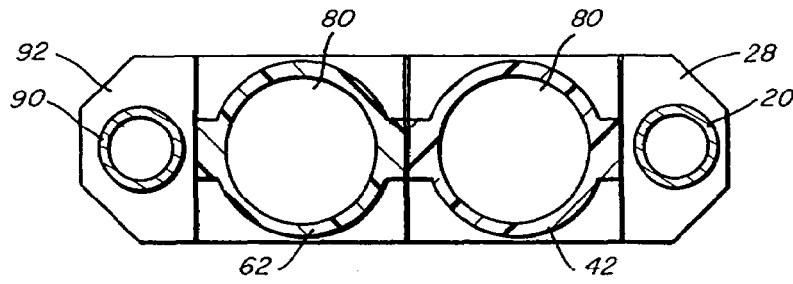


FIG. 5

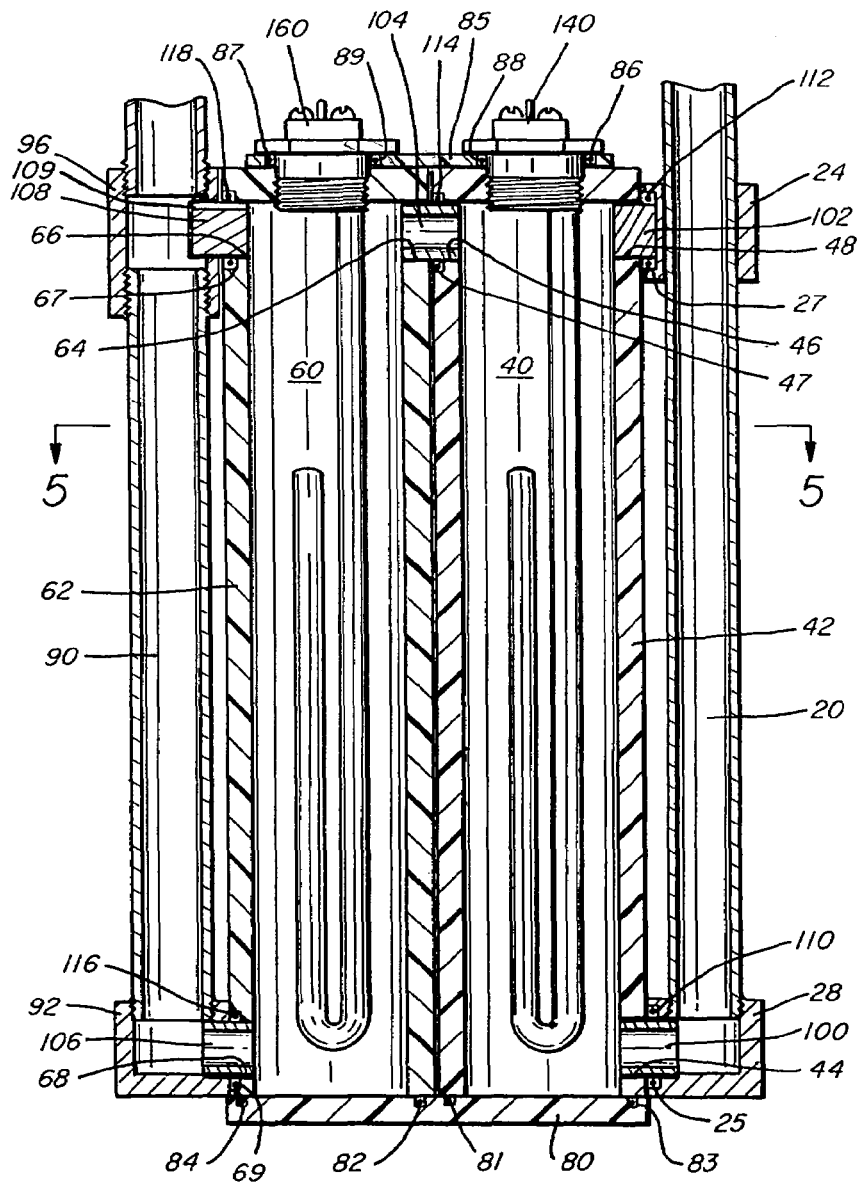


FIG. 4

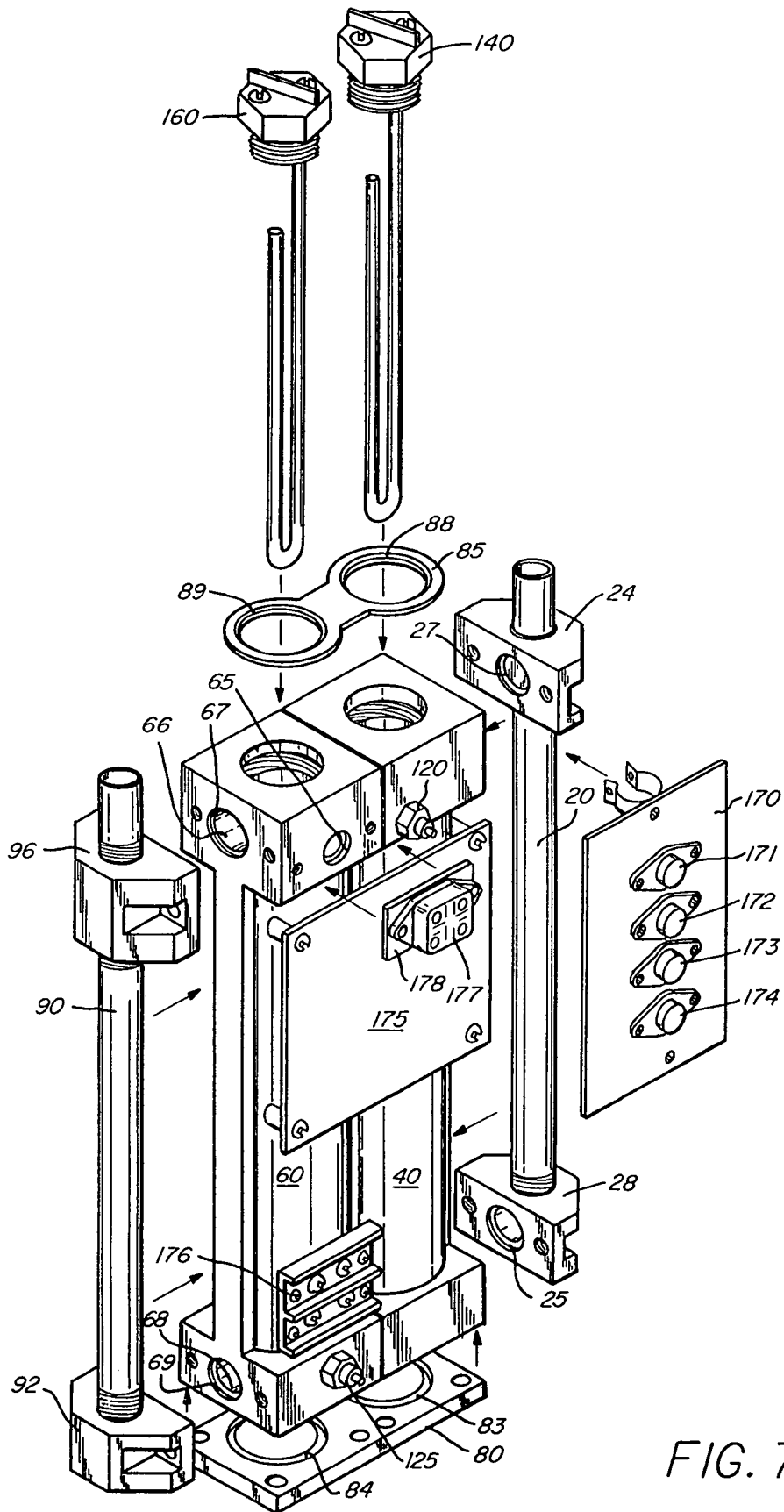


FIG. 7

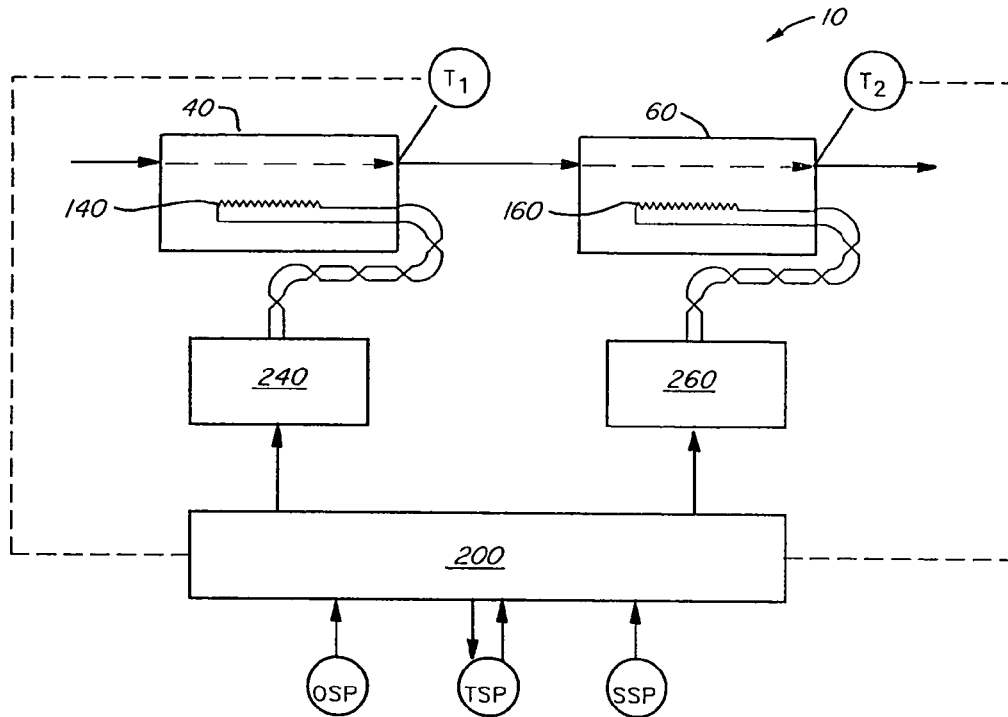


FIG. 8

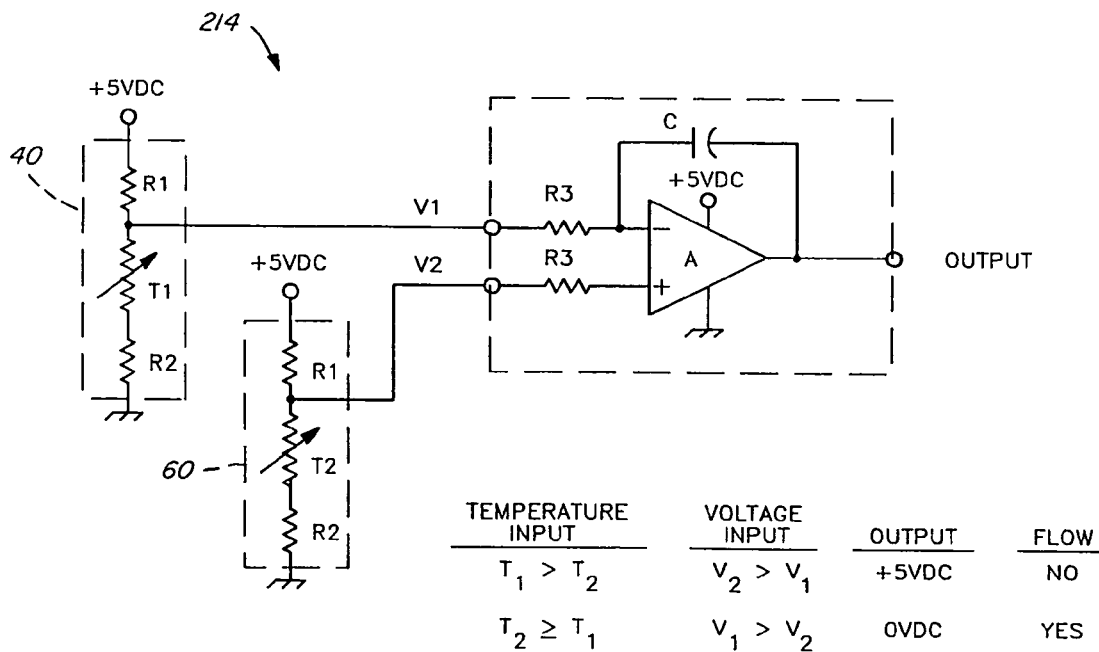


FIG. 9

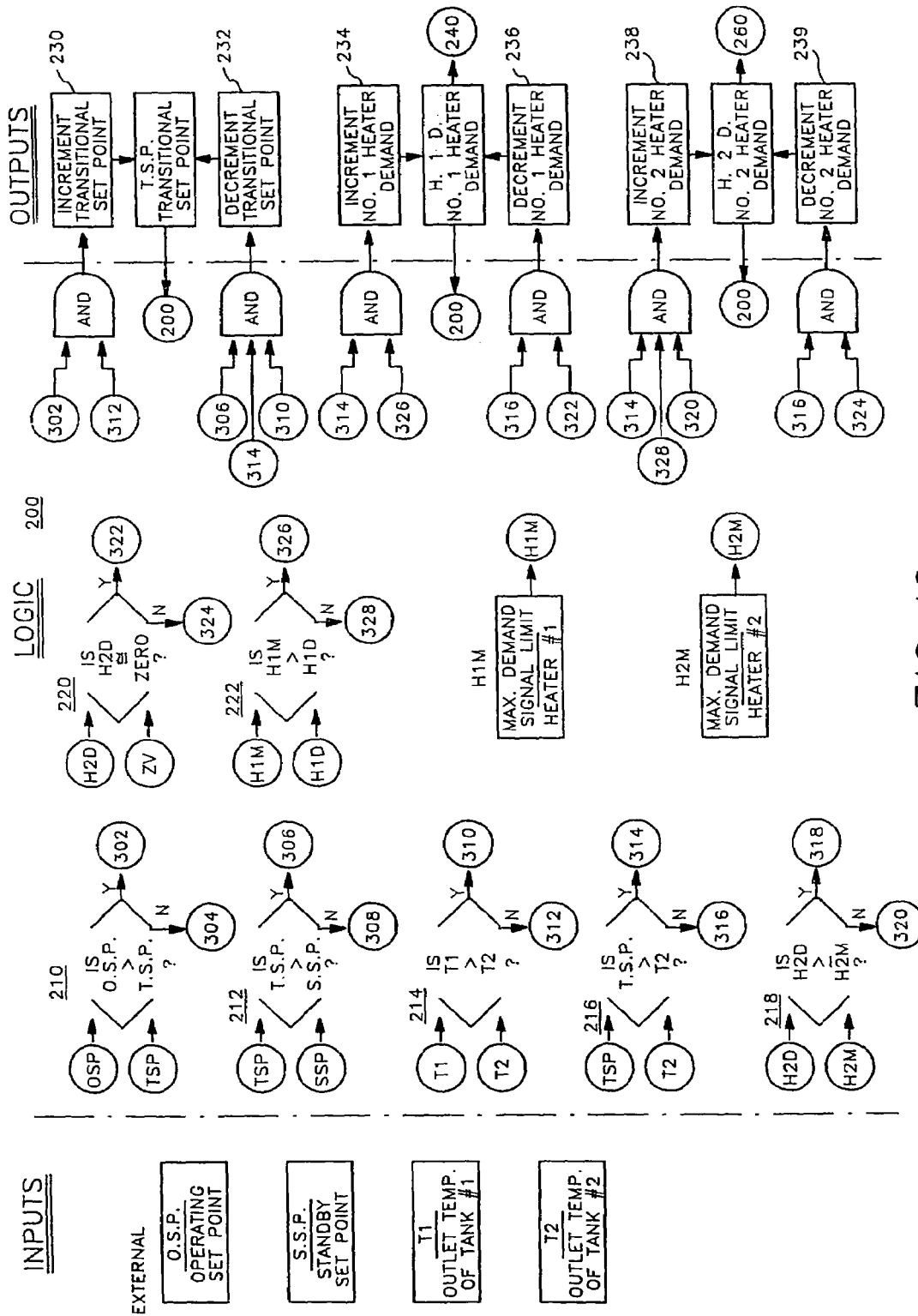


FIG. 10

THERMO-PLASTIC HEAT EXCHANGER

This is a Continuation of application Ser. No. 07/521,541, filed May 10, 1990 now U.S. Pat. No. 5,216,743.

FIELD OF THE INVENTION

The present invention generally relates to a flow-through heating apparatus for the instantaneous heating of fluids, i.e., water, and, more particularly, is concerned with a self-insulating, easy to install thermo-plastic heat exchanger of expandable modular construction for heating water without the use of a storage tank.

The typical hot water heater which has been in use for several decades now is a storage tank heater which is made of metal. These heaters have several disadvantages including a limitation upon the amount of hot water which can be stored and therefore used at a given time, energy being wasted in that the supply of water must continually be reheated, the possibility of harmful gas leaks, the potential for fires and explosions since a majority of these heaters in residential applications are gas heaters, and the heaters take up a large amount of space since a storage tank is needed. These heaters are generally located far from the point of delivery of the hot water resulting in heat loss between the storage tank and the point of delivery as well as significant loss and waste of potable water that is senselessly discharged down the drain while waiting for hot water to reach the fixture.

At the time when conventional storage tank hot water heaters became widely accepted, we did not have the benefit of the improved plastic materials now available. Engineering plastics now provide a lightweight, inexpensive alternative to metals for use in structures for handling hot water.

The need for domestic hot water is typically intermittent and of relatively short duration. State of the art design now allows for continuous flow-through type hot water heaters which only require that water be heated once and at the time of use. The advantages of an instantaneous flow-through hot water heater include savings on water heating bills, savings on potable water because of the ability to install near major points of use, increased safety through the use of electric heaters eliminating the need for gas and open flames, less space requirements since no storage tank is required, ease of maintenance, lower cost of repairs and the lifestyle benefits associated with a continuous supply of hot water. Problems resulting from corrosion of the tank can also be eliminated through the use of plastics as the material used for many of the components in the hot water heater system.

Other continuous flow water heaters have been described. U.S. Pat. No. 3,898,428 to Dye describes an inline water heating apparatus which has a cylindrical heater element surrounded by a length of helically corrugated tubing. U.S. Pat. No. 4,567,350 to Todd describes an instantaneous electric water heater which includes five water heating chambers which are connected by lengths of metal mixing pipes. The heating chambers include electrical heating elements, and a pressure relief valve is located at the bottom of the last heating chamber. U.S. Pat. No. 4,604,515 to Davidson discloses a tankless electric water heater and includes four heating chambers which are arranged as pie-like portions of a cylinder. Each chamber has a heating element and a separate temperature sensor, and one of the chambers includes a pressure relief valve. U.S. Pat. No. 4,645,907 to Salton describes an electric water heater which includes a casing with three separate heating elements.

The patents described above have several shortcomings. The patents fail to comprehend the design of a flow-through

instantaneous water heater as described herein as my invention which can be constructed in series from any desirable number of flow-through instantaneous water heating compartments, usually assembled as a series of two-compartment modules, to meet the hot water output requirements of the user's application. These patents also fail to recognize the advantages of the invention that the hot water heater compartments can be constructed from plastic, that the compartments should and can be constructed for ease of draining and cleaning for maintenance purposes and removal of particulate matter which can clog the system, to construct with off the shelf type components easily obtainable for installation and replacement, the importance of the capability to determine the temperature at the outlet of each compartment, the importance of venting entrapped air or gas from the upper end of each and every separate compartment used in the hot water heating system during normal operations as opposed to using pressure relief valves and in only some of the compartments, solving problems associated with overtemperature conditions due to inaccuracies from reading the temperature of the fluid at the very top of the compartment where steam can collect if gases are not vented and the importance of incorporating, optionally, an electronic control system into the operation of the heating system for detecting water level and for electronically detecting flow (without moving parts) in order to determine if the system is in an operational or a stand-by state, and for sequentially modulating the heating elements in consecutive compartments in order to achieve a desirable output temperature from the system which will shut off the heating elements when temperatures within the compartments reach excessive levels.

Consequently, a need exists for significant improvements in complete flow-through instantaneous water heating systems with the objective of solving all of the above-mentioned disadvantages.

SUMMARY OF THE INVENTION

The present invention provides a flow-through instantaneous fluid heater system designed to satisfy the aforementioned needs. The system incorporates the use of one or more compartments, usually assembled in two compartment modules connected in series. Each compartment includes a casing having a hollow cylindrical interior region. An inlet aperture is located at one end of the casing and an outlet aperture is located at the other end of the casing. The lower end of each casing is closed by a removable base and the upper end of the casing is closed by a top plate and a heating element. The heating element is positioned axially in the interior region of the compartment. The heating element is activated by a control system which senses and compares temperatures of the water at the compartment outlets. The control system uses temperature comparisons to detect flow through the system to determine whether the heating elements should be activated to maintain the fluid at a stand-by temperature or at an operational temperature.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is an elevational view of a two compartment flow-through heating apparatus representing a single module of the water heater.

FIG. 2 is a side view of a two compartment flow-through heating apparatus.

FIG. 3 is a top view of a two compartment flow-through heating apparatus.

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FIG. 4 is a cross-sectional view of a two compartment flow-through heating apparatus shown in FIG. 1.

FIG. 5 is a cross-sectional view of a two compartment flow-through heating apparatus taken along the line 5-5 of FIG. 4.

FIG. 6 is an end view of the vent plug.

FIG. 7 is an exploded perspective view of the invention described herein incorporating two compartments.

FIG. 8 is a functional block diagram of the control system of the invention described herein.

FIG. 9 is a schematic of the flow detection device incorporated alternately in the herein described invention.

FIG. 10 is a functional block diagram of the control logic in accordance with this invention.

DETAILED DESCRIPTION OF THE INVENTION

Referring now to the drawings, and more particularly, to FIG. 1, there is shown one embodiment of the flow-through heating apparatus and system, generally designated 10, for the instantaneous heating of a fluid, preferably a liquid, such as, for example, water. For purposes of discussion of the embodiments of this invention, the heater will be discussed as if it is a water heater, the most common use for it. The instantaneous water heater 10 generally incorporates a few basic conduit elements joined in series, namely an inlet pipe 20 at the upstream end of the system 10, a first compartment 40, a second compartment 60 and a discharge pipe 90 at the downstream end of the system 10. The first compartment 40 and second compartment 60 contain heating elements 140 and 160, respectively, for the instantaneous heating of water as it passes through. For purposes of this invention two compartments will be considered to be a module for simple expansion purposes where needed.

As shown in FIGS. 1, 2 and 3, inlet pipe 20 is supported by an inlet pipe support 24. The inlet pipe support 24 includes O-ring groove 27, (FIG. 4), fits around the outer circumference of inlet pipe 20, and is attached to first compartment 40 by bolts 26. The lower end of inlet pipe 20 is threaded for connection to inlet fitting 28. Inlet fitting 28 is attached to the lower side proximate the lower end of first compartment 40 by bolts 29.

Sectioned drawings, FIGS. 4 and 5, show a first compartment 40, surrounded by a casing 42, as being a hollow, cylindrical interior region. Casing 42 is shown as being tubular, though not necessarily so, having a first aperture 44 located proximate the lower end and a second aperture 46 located proximate the upper end of casing 42. A third aperture 48 is optional to simplify the plastic molding process for modularity of compartments and if included is located proximate the upper end of casing 42 opposite second aperture 46. A connector 100, which is tubular in construction is used to connect inlet fitting 28 to first compartment 40 through the first aperture 44 to allow fluid communication from the inlet pipe 20 with first compartment 40. An O-ring 110 is seated in groove 25 in inlet fitting 28 in order to provide an effective seal between inlet fitting 28, connector 100 and first compartment casing 42.

As shown, third aperture 48 in first compartment 40 is closed by plug 102 and sealed using an O-ring 112 seated in groove 27. Plug 102 is cylindrical and solid.

Second aperture 46 is used for connecting the flow path of the water through the first compartment 40 to the second compartment 60. Connector 104 is used for making this connection between first compartment 40 and second compartment 60 and is positioned adjacent the top of first compartment 90. Connector 104 is the same as connector 100 and is

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mounted in second aperture 46 of first compartment 40 and in first aperture 64 of second compartment 60 and is sealed by O-ring 114 seated in groove 47 in first compartment 40.

Second compartment 60 is the same as or similar to first compartment 40. Second compartment 60 is a cylindrical longitudinal cavity in casing 62 having first aperture 64 and second aperture 66 proximate the upper end and third aperture 68 located proximate the lower end.

Both the first compartment 40 and second compartment 60 are closed at the lower end by a base 80 which is attached by bolts or other suitable means of attachment. Preferably, O-rings 81 and 82 will be placed in grooves 83 and 84 in base 80, respectively, in order to seal the lower end of the compartments 40 and 60. The base 80 is readily detachable and reattachable to allow for cleaning of corrosion and other particulate matter from the compartments 40 and 60 and heating elements 140 and 160 without removing electrical wiring. The casings 42 and 62 or base 80 could also be tapered and constructed with a valve for each compartment 40 and 60 to allow pneumatic or some other type of blow down without removal of base 80. It is to be understood that the base 80, while shown as a single piece closing both compartments 40 and 60, it could be manufactured as two separate pieces, one each to be connected to the bottom end of first compartment 40 and second compartment 60. As shown in FIG. 2, the lower end 88 of base 80 is preferably webbed to provide structural strength while saving on material costs.

Top plate 85 preferably provides an electrical ground means for the heating elements and is held against heating elements 140 and 160 when heating elements 140 and 160 are threaded or attached by other suitable means of attachment to casing 42 and 62. Though plate 85 is shown as a single plate, it is to be understood that top plate 85 could also be manufactured as two separate plates, one each to be attached to the tops of casing 42 and 62. Top plate 85 is preferably a grounding plate to be connected to any suitable grounding surface for grounding heaters 140 and 160.

As shown in FIG. 4, heating element 140 extends down through the opening in top plate 85 and extends axially through the interior region of first compartment 40. Heating element 140 extends downward in an axial direction into the hollow interior region of first compartment 40. The axial location of the heating element 140 within the hollow interior region is such that the heating element 140 is substantially equidistant from casing 42 at any point around the circumference of casing 42. The heating element 140 is seated on top plate 85 and preferably is attached to compartment 40 through a mating threaded connection. O-ring 86 is placed in groove 88 between heating element 140 and top plate 85 for sealing off the top end of first compartment 40. A preferable heating element for water is sized between 3500 and 7000 watts output based on the design rating of the specific heater. The uniformity of the heat transfer from the heating element 140 to the water flowing through first compartment 40 is enhanced due to the substantially symmetrical location of the element 140 with respect to the hollow cavity through which the fluid, water, will flow.

Heating element 160 extends down through the opening in top plate 85 and axially into the second compartment 60. Heating element 160 is the same as or similar to heating element 140. Heating element 160 is seated on top plate 85 and preferably is attached to compartment 60 through a mating threaded connection. O-ring 87 is placed in groove 89 between heating element 160 and top plate 85 for sealing off the top end of second compartment 60.

A temperature sensor or thermistor 120 (FIG. 7) protrudes into the interior region of first compartment casing 42 proximate

mate the second aperture **46** for sensing the temperature **T1** of the water flowing out of first compartment **40**. Sensor **120** may protrude within the compartment casing **42** from other positions so long as it is in the flow path of the water and proximate the second aperture. For purposes of this invention any water downstream from the first heating element **140** and upstream from second aperture **46** can be considered to be proximate the second aperture **46**.

A temperature sensor or thermistor **125** protrudes into the interior region of second compartment casing **62** proximate the third aperture **68** for sensing the temperature **T2** of the water flowing out of second compartment **60**. Sensor **125** may protrude within the compartment casing **62** from other positions so long as it is in the flow path of the water and proximate the third aperture **68**. For purposes of this invention, any water downstream from the second heating element **160** and upstream from third aperture **68** can be said to be proximate the third aperture **68**.

Discharge pipe **90** is connected to second compartment **60** through discharge fitting **92** and bleeder fitting **96**. Connector **106** is used for connecting second compartment **60** to discharge fitting **92** and is sealed by O-ring **116** which seats in groove **69** in casing **62**. Discharge fitting **92** is attached to second compartment **60** by bolts **94**. Discharge fitting **92** and bleeder fitting **96** may be threaded or attached by other suitable means to pipe **90**, or may be prefabricated as part of pipe **90**.

Fitting **96** is attached to second compartment **60** by bolts **94**. Vent plug **108** is mounted in second aperture **66** of second compartment **60** and vents air, steam and other gases into fitting **96** and from there into outlet pipe **90**. Vent plug **108** is partially sealed within second aperture **66** by O-ring **118** which is seated in groove **67** in casing **62**. As seen in FIG. 6, vent plug **108** has a channel **109** preferably positioned adjacent to the top of second compartment **60**. Channel **109** in vent plug **108** allows gases during normal operating conditions in first compartment **40** and second compartment **60** to be separated from the liquid and released into discharge pipe **90** and out of the system without requiring pressure to be built up before such gases are released. Channel **109** is large enough to allow the vapors to escape but small enough to prevent any appreciable liquid bypass. Of course as an alternative to aperture **66**, plug **108** and vent **109**, the casing could be cast without such aperture and a small vent hole could be drilled to allow passage of gases into fitting **96** and outlet pipe **90**.

Water flowing through inlet pipe **20** will enter the lower end of first compartment **40** and be heated by heater element **140** as the water rises within first compartment **40**. The water will then flow-through connector **104** and down through second compartment **60** as it is heated by heater element **160**. The water then reaches the lower end of second compartment **60** and is discharged through discharge fitting **92** and out discharge pipe **90**, which may be fabricated as a single piece if desired. Any gases which may build up in the system through the interaction of heaters **140** and **160** with the water will automatically rise to the top of first compartment **40** and second compartment **60** because of the lower density of the gases.

As shown in FIGS. 4 and 6, connector **104** and vent channel **109** located in vent plug **108** creates an outlet for these gases through discharge pipe **90** so that heating elements **140** and **160** will remain submerged at all times and so that temperature sensor **120** will sense a fluid temperature and not vapors. Water flowing through vent channel **109** in vent plug **108** will be limited because of the decreased area of vent channel **109**.

It is to be understood that all attachments made by bolts may be made by other suitable attachment means such as adhesive or sonic welding, for example, and that inlet pipe **20**, inlet fitting **28**, discharge fitting **92** and bleeder fitting **108** may each or all be made as pieces threadable or otherwise attachable to pipes **20** and **90** or as features manufactured into the pipes **20** and **90**. It is also to be understood that compartments **40** and **60** could be prefabricated as one piece which eliminates the need for connectors and O-rings between the two compartments although connection could still be made to additional compartments added on to the two compartments.

Referring now to FIG. 7, a more detailed view of the flow-through heating apparatus **10** shown in FIGS. 1-6 is shown. Triac heat sink **170** is to be mounted on inlet pipe **20**. Screw mounted triacs **171**, **172**, **173** and **174** are mounted on heat sink **170**. High limit thermostatic cut-off switch **177** and grounding plate **178** are to be connected over aperture **65** located in the upper end of second compartment **60**. High limit switch **177** senses excess temperature within the heating apparatus **10** and cuts-off heaters **140** and **160** when such overtemperature conditions are sensed. An optional control board mounting plate **175** is shown connected to first compartment **40** and second compartment **60** and electric input terminal **176** is shown connected to second compartment **60**. These terminals may be placed at any suitable location and are shown as described above merely for illustration.

FIG. 8 illustrates a two compartment fluid heating apparatus **10** for fluids, such as water, and includes first compartment **40** and second compartment **60**. Fluid enters compartment **40** where it is heated. The fluid leaves compartment **40** and then enters compartment **60** where it may also be heated. The fluid then exits from compartment **60**. The temperature of the fluid leaving compartment **40** is identified as temperature **T1** and the temperature of the fluid exiting compartment **60** is identified as temperature **T2**.

The design of control system **200** as described below illustrates a preferred control system design. Once given the control system concepts such design would be known to one of ordinary skill in the art for carrying out a preferred mode of the invention. Other control system designs known to one of ordinary skill in the art could also be used.

The control system logic **200** is shown and may include an optional water level permissive which enables the control function whenever sufficient water level is detected in the heating compartments using conductivity measurement means. Also it is shown to have an operating set point OSP, a transitional set point TSP and a stand-by set point SSP which controls when the heater is at rest. The stand-by set point SSP serves to prevent stand-by heating losses and to prevent the heating apparatus **10** from freezing when in a stand-by mode in a freezing location. The transitional set point TSP is the actual target temperature provided to the heating apparatus **10** by the logic **200**. It is a set point derived from operating set point OSP. The operating set point OSP is the selected temperature for hot fluid leaving the instantaneous flow-through heating apparatus **10** when the heating apparatus **10** is functioning. The transitional set point TSP is also derived from stand-by set point SSP. Stand-by set point SSP represents a lower set point than the operating set point OSP while transitional set point TSP is a value between SSP and OSP and preferably floats above the incoming temperature of the fluid and the freeze point of the fluid. The stand-by set point SSP functions to allow the fluid heating apparatus **10** to cool down, use less power and have lower heat losses when in a non-flow or stand-by mode. The operating set point OSP, stand-by set point SSP, temperature **T1** and temperature **T2** are all inputs to control system logic **200**. The transitional set point TSP is

internally generated within the control system logic **200**. The output of control system logic **200** is first heater drive **240** and second heater drive **260**. Heater drive **240** provides energy to heater **140** which is located in compartment **40** and heater drive **260** provides energy to heater **160** which is located in compartment **60**.

As previously discussed, the logic **200** as shown permits a time delayed transition between the operating set point OSP and stand by set point SSP which is known as transitional set point TSP. If the designer chooses, the transition time can be established as instantaneous, in which case the transition set point TSP becomes equal to either operating set point OSP or slightly higher than the stand by set point SSP based upon whether there is flow through the heating apparatus **10** as determined by the relationship between temperature **T1** and temperature **T2**. With slight modification one skilled in the art can eliminate the sophistication of TSP and design the units logic to operate at either OSP and SSP based on the existence of flow which is determined by the relationship between **T1** and **T2**. A designer can likewise choose transition set point TSP to be a floating value determined by a fixed number added to temperature **T1** or subtracted from temperature **T2**. Thus (depending upon whether flow is detected by the relationship between temperatures **T1** and **T2**) the transitional set point TSP (regardless of whether it is instantaneous or floating) is modified to a design chosen dead band range around operating or stand-by condition. Typical values for a domestic home water heater might be an operating set point OSP of 145° Fahrenheit and a stand-by set point SSP of 40° Fahrenheit or some other value above the freezing point of the fluid being conducted through the heater **10**.

Now referring to FIG. 9, an example of logic switch implementation for FIG. 10, there is shown a schematic diagram for the flow switch circuit, generally designated **214**, which is an analog switch which differentiates between two analog inputs and yields an output representing a logic 1 or a logic 0 based upon which of the two inputs is higher. These circuits are well known to those skilled in the art and function as switches throughout the control system of this embodiment.

The circuit **214** entails two input voltages **V1** and **V2** which respectively represent the compartment outlet temperatures of the first compartment **40** and the second compartment **60** through current limiting resistors **R3** into an operational amplifier **A** which has a tie back capacitor **C** to the inverting input. Typical components and/or values for such components shown in FIG. 9 would be as follows: Thermistors **T1** and **T2**, General Automotive Specialties number 25502; resistors **R1**, approximately 800 to 1200 ohms; resistors **R2**, 0 ohms when using General Automotive number 25502 (the case of the thermistor is grounded and **R2** is automatically 0). Resistors **R3** serve only a current limiting function and may be any value between 1,000 ohms and 100,000 ohms; the tie back capacitor **C** is typically between 0.1 to 0.4 microfarads; the operational amplifier **A** would typically be ¼ of a Motorola integrated circuit number MC3403P. Others may be used, of course, but the foregoing components may be used with satisfactory results.

The internal logic **200** for controlling the flow-through heating apparatus **10** is unique because it incorporates flow detection without requiring a conventional flow switch. The electronic flow detection is based on the following principle: First heater **140** will maintain temperature **T1** higher than temperature **T2** during a stand-by mode when there is no flow through the heating apparatus **10**; when flow begins the warmer water from compartment **40** is forced into compartment **60** causing **T2** to become equal or nearly equal to **T1** thereby indicating flow; and when the heaters **140** and **160** for

the fluid are activated or heated sequentially in such a manner that heater **140** is activated sequentially ahead of heater **160** when flow starts and are deactivated sequentially in such a manner that heater **160** shuts down sequentially ahead of the shutdown of heater **140** when flow stops, then flow detection can be based on the relationship between two separate locations or chamber such as temperature **T1** in compartment **40** and temperature **T2** in compartment **60**. Given the flow detection concept, one skilled in the art could design the flow detection method to operate based on the temperature relationship between any two locations within the heater, such as the temperature relationship between the incoming fluid supply **20** to the fluid in compartment **40**. For flow detection one temperature sensor must be located downstream from another and a heating means must be positioned such that a temperature differential is maintained between the sensors when there is no fluid flow. This invention controls the activation of the heaters **140** and **160** based on the flow detection principle and, because such flow detection is done without mechanical moving parts, such detection is quite reliable and effective. For operation, the flow switch **214** only requires that heat be applied in the first compartment **40** and then only enough to maintain the temperature at or above the standby set point SSP.

The control system uses the temperature sensor **120** located in the first compartment **40** to measure a value for **T1** and the temperature sensor **125** located in the second compartment **60** to measure a value for **T2** the difference between the temperatures of the two compartments is used to detect flow. When there is no fluid flow, heat is first added to the fluid in the first compartment **40** through the first heating element **140** in order to maintain the fluid in the first compartment **40** at or above the stand-by set point temperature SSP. In this state, the temperature **T1** in the first compartment **40** will be higher than the temperature **T2** in the second compartment **60**. In a situation where there is no flow and where temperature **T1** drifts in such a manner that it approaches **T2** and flow is indicated by output signal **312** such a condition lasts only momentarily because the following sequence of events occurs. As seen in FIG. 10, TSP is incremented by output signals **302** and **312**; heater No. 1 is incremented by signals **314** and **326**, temperature **T1** increases quickly because there is no flow; **T1** becomes higher than **T2** which restores the "no flow" signal **310**; TSP is decremented by output signals **306**, **310**, and **314**; heater No. 1 demand is decremented by output signals **316** and **322**; and the "no flow" stand-by state is restored.

When the fluid begins to flow, even though heat will be added, the temperature **T1** in the first compartment **40** will fall below the temperature **T2** in the second compartment **60** and by comparing these two temperatures **T1** and **T2**, or the temperature differential, the control system determines that there is flow through the system. When the control system detects flow the set point normally changes from an idle or transitional set point TSP to an operating set point OSP as described below and shown in FIG. 10. The operating set point OSP is generally equal to the desired output temperature of the system.

When fluid stops flowing or flows at very low rates through the system the temperature sensed in the first and second compartments **40** and **60** will begin to equalize and when flow stops the temperature **T1** in the first compartment **40** will exceed the temperature **T2** in the second compartment **60**. The control logic **200**, by comparing the temperature differential or by registering a low first heater demand **H1D**, will determine that there is a "no flow" state and the furthest downstream heating element which is activated will be de-

remented until it is deactivated at which time, if required, the adjacent heating element will be decremented so that the fluid temperature will be changed from operating set point OSP to a transitional set point TSP, approaching stand-by set point SSP, between operational set point OSP and stand-by set point SSP to reduce stand-by losses in energy.

The stand-by set point temperature SSP may be a floating set point temperature or a fixed point temperature as well. A preferable floating stand-by set point temperature SSP will float to remain at a margin of 8° or 10° Fahrenheit above the inlet temperature to the water heater system **10** but it should always be maintained at the margin selected above the freezing temperature of the fluid.

Logic element **214**, as described, is comparable to each of the other logic elements shown in FIG. **10**, these being logic elements **210**, **212**, **216**, **218**, **220** and **222**.

Where appropriate, the control system will include electrical conductivity to detect an acceptable water level in the compartments as a permissive for the application of power to the control system logic. An electrical contact pair (not shown) is located proximate to thermistors **120** and **125** for detecting the presence of a full compartment of water through conductivity means as an optional permissive to operation of the heating apparatus **10**.

FIG. **10** outlines the design logic for a two chamber heating apparatus **10** using temperature derived electronic flow detection, it being understood that such control logic system **200** is applicable for any pair of a series of chambers greater than two, which may be assembled together. On the left side of FIG. **10** are the four inputs to the control system logic **200**, namely, operating set point OSP, stand-by set point SSP, outlet temperature T1 of first compartment **40**, and outlet temperature T2 of compartment **60**.

The logic required to operate the two compartment **40** and **60**, two heater element **140** and **160**, heating apparatus **10** consists of seven analog logic switches **210**, **212**, **214**, **216**, **218**, **220** and **222**, two maximum demand limit set points H1M and H2M one each for first heater **140** and second heater **160**; six logic "AND" gates are required to complete the logic; three additional inputs to the logic are generated from the outputs: These are transitional set point TSP, first heater demand H1D and second heater demand H2D.

There are six outputs from heater control logic **200**. The first output **230** functions to increment the transitional set point TSP and the second output **232** functions to decrement the transitional set point TSP.

The third output **234** of the heater logic **200** is to increment the demand of the first heater **140** and the fourth output **236** is to decrement the demand of the first heater **140**. These two outputs **234** and **236** go to first heater demand H1D which is also provided as a signal back into logic **200**.

The fifth output **238** of the heater logic **200** is to increment the demand of the second heater **160** and the sixth output **239** is to decrement the demand of the second heater **160**. These two outputs **238** and **239** go to second heater demand H2D which is also provided as a signal back into logic **200**.

The functioning of internal logic **200** shown in FIG. **10** is described as follows. As shown, the conditions required to increment the transitional set point TSP are a yes output **302** from logic **210** and a no output **312** from logic **214**. This output, **230**, is used to increment the transitional set point TSP above the stand-by set point SSP but no higher than the operating set point OSP. The conditions required for output signal **232** to decrement the transitional set point TSP are a yes output **306** from logic **212**, a yes output **310** from logic gate **214** and preferably also includes a yes output **314** from logic gate **216**. Yes output **306** results when the transitional set

point TSP is greater than the stand-by set point SSP. Yes output **310** results when temperature T1 is greater than temperature T2. Yes output **314** results when the transitional set point TSP is greater than temperature T2 which limits the transitional set point TSP to tracking temperature T2 during cool down when the heating apparatus **10** is in a stand-by state.

First heater demand H1D is controlled by increment output signal **234** and decrement output signal **236** provided through logic "AND" gates. The conditions required to increment signal **234** the first heater demand H1D are a yes outputs **314** and **326**, respectively from logic gates **216** and **222**. These conditions are met in logic gate **216** when transition set point TSP is greater than temperature T2 and are met in logic gate **222** when first heater maximum demand limit H1M is greater than first heater demand H1D. Thus, the transitional set point TSP is calling for more heat and the first heater maximum H1M limit has not been reached.

The conditions required to decrement signal **236** the first heater demand H1D are a no output **316** from analog logic switch gate **216** and a yes output **322** from logic gate **220**. No output **316** results when transitional set point TSP is not greater than temperature T2. Yes output **322** results in analog logic switch **220** when the second heater demand H2D is substantially equal to zero ZV which preferably results when 0.05 volts are registered although other voltage reading limits can be used. In brief, if the outlet temperature T2 exceeds the transitional set point TSP and the second heater demand H2D is substantially zero, then decrement the first heater demand H1D.

The second heater demand H2D is controlled by increment signal **238** and decrement signal **239** provided through logic "AND" gates. The conditions required to increment signal **238** the second heater demand H2D are a yes output **314** from logic gate **216**, a no output **328** from logic gate **222** and a no output **320** from logic gate **218**. A yes output **314** results in logic gate **216** when the transitional set point TSP is greater than temperature T2. A no output **328** results from logic gate **222** when the maximum capability of the first heater H1M is not greater than the first heater demand H1D. A no output **320** results from logic gate **218** when the second heater demand H2D is not greater than or equal to the maximum capability of the second heater H2M. In brief, if the outlet temperature T2 is less than the target temperature TSP, the demand of the first heater H1D is at maximum capability H1M and the demand of the second heater H2D is not at maximum capability H2M, then the demand on the second heater H2D should be incremented.

The conditions required to decrement signal **239** the second heater demand H2D are a no output **316** from logic gate **216** and a no output **324** from logic gate **220**. A no output **316** results in logic gate **216** when the transitional set point TSP is not greater than temperature T2. A no output **324** results from logic gate **220** when the second heater demand H2D is not substantially equal to zero ZV. In brief, if the outlet temperature T2 is greater than or equal to the target temperature TSP and there is a demand on the second heater H2D, such demand on the second heater H2D should be decremented.

For simplicity, all of the above has been drawn and discussed based on a two compartment, two heater element fluid heating apparatus **10** for such fluids as domestic water. The same logic can be applied to control of a multi-element, multi-compartment heating apparatus with more than two heating elements and more than two compartments simply by incorporating all additional heating elements within the additional compartments sequentially after heating element **160** and compartment **60**. The designer can adapt the invention to

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the output needs of the end user by incorporating the necessary control system, and number of compartments and heating elements. Thus, one skilled in the art would simply sequence each successive heater to the limit required.

Likewise, in a heating apparatus **10** having more than two compartments one would separate temperature T2 into two separate measurements. Temperature T2 represented in logic element **214** used to determine if flow exists would be sensed by temperature sensor **125** located in the second sequential compartment **40**. However, temperature T2 used as the main heater control input in logic element **216** would preferably be sensed from the last sequential compartment (e.g. if there are six compartments, in the sixth compartment).

Likewise, one skilled in the art can use the inputs to analog logic switches **214** and **216** also as inputs to differential amplifiers to establish rate or acceleration/deceleration limits for a moving transitional set point TSP, first heater demand H1D and second heater demand H2D for even more precise control.

In the preferred embodiment, transitional set point TSP, first heater demand H1D and second heater demand H2D represent analog memory units operating between 0 and 5 volts d/c. Their output is converted to asynchronous pulses using a pulse width modulator such as Motorola MC34060 whose output is used to drive NOR logic drivers such as Motorola SN74LS28N which in turn drive optical isolation units such as Motorola MOC3040. The optical isolation units are directly connected to triac switches which control power to the heating elements **140** and **160**. Of course equivalent components are known which can accomplish the results set forth above.

The control system uses the pulse width modulator to modulate each of the heating elements in each compartment in response to the comparison made between the set point SSP or TSP and the temperature as sensed at the outlet of each compartment. One object of the control system is to achieve a constant outlet temperature from the instantaneous water heater as determined by the user of the heater. This object is achieved by sequentially modulating the activation or "on" time of the heating element adjacent to the last sequential heating element which is fully on until the desired outlet temperature from the entire system is achieved. If the user of the system then desires to lower the outlet temperature of the system the control system will then reverse itself to sequentially modulate the deactivation of the heating elements and shut off heating elements as required to allow the outlet temperature of the fluid to lower. The acceleration of the duty cycle of modulation can be adjusted to either be an increasing, decreasing or constant rate of acceleration or deceleration depending upon the needs of the system.

When hot water is desired from the heating apparatus **10** at rest, the control system will initially begin to modulate the first heating element **140** located in the first compartment **40**. The percentage "on" time of the first heating element **140** will continue to increase until either a first switching point temperature is reached (at which time the first heating element **140** goes from a high duty cycle to a fully on position) or until the desired outlet temperature from the system is reached. If the first switching point temperature is reached prior to reaching the outlet temperature, the first heating element **140** will go from a high duty cycle to a fully on position and the second heating element **160** will begin to modulate. The duty cycle of the second heating element **160** will increase once again until the desired outlet temperature is reached or until it is turned fully on. If it is turned fully on and a third sequential compartment is included, then the process will continue as

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described above. If only two compartments are included, the system will then be operating at maximum output capability.

An embodiment used for electronic control of electric heating elements has been described. However, the output increment and decrement signals could be provided to a stepping motor which sets a pilot valve for a gas operated heater as well. It is not the intention to limit this invention to either electric or gas heating, since either mode of heating can be applied and incorporated into the invention.

The control system utilizing the control logic **200** and flow detection device **214** of the present invention as shown in FIGS. **8**, **9** and **10** preferably operates with two or more compartments although one compartment may be used as well. If only one compartment is used, the temperature must be sensed both at or proximate the inlet end and at or proximate the outlet end of such compartment.

As previously described for the two compartment embodiment the temperature sensors **120** and **125** are located proximate the outlet aperture of the first and second compartments **40** and **60**. If there are more than two compartments, the preferred embodiment of this invention need only include temperature sensors in the first and second compartments and in the last sequential compartment. However, temperature sensors may be located in each and every compartment or in the inlet and/or outlet pipes as well. The control system uses these temperature sensors to detect the flow of a fluid through the system, to detect overtemperature conditions within the system, and in order to determine whether heating elements within the system should be activated in order to achieve a desired output temperature of the fluid flowing out of the system.

When there are more than two compartments, the control system can either establish an operating set point OSP for each compartment separately or can maintain an operating set point OSP for only the outlet from the entire system. The operating and stand-by set points are both adjustable or variable. The operating set point OSP may be set before the instantaneous water heater is installed or may be adjusted by the user. If temperature sensors are included in each compartment, the control system can compare the temperature reading at the outlet of each compartment as sensed by the temperature sensors to the respective set point temperatures. However, in the preferred embodiment, the control system will compare the set point temperature with the temperature reading at the outlet from the entire system as sensed by the temperature sensor in the last sequential compartment.

The control system logic **200** also includes an overtemperature shut down feature. When the sensor **125** senses that the outlet temperature T2 of the second compartment **60** (or the final compartment in a multiple compartment system) exceeds the transitional set point TSP, the control system logic **200** will determine that the first compartment **40** has reached an overtemperature and will decrement the heating elements **140** and **160**. The heating elements **140** and **160** will be modulated back on again as soon as temperature T2 cools down below the transitional set point temperature TSP. The control system logic **200** incorporates an additional overtemperature shut down feature through input from high limit thermostatic cut-off switch **177** which will switch off the heating elements **140** and **160** in the event that overtemperature conditions exist due to a failure in the control logic **200**, sensors **120** or **125**, etc.

All of the parts used to make the flow-through heating apparatus can be made from plastic except for the electronic control and wiring; heating elements **140** and **160**, the temperature sensors **120** and **125**; O-rings and miscellaneous hardware. Through the use of plastics, the compartments can

be made at a low cost while being non-corrodible, self-insulating, lightweight, sturdy, durable and capable of operating at temperatures above 150° Fahrenheit. High temperature thermoplastic resins can be used to satisfy the engineering design requirements. Preferable high temperature thermoplastic is a group of resins sold under the registered trademarks “NORYL” and “ULTEM” by the General Electric Company. “NORYL” and “ULTEM” can be used for operational temperatures up to and exceeding 180° Fahrenheit. “NORYL” resins retain tensile and flexural strength and modulus at temperatures above 200° Fahrenheit, have relatively low coefficients of thermal expansion (between 1.4 and 4.1 in/in/° F. $\times 10^{-5}$), allow for a wide choice of heat deflection temperatures while under load, have low water absorption rates at elevated temperatures which contributes to dimensional stability under high water temperature conditions and has low heat loss rates. “ULTEM” is useful in applications where a high resistance to chemical degradation from petroleum products is needed and is more stable than “NORYL” at high temperatures. Other materials such as ceramic may also be used for construction of the compartments. Various operating temperatures can be implemented by the designer or installer through the stand-by set point SSP and the operating set point OSP which may be set manually. The placement of O-rings and grooves can be varied between connecting parts. However, it is intended that the O-rings and grooves be placed for modularity and compatibility of the compartments. The compartments could also be sealed by other means such as chemically or by sonic welding.

The preferred embodiment of this invention has been shown and described above. It is to be understood that minor changes in the details, construction and arrangement of the parts may be made without departing from the spirit or scope of the invention as claimed.

What is claimed is:

1. A water heater for the substantially instantaneous heating of water, said water heater comprising:

at least one compartment having an inlet aperture located proximate one end thereof and an outlet aperture located proximate the opposing end thereof, said at least one compartment including heating means and temperature sensing means, a downstream flowline in fluid communication with said outlet aperture for transmitting heated water downstream from said at least one compartment, and further including a vent aperture having a fluid flow restriction greater than said outlet aperture for automatically and continuously venting gas from a portion of said at least one compartment spaced from said outlet aperture during operation of the water heater, said vent aperture being positioned for venting gas from an upper portion of said at least one compartment to said downstream flowline via a vent path substantially within or above a horizontal plane intersecting the vent aperture, such that the majority of water flows from said at least one compartment to said downstream flowline through said outlet aperture while a majority of gas within said at least one compartment flows through said vent aperture to said downstream flowline.

2. The water heater as defined in claim 1, wherein said at least one compartment includes a first generally elongate compartment and a second generally elongate compartment, the first compartment having a first inlet aperture located proximate one end thereof and a second outlet aperture located proximate an opposing end thereof, the first compartment including a first heating means and a first temperature sensing means, the second generally elongate compartment downstream from said first compartment and having a third

inlet aperture located proximate one end thereof and in fluid communication with said second outlet aperture, and a fourth outlet aperture located proximate the opposing end thereof, said second compartment including second heating means and second temperature sensing means, wherein said downstream flowline is in fluid communication with said fourth outlet aperture for transmitting heated water downstream from said second compartment, said second and third apertures together function for automatically and continuously venting gas from said first compartment to said second compartment during operation of said water heater, and said vent aperture has a restriction greater than said fourth outlet aperture for automatically and continuously venting gas from a portion of said second compartment, said vent aperture being spaced within said second compartment at a location substantially above said fourth aperture during operation of the water heater, such that the majority of water flows from said second compartment to said downstream flowline through said fourth outlet aperture while a majority of gas within said first compartment and said second compartment flows through said vent aperture to said downstream flowline.

3. The water heater as defined in claim 2, wherein said first inlet aperture is located at a lower end of said first compartment, said second outlet aperture is located at an upper end of said second compartment, said third inlet aperture is located at an upper end of said second compartment, said fourth outlet aperture is located at a lower end of said second compartment, and said vent aperture is located at an upper end of said second compartment.

4. The water heater as defined in claim 2, wherein each of said first and second compartments are defined by respective first and second housings, and sleeve-shaped connector for modular connection of said second outlet aperture and said third inlet aperture.

5. A flow-through heating apparatus for the substantially instantaneous heating of fluids, the apparatus comprising:

a generally elongate first compartment having a first inlet aperture located proximate one end thereof and a second outlet aperture located proximate the opposing end thereof, said first compartment including first heating means and first temperature sensing means, and a generally elongate second compartment downstream from said first compartment and having a third inlet aperture located proximate one end thereof and in fluid communication with said thereof, said second compartment including second heating means and second temperature sensing means, said first and second compartments defining opposing ends of said flow-through heating apparatus, the first temperature sensing means being located proximate the second outlet aperture, the second temperature sensing means being located proximate the fourth outlet aperture, and the second outlet aperture being positioned at an opposing end of said flow-through heating apparatus from the fourth outlet aperture, each of the first and second compartments defined by respective first and second housings substantially similarly configured, said second outlet aperture from said first housing having a modular connector for selective connection or removal from said third inlet aperture of said second housing, such that a selected number of compartments for said water heater may be altered by adding or deleting additional second housings.

6. The flow-through heating apparatus as defined in claim 5, further comprising

a planar flange for bolted interconnection to each of said first and second housings; and

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sealing means for sealing between said flanges on said first and second housings for fluid tight communication between said first and second compartments.

7. A flow-through heating apparatus for the substantially instantaneous heating of fluids, the apparatus comprising: 5

a first compartment having a first inlet aperture located proximate one end thereof and a second outlet aperture located proximate the opposing end thereof, said first compartment including first heating means and first temperature sensing means, and a second compartment 10 downstream from said first compartment and having a third inlet aperture located proximate one end thereof and in fluid communication with said second outlet aperture, and a fourth outlet aperture located proximate the opposing end thereof, said second compartment including 15 second heating means and second temperature sensing means, control means responsive to said first and second temperature sensing means for controlling activation of said first and second heating means, and flow detecting means responsive to said first and second temperature sensing means for detecting flow through said heating apparatus and for altering said control means in response thereto, said control means including a set point temperature selecting means which represents a desirable temperature of the fluid output from said heating apparatus, whereby when said flow detecting means detects flow, said set point temperature selecting means will select an operational set point temperature, and when said flow detecting means fails to detect flow at said set point temperature, said selecting means will 20 select a standby set point temperature less than said operational set point temperature.

8. The flow-through heating apparatus as defined in claim 7, wherein said control means includes modulating means for varying the percentage of activation time of said heating means within each of said first and second compartments sequentially in a continuous and random manner such that the sensed temperature will approach the set point temperature. 25

9. The flow-through heating apparatus as defined in claim 8, wherein said flow detecting means comprises temperature comparison means for comparing the temperature sensed by the first and second temperature sensing means. 30

10. The flow-through heating apparatus as defined in claim 8, wherein said first and second compartments each include a readily detachable and reattachable draining and cleaning means located at one end of said compartments, whereby the entire interior region of said first and second compartments is directly assessed by the removal of said draining and cleaning means such that fluid and solids may be readily drained and flushed from said compartments and the interior region of 35 said compartments may be cleaned, and each of said first and second compartments is formed from respective first and second housing fabricated from a self-insulating, high temperature resistant, chemically resistant thermoplastic. 40

11. A flow-through heating apparatus for the substantially instantaneous heating of fluids, the apparatus comprising: 45

a first compartment having a first inlet aperture located proximate one end thereof and a second outlet aperture located proximate the opposing end thereof, said first compartment including first heating means and first temperature sensing means, and a second compartment 50 downstream from said first compartment and having a third inlet aperture located proximate one end thereof and in fluid communication with said second outlet aperture, and a fourth outlet aperture located proximate the opposing end thereof, said second compartment including 55 second heating means and second temperature sens-

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ing means, control means responsive to said first and second temperature sensing means for controlling actuation of said first and second heating means, said control means including sequencing means for selectively actuating said first heating means prior to activating said second heating means, and further including modulating means for both incrementing and decrementing on-time for at least one of said first and second heating means to achieve a substantially constant temperature of fluid output from said heating apparatus.

12. The heating apparatus as defined in claim 11, wherein said control means includes a set point temperature selecting means which represents a desirable temperature of the fluid output from said heating apparatus, and further including flow detecting means responsive to said first and second temperature sensing means for detecting flow said heating apparatus and for altering said control means in response thereto.

13. The flow-through heating apparatus as defined in claim 5, wherein the first compartment has a first flange surrounding the first inlet aperture, and the second compartment has a second flange surrounding the fourth outlet aperture, such that a plurality of first and second assembled compartments may be interconnected at the first and second flanges with the fourth outlet aperture of one first and second compartment in fluid communication with the first inlet aperture of another first and second compartment. 20

14. The flow-through heating apparatus as defined in claim 13, wherein the first inlet aperture is located proximate a lower end of the generally elongate first compartment, the third inlet aperture is located proximate an upper end of the generally elongate second compartment, and the fourth outlet aperture is located proximate a lower end of the second compartment. 25

15. A heater apparatus designed for heating of a continuous flow of fluids therethrough comprising one or more modules disposed in serial fashion, each of said modules constituting a modular apparatus comprising: 30

- (a) a first chamber and a second chamber each for the receipt of a flow of fluid therethrough and wherein the flow of fluid enters the first chamber at one end and exits at the other end whereupon it enters the second chamber at one end and exits at the other end;
- (b) a first temperature sensing means operably disposed in the first chamber for measuring the temperature of fluid therethrough and a second temperature sensing means operably disposed in the second chamber for measuring the temperature of fluid therethrough, and a means for comparing the temperature of fluid in the first chamber against the temperature of fluid in the second chamber;
- (c) a heating element disposed in each of said chambers operably connected to said first and second temperature sensing means for measuring the temperature of fluid in each said first and second chambers and to said means for comparing the differences in temperature of fluid therein;
- (d) a means for energizing each of said heating elements selectively;
- (e) a temperature set means operatively connected to each of said heating elements for the separate actuation thereof;
- (f) an electronic means coupling each said temperature measuring means to said temperature set means so that each of said heating elements are selectively energized when the temperature of fluid in either of the chambers is lower than the temperature set means; and
- (g) said means for energizing the heating elements comprises means for energizing the heating element prox-

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mate to the fluid entering the first module when the temperature of the fluid is below that which is desired and wherein said means for energizing said heating element proximate to the entering fluid in the first module continues to heat the fluid until a preset temperature is reached.

16. The heater apparatus of claim 15, wherein the number of said modules is determined by the predicted volume of fluid flow such that a larger quantitative fluid flow requires a heater apparatus having more modules than a predicted lower volume of fluid flow, each of said modules connected serially to the preceding modules and wherein each of said modules comprises first and second chambers having heating elements therein operably connected to temperature sensing and energizing means.

17. The heater apparatus of claim 16, wherein at least one of said chambers is characterized by venting means for releasing entrapped air or gasses therewithin.

18. A heating apparatus for heating a flow of fluid while it continuously travels therethrough having one or more modules, and wherein each of said modules are characterized by a first and second chamber, and wherein each of said chambers having a heating means disposed therein, the improvement comprising:

- (a) an electronic control means operatively coupled to each said heating means in each chamber and to a temperature sensing means disposed at one end of the first chamber and at the opposing end of the second chamber so as to sense the temperature of the fluid passing thereby at each location and for energizing each of said heating means selectively when the temperature of the fluid in the first chamber is less than a predetermined temperature or for energizing the heating means in the second chamber when the temperature of the fluid is less than the predetermined temperature.

19. The heater apparatus of claim 18, wherein a flow volume detection means is operatively connected to the heater apparatus for measuring the fluid volume flow therethrough and including a temperature sensor means located at each of two positions in the heater apparatus for detecting a differential in temperature therebetween to thereby ascertain the existence of flow within the apparatus.

20. The heater apparatus of claim 18, wherein the heater apparatus includes a temperature sensing means to detect the temperature of fluid departing from each chamber, and wherein the temperature sensing means is operatively coupled to a temperature set means such that the temperature sensing means energizes the heating means in the departing chamber until the fluid departing the last chamber reaches a temperature equivalent to the temperature required by the temperature set means.

21. A heater apparatus designed for heating of a continuous flow of fluids therethrough comprising one or more modules

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disposed in serial fashion, each of said modules constituting a modular apparatus comprising:

- (a) a first chamber and a second chamber each for the receipt of a flow of fluid therethrough and wherein the flow of fluid enters the first chamber at one end and exits at the other end whereupon it enters the second chamber at one end and exits at the other end;
- (b) a first temperature sensing means operably disposed in the first chamber for measuring the temperature of fluid therethrough and a second temperature sensing means operably disposed in the second chamber for measuring the temperature of fluid therethrough, and a means for comparing the temperature of fluid in the first chamber against the temperature of fluid in the second chamber;
- (c) a heating element disposed in each of said chambers operably connected to said first and second temperature sensing means for measuring the temperature of fluid in each said first and second chambers and to said means for comparing the differences in temperature of fluid therein;
- (d) a means for energizing each of said heating elements selectively;
- (e) a temperature set means operatively connected to each of said heating elements for the separate actuation thereof;
- (f) an electronic means coupling each said temperature measuring means to said temperature set means so that each of said heating elements are selectively energized when the temperature of fluid in either of the chambers is lower than the temperature set means; and
- (g) said means for energizing the heating elements comprises means for energizing the heating element proximate to the fluid departing the last module when the temperature of the fluid is below that which is desired and wherein said means for energizing said heating element proximate to the departing fluid in the last module continues to heat the fluid until a preset temperature is reached.

22. The heater apparatus of claim 21, wherein the number of said modules is determined by the predicted volume of fluid flow such that a larger quantitative fluid flow requires a heater apparatus having more modules than a predicted lower volume of fluid flow, each of said modules connected serially to the preceding modules and wherein each of said modules comprises first and second chambers having heating elements therein operably connected to temperature sensing and energizing means.

23. The heater apparatus of claim 22, wherein at least one of said chambers is characterized by venting means for releasing entrapped air or gasses therewithin.

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