United States Patent

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[54] FLUID HEATING APPARATUS

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[51] **Int. Cl.** **H05b 3/60**, H05b 1/02

[58] **Field of Search** 219/284–295, 271–276, 219/341

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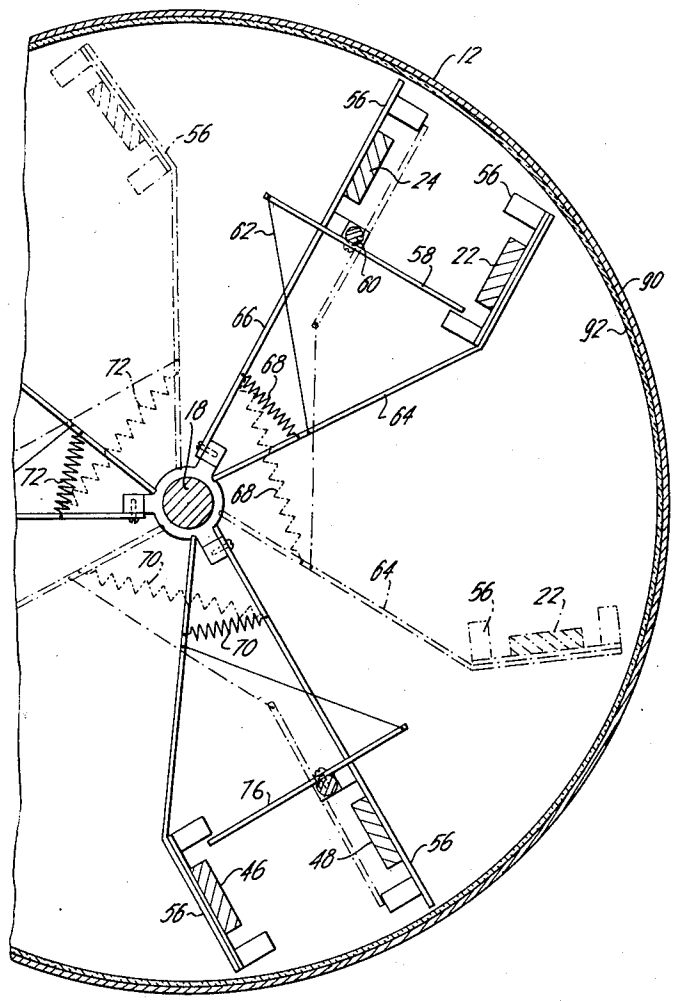
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[57] **ABSTRACT**

A fluid is heated as it passes through the tank of an apparatus in which one or more pairs of electrodes are provided. The fluid is heated by a current which flows between the electrodes. At least one electrode of each pair is movable so that the distance between the electrodes can be varied to modulate the current flow in accordance with the quantity of heat to be added to the fluid. Further modulation of the current can be accomplished by placing an electrically insulating shutter between the electrodes. This shutter moves in conjunction with a movable electrode to vary the extent to which it blocks the most direct current path. The electrical power used by the apparatus can be limited to prevent high peak power demands.

17 Claims, 7 Drawing Figures



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3 Sheets-Sheet 1

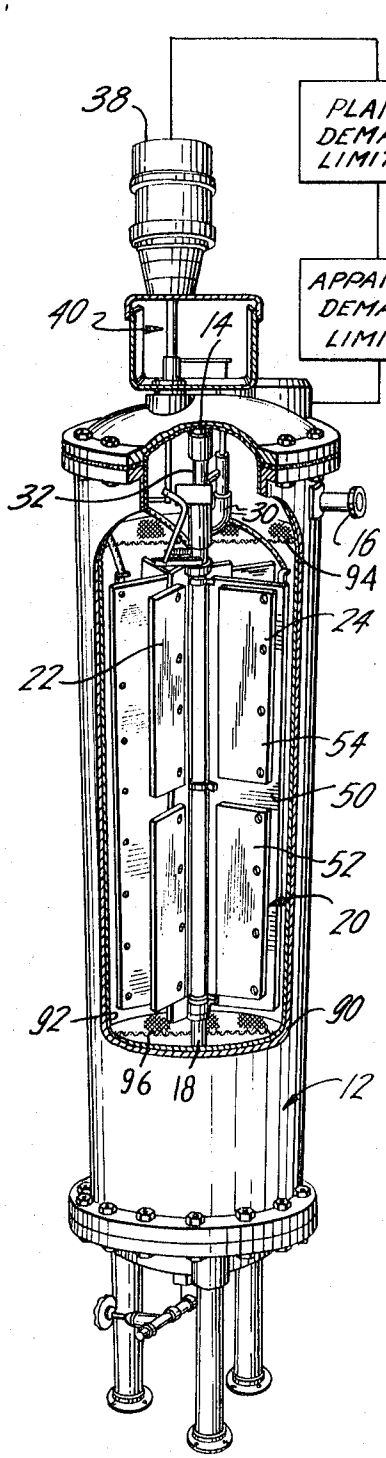


FIG.1

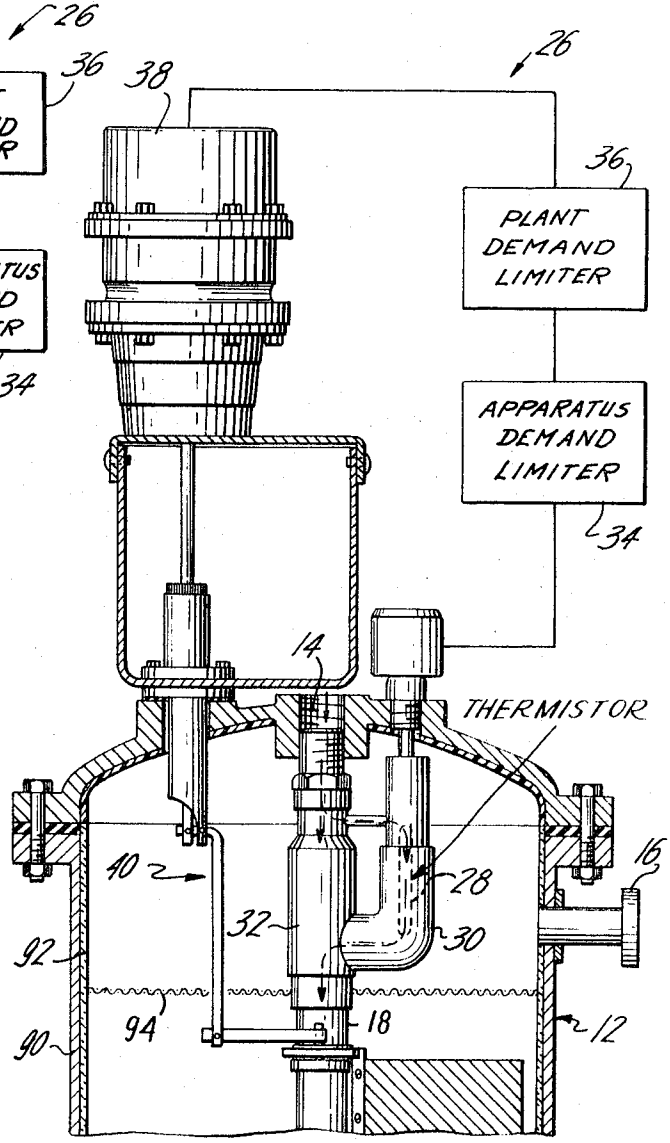


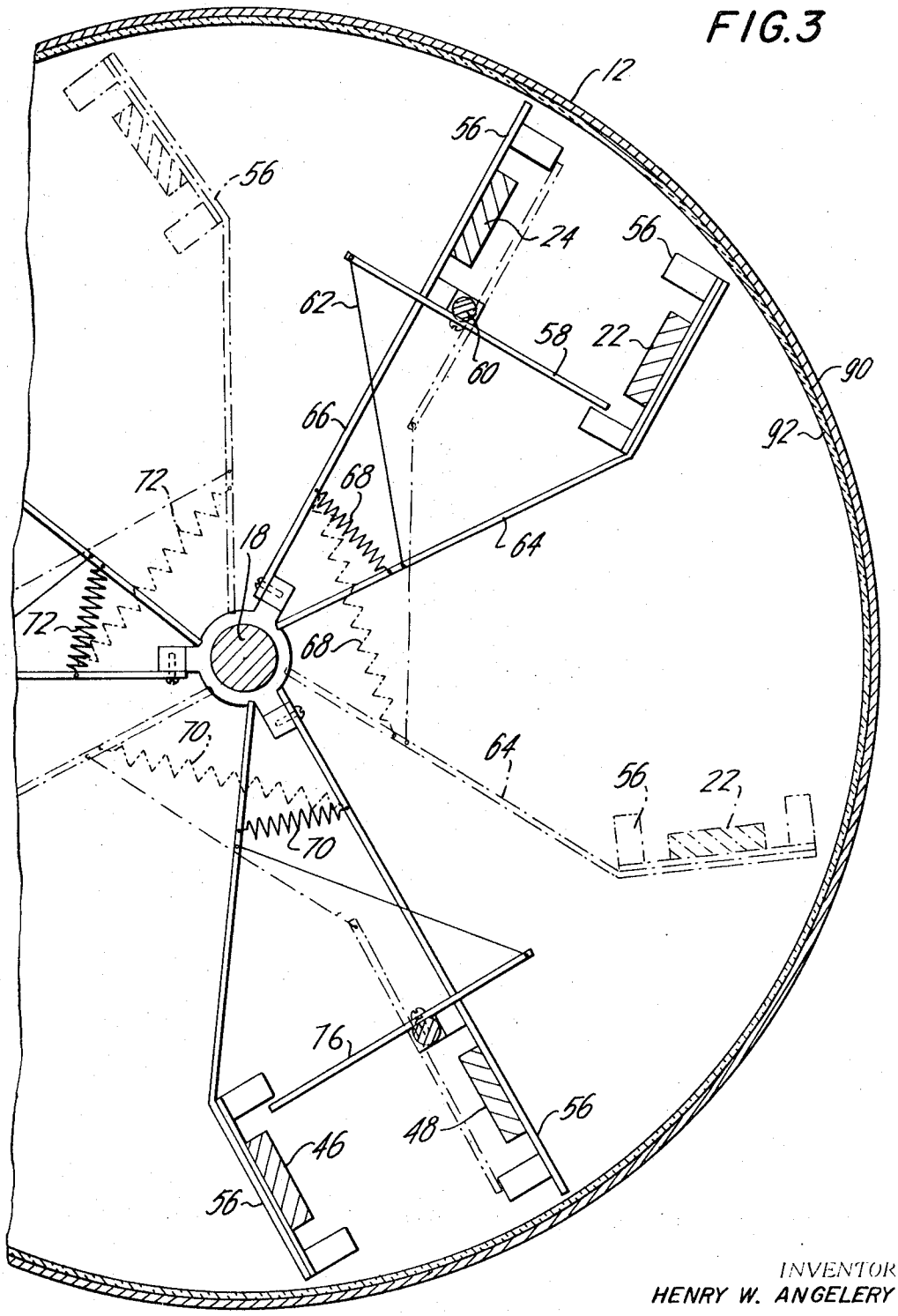
FIG.2

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FIG. 3



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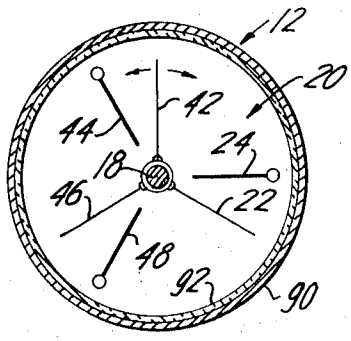
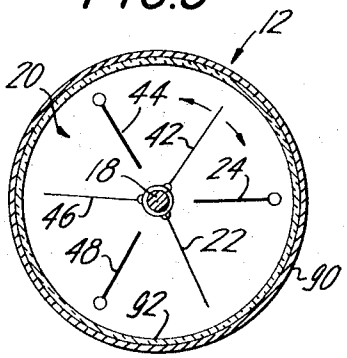


FIG. 4

FIG. 5



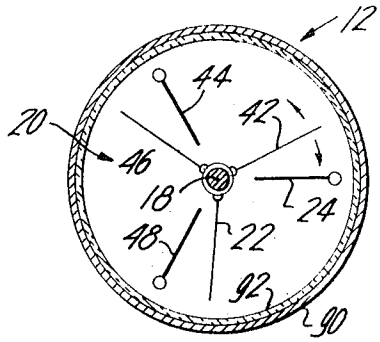


FIG. 6

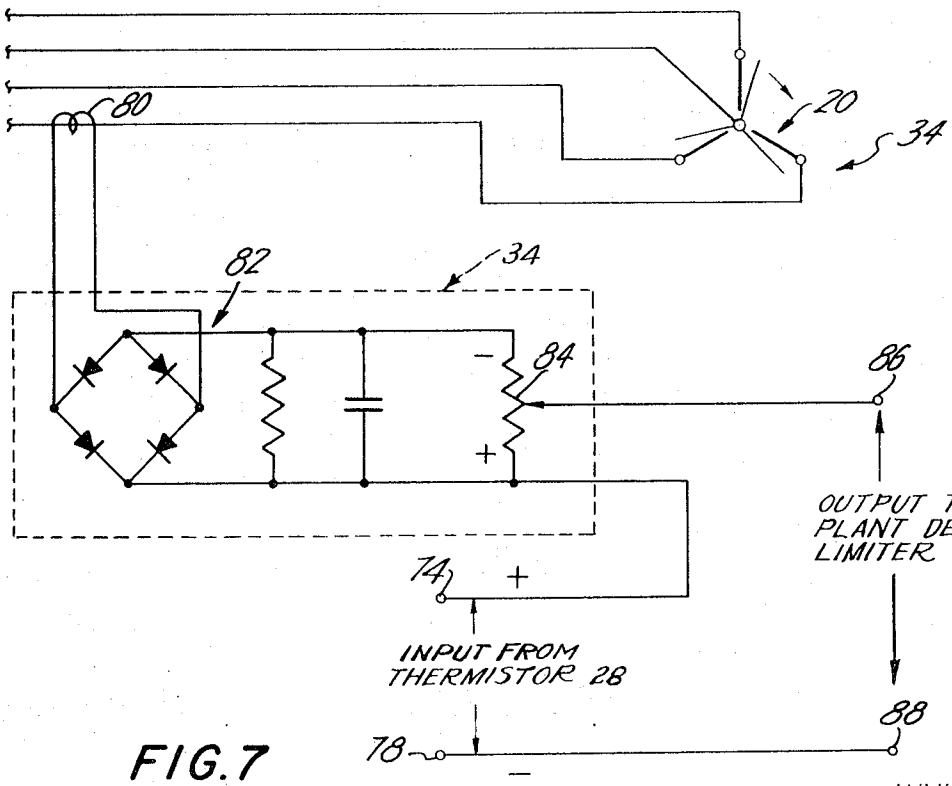


FIG. 7

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FLUID HEATING APPARATUS

BACKGROUND OF THE INVENTION

This invention relates to electrically operated fluid heaters, and more particularly to an electrically operated fluid heater in which the electrodes are movable relative to each other to modulate the current flow.

A variety of types of apparatus are known in which a fluid to be heated is passed through a tank in which one or more pairs of electrodes are provided. The fluid which flows through the tank is heated by the current that flows between the electrodes.

In those environments in which it is desired to employ an electric fluid heater it is often found that the quantity of heat to be added to the fluid is not constant. For instance, electric heaters are often used to heat water, and the amount of heat which must be added is dependent not only upon the ambient temperature of the surrounding environment but also upon the demand for heated water at any particular time. Accordingly, a number of systems have been developed which permit modulation of the current flow in accordance with the quantity of heat to be added to the fluid. One such system utilizes a voltage divider to vary, by discrete steps, the potential difference between the electrodes. Another system for modulating the current flow is disclosed in my earlier U.S. Pat. No. 3,356,827 which was issued on Dec. 5, 1967.

A number of problems commonly associated with previously known electric fluid heaters which modulate the current flow to vary the quantity of heat added to the fluid have prevented their utilization to the fullest extent. Some important factors in this respect are the complexity, durability, and maintenance requirements of the devices as well as the effectiveness with which the space occupied by the devices is utilized.

Another important problem associated with some previously known heating apparatus is their tendency to produce high electrical power demands during transient operating conditions. It is well known by those familiar with the pertinent technology that the cost of operating an electrical device is dependent, to a large degree, upon the maximum demands which it makes upon the power supply as it is operated over a period of time under varying conditions. The construction of many electric heaters is such that they make a very large demand upon the power supply when they are first turned on and at other times when their electrical operating parameters have not been stabilized.

It will be understood from the above discussion that there is presently a recognized need for an improved apparatus for heating fluids electrically. This need exists not only in the area of heating water but in a wide variety of other applications such as heating oil and making steam.

SUMMARY OF THE INVENTION

The present invention comprises an apparatus for heating fluids electrically. At least one pair of electrodes between which a current can be passed to heat the fluid is disposed within a tank which is provided with an inlet and an outlet for the fluid. One of the electrodes of each pair is movable with respect to the other, and a control means is provided for varying the distance between the electrodes whereby the current flow can be modulated in accordance with the quantity of heat to be added to the fluid flowing through the tank.

The apparatus may include an electrically insulating shutter movably disposed between the electrodes whereby a portion of the most direct current path can be blocked. The shutter is operatively connected to the control means whereby it is caused to block the most direct path of current flow to a greater extent when the electrodes are relatively far apart than when they are relatively close together.

It is preferred, although not necessary, to provide a means for biasing each movable electrode toward the position in which it is farthest from the corresponding stationary electrode whereby the current is reduced to a minimum in the event of an interruption of the power supply or a malfunction of the apparatus. The biasing means can be arranged to cooperate with the control means for causing the apparatus to commence operation with the electrodes in the position in which they are farthest apart whereby the effects of transient conditions upon the power demands of the apparatus are minimized.

It is convenient in most situations in which the invention is to be utilized to employ three pairs of electrodes, one electrode of each pair being connected to one phase of a conventional three phase alternating current power supply. The electrodes can be arranged so that they are disposed radially about a supporting shaft which is centrally disposed within a cylindrical tank through which the fluid passes.

BRIEF DESCRIPTION OF THE DRAWINGS

For a more complete description of the invention, reference may be had to the following detailed description of an exemplary embodiment of the invention taken in conjunction with the accompanying figures of the drawings in which:

FIG. **1** is a partially broken away three dimensional pictorial representation of an electrical fluid heating apparatus constructed in accordance with the invention;

FIG. **2** is a sectional side elevation of the upper portion of the apparatus shown in FIG. **1**;

FIG. **3** is a top view in section of another embodiment of the invention;

FIGS. **4**, **5**, and **6** are schematic representations of top views in section of the apparatus shown in FIG. **1**, each figure showing the apparatus under different operating conditions; and

FIG. **7** is a schematic diagram of an electrical circuit which may be employed in the apparatus of FIGS. **1** or **3**.

DESCRIPTION OF THE PREFERRED EMBODIMENT

An apparatus for electrically heating a fluid is shown in FIG. **1**. It includes a cylindrical tank **12** through which the fluid to be heated can flow via an inlet **14** and an outlet **16**. A vertical supporting shaft **18** is centrally disposed within the tank **12**. The shaft **18** is hollow and serves as a conduit through which the entering fluid flows to the bottom of the tank **12** after which it is heated as it rises and is thus discharged through the outlet **16** which is located near the top of the tank **12**.

A portion of the tank **12** has been broken away in FIG. **1** to expose a plurality of electrodes **20**, disposed radially about the shaft **18**, between which a current is passed to heat the fluid as it rises through the tank **12**. One cooperating pair of electrodes **22** and **24** can be seen most clearly. The electrode **22**, of this pair, is pivotably movable about the shaft **18**.

A control means **26** for controlling the distance between the electrodes **20** whereby the current flow can be modulated in accordance with the quantity of heat to be added to the fluid can be seen most clearly in FIG. **2**. The control means **26** comprises a thermistor **28** disposed within a conduit **30** which is connected to a pipe **32** through which a portion of the fluid flows after entering the tank **12** through the inlet **14** but before entering the hollow shaft **18**. Additional fluid enters the conduit **30** from the interior of the tank **12** through an opening **33**. An arrangement of this type is disclosed in my earlier U.S. Pat. No. 2,946,508 which was issued on July 26, 1960.

The thermistor **28** forms part of a sensing means for sensing the condition of the fluid. If the apparatus is to be used for certain applications, such as the making of steam, it may be desirable to use a sensing means that is responsive to pressure rather than temperature.

The control means **26** further comprises an apparatus demand limiter **34** arranged to receive an input signal originating from the thermistor **28** and another input signal representative of the current flow into the electrodes **20**. The output of the apparatus demand limiter **34** is supplied to a plant demand limiter **36** which modifies that output in accordance with power demands of other equipment. The output of the plant demand limiter **36** is supplied to an electromotive unit **38**

which, via a mechanical linkage 40, determines the position of the movable electrode 22 as well as the other movable electrodes disposed about the supporting shaft 18.

Although the operation of the control means 26 is explained in greater detail below, it should be understood at this point that when conditions dictate that a larger quantity of heat should be added to the fluid flowing through the tank 12, the linkage 40 causes the movable electrode 22 to move closer to the corresponding stationary electrode 24. The movable electrode of each of the other pairs of electrodes 20 is moved in a similar fashion. When the electrodes 20 of each pair are closer together there is, of course, a shorter path through the fluid through which the current must pass and the resistance between the electrodes 20 is thus diminished. Because of the diminished resistance, the current flow between the electrodes 20 is increased, and the quantity of heat energy added to the fluid is increased.

Thus, the use of movable electrodes provides a means for modulating the current flow through the fluid although the voltage between the electrodes 20 remains constant at all times, thereby allowing the current flow to be continuously modulated over a wide range. This feature of the apparatus is, of course, highly advantageous when compared to a system in which current modulation takes place over a series of discrete steps. In the latter type of system, conditions may call for a level of current flow which falls between the levels corresponding to two adjacent steps. Under these circumstances the apparatus would be forced to continuously switch back and forth between the two closest steps thus leading to repeated transient conditions which would increase the power demand and produce unnecessary wear on the moving parts of the apparatus. In the present invention, the electrodes of each pair simply seek the one position in which the distance between them produces the precise level of current flow required. In this way, the current flow is modulated in accordance with changes in water temperature, water conductivity, water flow rate, and changes in power supply voltage.

The relative movement of the electrodes 20 in order to modulate the current flow is illustrated most clearly in FIGS. 4 through 6. Here the electrodes 22 and 24, which are most visible in FIG. 1, are shown from above as are a second pair of electrodes 42 and 44 and a third pair of electrodes 46 and 48. In FIG. 4, the electrodes 20 are shown in a position in which the two electrodes of each pair are relatively close together whereby a relatively large current flows between the electrodes 20 and a consequently large quantity of heat is added to the fluid. As shown in FIG. 5, the movable electrodes 22, 42, and 46 have been rotated in a counterclockwise direction to increase their distance from the corresponding stationary electrodes 24, 44, and 48 with which they form pairs. In FIG. 6, the electrodes 20 are shown in a position in which the two electrodes which form each pair are positioned relatively far apart to produce a small current flow and a correspondingly small quantity of heat.

It can be seen from FIG. 6 that when the electrodes 20 that form each pair are separated by the greatest distance, the movable electrode of each pair comes into close proximity with the stationary electrode of another pair. (For instance, the movable electrode 22 moves close to the stationary electrode 48.) This presents the problem of undesirable current flow between two electrodes which are not part of the same pair. Undesired current flow is substantially prevented by providing at least one electrode of each pair with an electrically insulating shield. In the embodiment of FIG. 1, this shield takes the form of a supporting partition 50 on which the electrode 24 is mounted. It should be noted here that the electrode 24 actually includes two separate elements 52 and 54 which could be thought of as separate electrodes. They are treated here, however, as one electrode because they are electrically connected to operate together. Actually, any number of separate elements may be used to form one electrode having the desired surface area. It is sometimes desirable to use a plurality of cylindrical rods rather than flat plates as shown in the drawings.

In FIGS. 4, 5, and 6 the electrodes 20 are shown schematically. Thus, the stationary electrodes 24, 44, and 48 are not shown as being attached to the shaft 18. They may, however, be supported in this manner as shown in FIG. 1.

A modification of the apparatus of FIG. 1 is shown in FIG. 3. Similar components are designated by the same numbers as are used in FIG. 1. The operation of this apparatus will be explained with reference to the pair of corresponding electrodes 22 and 24. As in FIG. 1, both are supported by the shaft 18. The electrode 24 is supported in a stationary position whereas the electrode 22 is pivotable about the shaft 18. Each electrode is partially surrounded by a shield 56 which blocks current flow between any two electrodes 20 that are not part of the same pair. The shields 56 are preferably shaped so as to expose only on face of each of the electrodes 20 to the fluid through which the current is conducted. This tends to confine the current flow and increase the efficiency of the apparatus.

An electrically insulating shutter is associated with each pair of the electrodes 20. The construction and operation of these shutters will be described with respect to a shutter 58 which is associated with the electrodes 22 and 24. The shutter 58 is pivotably attached to the electrode 24 via a connection 60 mounted on the shield 56 which partially surrounds the electrode 24. The shutter 58 is connected, by a cable 62, to a member 64 which attaches the electrode 22 to the supporting shaft 18. Thus, as the electrode 22 moves away from the position shown in solid lines in FIG. 3 to the position shown in phantom lines in FIG. 3, the shutter 58 is pivoted about the connection 60 and moved conjunctively with the electrode 22 to block the most direct current path between the electrodes 22 and 24. When the electrodes 22 and 24 are returned to the position shown in solid lines, the shutter 58 also returns to the position shown in solid lines in which it is substantially clear of the most direct current path between the electrodes 22 and 24. Thus, the shutter 58 magnifies the effect of moving the electrodes 22 and 24 and contributes to the modulation of the current flow. Because the shutter 58 is connected to the member 62 which supports the electrode 22, it is operatively connected, via the linkage 40, to the control means 26.

The member 64 which attaches the electrode 22 to the shaft 18 is connected to a member 66 which supports the electrode 24 by a compression spring 68 which tends to push the electrodes 22 and 24 apart. Thus the spring 68, together with a spring 70 and a spring 72 which are associated with the other electrodes 20, forms a biasing means which is arranged to cooperate with the control means 26 for causing the apparatus to commence operation with the electrodes 20 in the position in which they are farthest apart whereby the effects of transient conditions upon the electrical power demands of the apparatus are minimized. It is a particularly desirable feature of the apparatus that the electrodes 20, because they are biased toward the position in which they are farthest apart, will move to a position in which the current flow is minimized or completely shut off in the event of a malfunction or a power failure.

The springs 68, 70, and 72 also serve as conductors by which the movable electrodes 22, 42, and 46 are connected to the power supply. The use of the springs 68, 70, and 72 as conductors is preferable to the use of conventional flexible wires which have a tendency to break due to the continuous bending brought about by the relative motion of the electrodes 20. The use of the springs 68, 70, and 72 is, of course, common to the embodiments of the invention illustrated in FIGS. 1 and 3. The use of the shutter 58, as well as a shutter 74 (not visible in FIG. 3) associated with the electrodes 42 and 44 and a shutter 76 associated with the electrodes 46 and 48, is generally preferred when relatively high voltages are employed. The shutters 58, 74, and 76 are not needed under all circumstances and modulation of the current may be brought about entirely by the movement of the electrodes 20.

The control means 26 for controlling the distance between the electrodes 20 will now be described in greater detail. As mentioned above, the temperature of the fluid is sensed by the thermistor 28 which functions as a means for sensing the con-

dition of the fluid. The output of the thermistor **28** is supplied to the apparatus demand limiter **34** which is shown schematically in FIG. **7**. The apparatus demand limiter **34** functions as a first demand limiting means for limiting the power demands of the apparatus. It is responsive to the power input to the electrodes **20** and the output of the thermistor **28**. Thus, the output signal of the thermistor **28** is an electrical potential which appears across the terminals **76** and **78** as an input to the apparatus demand limiter **34**. Another input to the apparatus demand limiter **34** is derived from the current supplied to the electrodes **20** which induces another current in the windings of a current transformer **80** which is in turn applied to a rectifier **82**. The output of the rectifier **82** is taken from an adjustable voltage divider **84** and added in reverse series to the output of the thermistor **28**. Thus, the difference between the output of the voltage divider **84** and the input from the thermistor **28** equals the output of the apparatus demand limiter **34**.

The purpose of the apparatus demand limiter **34** is to prevent the power demands of the apparatus from increasing to a value at which it would not be advisable to operate the heater. Thus, as the need for power indicated by the thermistor **28** increases, it is compensated for to a greater and greater extent by the output of the voltage divider **84** which is responsive to the power supplied to the apparatus. The parameters of the circuit shown in FIG. **7** are selected so that the output of the apparatus demand limiter **34** at a terminal **86** and a terminal **88** will stabilize before the power demand becomes undesirably high.

The apparatus shown in FIG. **7**, utilizes a three phase alternating current power supply and three pairs of electrodes **20**. The rectifier **82** is responsive to the current taken from only one of the three phases of the power supply. Because this one phase may always be representative of the total power, it is sometimes desirable to utilize three current transformers each of which is responsive to one of the three phases. It is then necessary to substitute a three phase full wave rectifier for the rectifier **82** of the apparatus demand limiter **34** shown in FIG. **7**.

The output of the apparatus demand limiter **34** taken from the terminals **86** and **88** is supplied to the plant demand limiter **36**. This device is similar to the apparatus demand limiter **34** but is responsive to the current flow through the main power line leading to a plant or a group of electrical machines. It limits the output of the apparatus demand limiter **34** in accordance with the power demands of other equipment before the output of the apparatus demand limiter **34** is supplied to the electromotive unit **38**. Thus, the plant demand limiter **36** functions as a second demand limiting means for limiting the power demands of the heater which is responsive to the output of the first demand limiting means (the apparatus demand limiter **34**) and the power input to other equipment. The purpose of this arrangement is to prevent the use of large amounts of power by the heater when high power demands are being made by other equipment. This is desirable in environments in which it is possible to postpone the heating of the fluid until a time when it is more desirable to consume electrical power. This is often the case when the apparatus is used to heat water. Accordingly, the arrangement described above causes the apparatus to consume electrical power during time periods when it is most optimally available. It is possible, of course, to eliminate the plant demand limiter **36** and supply the output of the apparatus demand limiter **34** directly to the electromotive unit **38** in situations in which the plant demand limiter **36** is deemed unneeded or unnecessary.

It will be noted that the invention can conveniently be arranged to utilize a conventional three phase alternating current power supply as shown in FIG. **7**. Each phase of the power supply is connected to one pair of the electrodes **20**. The three phases can be either delta connected or wye connected. In most situations a four wire wye connection (utilizing a ground) is preferred for reasons of safety. It is also advisable to separately ground an outer steel shell **90** of the tank **12** although it is insulated by an internal layer **92** preferably comprising a teflon or ceramic dielectric sleeve. The control means **26** together with any other electrical controls or meters accessible to the operator should be operated at a relatively low voltage and isolated from the power supplied to the electrodes **20**.

An additional safety feature of the apparatus is the provision of a wire screen **94** disposed above the electrodes **20** and a wire screen **96** disposed below the electrodes **20**. (Most of the screen **94** is broken away in FIG. **1** to expose the other parts of the apparatus.) Both of the screens **94** and **96** are connected to neutral. Thus, any stray current from the electrodes **20** will be conducted away through the adjacent screens **94** and **96** and will not flow to the walls of the tank **12** which are exposed to personnel in the area. Safety is further improved by connecting the shaft **18** to neutral and by isolating it electrically from the shell **90** of the tank **12**.

It can be seen from the description above that the present invention possesses a number of important advantages in comparison to previously known devices. Some of these advantages are the continuous moduability of the current flow, the avoidance of high power demands attributable to transient conditions, and the ability to limit power demands to provide for the most efficient utilization of the electrical power available. Another advantage is the compact arrangement of the components to efficiently utilize the space required by the heater. The arrangement of the components also facilitates the assembly and repair of the apparatus.

It will be understood by those skilled in the art that the above described embodiment is meant to be merely exemplary and that it is susceptible of variation and modification without departing from the spirit and scope of the invention. Therefore, the invention is not deemed to be limited except as defined in the appended claims.

I claim:

1. An apparatus for electrically heating fluids comprising a cylindrical tank in which the fluid can be heated, said tank having an inlet and an outlet for the fluid, a vertical supporting shaft centrally disposed within said tank, a plurality of pairs of electrodes disposed radially about said shaft, at least one electrode of each pair being pivotably movable about said shaft whereby the distance between the two electrodes of a pair can be varied by changing the position of the movable electrode, a plurality of electrically insulating shutters one of which is associated with each pair of electrodes, each shutter being pivotably supported and movable into a position in which it blocks at least a part of the most direct current path between the electrodes of the associated pair to modulate the current flow, and an electromotive control means responsive to a condition of the fluid for controlling the position of said electrodes and said shutters.

2. The apparatus of claim **1** further comprising a means for biasing the movable electrode of a pair of electrodes toward the position in which it is farthest from the opposite electrode whereby the current is reduced to a minimum in the event of an interruption of the power supply or a malfunction of the apparatus.

3. The apparatus of claim **2** wherein said biasing means is arranged to cooperate with said control means to cause the apparatus to commence operation with the electrodes of each pair in the position in which they are farthest apart whereby the effects of transient conditions upon the power demands of the apparatus are minimized.

4. The apparatus of claim **1** wherein said control means comprises a sensing means for sensing the condition of the fluid and demand limiting means for limiting the power demand of the apparatus, said demand limiting means being responsive to the power input to said electrodes and the output of said sensing means.

5. The apparatus of claim **1** wherein said control means comprises a sensing means for sensing the condition of the fluid, a first demand limiting means for limiting the power demands of the apparatus, said first demand limiting means

being responsive to the power input to said electrodes and the output of said sensing means, and a second demand limiting means for limiting the power demands of the apparatus responsive to the output of the first demand limiting means and the power input to other equipment whereby the apparatus is caused to consume electrical power during time periods when it is most optimally available.

6. The apparatus of claim 1 further comprising a plurality of wire screens disposed adjacent to said electrodes, said screens being electrically connected to neutral whereby any stray current from said electrodes is prevented from flowing to the walls of the tank and creating a safety hazard.

7. The apparatus of claim 1 wherein there are three pairs of electrodes each of which is arranged to be connected to one phase of a three phase alternating current power supply.

8. The apparatus of claim 1 further comprising a means for connecting said shutters to said pivotable electrodes for movement therewith, thereby blocking the most direct current path and reducing the current flow to a greater extent when said electrodes are relatively far apart.

9. An apparatus for electrically heating fluids comprising a tank in which the fluid can be heated, said tank having an inlet and an outlet for the fluid, at least one pair of electrodes disposed within the tank between which a current can be passed to heat the fluid, at least one of the electrodes being movable, an electromotive control means responsive to a condition of the fluid for controlling the position of the movable electrode, and an electrically insulating shutter pivotably supported within said tank and movable into a position in which it blocks at least part of the most direct current path between the electrodes, the shutter being connected to the movable electrode for cooperative movement therewith so that it blocks a greater portion of the most direct current path when the electrodes are relatively far apart than when the electrodes are relatively close together.

10. The apparatus of claim 9 further comprising a means for biasing the electrodes of each pair toward the position in which they are farthest apart whereby the current is reduced to a minimum in the event of an interruption of the power supply or a malfunction of the apparatus.

11. The apparatus of claim 10 wherein said biasing means is arranged to cooperate with said control means to cause the apparatus to commence operation with the electrodes in the position in which they are farthest apart whereby the effects of transient conditions upon the power demands of the apparatus are minimized.

12. The apparatus of claim 9 wherein said control means comprises a sensing means for sensing the condition of the fluid and a demand limiting means for limiting the power demands of the apparatus, said demand limiting means being responsive to the power input to said electrodes and the output of said sensing means.

13. The apparatus of claim 9 wherein said control means comprises a sensing means for sensing the condition of the fluid as it enters said tank, a first demand limiting means for limiting the power demands of the apparatus, said first demand limiting means being responsive to the power input to said electrodes and the output of said sensing means, and a second demand limiting means for limiting the power demands of the apparatus responsive to the output of said first demand limiting means and the power input to other equipment whereby the apparatus is caused to consume electrical power during time periods when it is most optimally available.

14. An apparatus for electrically heating fluids comprising a vertically disposed cylindrical tank in which the fluid can be heated, a vertical supporting shaft centrally disposed within said tank, at least three pairs of electrodes that extend radially from said shaft, at least one electrode of each pair being pivotable about said shaft whereby the distance between the two electrodes of a pair can be varied by moving the pivotable electrode, each pair of electrodes being adapted to be connected to one phase of a three phase power supply, an electromotive control means responsive to a condition of the fluid for controlling the position of said pivotable electrodes, a sensing means for sensing a condition of the fluid as it enters said tank, a means for biasing the pivotable electrode of each pair toward the position in which it is farthest from the opposite electrode, said biasing means being arranged to cooperate with the control means for causing the apparatus to commence operation with said electrodes in the position in which they are farthest apart whereby the effects of transient conditions upon power demands of the apparatus are minimized, and a demand limiting means for limiting power demands of the apparatus responsive to the output of said sensing means and the power input to the electrodes.

15. The apparatus of claim 14 wherein at least one electrically insulating shield is provided which blocks current flow between two electrodes that are not part of the same pair.

16. The apparatus of claim 15 further comprising a plurality of wire screens disposed adjacent to said electrodes, said screens being electrically connected to neutral whereby any stray current from said electrodes is prevented from flowing to the walls of the tank and creating a safety hazard.

17. The apparatus of claim 14 wherein said biasing means comprises springs which are arranged to conduct current to said pivotable electrodes.

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