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(54) **A method and apparatus for heating liquid.**

(57) A method and apparatus for providing an instantaneous supply of heated liquid on demand is disclosed. The novel method of the invention includes the step of feeding liquid to be heated to a heating chamber (1) wherein the flow of incoming liquid enters the chamber substantially and uniformly over the base (20) of the heating elements (4) within the chamber. The novel apparatus of the invention includes a heating chamber (1) having a liquid dispersing means (18) at the inlet (2) for dispersing the flow of incoming liquid throughout a substantial portion of the flow cross-section of the heating chamber.

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A METHOD AND APPARATUS FOR HEATING LIQUID

BACKGROUND OF THE INVENTION

This invention relates generally to the field of fluid heaters, and is particularly directed to a novel method and apparatus for providing an instantaneous and continuous supply of heated liquid on demand.

Using the method and apparatus of the present invention, liquids, such as water, may be efficiently and economically heated substantially on demand at the point of delivery.

Methods and systems known in the prior art for heating liquids wastefully and inefficiently consume great amounts of energy. In the conventional water heater, for example, a large reservoir of water is stored at a remote location and heated to a predetermined temperature. Water heaters of this type are deficient in a number of ways. First, such heaters consume energy during both in-use and non-use periods. Second, remotely located water heaters require the installation of two separate plumbing systems, one system for cold water and a second system for hot water. Conventional hot water heaters are further deficient due to so-called "cold water delay." Cold water delay occurs as a result of residual water remaining in the piping system which cools after the faucet or tap is turned off. When hot water is again required, cool water flows from the open faucet until the residual water is flushed from the system. Moreover, during this lag period, cold water flows into the storage reservoir further lowering the temperature of the heated water, requiring additional energy to compensate for the suddenly lowered temperature. Conventional water heaters are further deficient due to the large amount of heat lost in moving the heated water through the piping system and the special space considerations required by such water heaters.

There are rapid response liquid heaters known in the prior art which attempt to overcome the deficiencies of the reservoir type water heater. For example, U.S. Patent No. 3,952,182 to Flanders and U.S. Patent No. 3,673,385 to Drugmand et al disclose fluid heaters adapted for instantaneously heating relatively small bodies or flow increments of fluid to a predetermined temperature. These fluid heaters are also unsatisfactory because they are susceptible to developing so-called "hot spots" which can lead to overheating of the fluid and generation of steam. Such heaters are, therefore, particularly unsuitable for use in the home.

SUMMARY OF THE INVENTION

One object of the present invention is to overcome the disadvantages of the prior art devices by providing an in-line liquid heater which is efficient and inexpensive to manufacture and operate.

Another object of the present invention is to provide an in-line liquid heater which substantially and uniformly heats liquid flowing through it without the formation of potentially dangerous vapor bubbles.

The in-line liquid heating device of the present invention overcomes many of the deficiencies inherent in liquid heating devices known in the prior art and comprises an elongated heating chamber having an inlet at the base for receiving liquid to be heated and an outlet at the top for discharging heated liquid. High power electrical resistance heating elements are positioned inside the heating chamber for heating a continuous flow of liquid flowing through the chamber. Electrical power to the heating elements is provided through a set of relay contactors which are controlled by a flow responsive switch, a thermostat and a high temperature cut-out switch. The flow responsive switch prevents electrical power from being applied to the heating elements until a flow of liquid through the device is sensed, e.g., when a hot water faucet is turned on. The thermostat controls the temperature of the liquid discharged from the heating chamber and is connected to de-energize the heating elements when a predetermined temperature level is reached. The high temperature cut-out switch is a safety device designed to de-energize the heating elements should the thermostat fail or for some other reason the temperature inside the heating chamber reaches a dangerous level. The in-line liquid heating device of the present invention also includes a pressure relief valve for preventing excessive pressure from building inside the heating chamber.

Suprisingly, it has been discovered that the configuration of the in-line liquid heating device of the invention yields superior and unexpected results in that rapid and efficient heating occurs without the formation of vapor bubbles so prevalent in the prior art systems. This result is obtained by the presence of a deflection baffle at the inlet of the heating chamber for dispersing the flow of incoming liquid across substantially and uniformly the entire flow cross-section of the heating chamber. As mentioned above, rapid liquid heaters known in the prior art are unsatisfactory for a number of reasons, including the uncontrolled formation of hot spots. Hot spots tend to cause scalding and overheating and the formation of vapor bubbles. Inclusion of the deflection baffle at the inlet to the heating chamber substantially prevents the formation of hot spots and their attendant problems in the heating chamber as explained below.

Optimum performance of a liquid heating device is realized when incoming cold liquid is efficiently heated to a predetermined temperature with no vapor production (localized boiling). Since heat evolution occurs essentially uniformly over the surface of the heating elements, the element sheaths should be as uniformly cooled by the liquid flow as possible. This maximizes thermal transfer efficiency and eliminates hot spots that would be caused by stagnant flow conditions. While turbulent flow conditions induced throughout a heating chamber (such as by utilizing prior art finned or convoluted heat exchange elements) maximize local heat transfer (i.e., localized turbulence) by reducing the thickness of the boundary layer along the element sheaths, it could occur at the expense of reduced flow elsewhere, and its concomitant adverse heat transfer, if attention is not given to prevent it.

The deflection baffle at the inlet of the heating chamber produces a controlled amount and uniform distribution of turbulence adjacent the inlet end or base of the chamber, which results in optimized flow and heat transfer conditions along the length of the heating chamber. This feature allows the in-line liquid heater of the present invention to utilize the high electrical power input and heat transfer (without vapor production) necessary for a truly adequate liquid heater of the instant demand category.

In the in-line liquid heating device of the present invention, the inlet to the heating chamber is located near the base of the heating element. This ensures sufficient liquid flow over the heating element base. The outlet from the heating chamber is located beyond the downstream end of the heating element to provide sufficient head room to avoid a stagnant area of liquid at the end of the heating chamber which otherwise would be in contact with the heating element. The heating chamber is also of sufficient size that enough water remains in the chamber to absorb residual heat from the heating elements when the flow of liquid is stopped without boiling.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a front elevational view of the in-line liquid heater of the present invention showing the heating chamber and the associated control devices.

Figure 2 is a circuit schematic showing the interconnection of the heating elements, control relay contactors, flow responsive switch, thermostat and high temperature cut-out switch.

Figure 3 is a front elevational view of the heating chamber of the in-line liquid heater of the present invention showing the water inlet.

Figure 4 is a perspective view of the liquid deflection baffle used at the inlet of the heating chamber.

Figures 5 and 6 illustrate the movement of incoming water into a prior art heating chamber, without the liquid dispersing baffle of the present invention.

Figures 7 and 8 illustrate the movement of incoming water into the heating chamber with the liquid dispersing baffle of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

The in-line liquid heater which is the subject of this invention consists of a number of interrelated elements, all of which are shown in at least some detail in Figure 1. Each component will be explained in detail below.

Basically, the in-line liquid heater comprises elongated heating chamber 1 having an inlet 2 for receiving liquid to be heated and outlet 3 for discharging heated liquid. Electrical heating element 4 is disposed inside heating chamber 1 for heating the liquid as the liquid flows downstream from inlet 2 to outlet 3. Heating element 4 extends into heating chamber 1 from the base 20 end of the chamber through a threaded connection. Electrical power to heating element 4 is provided through relay contactors 6-8. Relay contactors 6-8 are controlled by flow responsive switch 11, thermostat 10 and its associated thermocouple 12, and high temperature cut-out switch 9 and its associated thermocouple 13. The in-line liquid heater of this invention also includes pressure relief valve 14 which prevents excessive pressure from building inside heating chamber 1. An important feature of this invention is the presence of deflector baffle 18, shown in Figure 4, in inlet 2 of heating chamber 1. Deflector baffle 18 directs and disperses the flow of incoming liquid to provide a uniform flow of liquid through substantially the entire flow cross-section of heating chamber 1 as will be explained below. Such a flow of liquid through the heating chamber is necessary to prevent the creation of hot spots and improves overall heat transfer.

With further reference to Figure 1, heating chamber 1 may be fabricated from any material that can be rigidly formed and has high strength and is capable of withstanding temperature well above the operating range of the in-line heater. Such materials include copper and cadminum, and certain man-made materials such as fiberglass. As shown in Figure 1, heating element 4 enters the base or upstream end of heating chamber 1. Heating element 4 may comprise a plurality of individual elements as shown, or may consist of a single element. Heating element 4 may also be fabricated in a variety of geometric configurations. However, the Applicants have realized that heating elements having a smooth sheath topography as shown, are superior to using finned or convoluted element surfaces by reason of their lower cost, freedom from stagnant liquid flow (which would occur behind the fins), and freedom from corrosion and scale buildup.

Fuse block 25 and relay contactors 6-8 may be selected from a variety of commercially available fuse blocks and relay contactors and are selected based upon the wattage rating of heating element 4. Two-stage thermostat 10 and high temperature cut-out switch 9 and their associated thermocouples 12 and 13 may also be selected from a variety of commercially available devices. In the preferred embodiment of the invention, thermostat 10 is a two-stage thermostat and is used to control the temperature of the liquid discharged at outlet 3 of chamber 1 within a predetermined temperature range. A conventional high temperature cut-out switch 9 is used to interrupt electrical power to heating element 4 should the temperature inside heating chamber 1 rise to a predetermined dangerous level. A conventional flow responsive switch 11 provides an output signal when a flow of liquid at inlet 2 of heating chamber 1 is sensed. Flow responsive switch 11 may, for example, be a series F60 device manufactured by Johnson Controls, Inc. Flow responsive switch 11, together with thermostat 10, high temperature cut-out switch 9 and relay contactors 6-8 control application of electrical power to heating element 4 as will be explained below in connection with Figure 2. A conventional relief valve 14 is provided to relieve excessive pressure which may build up inside heating chamber 1.

With reference to Figure 2, a schematic diagram is shown illustrating the electrical interconnection of heating element 4 (represented by individual elements 15-17), relay contactor 6-7, thermostat 10, high limit switch 9, flow responsive switch 11 and fuse block 25 wherein the included elements 15-17 are each connected to a three-phase power source 5. It is contemplated that the elements may also be connected to a single phase source. It is also contemplated that heating element 4 may be of a wattage rating selected to provide a desired rise in temperature of the liquid entering chamber 1 to achieve a liquid discharge temperature of a desired level and at a desired flow rate. For example, it has been found that in the present invention, a 13,500 watt heating element can produce a temperature rise of 70°F at a flow rate of 1.5 gallons per minute and a 15,000 watt heating element can produce a temperature rise of 70°F at a flow rate of 5 gallons per minute. Such temperature rises and flow rates were obtained using a heating chamber of approximately 16 inches in length and 2 inches in diameter.

In the preferred embodiment of the invention, electrical power to one of the individual heating elements, as for example 17, is controlled by flow switch 11 and high temperature cut-out switch 9. Individual elements 15 and 16 are further controlled by two-stage thermostat 10. In operation, individual elements 15-17 are de-energized until a flow of liquid is sensed by flow switch 11. When a flow of liquid is sensed, individual elements 15-17 are energized until the temperature of the discharged liquid reaches a perdetermined upper temperature, e.g., 130°F. When the predetermined upper temperature is reached, individual elements 16 and 17 are de-energized until such time as the temperature of the discharged liquid reaches a predetermined lower temperature, e.g., 126°F, and individual elements 15 and 16 are then re-energized.

Figure 3 illustrates the location of deflector baffle 18, shown in Figure 4, at inlet 2' of chamber 1. As shown in Figure 4, deflection baffle 18 may be fabricated from a wide variety of materials that can be rigidly formed and can withstand temperatures well above the normal operating range of the in-line heater. Deflection baffle 18 has a formed portion or lip 19 which directs the incoming flow of liquid to produce a controlled amount and distribution of turbulence as shown in Figures 7 and 8. This results in optimized flow and heat transfer conditions up the entire length of heating chamber 1. Formed portion 19 of deflection baffle 18 serves to both direct the incoming liquid flow downward toward base 20 and also diverge (fan out) the stream across a substantial portion of the cross-section of heating chamber 1. This results in turbulent mixing of the incoming stream of liquid downward along base 20 of heating element 4 with liquid already in heating chamber 1. The stream is spread sufficiently to uniformly cover the entire element cluster. The significant result of the turbulence in the lower end of heating chamber 1 is that the mixing that takes place results in a more uniform flow up along the element cluster as shown. This minimizes the probability of hot spots occurring along the element sheaths. The sides of the element cluster are therefore more equally cooled.

Deflection baffle 18 creates the optimum liquid flow pattern by dispersing the flow of incoming liquid to heating chamber 1 at inlet 2 substantially and uniformly over the base of heating chamber 1. It is believed that this produces a uniform laminar flow of liquid along the heating chamber over substantially all of the surface area of heating element 4. Deflection baffle 18 further minimizes undesired rotational flow of the liquid through heating chamber 1. Rotational flow of the liquid can result in localized turbulence which would not permit efficient and maximum heat transfer between heating element 4 and the liquid. This condition is produced because the liquid would not uniformly flow over substantially all of the surface area of heating element 4, resulting in the formation of hot spots in the heating chamber 1.

When operating an immersion heating element at high power density (in terms of watts per square inch of sheath area), it is essential that sufficient liquid flow be maintained over the entire length of the element. This is the function deflection baffle 18 serves. Figure 5 illustrates the effect of a straight inlet as known in the prior art. Fluid enters the heating chamber as an undiverged stream. Some divergence of flow occurs as the incoming fluid impinges the heating elements as shown in Figure 6. The main portion of the stream, however, will simply flow between the elements and spread along the opposite wall of the heating chamber. This results in a pronounced upward flow along the opposite wall at the expense of flow upward along the elements nearest the inlet. This imbalanced flow pattern can be contrasted to that shown in Figure 7 which results from the baffled inlet of the present invention. The folded over tube edge serves to both direct the incoming liquid flow downward against the base and also diverge (fan out) the stream (Figure 8). This results in turbulent mixing of the incoming stream downward along the base of the heating element with liquid already in the heating chamber. The stream is spread sufficiently and uniformly over the cross-section of the chamber to cover the entire element cluster. The significant result of the turbulence in the lower end of the heating chamber is that the mixing that takes place apparently results in a more uniform flow up along the element cluster as shown in Figure 7. This minimizes the probability of hot spots occurring along the element sheaths. The two sides of the element cluster are therefore more equally cooled.

In summary, the inlet baffle feature of the in-line liquid heating device of the present invention optimizes the liquid flow pattern within the heating chamber, allowing the high power density needed for desired volume flow rates and adequate temperature rise without steam generation problems. This method is superior to using finned or convoluted element surfaces by reason of the following: (1) the use of lower cost, smooth sheath immersion heaters is permitted; (2) the possibility of stagnant flow regions behind fins is eliminated; and (3) corrosion and scale buildup problems will be less due to the smooth sheath topography and reduced surface area.

Obviously, many modifications and variations of the above-described preferred embodiment will become apparent to those skilled in the art from a reading of this disclosure. It should be realized that the invention is not limited to the particular apparatus disclosed, but its scope is intended to be governed only by the scope of the appended claims.

CLAIMS:

1. An in-line liquid heating device for providing an instantaneous supply of heated liquid on demand, said liquid heating device comprising a liquid heating chamber (1) having an inlet (2) for receiving liquid to be heated and an outlet (3) for discharging heated liquid, heating means (4) mounted in said heating chamber for heating the liquid and dispersing means (18) for dispersing the flow of liquid entering said heating chamber throughout a substantial portion of the flow cross-section of said heating chamber to substantially prevent the formation of areas of stagnant liquid in said heating chamber while liquid is being discharged through said outlet.

2. The in-line liquid heating device of claim 1, wherein said liquid heating chamber (1) comprises an upstream end and a downstream end, said inlet (2) being located adjacent the upstream end of said chamber and said outlet (3) being located adjacent the downstream end of said chamber and wherein said heating means (4) comprises a base portion (20) coupled to said chamber and having at least one heating element extending into said liquid heating chamber from the upstream end.

3. The in-line liquid heating device of claim 2, wherein said dispersing means (18) disperses the flow of liquid entering said heating chamber (1) at said inlet (2) substantially and uniformly over the base (20) whereby fluid movement through said chamber from said upstream end and to said downstream end is produced in a uniform laminar flow along the heating means (4).

4. The in-line liquid heating device of claim 2,

wherein said dispersing means (18) substantially minimizes rotational flow of the liquid as it moves from said upstream end to said downstream end.

5. The in-line liquid heating device of claim 2, wherein said dispersing means (18) substantially eliminates localized turbulence of said liquid as it moves from said upstream end to said downstream end.

6. The in-line liquid heating device of claim 2, wherein the transfer of heat between said heating means (4) and the liquid is uniform over substantially all of the surface area of said heating element.

7. The in-line liquid heating device of claim 2, wherein said heating element is an electrical resistance heating element.

8. The in-line liquid heating device of claim 1, further comprising flow sensing means (11), operatively coupled to said inlet (2), for sensing a flow of liquid entering said heating chamber (1), and sensing means being coupled to said heating means (4) for activating said heating means to thereby heat said liquid when a liquid flow is sensed.

9. The in-line liquid heating device of claim 8, wherein said flow sensing means (11) is an electrical flow responsive switch.

10. The in-line liquid heating device of claim 1, further comprising temperature control means (10) operatively coupled to said chamber (1) and said heating means (4) for maintaining the liquid discharged from said outlet (3) within a predetermined temperature range.

11. The in-line liquid heating device of claim 10, wherein said temperature control means (10) is a two-stage

thermostat.

12. The in-line liquid heating device of claim 1, further comprising a high temperature safety cutoff means (9) for deactivating said heating means (4) when the temperature of said heating chamber (1) exceeds a predetermined temperature.

13. The in-line liquid heating device of claim 12, wherein said high temperature safety cutoff means (9) is a high temperature limit switch.

14. The in-line liquid heating device of claim 1, further comprising a high pressure safety relief means (14) operatively coupled to said chamber (1) for relieving the pressure within said chamber when a predetermined high pressure is exceeded.

15. The in-line liquid heating device of claim 14, wherein said high pressure safety relief means (14) is a pressure relief valve.

16. In an in-line liquid heating device for providing an instantaneous supply of heated liquid on demand of the type having a base (20), a liquid heating chamber (1) coupled to the base having an inlet (2) at an upstream end of said chamber adjacent said base and an outlet (3) adjacent a downstream end of said chamber, and heating means (4) in said chamber extending from said base for heating the liquid, the improvement comprising dispersing means (18) for dispersing the flow of liquid entering said heating chamber at said inlet substantially and uniformly over the base wherein the transfer of heat between said heating means and liquid is uniform over substantially all of the surface area of said heating element.

17. A method for providing an instantaneous supply of uniformly heated liquid from an in-line on-demand heater having a base (20), a liquid heating chamber (1) coupled to said base having an inlet (2) at an upstream end of said chamber adjacent said base and an outlet (3) adjacent a downstream end of said chamber and heating means (4) in said chamber extending from said base for heating the liquid, the method comprising the steps of feeding unheated liquid to said chamber through said inlet, dispersing the flow of incoming liquid entering said chamber substantially and uniformly over said base wherein the transfer of heat between said heating means and the liquid is uniform over substantially all of the surface area of said heating element and removing heated liquid to said outlet.

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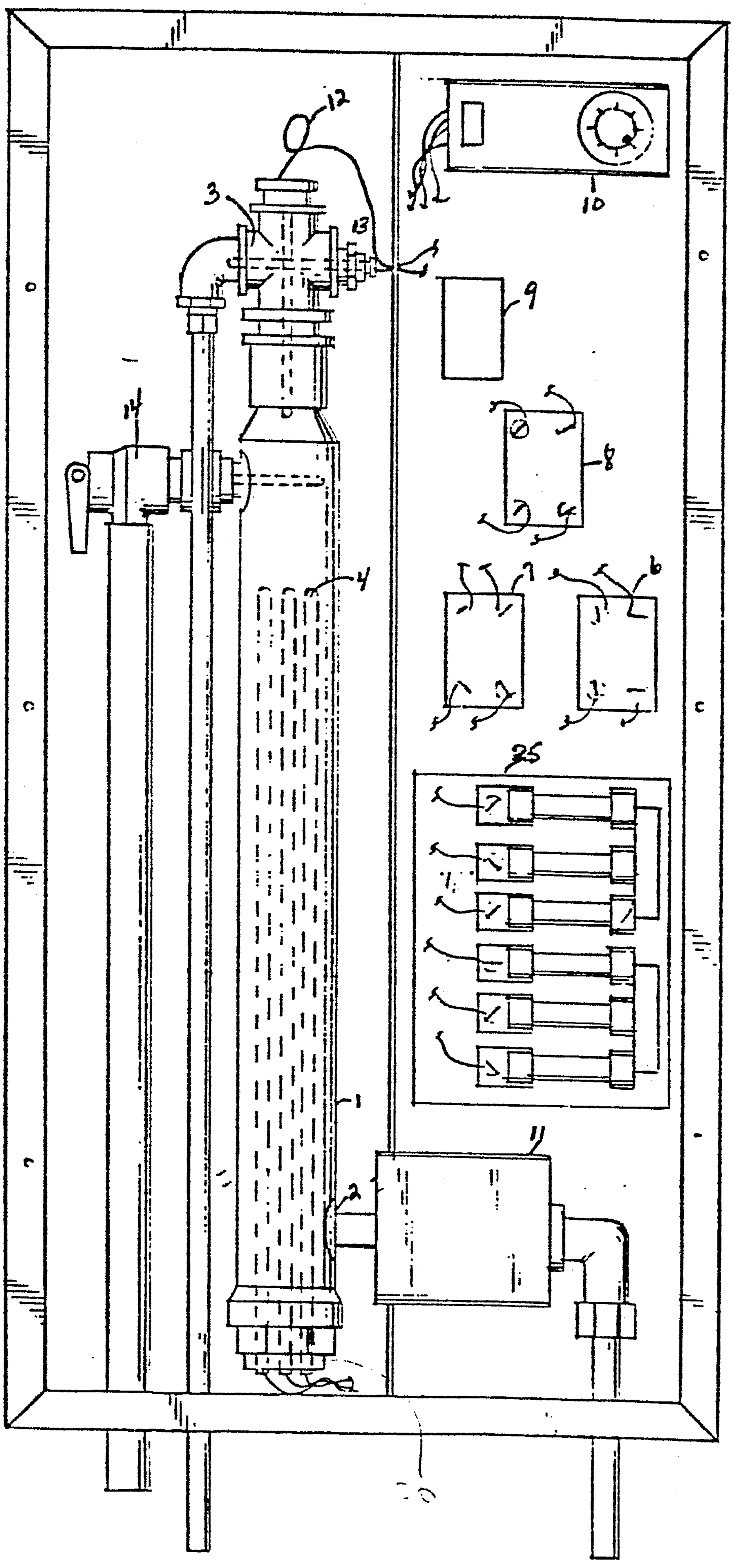
FIG. 1.



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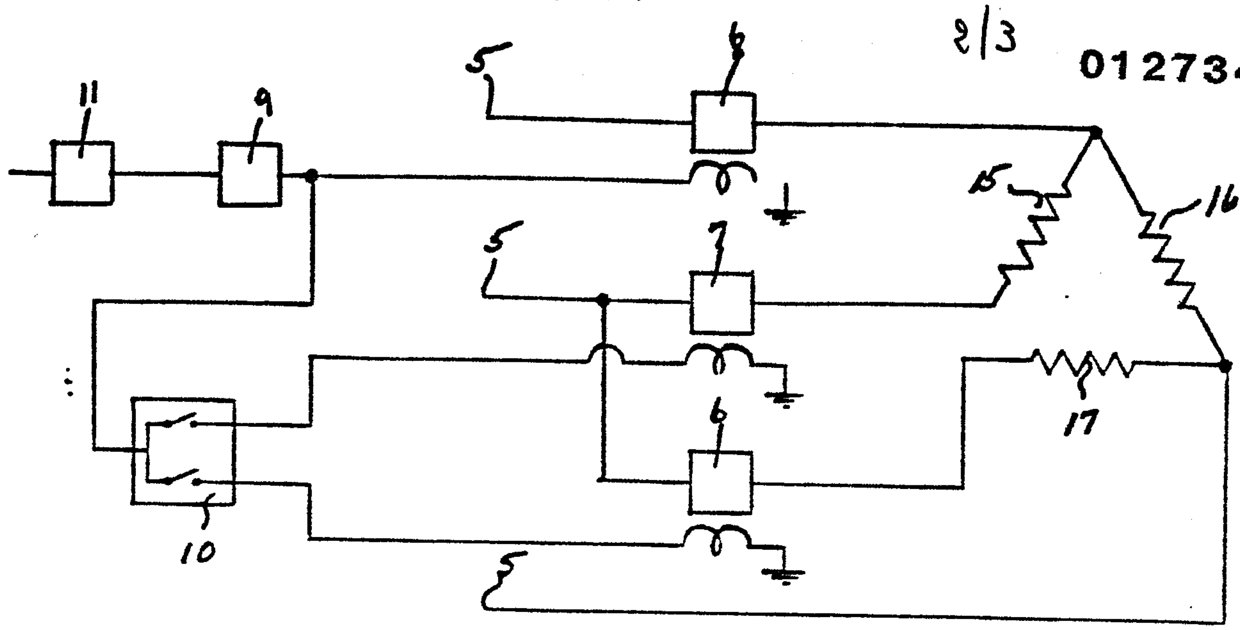
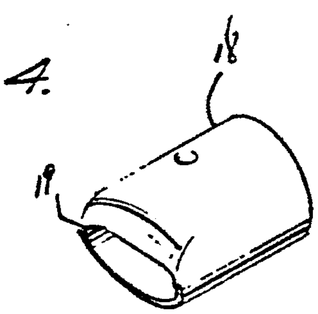


FIG. 2.

FIG. 4.



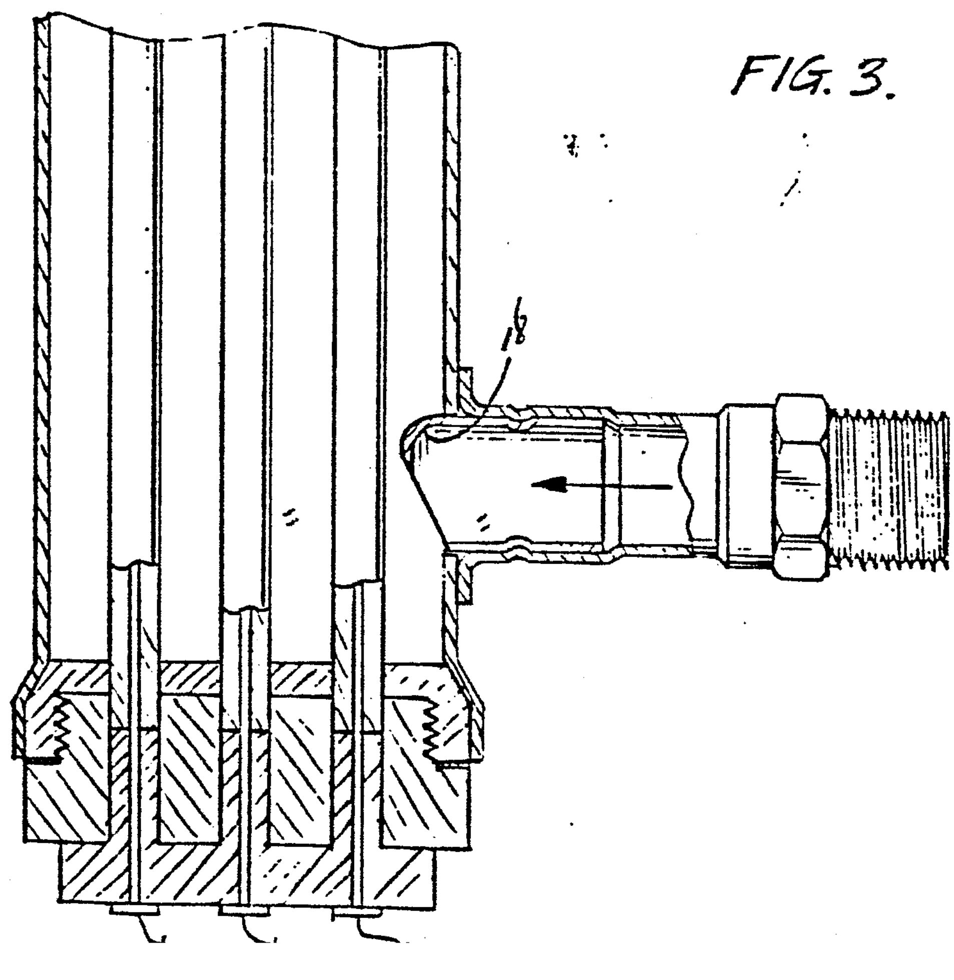


FIG. 3.

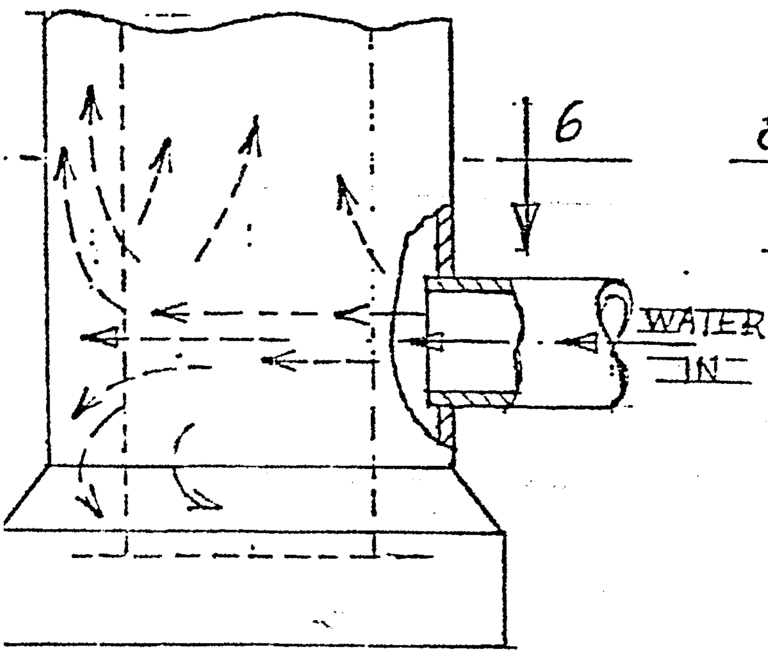


FIG. 5
PRIOR ART

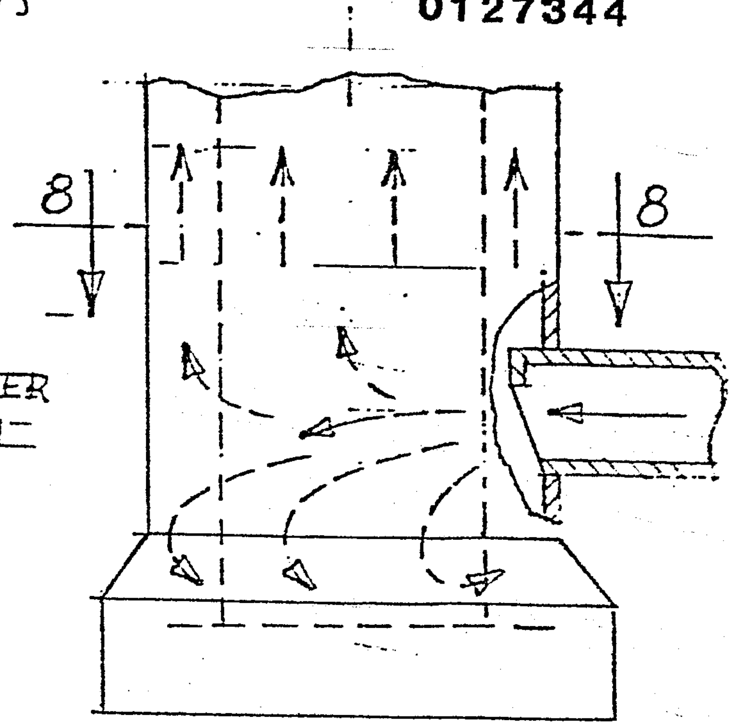


FIG. 7

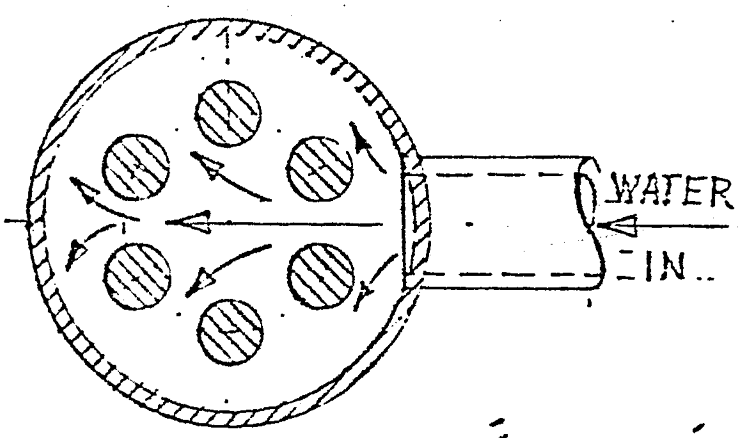


FIG. 6
PRIOR ART

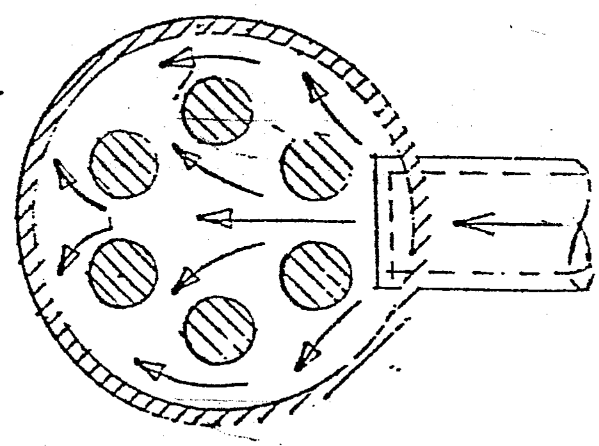


FIG. 8