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US 4563571 A
US 1519395 A

(58) Field of Search:
INT CL **F24H, H05B**
Other: **On-line databases: EPODOC, WPI**

(54) Title of the Invention: **An electric water heater**
Abstract Title: **Electric water heater**

(57) An electric water heater 10 comprises a body 12 defining a chamber 18 with a pre-heat tube 20, an outer heater tube 24 and an inner heater tube 28 arranged within it, where each tube acts as heater substrate. The pre-heat tube is arranged around the outer heater tube. The outer heater tube has a thin film conductive resistance heater (24a, b, c) coating on its outer surface and the inner heater tube has a thin film conductive resistance heater (28a, b, c) coating on its inner surface. Each resistance heater may comprise three separate sections. Water passes into the body via an inlet port 14 and flows over the pre-heat tube in a pre-heat flow annular passageway 22 defined between the pre-heat tube and the body. The pre-heated water then passes over the non-coated surfaces of the heater tubes, within the annulus 30 defined between the outer and inner heater tubes, to be heated before flowing out of the body via an outlet port 16. A device is provided to induce helical flow in the fluid flowing through the water heater. Preferably, a venturi narrowing of the flow path is used to accelerate the flow between heater sections.

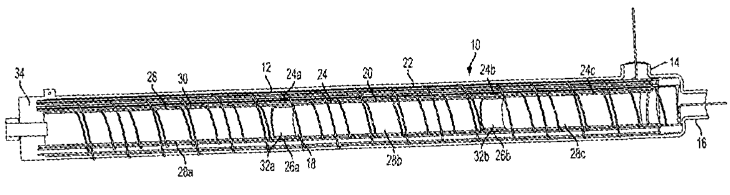

FIG. 1

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At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

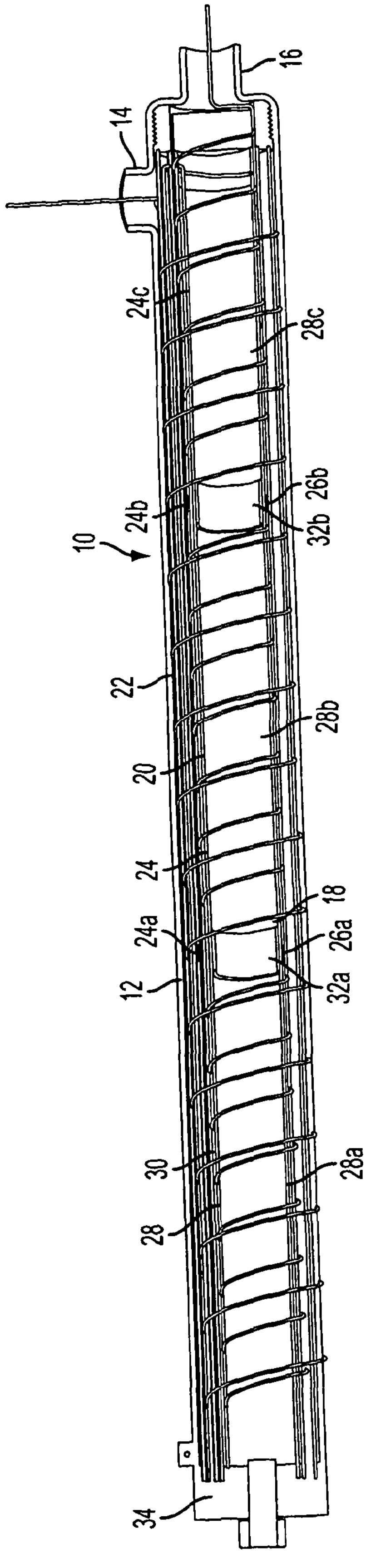
16
14
24c
28c
24b
26b
32b
10
22
28b
20
24
18
24a
26a
12
32a
30
28a
28
34

FIG. 1

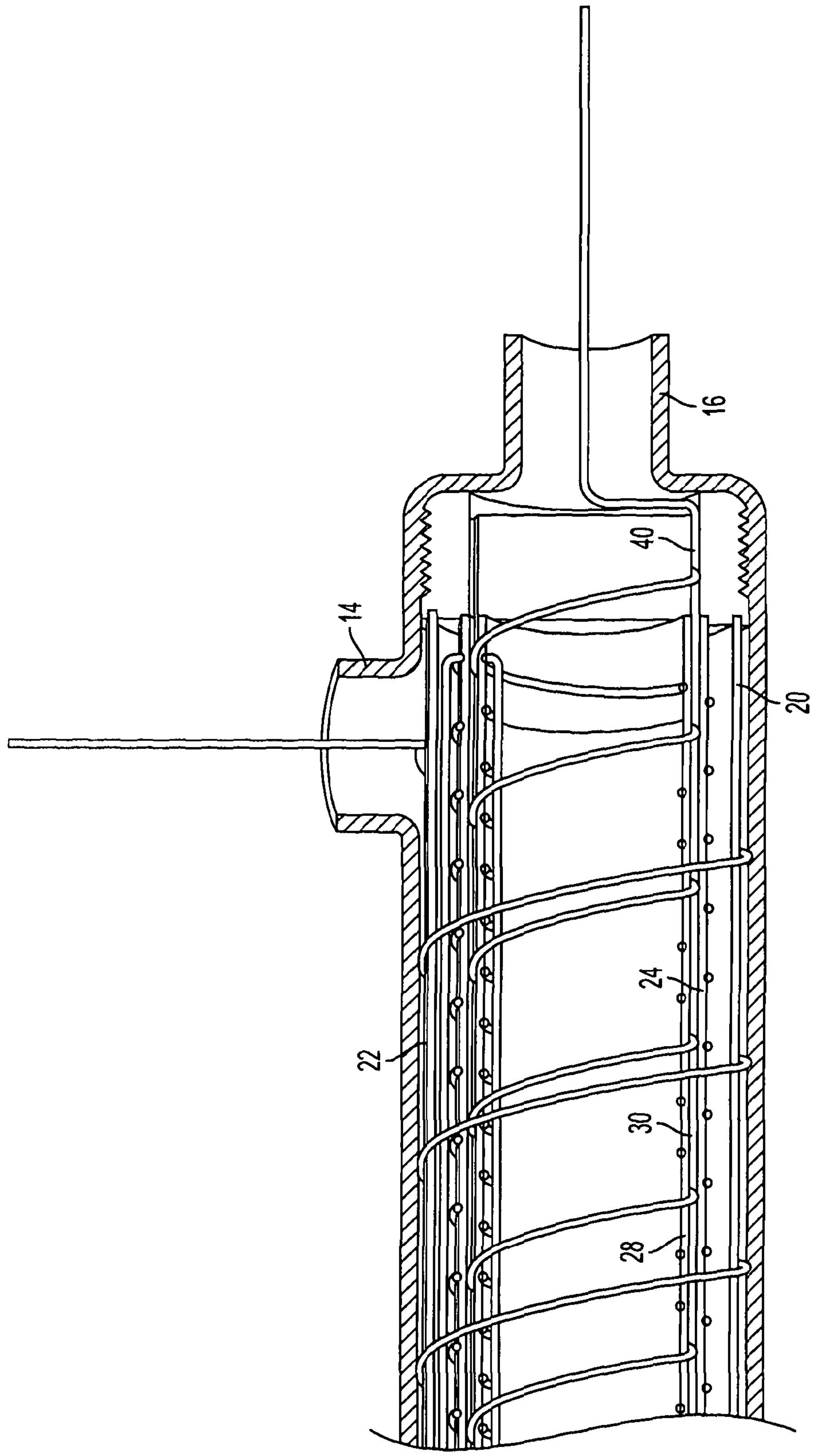

FIG. 2

12 11 10

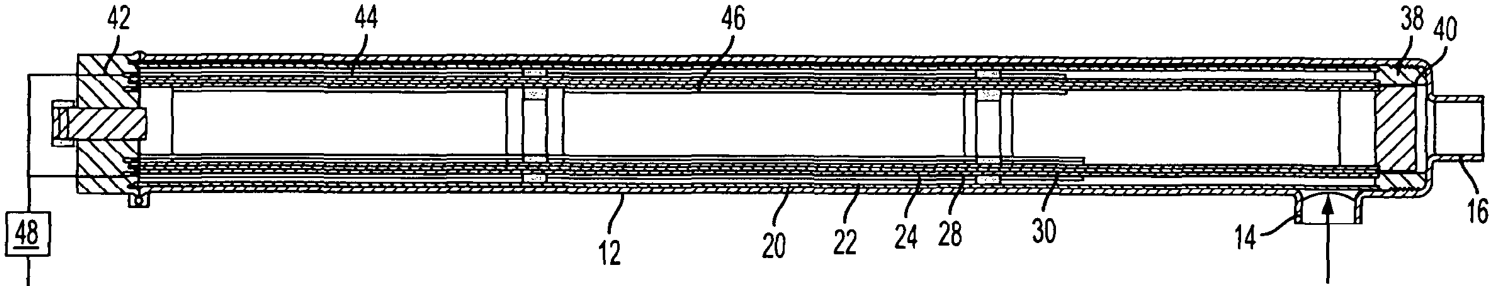

FIG. 4

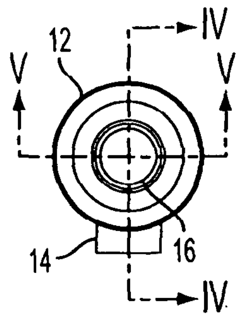

FIG. 3

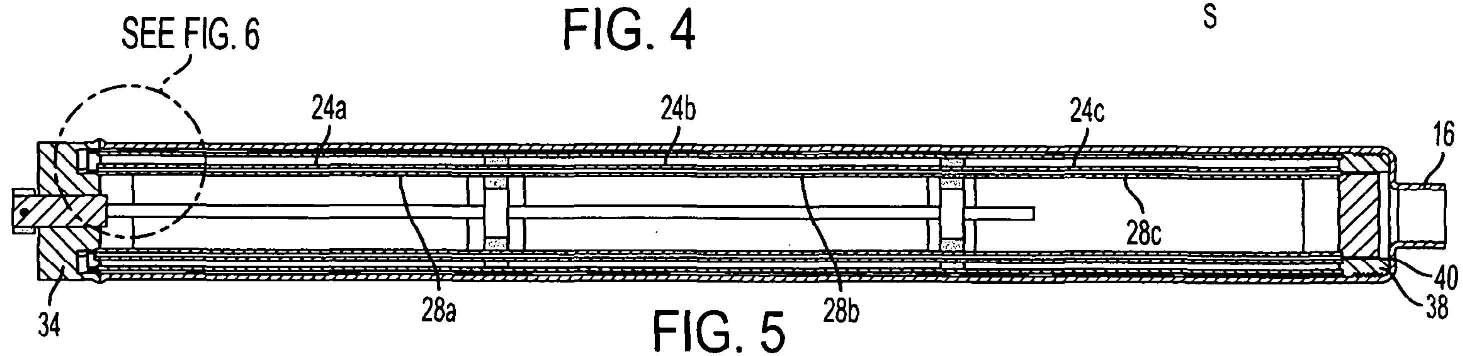

FIG. 5

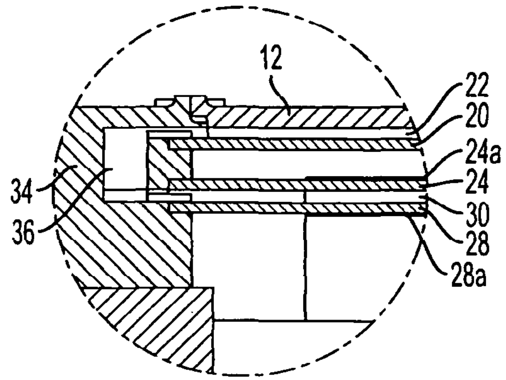

FIG. 6

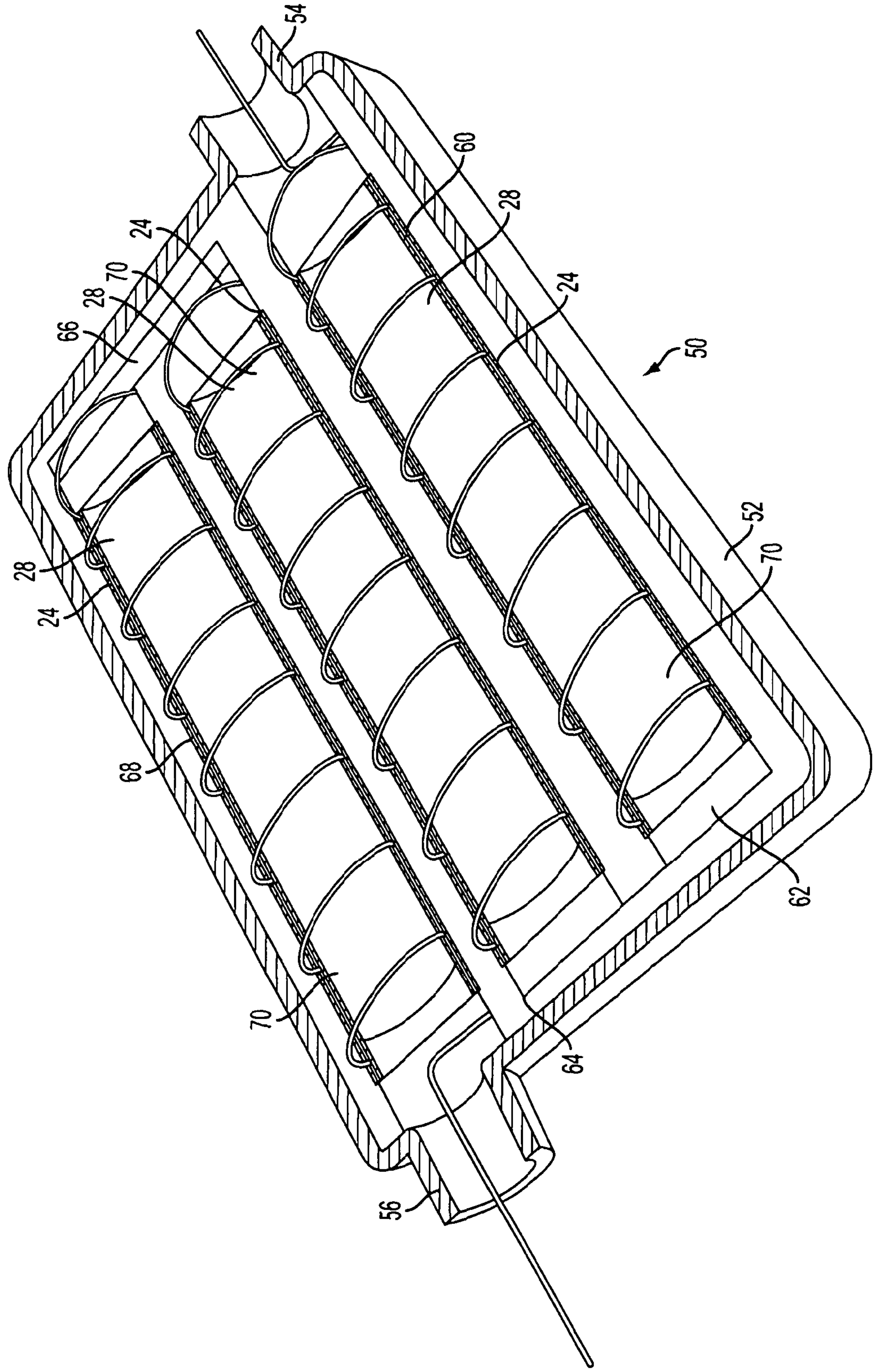

FIG. 7

12 11 10

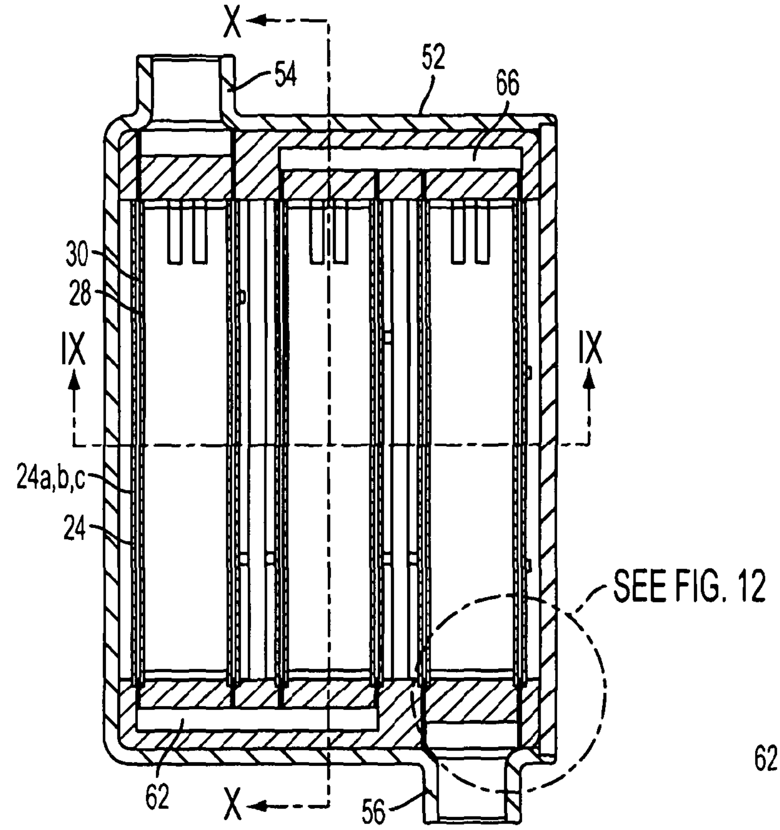

FIG. 8

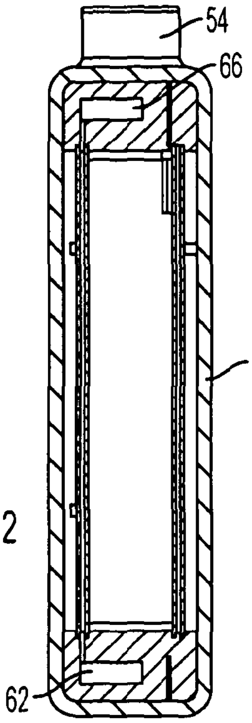

FIG. 10

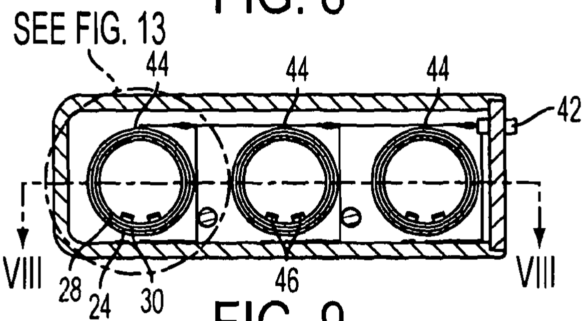

FIG. 9

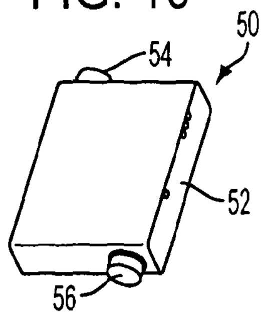

FIG. 11

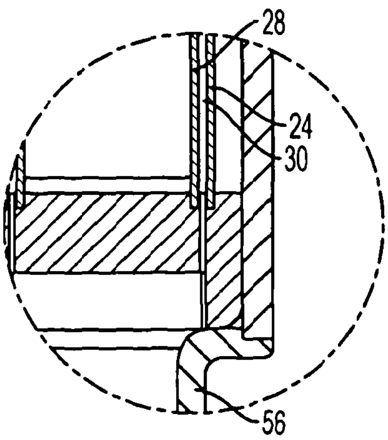

FIG. 12

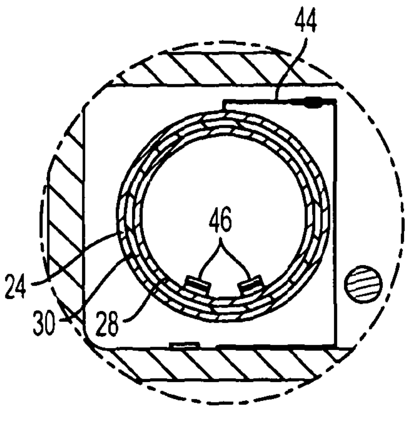

FIG. 13

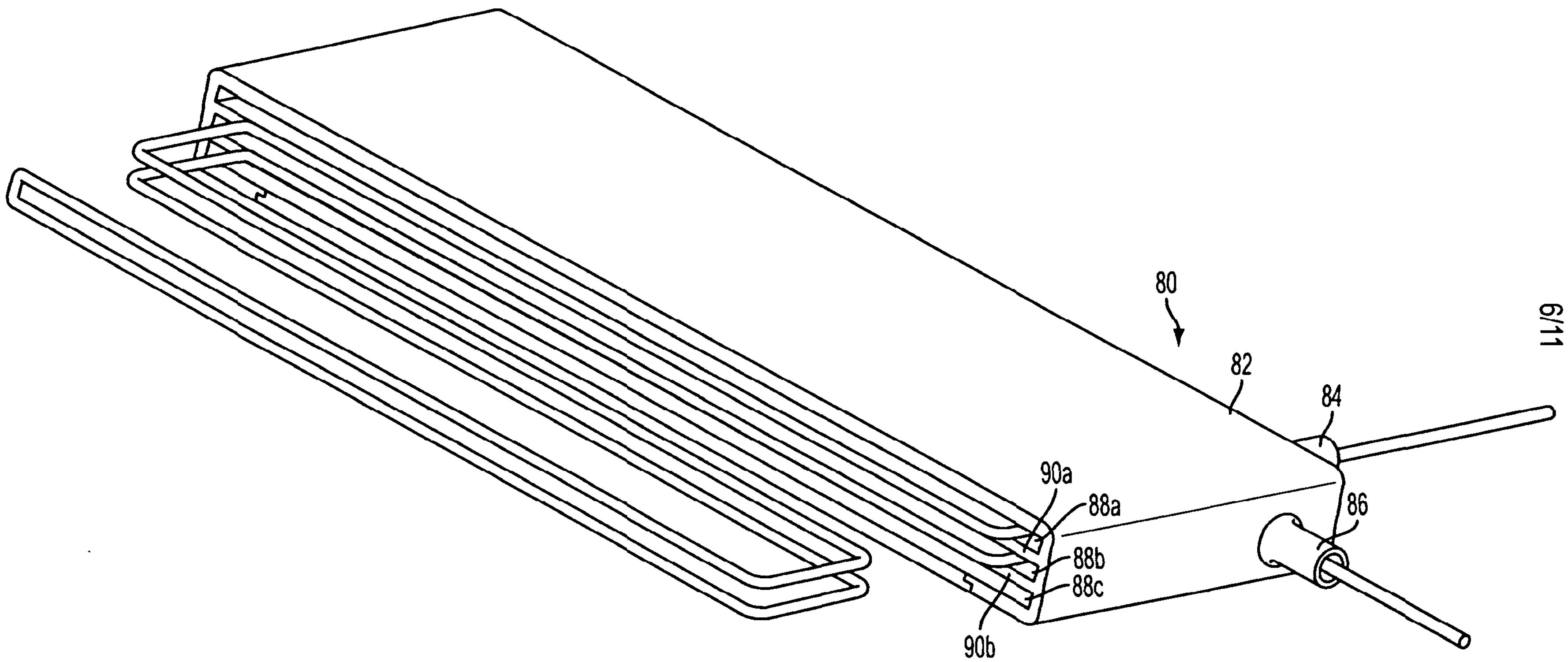

FIG. 14

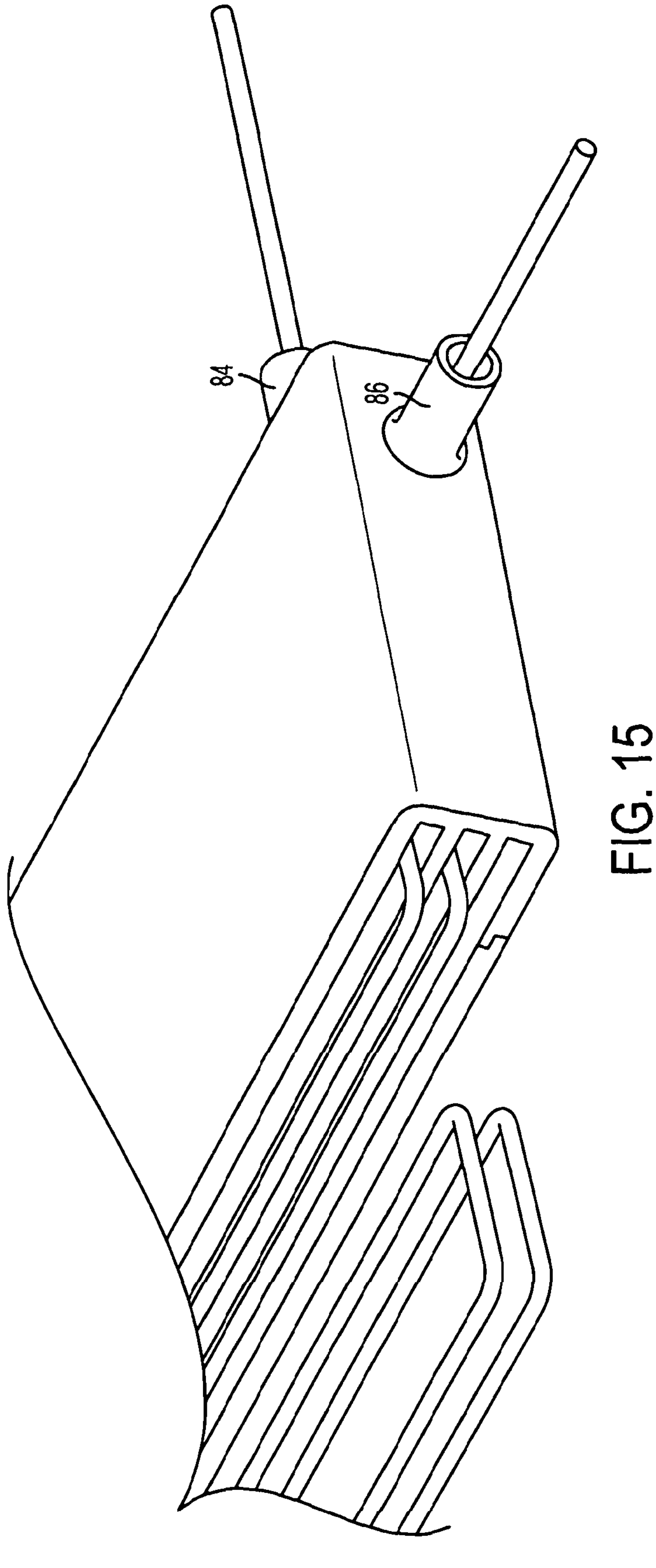

FIG. 15

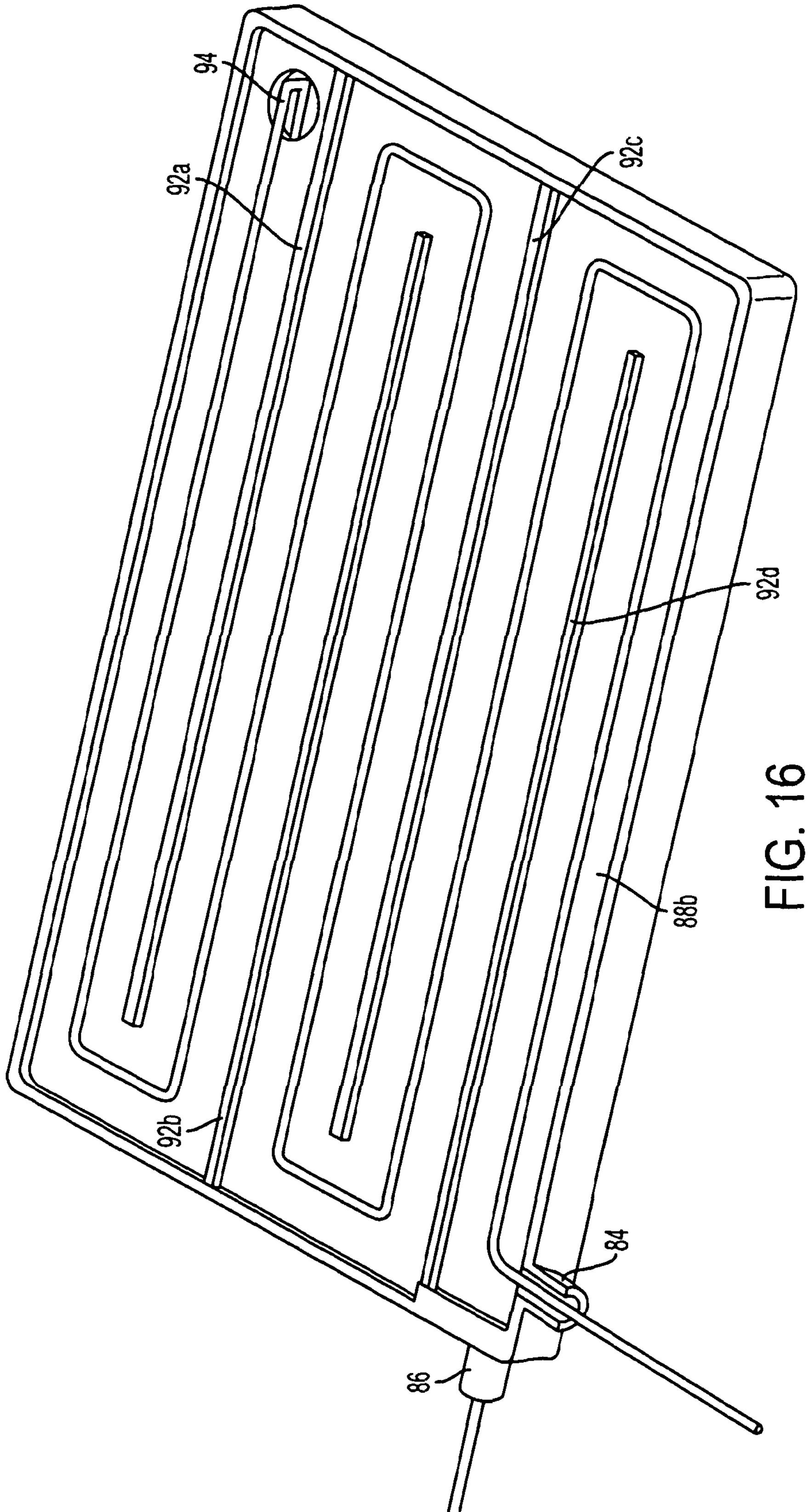

FIG. 16

12 11 10

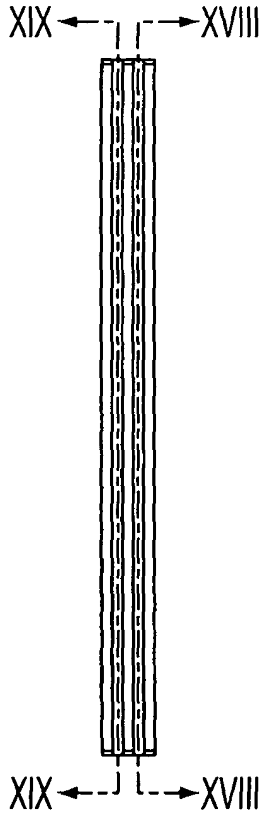

FIG. 17

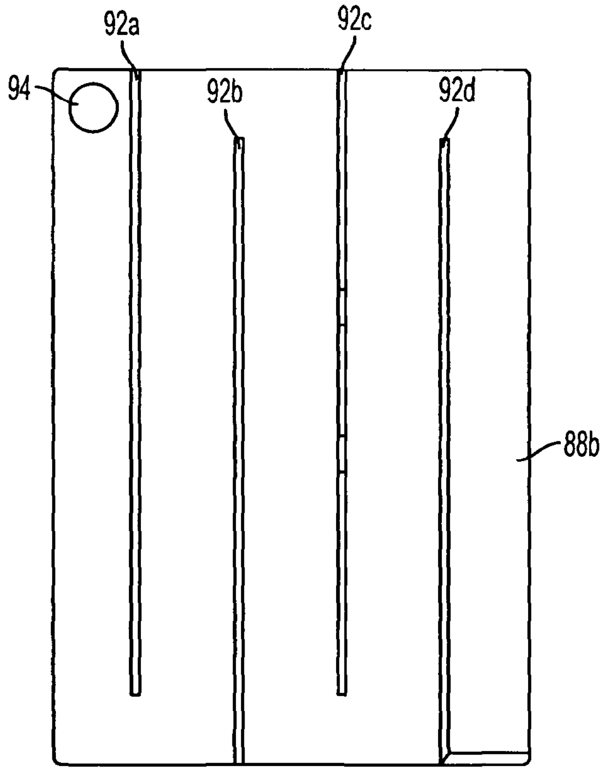

FIG. 18

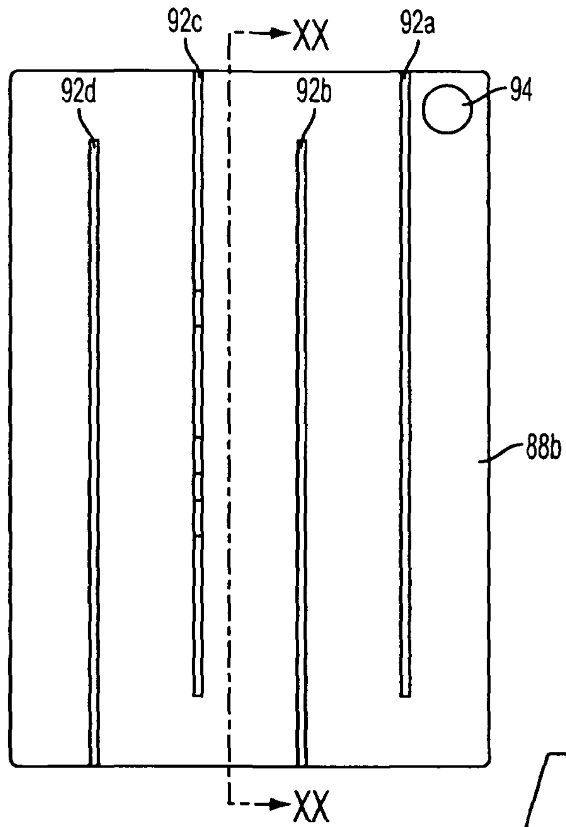

FIG. 19

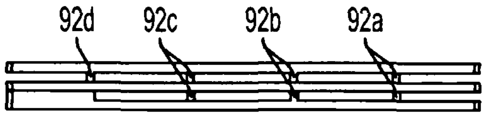

FIG. 20

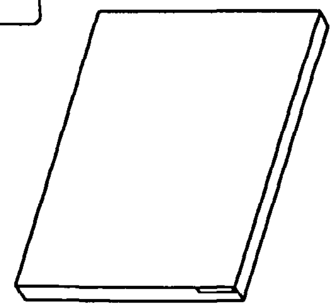

FIG. 21

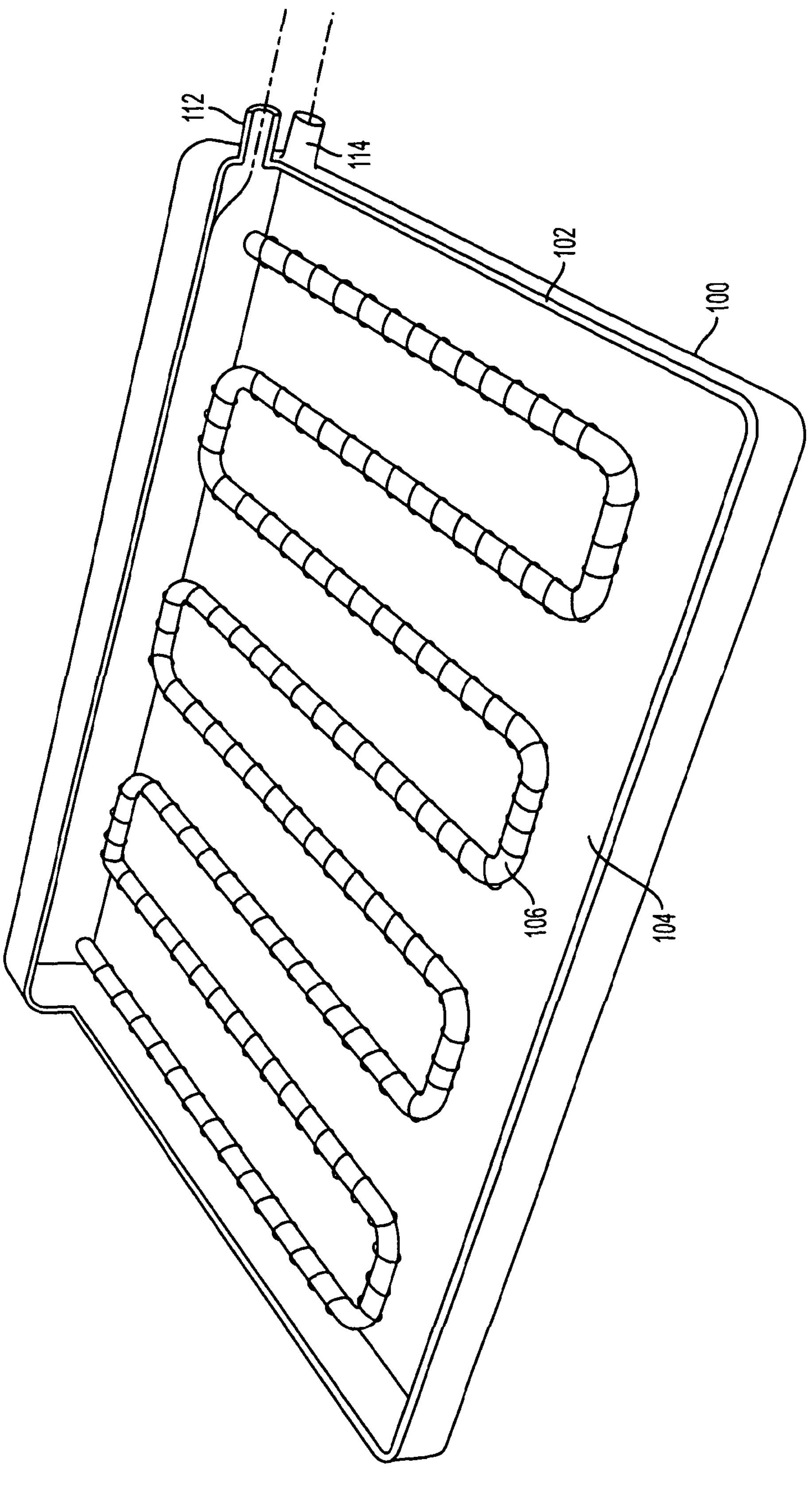

FIG. 22

12 11 10

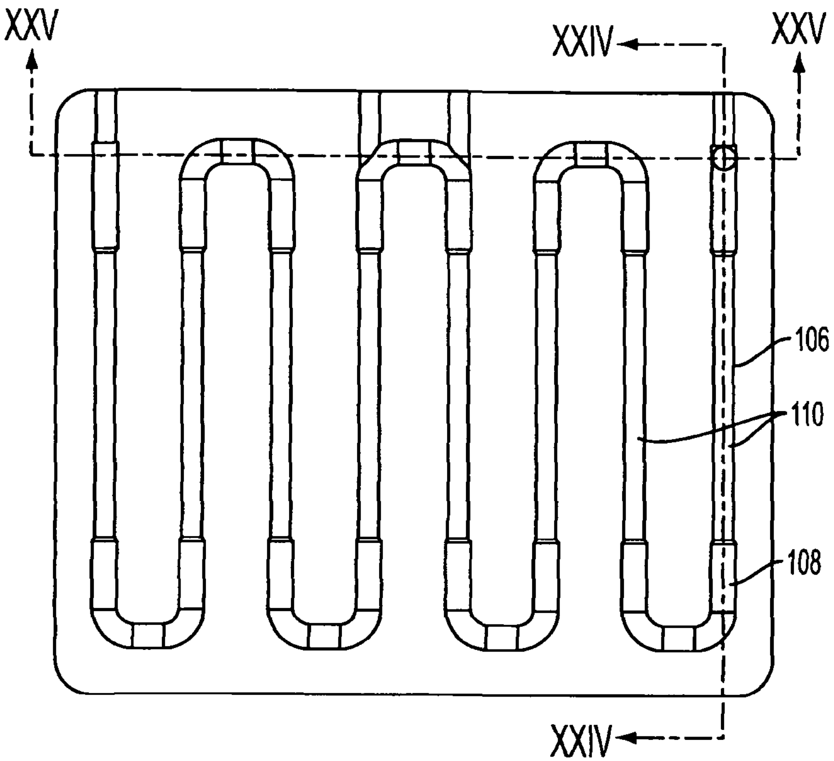

FIG. 23

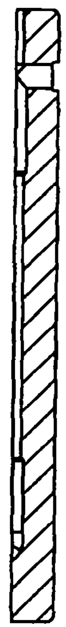

FIG. 24

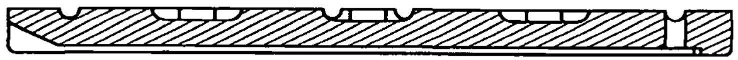

FIG. 25

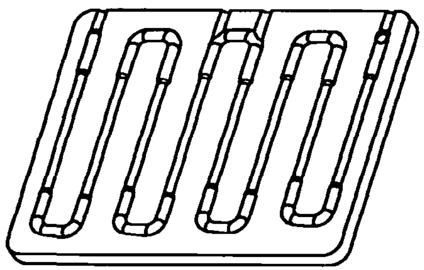

FIG. 26

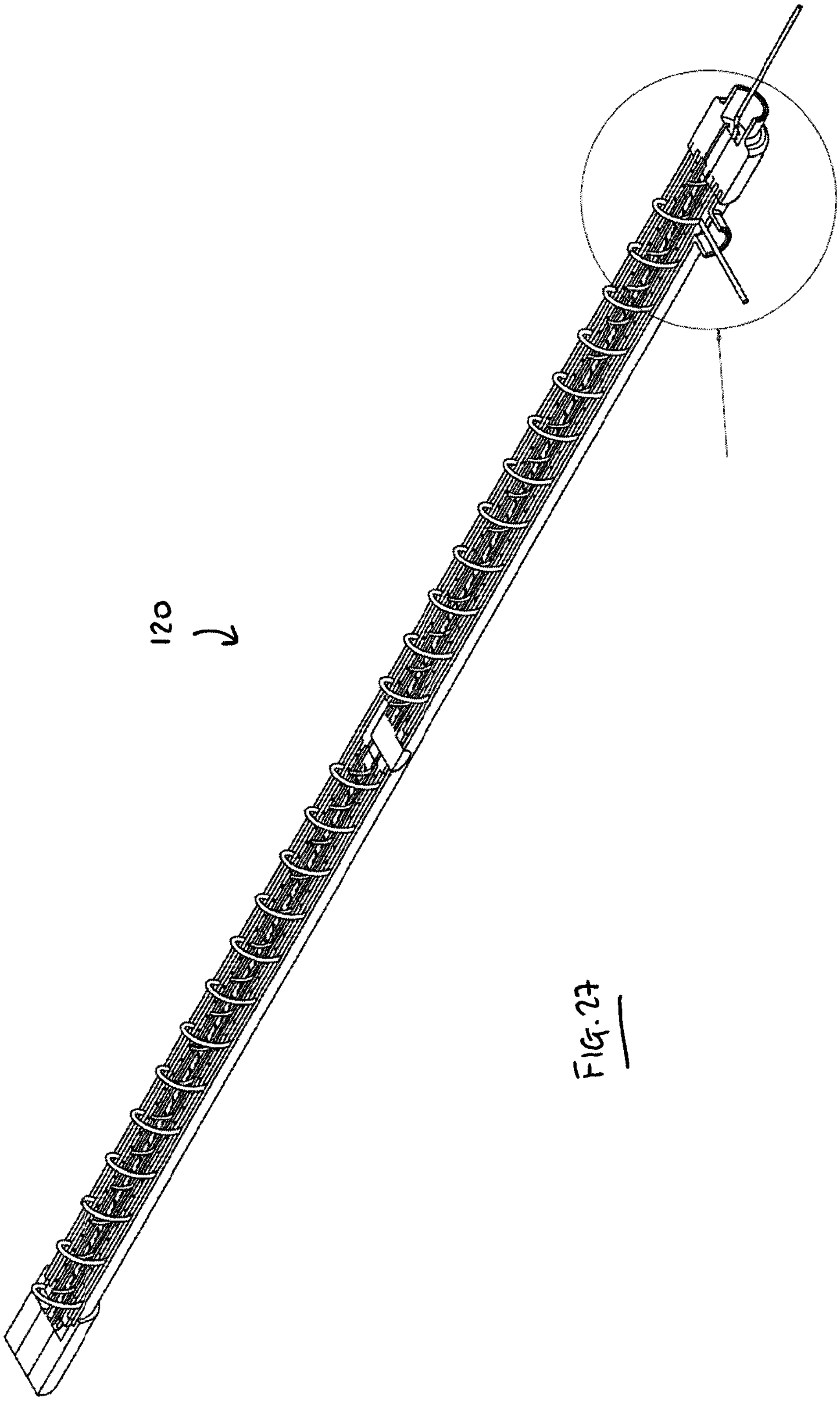

FIG. 27

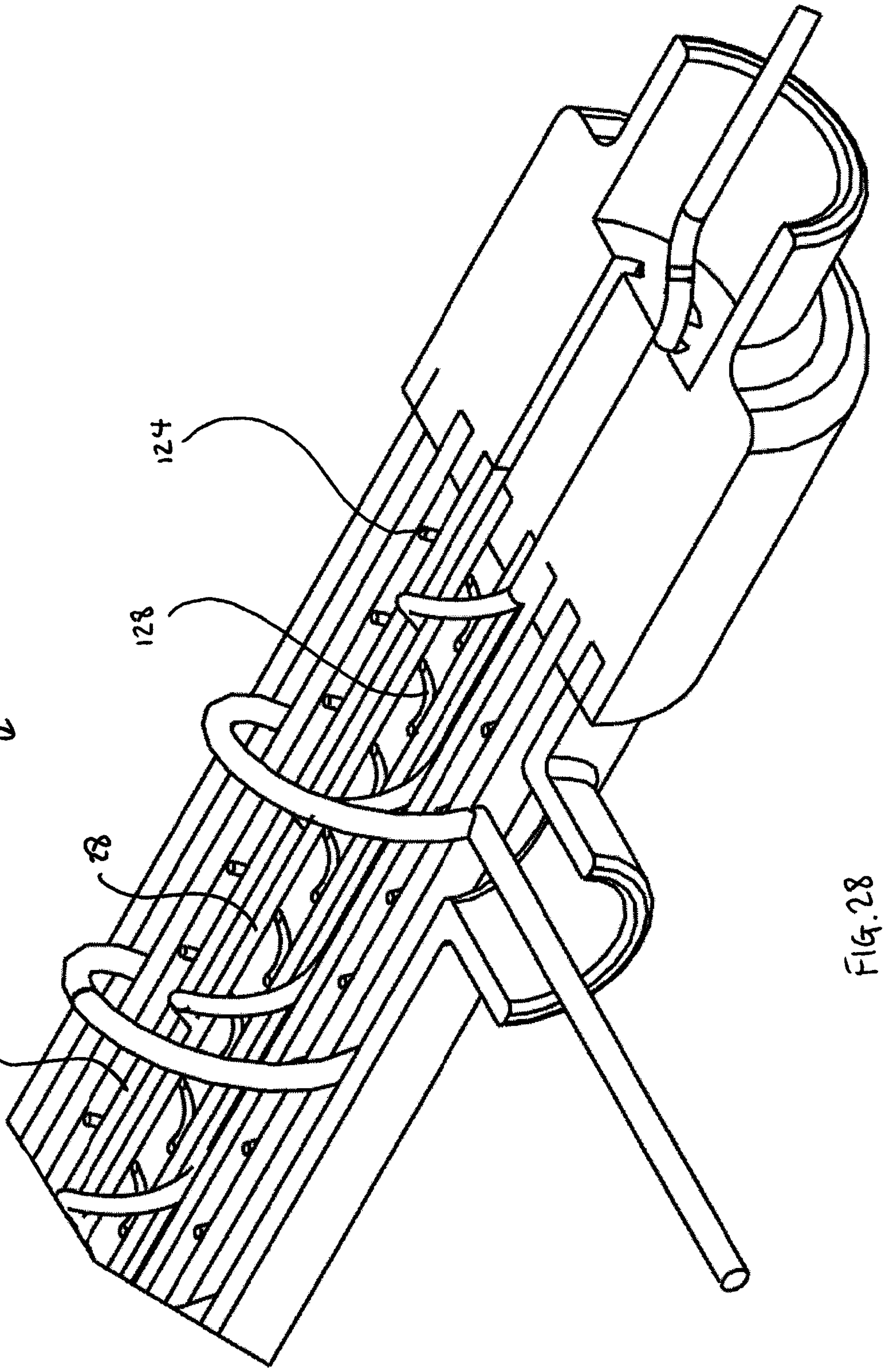

FIG.28

An Electric Water Heater

The invention relates to electric water heaters, particularly, although not exclusively limited to electric water heaters for heating water for a domestic shower.

Electric water heaters can be used to heat water for domestic showers. Such heaters are usually rather unsophisticated comprising a conventional heating element encased within a copper/plastic container. In particular, such arrangements suffer from a poor flow rate due to limits on the amount of heat that can be transferred to the water flowing through such water heaters.

Thin film conductive resistance heaters are known. Thin film is a term of art referring to coatings of nanometre to several micrometre thickness. Thin film coatings are applied with a variety of specialist techniques such as, non-exhaustively, chemical solution deposition (CSD), chemical vapor deposition (CVD), Plasma enhanced CVD, physical vapor deposition, sputtering, etc. British Patent Publication No.2327028 describes the use of Ta Al, Ni-Cr alloy, SnO_2, HfB_2 and Ta as coatings on a glass substrate to heat water.

International Patent Publication WO01/67819 describes the use of conductive thin film on glass substrate tubes to heat water. IR radiant tungsten elements are also known to heat water as shown in US patent no. 6909841.

It is an object of the invention to provide an improved electric water heater.

According to a first aspect of the invention, there is provided an electric water heater comprising a body defining a chamber with a heater substrate arranged in the chamber, the heater substrate comprising a substrate having a conductive resistance heater applied to or around a surface thereof, the substrate thereby comprising an at least partially covered surface and an opposite non-covered surface, a pre-heat substrate being arranged in the chamber, spaced from the heater substrate and facing the at least partially covered surface thereof, the body defining an inlet to the chamber and an outlet from the chamber, a pre-heat flow path extending from the inlet over a surface of the pre-heat substrate and a heater flow path extending from the pre-heat flow path over the opposite surface of the heater substrate.

In that way, heat generated by the conductive resistance heater which would otherwise not be transferred to water flowing through the heater is transferred as it heats the pre-heat substrate and is transferred from the pre-heat substrate to the water as the water flows along the pre-heat flow path. This improves the heater efficiency.

The heater substrate may be a flat plate. Alternatively, the heater substrate may comprise a tube. Preferably, the heater substrate comprises a first inner tubular heater substrate arranged within a second outer tubular heater substrate, the conductive resistance heater being applied to or around at least a part of the inner surface of the inner tubular heater substrate and at least a part of the outer surface of the outer tubular heater substrate. In such a case, the pre-heat substrate may comprise a further outer tubular substrate arranged around the outer tubular heater substrate. Where the heater substrate comprises inner and outer tubes defining an annular flow path, a helical flow inducer may be provided to induce helical flow in the annular flow path. The conductive resistance heater may comprise a thin film conductive resistance heater, a tungsten wire wound element or a combination thereof. Where the conductive resistance heater is a tungsten wire wound element, the inner surface of the body defining the chamber is preferably reflective.

According to a second aspect of the invention there is provided an electric water heater comprising a body in which a conductive resistance heater is arranged on a substrate, an annular flow path is defined around the substrate and a helical flow inducer is provided to induce helical flow in fluid flowing in the annular flow path.

In that way, by inducing the helical flow along the annular flow path, the amount of heat transferred to fluid flowing along the flow path is increased for a particular length of flow path. This increases the efficiency of the device and enables the device to be made more compact for the same amount of heat transfer.

In the heater of the second aspect, the body preferably defines a chamber within which the conductive resistance heater is arranged, a pre-heat substrate also being arranged in the chamber, spaced from the heater substrate and facing the heater, the body defining a pre-heat flow path extending over a surface of the pre-heat substrate which terminates in the annular flow path.

In the electric water heater according to the second aspect, the conductive resistance heater preferably comprises an inner tubular heater substrate with a conductive resistance heater applied to at least part of the inner surface thereof and an outer tubular heater substrate with a conductive resistance heater applied to at least part of the outer surface thereof, the inner tubular heater substrate being arranged within the outer tubular heater substrate so as to define the annular flow path.

According to a third aspect of the invention, there is provided an electric water heater comprising a body defining a chamber, an inner tubular heater substrate and an outer tubular heater substrate, the inner tubular heater substrate arranged within the outer tubular heater substrate, a conductive resistive heater applied to at least part of the inner surface of the inner tubular heater substrate and a conductive resistance heater applied to at least part of the outer surface of the outer tubular heater substrate, a flow path defined between the inner surface of the outer tubular heater substrate and the outer surface of the inner tubular heater substrate.

The arrangement of the third aspect of the invention maximises the surface area of heating applied to water flowing in a tubular flow path.

The electric water heater of a third aspect of the invention preferably further comprises a pre-heat substrate arranged in the chamber, spaced from the thin film conductive resistance heater applied to at least part of the outer surface of the outer tubular heater substrate and a pre-heat flow path is formed in the chamber extending over the pre-heat substrate, terminating in the flow path defined between the inner surface of the outer tubular heater substrate and the outer surface of the inner tubular heater substrate.

A helical flow inducer is preferably provided in the flow path defined between the outer and inner tubular heater substrates.

In a preferred feature of the third aspect of the invention or of the first and second aspects of the invention where the heater substrate comprises inner and outer tubular heater substrates, the tubular heaters may range from 3mm to 50mm in diameter. The conductive resistance heater may comprise a thin film conductive resistance heater, a tungsten wire wound element or a combination thereof.

According to a fourth aspect of the invention, there is provided an electric water heater comprising a body defining a chamber, a first heater substrate having a thin film conductive resistance heater applied to a surface thereof so that the first heater substrate has an at least partially coated surface and a non-coated surface, a second heater substrate having a thin film conductive resistance heater applied to a surface thereof so that the second heater substrate has an at least partially coated surface and a non-coated surface, the first and second heater substrates being configured in the chamber such that the respective non-coated surfaces thereof face each other and are spaced apart to define a heater flow path through which water can flow to be heated.

In that way, water passing between the substrates is heated from both sides in a compact heater arrangement.

The heater preferably comprises a further pair of heater substrates with a heater flow path arranged therebetween.

In a particularly preferred embodiment of the fourth aspect of the invention, the heater comprises a first outer heater substrate with a thin film conductive resistance heater applied to one surface thereof, a middle heater substrate comprising two spaced substrates with a thin film conductive resistance heater applied to one of the facing surfaces of the two spaced substrates and a second outer heater substrate with a thin film conductive resistance heater applied to one surface thereof, the heater substrates being configured in the chamber so that the non-coated surface of the first outer heater substrate faces one of the non-coated surfaces of the middle heater substrate and the other non-coated surface of the middle heater substrate faces the non-coated surface of the second outer heater substrate, whereby a first heater flow path is formed between the first outer heater substrate and the middle heater substrate and a second heater flow path is formed between the middle heater substrate and the second outer heater substrate.

The heater flow path of the first or fourth aspects of the invention, the annular flow path of the second aspect of the invention or the flow path defined between inner and outer tubular heater substrates of the third aspect of the invention is preferably 0.3mm to 1mm wide.

The thin film conductive resistance heater applied to a surface in either the first, third or fourth aspects of the invention is preferably applied to three, separate lengths of the substrate. Where the thin film conductive resistance heater is applied to the outer surface of the outer tubular heater substrate and the inner surface of the inner tubular heater substrate, the thin film conductive resistance heater is applied in three separate corresponding lengths to both the respective inner and outer surface of the inner and outer tubes.

Each separate length of thin film conductive resistance heater applied to the surface may be arranged to provide 1.5Kw to 1.75Kw of heat power.

According to any of the aspects of the invention, the flow path past the heater preferably includes features to decelerate the flow past the heater and to accelerate the flow beyond the heater. Where multiple heater sections are provided, the flow path may include features to decelerate the flow at the heater section and accelerate the flow between the heater sections. Such features may include a venturi narrowing of the flow path between the heater sections.

The thin film conductive resistance heater is preferably arranged to deliver 40-45 watts per cm^2 of heating power. The substrate of any of the heaters of any of the three aspects of the invention is preferably intended to raise the surface temperature thereof to at least 400-450^{0}C, preferably to 1000^{0}C.

The substrate may comprise a thermally conductive, electrically non-conductive material such as quartz, Pyrex glass, ceramic or polymer. Alternatively, the substrate comprises a thermally conductive, electrically conductive material with a non-conductive coating, such as a ferrous or non-ferrous alloy with an appropriate non-conductive coating, such as an engineering polymer, glass or non-conductive paint.

Electrical conductor connections to the thin film conductive resistance heater coatings may be of ceramic or coated insulated buzz-bar design, standard high temperature tri-rated conductors or electrical contact slip ring design.

Electrical water heaters in accordance with the invention will now be described in detail by way of example and with reference to the accompanying drawings, in which:-

Fig.1 is a cutaway perspective view of an electric water heater in accordance with the first, second and third aspects of the invention,

Fig.2 is a view similar to Fig.1 showing the inlet and outlet parts of the water heater to a larger scale,

Fig.3 is an end elevation of the water heater of Figs.1 and 2,

Fig.4 is a cross-section of the water heater of Figs.1 to 3 taken on lines IV-IV in Fig.3,

Fig.5 is a cross-section of the electric water heater of Figs.1 to 4 taken on lines V-V in Fig.3,

Fig.6 is an enlarged sectional view of the detail ringed in Fig.5,

Fig.7 is a cutaway perspective view of an electric water heater in accordance with the second and third aspects of the invention,

Fig.8 is a cross-sectional view of the electric water heater of Fig.7,

Fig.9 is a cross-sectional view of the water heater of Fig.7 and 8 looking in the direction of IX-IX in Fig.8,

Fig.10 is a cross-section of the water heater of Figs.7 to 9 taken on line X-X in Fig.8,

Fig.11 is a perspective view of the water heater of Figs.7 to 10,

Fig.12 is an enlarged sectional view similar to Fig.8 of the detail ringed in Fig.8,

Fig.13 is an enlarged sectional view similar to Fig.9 of the detail ringed in Fig.9,

Fig.14 is a perspective view of part of a further electric water heater in accordance with the fourth aspect of the invention,

Fig.15 is an enlarged view of part of the water heater of Fig.14,

Fig.16 is a perspective view of the water heater of Fig.14 with a horizontal slice cut away of the top most layer,

Fig.17 is a side elevation of the water heater of Figs.14 to 16,

Fig.18 is a plan sectional view of the water heater of Figs.14 to 17 taken on line XVIII-XVIII in Fig.17,

Fig.19 is a plan sectional view of the water heater of Figs.14 to 17 taken on line XIX-XIX in Fig.17,

Fig.20 is an end elevation of the water heater of Figs. 14 to 17 looking in the direction of arrow XX in Fig.19,

Fig.21 is a perspective view of the water heater of Figs.14 to 20,

Fig.22 is a cutaway perspective view of a water heater in accordance with the second aspect of the invention,

Fig.23 is a plan view of the cutaway of the heater of Fig.22,

Fig.24 is a side-sectional view of the heater of Figs.22 and 23 taken on line XXIV-XXIV in Fig.23,

Fig.25 is an end sectional view of the heater of Figs.22 to 24 taken on line XXV-XXV to Fig.23,

Fig.26 is a perspective view of the cutaway of the heater of Figs.22 to 25,

Fig.27 is a cut-away perspective view of an electric water heater in accordance with the first to third aspects of the invention, and

Fig.28 is a view similar to Fig.27 showing the inlet and outlet parts of the water heater of figure 27 to a larger scale.

In Fig.1, an electric water heater 10 comprises an elongate hollow tubular body 12 with an inlet port 14 and an outlet port 16. The inlet port 14 is arranged adjacent one end of the tubular body 12 projecting radially from the cylindrical surface thereof. The outlet port 16 projects axially from end of the body at the same end as the inlet port 14.

The body 12 is hollow and forms a chamber 18. A pre-heat tube 20 is arranged within the chamber 18 coaxially with the body 12. The outer surface of the pre-heat tube 20 is spaced radially inwardly of the inner surface of the body 12 so as to form an annular pre-heat flow passageway 22.

An outer heater tube 24 is arranged within the pre-heat tube 20 and coaxially therewith. The outer heater tube 24 is coated on its outer surface in three spaced regions with a thin film conductive resistance heater of known material at 24a, b and c. The difference in diameter between the outer surface of the outer heater tube and the inner surface of the pre-heat tube is enough to form a gap between the thin film conductive resistance heater sections and the inner surface of the pre-heat tube 20.

The three thin film conductive resistance heater sections are spaced apart by two bare portions 26a, 26b arranged respectively between the heater sections 24a, 24b and 24b, 24c. An inner heater tube 28 is arranged within the outer heater tube 24, coaxially therewith. The outer surface of the inner heater tube is spaced radially inwardly from the inner surface of the outer heater tube 24 to define a heater flow path 30. The inner heater tube 28 has three spaced thin film conductive resistance heater sections 28a, b, c which are co-extensive with the thin film conductive resistance heater sections 24a, b, c, on the outer heater tube 24. The inner thin film conductive resistance heater sections are formed on the inner surface of the inner heater tube 28. Again, the inner thin film conductive resistance heater sections are spaced apart by bare portions 32a, b of the inner heater tube 28, so that the bare portion 32a is formed between the inner thin film conductive resistance heater sections 28a, 28b and the bare portion 32b is formed between the thin film conductive resistive heater sections 28b, c. Although not shown in Figs.1 to 6, the thickness of the wall of either or both of the heater tubes 24, 28 may be increased in the region of the bare portions, 26, 32 so as to narrow the heater flow path 30 between the heater sections 24a, b, c, 28a, b, c. Water flowing in the narrowed parts of the heater flow path is accelerated by the narrowing.

The respective ends of the pre-heat tube 20, outer heater tube 24 and inner heater tube 28 are received in an end gasket 34 at their ends spaced from the inlet and outlet ports 14, 16 of the body 12. The gasket 34 is formed so as to define a flow path from the pre-heat flow passageway 22 to the heater flow path 30 but to close off the end of the space between the pre-heat tube 20 and the outer heater tube 24. This flow arrangement is best shown in Fig.6 where the flow path between heat flow passageway 22 and the heater flow path 30 is indicated with reference number 36. The inlet/outlet port ends of the pre-heat tube 20, outer heater tube 24 and inner heater tube 28 are received in an inlet/outlet gasket 38. The inlet/outlet gasket 38 closes off the end of the pre-heat flow passageway 22 but is open to the heater flow path 30 to define an outlet passageway 40 from the end of the heater flow path 30 to the outlet port 16.

The end gasket 34 allows passage of an electrical supply contact 42 which, in turn, branches into an outer heater section contact 44 and an inner heater contact 46. The outer heater contact 44 is connected in parallel to the respective outer thin film conductive resistance heater sections 24a, b, c and the inner heater contact is connected in parallel to the inner thin film conductive resistance heater sections 28a, b, c. The outer and inner heater contacts 44, 46 can be applied to the respective outer and inner heater tubes 24, 28 in the same way as the thin film conductive resistance heater sections are applied. Alternatively, separate electrically conductive wires can be soldered to the thin film conductive resistance heater sections. The electrical supply contact 42 is of known form, for example of ceramic buzz bar design.

The pre-heat tube 20, the outer heater tube 24 and the inner heater tube 28 will typically be formed from Pyrex glass, although any thermally conductive material of sufficient strength could be used. Where a thermally conductive, electrically conductive material is used, a non-conductive coating must be applied prior to application of the thin film conductive resistance heater sections. The body 12 is preferably formed from a plastics material.

The flow path of water to be heated through the heater 10 is best illustrated in Figs.1 and 2. In Fig.1, it can be seen that the water enters through inlet port 14 and passes along the annular pre-heat flow passageway 22 between the outer surface of the pre-heat tube 20 and the inner surface of the body 12. The pre-heat tube 20 is heated by means of the waste heat escaping from the outer surface of the thin film conductive resistance heater sections 24a, b, c on the outer heater tube 24. This serves to pre-heat the water passing along the pre-heat flow passageway 22 before it enters the heater flow path 30. The water passes along the pre-heat flow passageway 22 to the end gasket 34, through the flow path 36 and into the heater flow path 30. The water then passes along the heater flow path 30 between the inner and outer heater tubes 24, 28 with the respective thin film conductive resistance heater sections 24a, b, c, 28a, b, c. The heated water then passes to the inlet/outlet gasket 38, through the outlet passageway 40 to the outlet port 16.

The thin film conductive resistance heater sections 24a, b and 28a, b each provide 1.5kW of heating power while the end heater sections 24c, 28c provide 1.75kW of heating power. The electric water heater 10 is supplied with electricity from a mains electricity supply and a controller 48 can selectively power one or more of the heater sections 24a, b, c, 28a, b, c. Water is supplied from a supply S which may be a domestic mains water supply or a separate water supply such as a header tank. The water may be cold or warm when supplied and may be supplied either at domestic mains pressure or the pressure may be determined by means of a pump upstream of the inlet 14.

By introducing the supplied water substantially tangentially of the cylinder, the water flowing along the pre-heat tube 20 flows helically as illustrated in Figs.1 and 2. Likewise, the flow path 36 is arranged to introduce the water from the pre-heat flow passageway 22 to the heater flow path 30 with a helical flow, again as illustrated in Figs.1 and 2. If necessary, baffles (not shown) may be provided in the pre-heat flow passageway and/or the heater flow path 30 to maintain the helical flow. Helical flow of the water in the pre-heat flow passageway and heater flow path is preferred as it increases the contact time of water flowing in the passageway and path for a unit length of the water heater 10.

In Fig.7 an alternative electric water heater 50 is illustrated. The water heater 50 is similar in some respects to the heater of Figs.1 to 6 and parts corresponding to parts in Figs.1 to 6 carry the same reference numerals.

The heater 50 does not have a pre-heat tube. Instead, it comprises three sets of the inner and outer heater tubes 24, 28 arranged in series. The body 52 is substantially rectangular in plan with an inlet port 54 formed at one corner thereof and an outlet port 56 formed at the diagonally opposite corner thereof. The body 52 is hollow and defines a sinuous flow path 58.

The sinuous flow path 58 comprises a first tubular cavity 60 which extends from the inlet port 54 to the opposite edge of the body 52, a first cross flow path 62 extending from the end of the first tubular cavity 60 spaced from the inlet port 54 parallel with the edge of the body 52 in which the outlet port 56 is formed, a second tubular cavity 64 extending from the end of the first cross flow path 62 to the opposite edge of the body, in which the inlet port 54 is formed. The second tubular cavity 64 terminates in a second cross flow path 66 which extends from the end of the second tubular cavity 64 parallel with the edge of the body 52 in which the inlet port 54 is formed. A third tubular cavity 68 extends from the end of the second cross flow path 66 to the outlet port 56.

A heater tube arrangement 70 is arranged in each tubular cavity 60, 64, 68. Each heater tube arrangement 70 comprises an outer heater tube 24 with three separate, spaced thin film conductive resistance heater sections 24a, b, c formed on the outer surface thereof, separated by bare portions 26a, 26b. An inner heater tube 28 is arranged coaxially within and spaced from the outer heater tube 24. The inner heater tube 28 has three thin film conductive resistance heater sections 28a, b, c formed coextensively with the outer thin film conductive resistance heater sections 24a, b, c on the outer heater tube 24. Again, the inner thin film conductive resistance heater sections are separated by respective bare portions 32a, 32b as illustrated in Figs.1 to 6. The inner surface of the outer heater tube and the outer surface of the inner heater tube are spaced apart to form a heater flow path 30. The inner and outer heater tubes 24, 28 are secured by opposite end gaskets 34, 38 which allow flow of water from the inlet into the heater flow path 30, inducing a helical flow within the heater flow path 30. As illustrated in Fig.7, water flowing into the electrical water heater 50 passes via the inlet port 54 to the heater tube arrangements 70 in the first tubular cavity 60.

Water flows helically along the heater flow path 30, out of the first heater tube arrangement 70 and into the first cross flow path. The water passes along the first cross flow path 62 and into the second heater tube arrangement 70 arranged in the second tubular cavity. The heated water passes along the heater flow path in the second heater tube arrangement and out of that flow path into the second cross flow path 66. The water then flows along the second cross flow path 66 into the heater tube arrangement 70 in the third tubular cavity. The water flowing in the heater flow path 30 in the third heater tube arrangement is, again, flowing helically and the water passes out of the heater flow path in the third heater tube arrangement to the outlet port 56.

An electrical supply contact 42 is formed at the side of the body 52 which, in turn, is connected to outer heater contacts 44 and inner heater contacts 46 in similar manner to the water heater of Figs.1 to 6.

A further alternative electrical water heater 80 is shown in Figs.14 to 21. The water heater 80 comprises a hollow body 82 of cuboidal form. An inlet port 84 is formed in one face of the body 82 and an outlet port 86 is formed in another face.

The hollow body 82 contains three stacked, spaced heater plates 88a, b, c. The space between the first and second heater plates 88a, 88b defines a first heater flow path 90a and the space between the second and third heater plates 88b, 88c defines the second heater flow path 90b.

A series of ribs 92a, b, c, d extend alternatively from opposite end walls of the body 82 in each flow path 90a, 90b so as to define a sinuous flow path as shown in Fig.16.

The heater plate 88a has a thin film conductive resistance heater applied to its outer surface (uppermost in Fig.14). The heater plate 88b is formed by applying a thin film conductive resistance heater to one side of a first plate and covering it with a second plate to form a sandwich formation.

Finally, the heater plate 88c has a thin film conductive resistance heater applied to its outer surface (lowermost in Fig.14). The thin film conductive resistance heater sections applied to the heater plates 88a, b, c are shown in broken lines in Fig.14. Those sections may be intermittent with uncoated sections therebetween or they may be continuous across the entire surface of the plate.

An aperture 94 is formed in the corner of the plate 88b, diagonally opposite to the inlet port 84. Water entering the inlet port 84 enters the heater flow path 90a between the heater plates 88a and 88b. As best shown in Fig.16, the water flows around the sinuous path defined by the ribs 92a to d and passes through the aperture 94 into the heater flow path 90b formed between the heater plates 88b and 88c. The water then flows around the sinuous path defined by the ribs 92a to d between the plates 88b and 88c and out of the outlet 86.

A further alternative water heater in accordance with the second aspect of the invention is shown in Figs.22 to 26. The heater 100 comprises a cuboidal body 102 which contains a ceramic filler 104 defining a sinuous flow passageway 106. Conventional electrical water heater elements (not shown) are arranged in the sinuous flow passageway 106 to define a small clearance between the inner wall of the flow passageway and the outer wall of the heating elements.

As shown in Fig.23, the diameter of the flow passageway 106 varies along this length. In particular, the diameter of the flow passageway widens at each bend 108 in the passageway and narrows in the straight portions 110.

The body 102 has an inlet port 112 and an outlet port 114 formed in the same face. Water can be injected through the inlet port 112 and then enters the sinuous flow, inducing a helical flow in the sinuous flow passageway. Additional baffles may be provided to main the helical flow along the length of the sinuous flow passageway. Water passing along the sinuous flow passageway is heated by the conventional heating element and leaves the body 102 through the outlet port 114.

In Figs. 27 and 28, an electric water heater 120 is shown which is identical to the water heater 10 of figure 1 except that the outer and inner heater tubes 24, 28 have tungsten wire wound elements 124, 128 as the conductive resistance heater in place of the thin film conductive resistance heaters 24a,b,c and 28a,b,c. The inner surface of the outer body is coated with a reflective material such as metal foil. Tungsten wire wound elements emit IR radiation and can elevate the temperature of the heater tubes 24, 28 to 1000^0C. This allows the same heat to be transferred to water flowing through the element in a much shorter distance, allowing more compact heater arrangements. The tungsten wire wound element can also be used in place of the thin film conductive resistance heaters on the other embodiments herein.

Claims

1. An electric water heater comprising a body defining a chamber with a heater substrate arranged in the chamber, the heater substrate comprising a substrate having a conductive resistance heater applied to or around a surface thereof, the substrate thereby comprising an at least partially covered surface and an opposite non-covered surface, a pre-heat substrate being arranged in the chamber, spaced from the heater substrate and facing the at least partially coated surface thereof, the body defining an inlet to the chamber and an outlet from the chamber, a pre-heat flow path extending from the inlet over a surface of the pre-heat substrate and a heater flow path extending from the pre-heat flow path over the non-coated surface of the heater substrate.

2. An electric water heater according to claim 1, in which the heater substrate is a flat plate.

3. An electric water heater according to claim 1, in which the heater substrate comprises a tube.

4. An electric water heater according to claim 1, in which the heater substrate comprises a first inner tubular heater substrate arranged within a second outer tubular heater substrate, the conductive resistance heater being applied to or around at least a part of the inner surface of the inner tubular heater substrate and at least a part of the outer surface of the outer tubular heater substrate.

5. An electric water heater according to claim 4, in which the pre-heat substrate comprises a further outer tubular substrate arranged around the outer tubular heater substrate.

6. An electric water heater according to claim 4 or 5, in which a helical flow path inducer may be provided to induce helical flow in the annular flow path.

7. An electric water heater according to any preceding claim in which the electrically conductive resistance heater is a thin film conductive resistance heater.

8. An electric water heater according to any of claims 1 to 6 in which the electrically conductive resistance heater is a tungsten wire wound element.

9. An electric water heater according to claim 4 in which one of the inner or outer tubular heater substrates has a thin film electrically conductive resistance heater applied thereto and the other of the inner or outer tubular heater substrates has a tungsten wire wound element applied thereto.

10. An electric water heater comprising a body in which a conductive resistance heater is arranged on a substrate, an annular flow path is defined around the substrate and a helical flow inducer is provided to induce helical flow in fluid flowing in the annular flow path.

11. An electric water heater according to claim 10, in which the body defines a chamber within which the conductive resistance heater is arranged, a pre-heat substrate also being arranged in the chamber, spaced from the heater substrate and facing the heater, the body defining a pre-heat flow path extending over a surface of the pre-heat substrate which terminates in the annular flow path.

12. An electric water heater according to claim 10 or 11, in which the conductive resistance heater comprises an inner tubular heater substrate with a conductive resistance heater applied to or around at least part of the inner surface thereof and an outer tubular heater substrate with a conductive resistance heater applied to or around at least part of the outer surface thereof, the inner tubular heater substrate being arranged within the outer tubular heater substrate so as to define the annular flow path.

13. An electric water heater according to any of claims 10 to 12 in which the electrically conductive resistance heater is a thin film conductive resistance heater.

14. An electric water heater according to any of claims 10 to 12 in which the electrically conductive resistance heater is a tungsten wire wound element.

15. An electric water heater according to claim 12 in which one of the inner or outer tubular heater substrates has a thin film electrically conductive resistance heater applied thereto and the other of the inner or outer tubular heater substrates has a tungsten wire wound element applied thereto.

16. An electric water heater comprising a body defining a chamber, an inner tubular heater substrate and an outer tubular heater substrate, the inner tubular heater substrate arranged within the outer tubular heater substrate, a conductive resistive heater applied to or around at least part of the inner surface of the inner tubular heater substrate and a conductive resistance heater applied to or around at least part of the outer surface of the outer tubular heater substrate, a flow path defined between the inner surface of the outer tubular heater substrate and the outer surface of the inner tubular heater substrate.

17. An electric water heater according to claim 16, in which the electric water heater further comprises a pre-heat substrate arranged in the chamber, spaced from the conductive resistance heater applied to at least part of the outer surface of the outer tubular heater substrate and a pre-heat flow path is formed in the chamber extending over the pre-heat substrate, terminating in the flow path defined between the inner surface of the outer tubular heater substrate and the outer surface of the inner tubular heater substrate.

18. An electric water heater according to claim 16 or 17, in which a helical flow inducer is provided in the flow path defined between the outer and inner tubular heater substrates.

19. An electric water heater according to any one of claims 3 to 6, 12 or 16 to 18 in which the tubular heaters range from 3mm to 50mm in diameter.

20. An electric water heater according to any of claims 16 to 18 in which the electrically conductive resistance heater is a thin film conductive resistance heater.

21. An electric water heater according to any of claims 16 to 18 in which the electrically conductive resistance heater is a tungsten wire wound element.

22. An electric water heater according to any of claims 16 to 18 in which one of the inner or outer tubular heater substrates has a thin film electrically conductive resistance heater applied thereto and the other of the inner or outer tubular heater substrates has a tungsten wire wound element applied thereto.

23. An electric water heater comprising a body defining a chamber, a first heater substrate having a thin film conductive resistance heater applied to a surface thereof so that the first heater substrate has an at least partially coated surface and a non-coated surface, a second heater substrate having a thin film conductive resistance heater applied to a surface thereof so that the second heater substrate has an at least partially coated surface and a non-coated surface, the first and second heater substrates being configured in the chamber such that the respective non-coated surfaces thereof face each other and are spaced apart to define a heater flow path through which water can flow to be heated.

24. An electric water heater according to claim 23, in which the heater comprises a further pair of heater substrates with a heater flow path arranged therebetween.

25. An electric water heater according to claim 23, in which the heater comprises a first outer heater substrate with a thin film conductive resistance heater applied to one surface thereof, a middle heater substrate comprising two spaced substrates with a thin film conductive resistance heater applied to one of the facing surfaces of the two spaced substrates and a second outer heater substrate with a thin film conductive resistance heater applied to one surface thereof, the heater substrates being configured in the chamber so that the non-coated surface of the first outer heater substrate faces one of the non-coated surfaces of the middle heater substrate and the other non-coated surface of the middle heater substrate faces the non-coated surface of the second outer

heater substrate, whereby a first heater flow path is formed between the first outer heater substrate and the middle heater substrate and a second heater flow path is formed between the middle heater substrate and the second outer heater substrate.

26. An electric water heater according to any preceding claim, in which the heater flow path, the annular flow path or the flow path defined between inner and outer tubular heater substrates is preferably 0.3mm to 1mm wide.

27. An electric water heater according to any one of claims 1 to 6 or 16 to 25, in which the conductive resistance heater is applied to three, separate lengths of the substrate.

28. An electric water heater according to any of claims 4 to 6 or 12 to 19 in which the conductive resistance heater is applied in three separate corresponding lengths to both the respective inner and outer surface of the inner and outer tubes.

29. An electric water heater according to claim 27 or 28, in which each separate length of thin film conductive resistance heater applied to the surface may be arranged to provide 1.5Kw to 1.75Kw of heat power.

30. An electric water heater according to any preceding claim, in which the flow path past the heater includes features to decelerate the flow past the heater and to accelerate the flow beyond the heater.

31. An electric water heater according to claim 30, in which, where multiple heater sections are provided, the flow path includes features to decelerate the flow at the heater section and accelerate the flow between the heater sections.

32. An electric water heater according to claim 31, in which such features include a venturi narrowing of the flow path between the heater sections.

33. An electric water heater according to any one of claims 1 to 6, 12 to 19 or 27 to 29, in which the thin film conductive resistance heater is arranged to deliver 40-45 watts per cm^2 of heating power.

34. An electric water heater according to any preceding claim, in which the substrate of any of the heaters is intended to raise the surface temperature thereof to at least 400-450^{0}C, preferably to 1000^{0}C.

35. An electric water heater according to any preceding claim, in which the substrate comprises a thermally conductive, electrically non-conductive material such as quartz, Pyrex glass, ceramic or polymer.

36. An electric water heater according to any of claims 1 to 34, in which the substrate comprises a thermally conductive, electrically conductive material with a non-conductive coating, such as a ferrous or non-ferrous alloy with an appropriate non-conductive coating, such as an engineering polymer, glass or non-conductive paint.

37. An electric water heater according to claim 1 in which the conductive resistance heater comprises a combination of a thin film conductive resistance heater, and a tungsten wire wound element.

38. An electric water heater according to claim 8 in which the inner surface of the body defining the chamber is reflective.

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Claims searched: 1-9, 19, 26-38 **Date of search:** 6 November 2009

Patents Act 1977: Search Report under Section 17

Documents considered to be relevant:

Category	Relevant to claims	Identity of document and passage or figure of particular relevance
X,Y	X:1, 3, 8, 34, 35 Y:7, 27, 37	WO98/31045 A (LUFRAN) - see whole document and figures 1 and 13.
X,Y	X:1, 3, 8, 35, 36 Y:7, 27, 37	US4563571 A (MATSUSHITA) - see whole document and figure 1.
X,Y	X:1, 3, 8, 35 Y:7, 27, 37	GB238648 A (MCQUINN) - see whole document and figure 1.
X,Y	X:1, 3, 34, 35 Y:7, 27	US5271086 A (ASAHI GLASS) - see whole document and figures 1 and 2.
X,Y	X:1, 3, 8, 35, at least Y:7, 27, 37	JP07004739 A (ASAHI GLASS II) and WPI Abstract Accession No. 1995-078662 [11] - see abstract and figure 3.
X,Y	X:1, 3, 8, 38, at least Y:7, 27, 37	SU1009405 A (MARSHENOV) and WPI Abstract Accession No. 1984-041136 [07] - see abstract and figure presented in document.
X,Y	X:1, 3, 8, at least Y:7, 27, 37	CN201129844 Y (NINGBO TIANMING) and WPI Abstract Accession No. 2008-M87407 [76] - see abstract and figure 4.
X,Y	X:1, 3 Y:7, 27	US1519395 A (CLENCH) - see whole document and figure 1.

Y	7, 27, 37	WO01/67819 A (COOPER) - see whole document and figures 1, 2, 4 and 5.

Categories:

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
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Field of Search:

Search of GB, EP, WO & US patent documents classified in the following areas of the UKC^X :

Worldwide search of patent documents classified in the following areas of the IPC

F24H; H05B

The following online and other databases have been used in the preparation of this search report

EPODOC, WPI

International Classification:

Subclass	Subgroup	Valid From
F24H	0001/10	01/01/2006
F24H	0001/14	01/01/2006
H05B	0003/44	01/01/2006
H05B	0003/46	01/01/2006