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(54) **BURNER VESSEL AND FLUID HEATER**

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(72) Inventor: **Matthew White**, Haywards Heath, West Sussex (GB)

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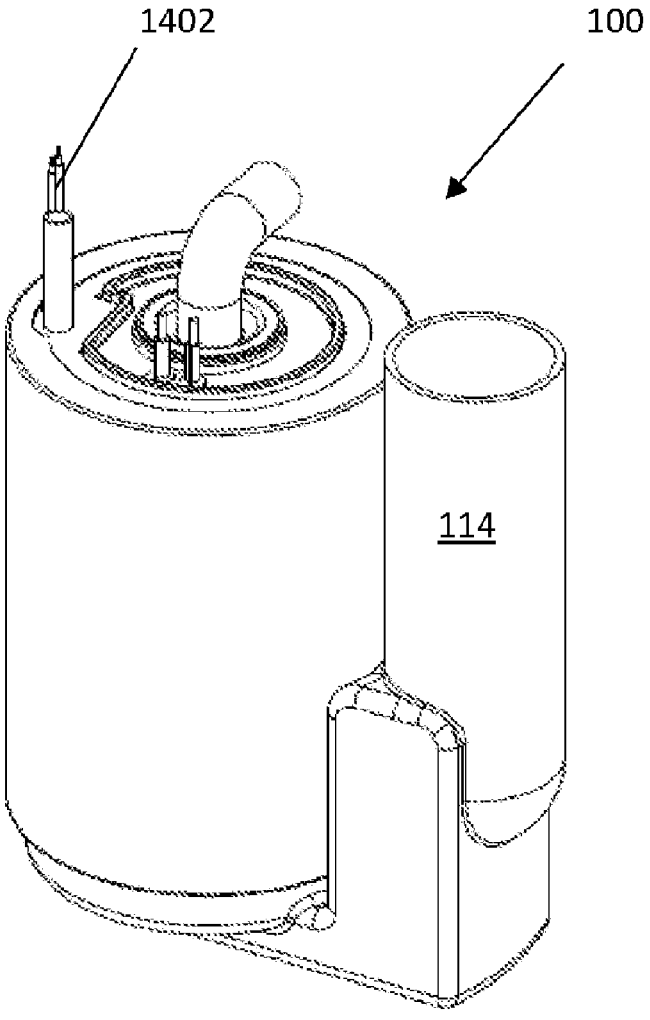
F24H 1/14 (2006.01)

(52) **U.S. Cl.**
CPC ***F24H 1/121*** (2013.01); ***F24H 1/124*** (2013.01); ***F24H 1/145*** (2013.01)

(57) **ABSTRACT**

Disclosed is a burner vessel (**5400**) for a hybrid electric-combustible fuel fluid heater arranged to heat fluid in one or more fluid circuits. The vessel comprises a vessel housing (**5401**) containing: a combustible fuel burner (**5405**) arranged to burn combustible fuel; and one or more electric heating elements (**5410**) arranged to generate heat and transfer the heat to said fluid in one or more fluid circuits. The vessel further comprises: a first cold fluid inlet (**5404**) arranged to input relatively cold fluid to the vessel; a first hot fluid outlet arranged to output relatively hot fluid from the vessel; a first fluid duct (**5403**) extending between the first cold fluid inlet and the first hot fluid outlet and arranged to convey fluid through the vessel; and a flue (**5407**) arranged to convey waste combustion gas from the vessel. Both the combustible fuel burner and the one or more electric heating elements are arranged to heat fluid in the first fluid duct.



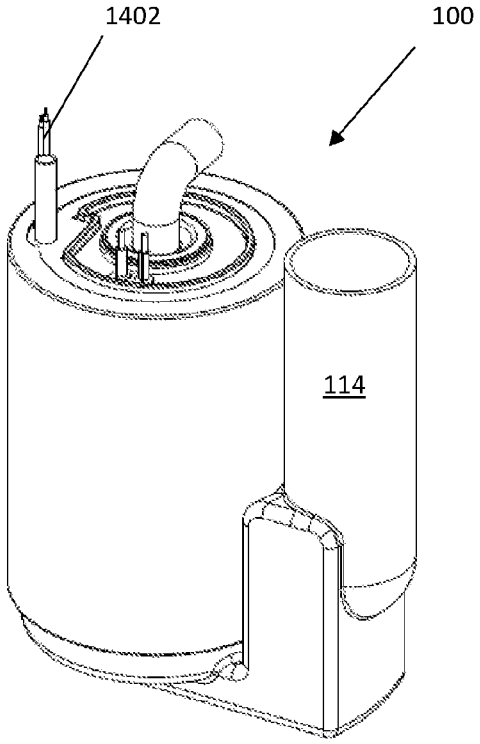


FIG. 1

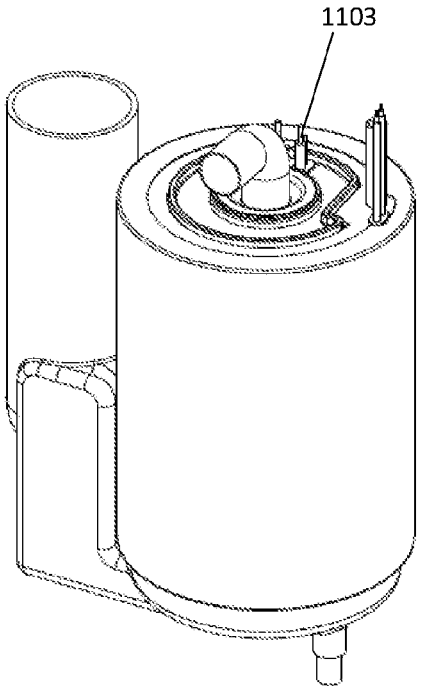


FIG. 2

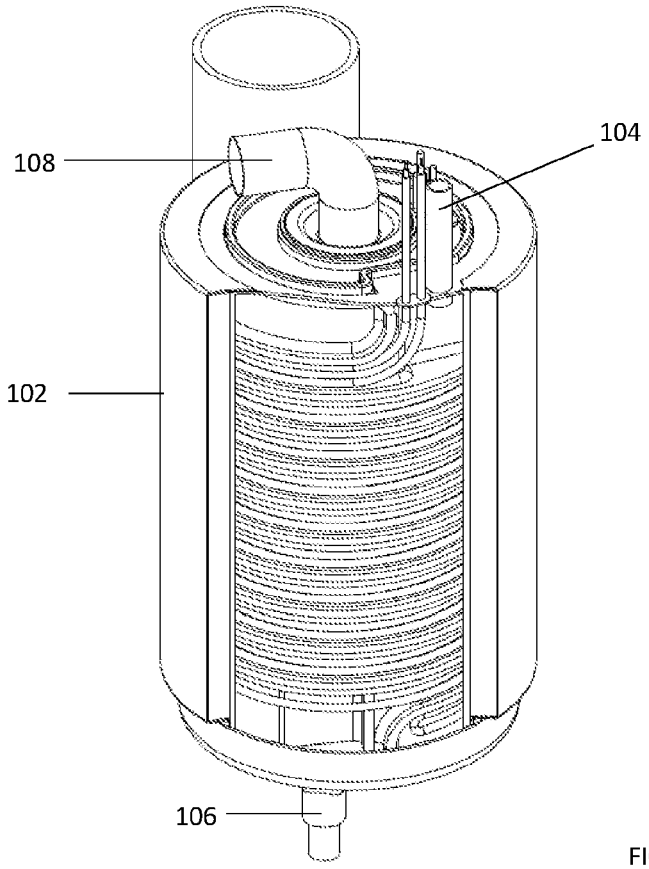
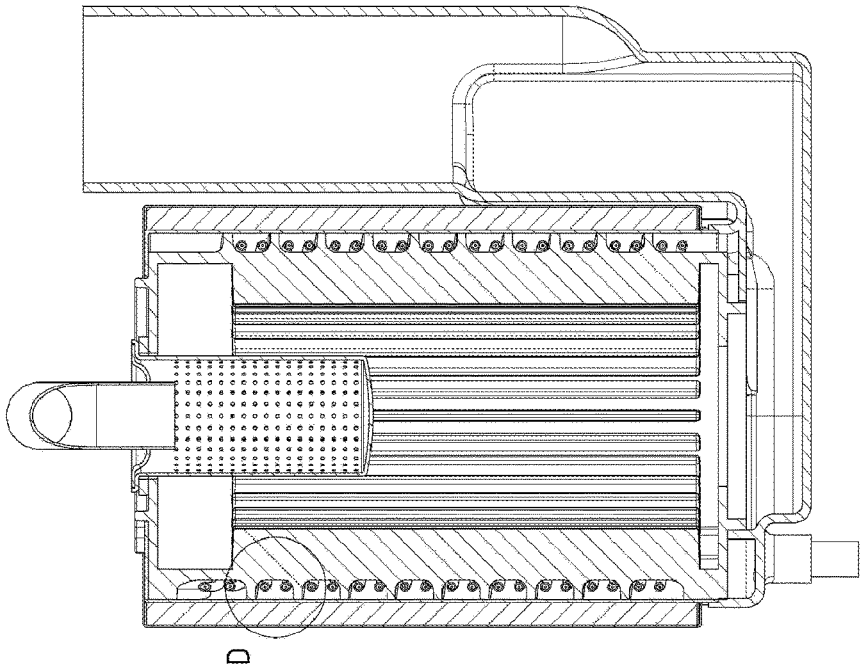


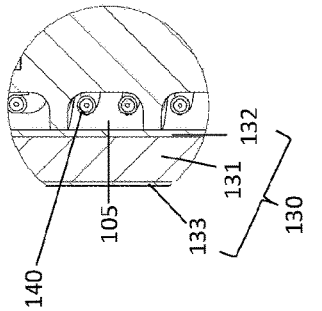
FIG. 3

FIG. 5



SECTION A-A

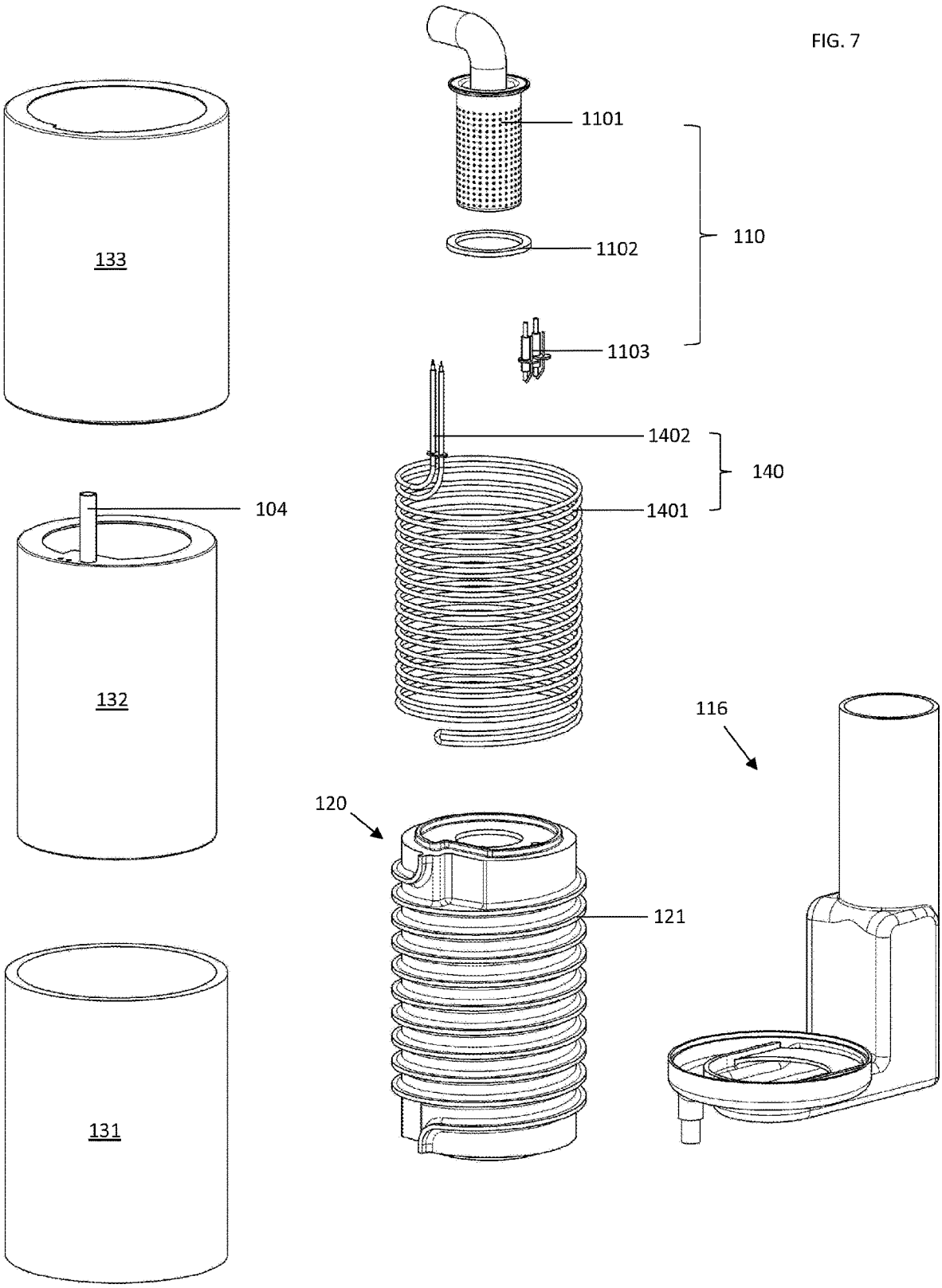
FIG. 6



DETAIL D
SCALE 2 : 2.5

FIG. 4

FIG. 7



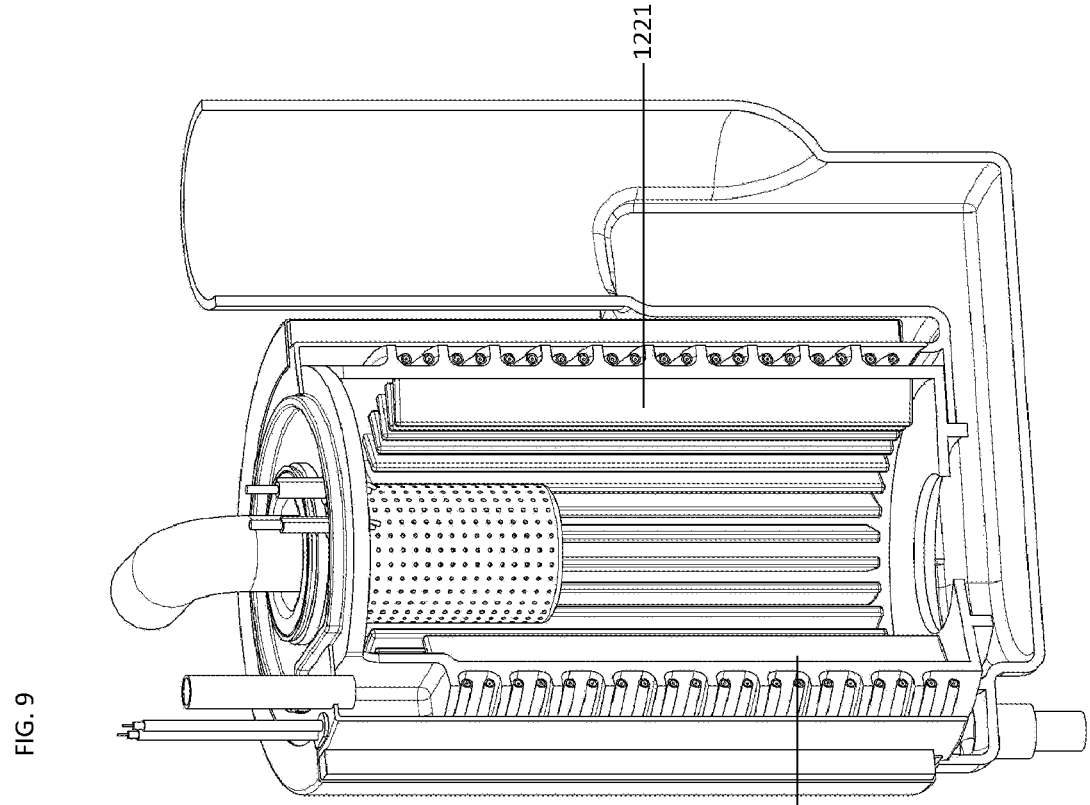


FIG. 9

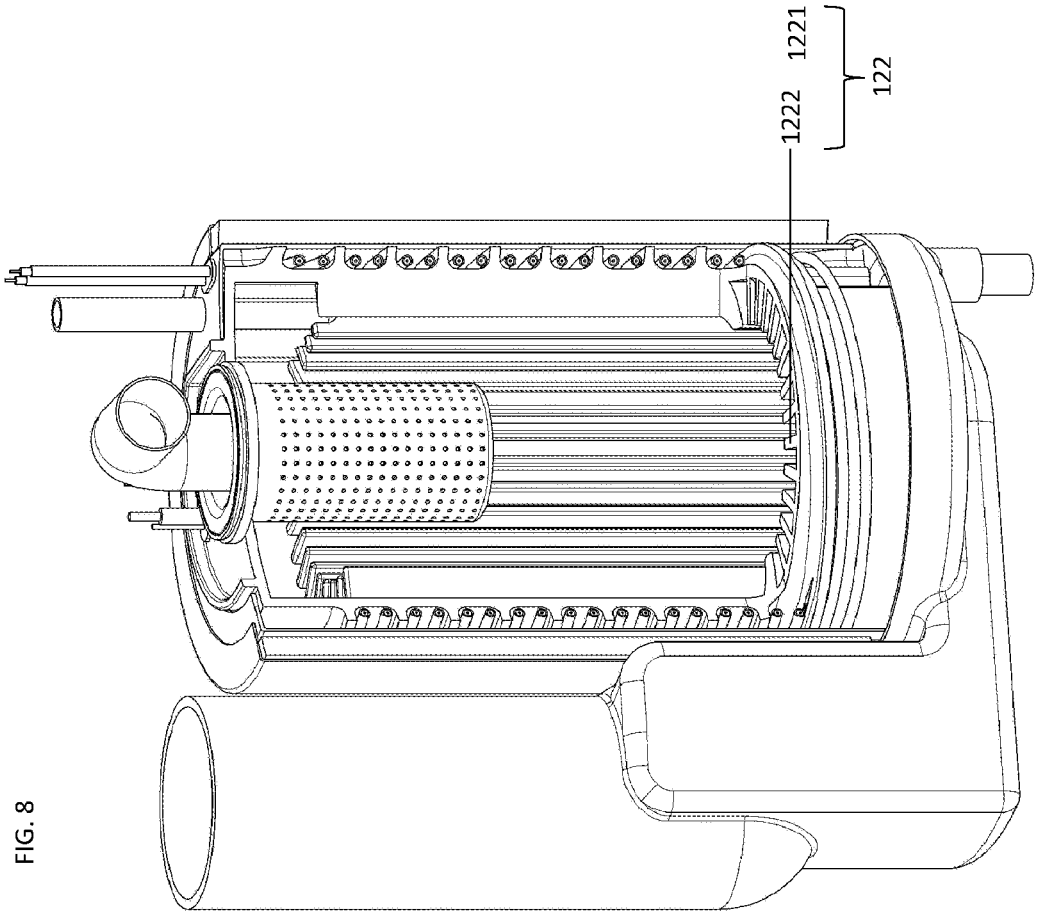
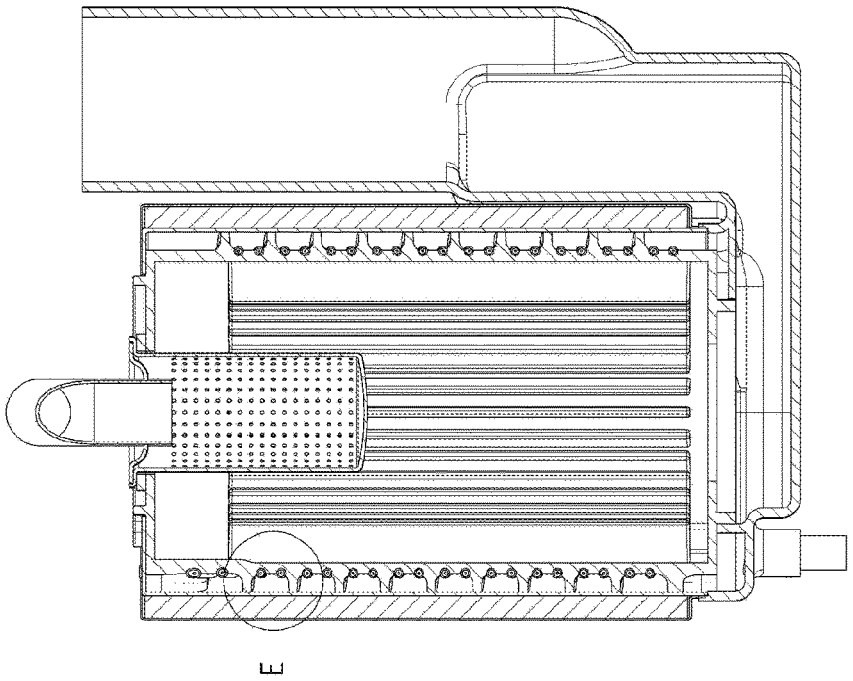


FIG. 8

FIG. 11



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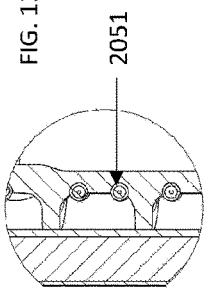
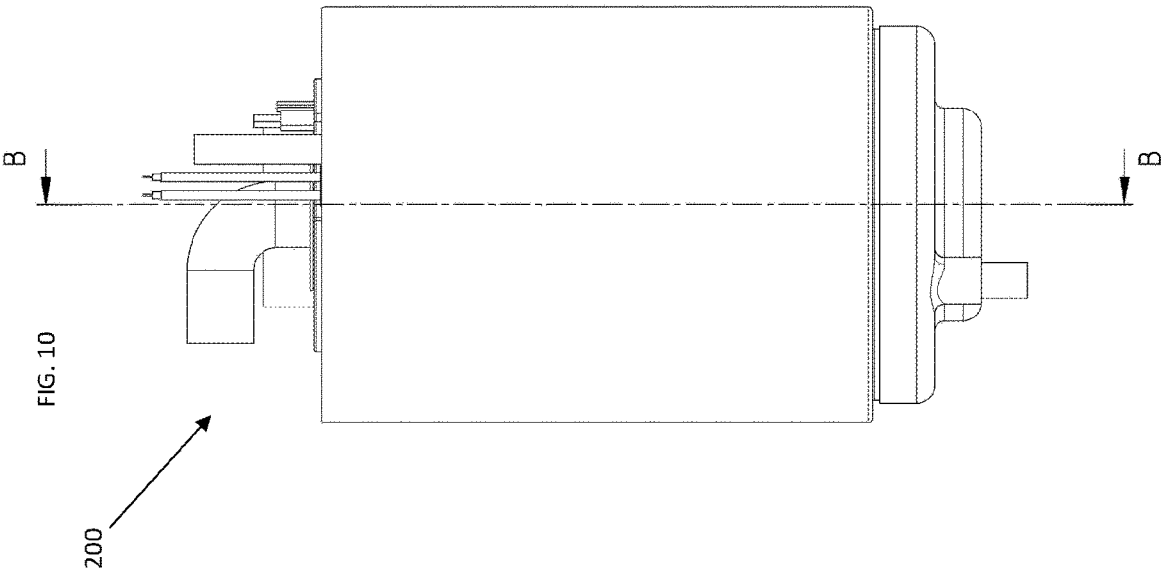


FIG. 10



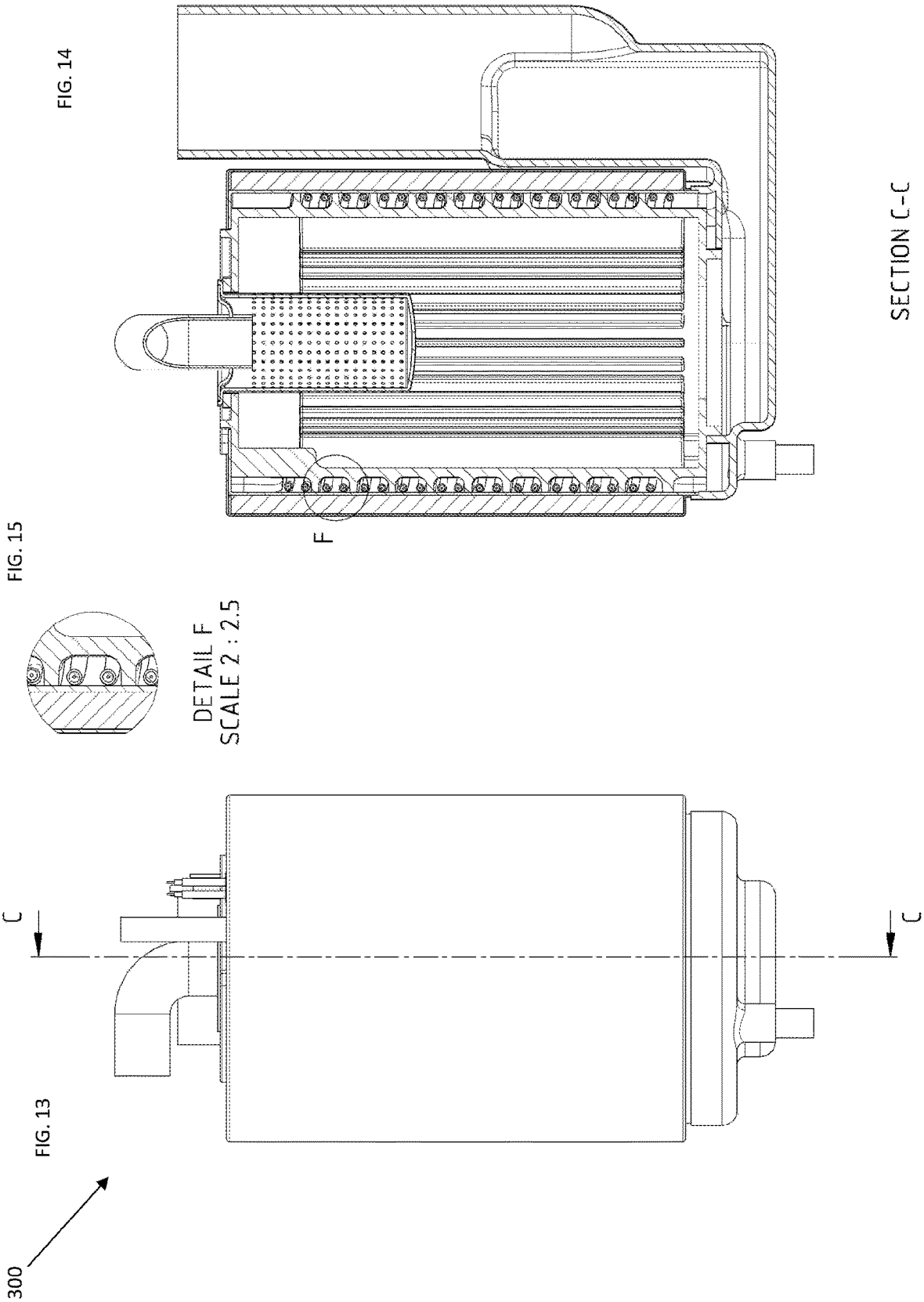


FIG. 14
SECTION C-C
F
FIG. 15
DETAIL F
SCALE 2 : 2.5
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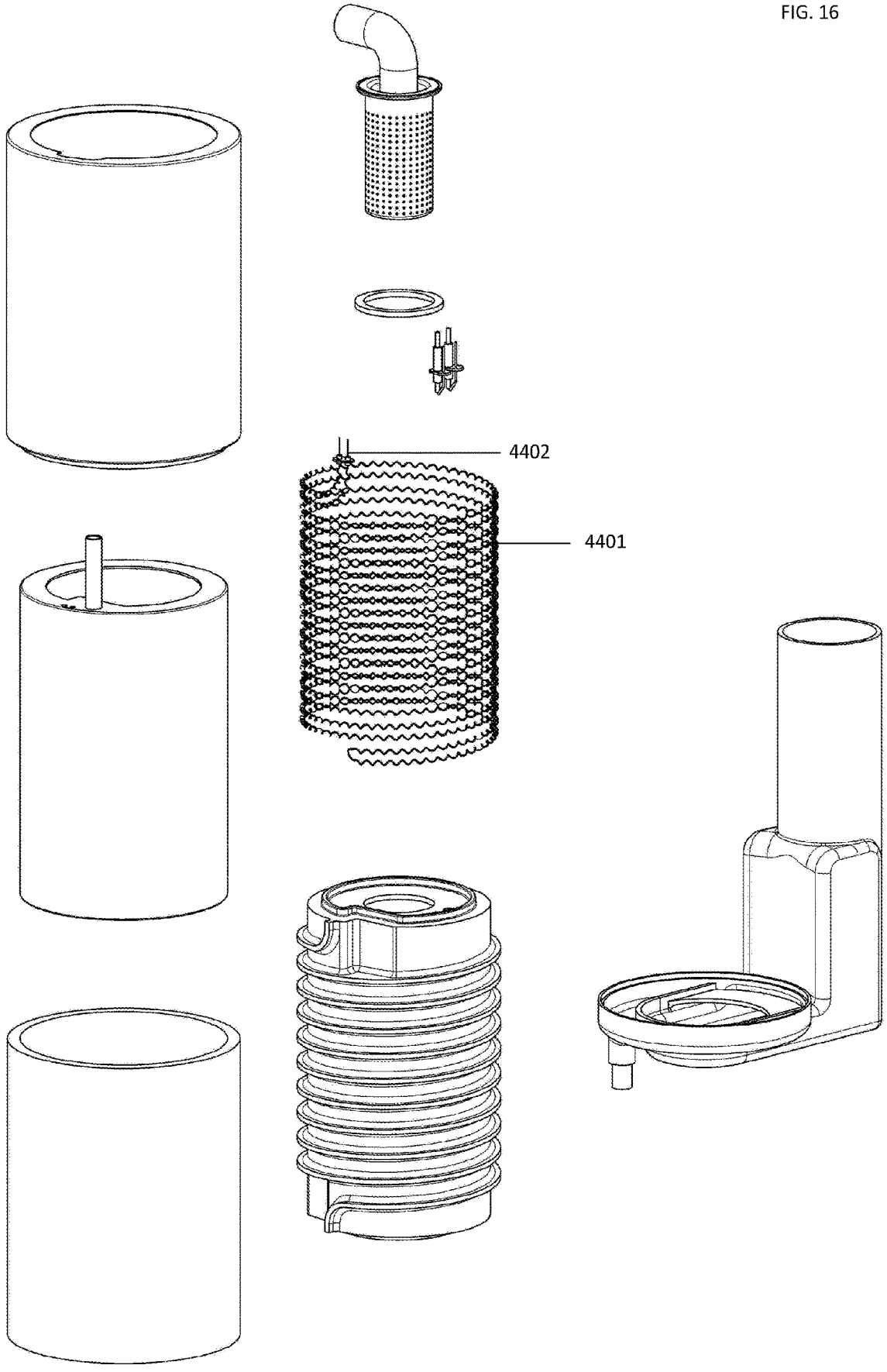
C
FIG. 13
300

FIG. 16



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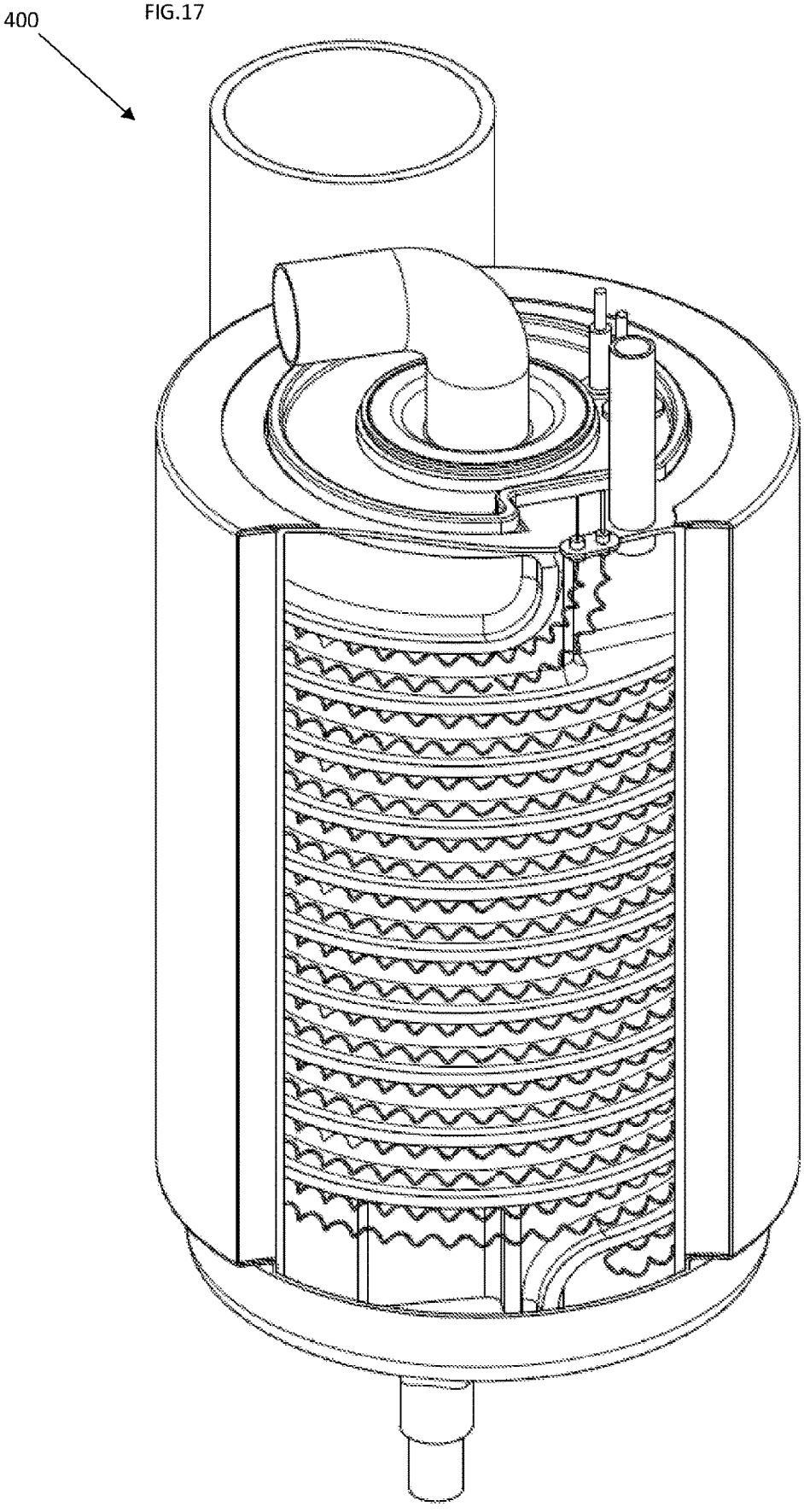

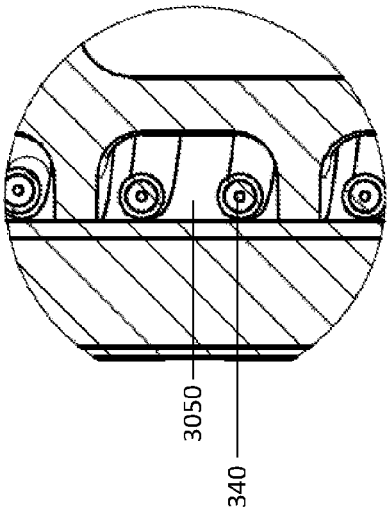

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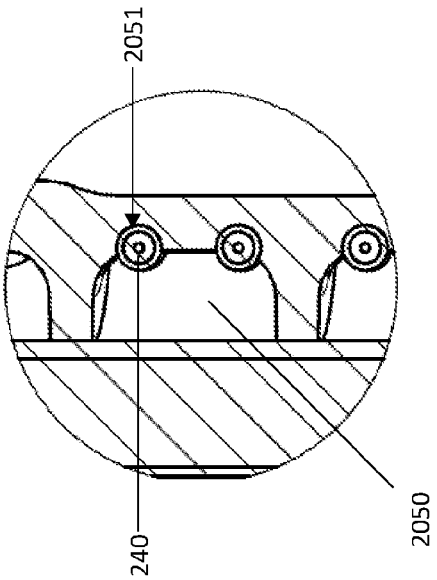

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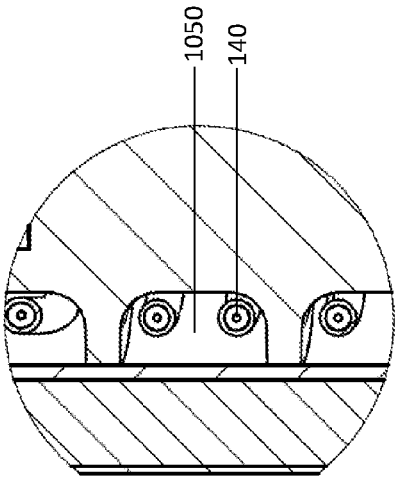

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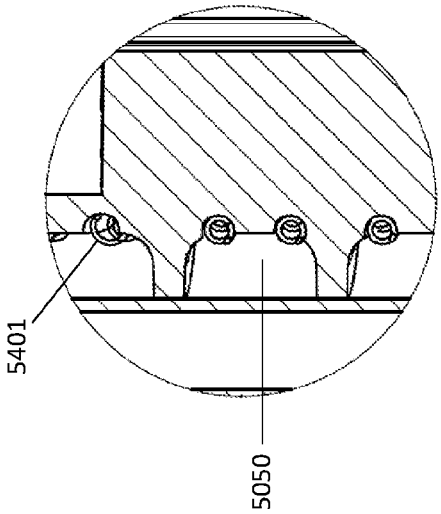

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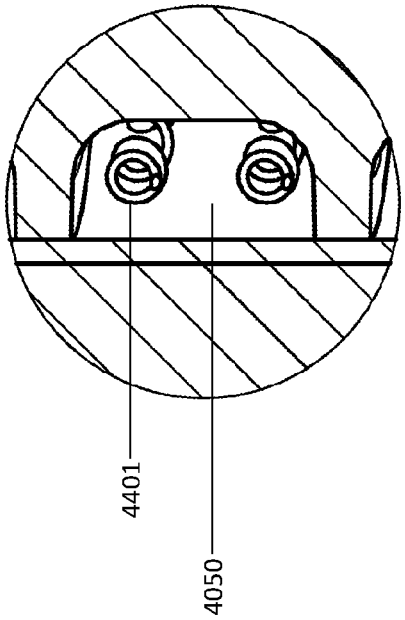

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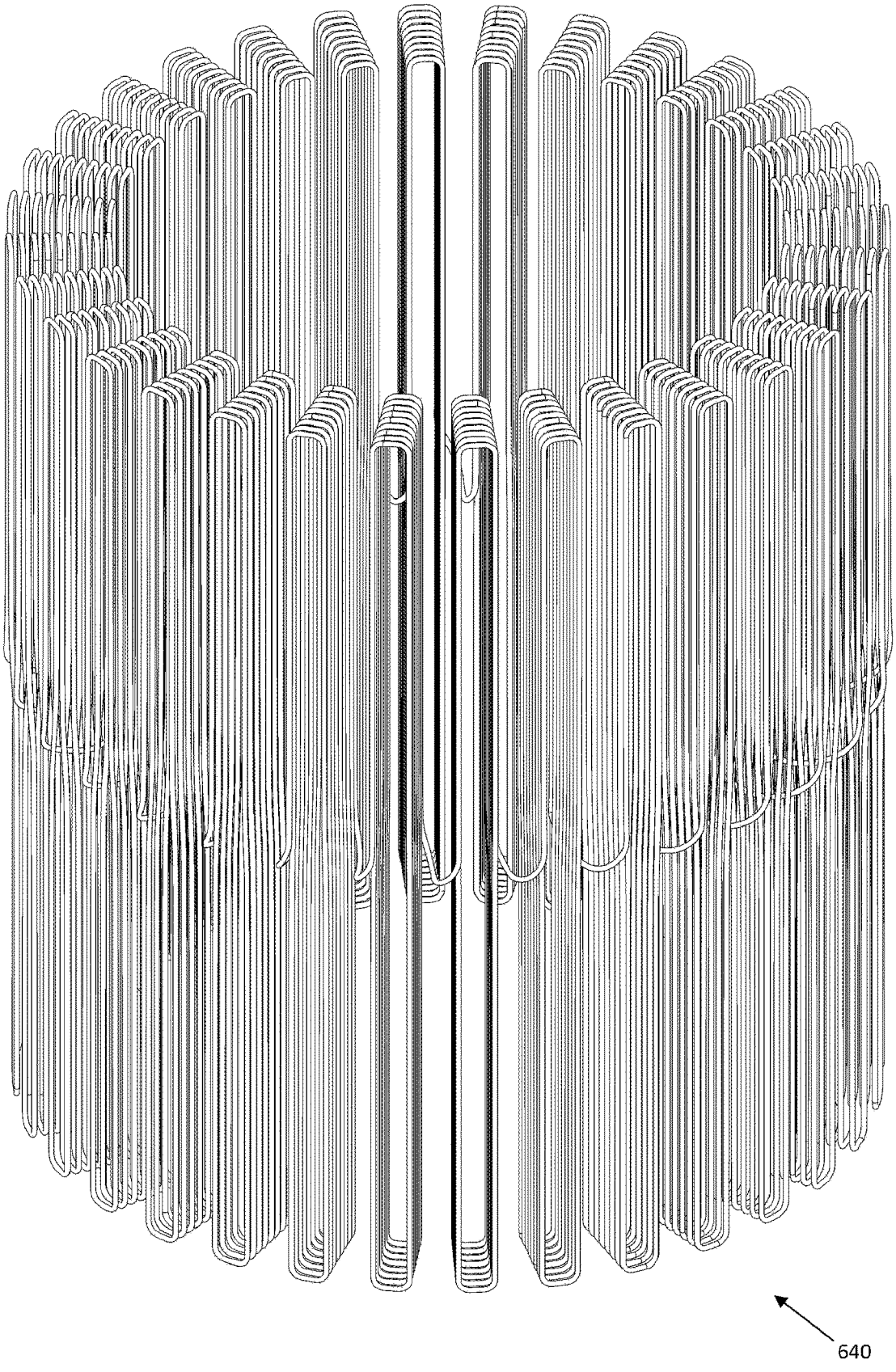
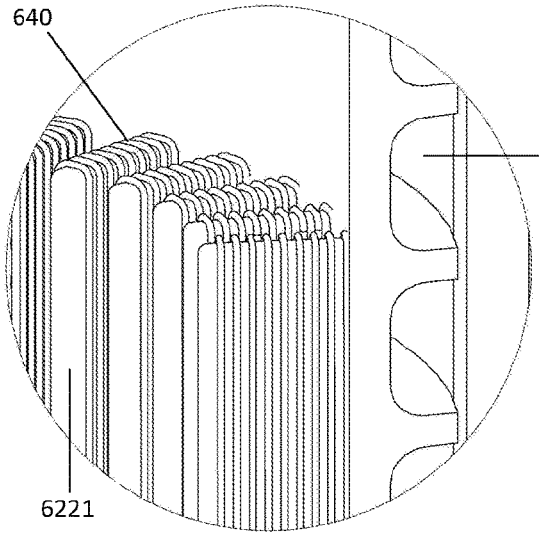
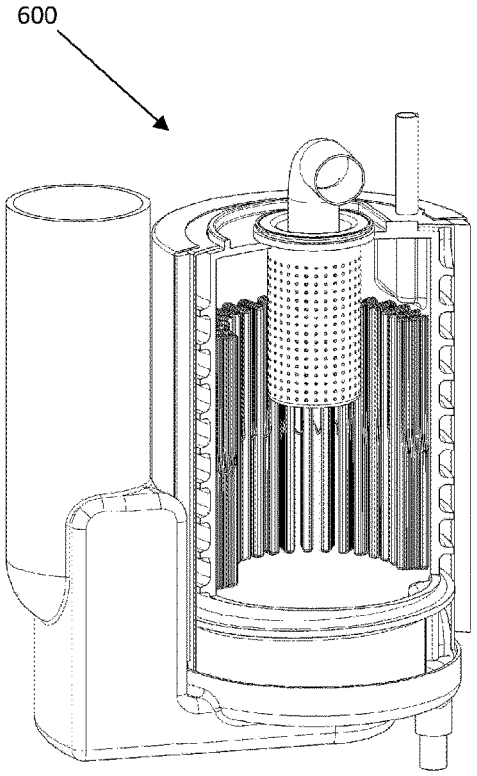


FIG. 23

FIG. 24





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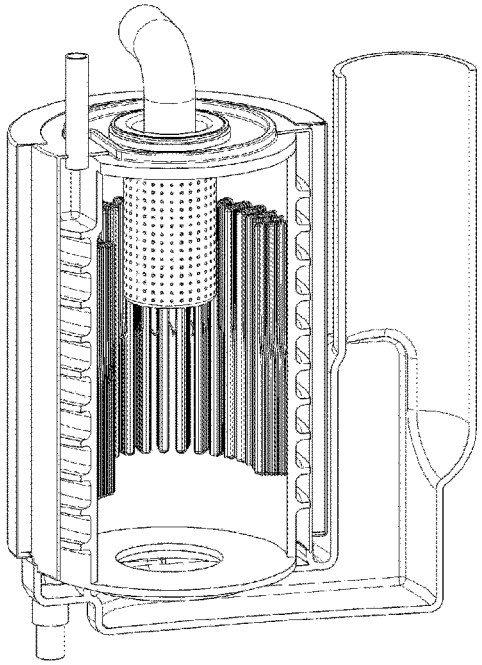

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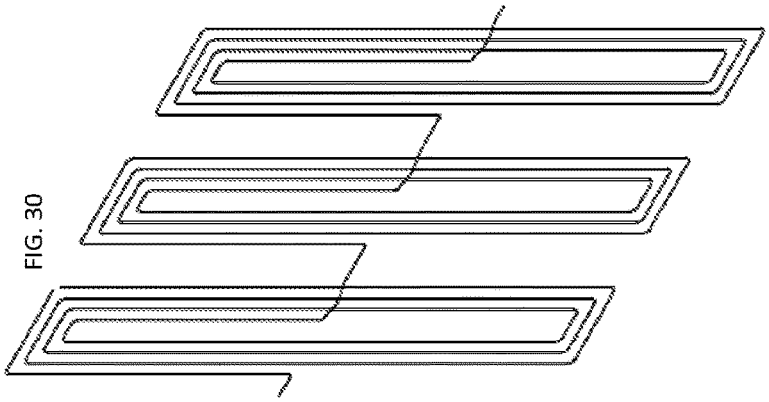

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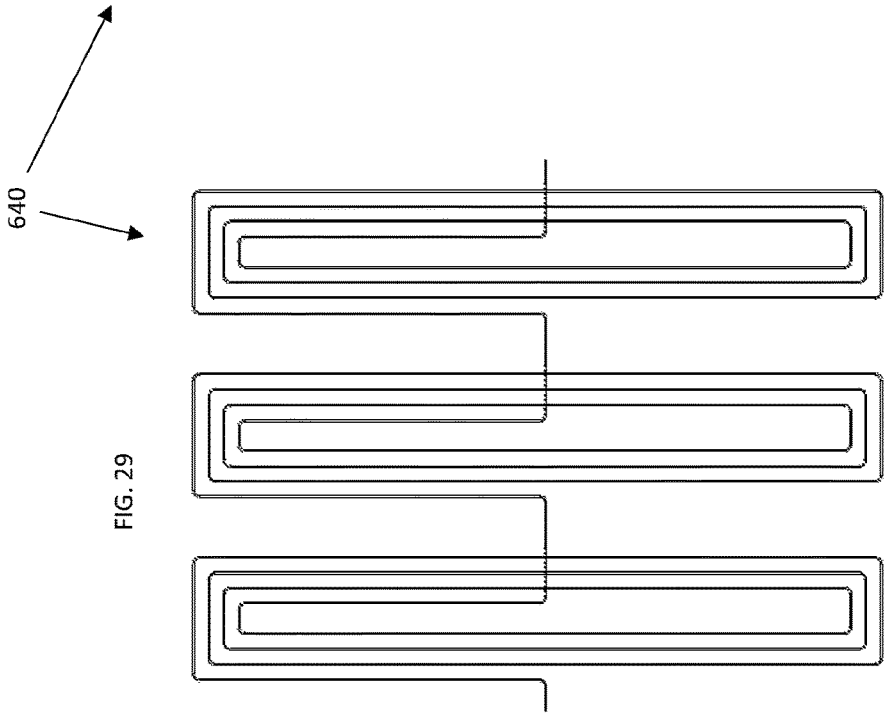

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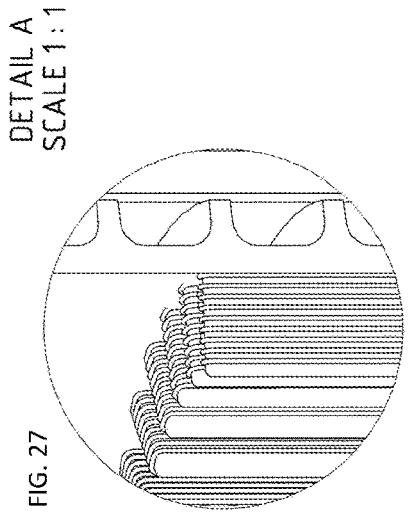
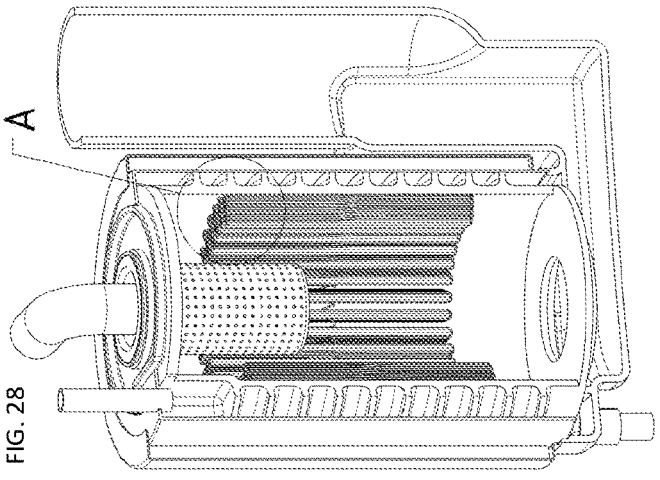


FIG. 27



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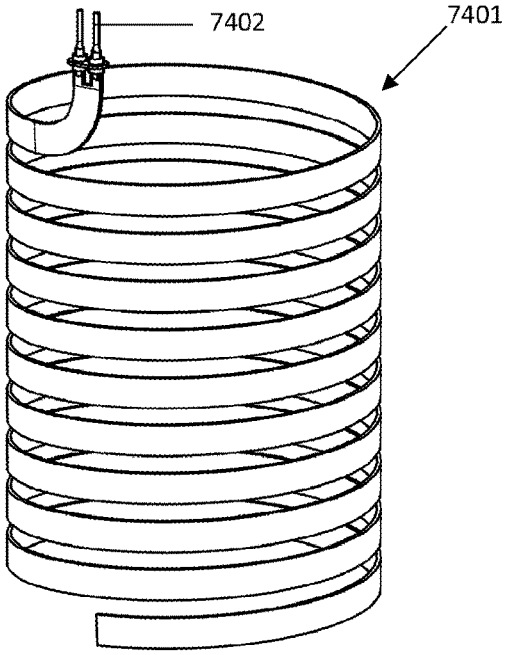

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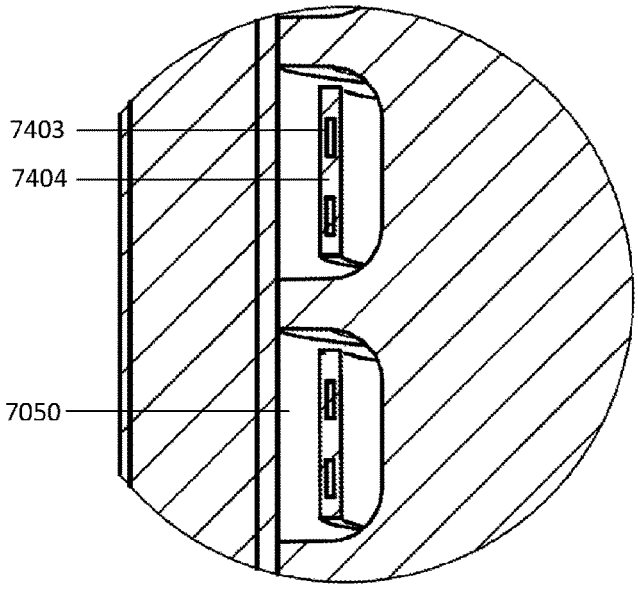
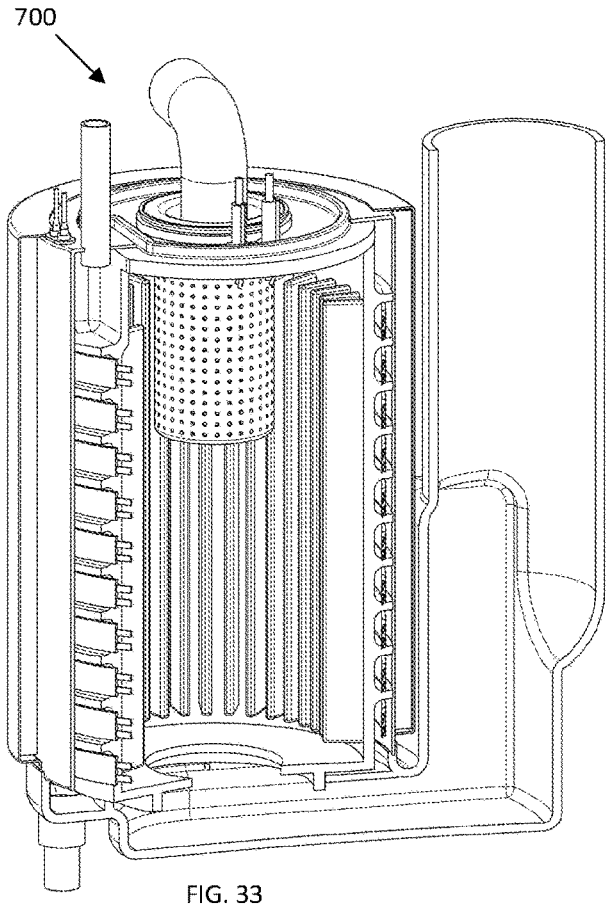


FIG. 32



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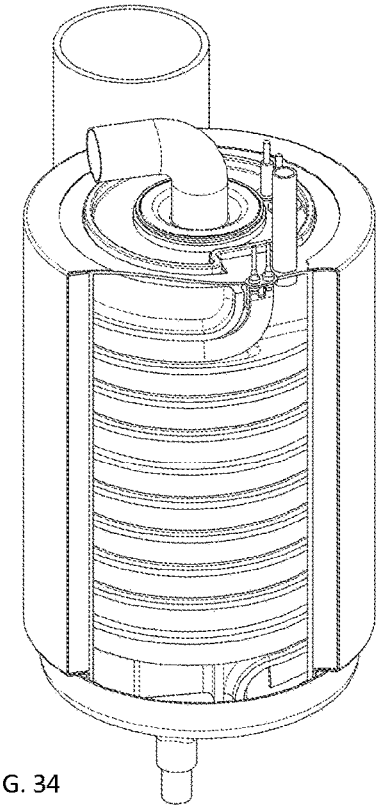

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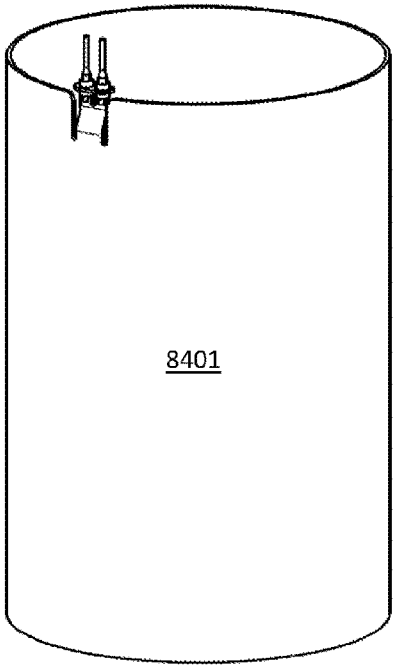

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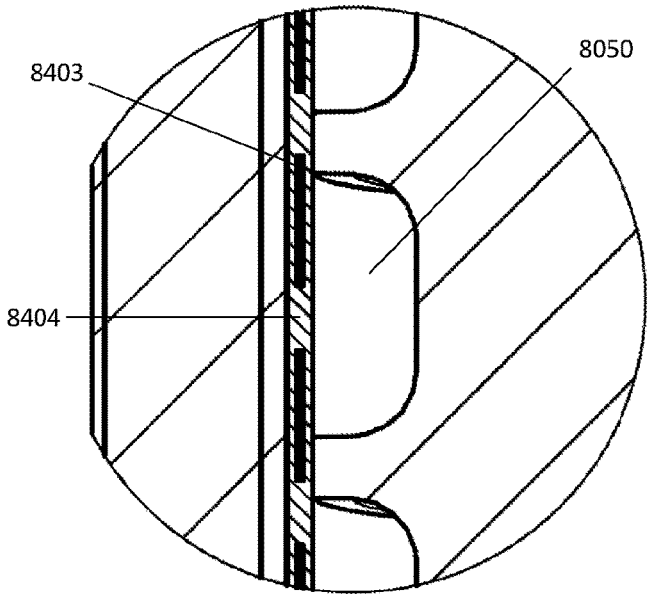

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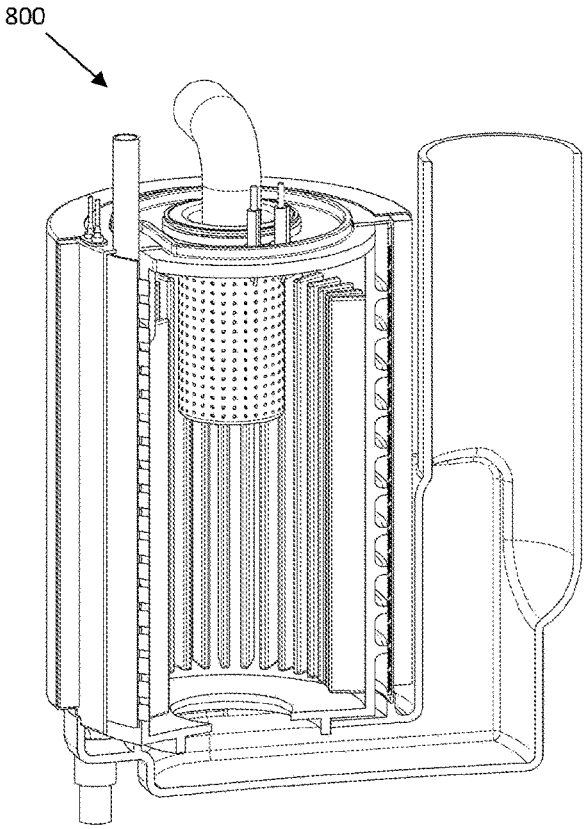


FIG. 37

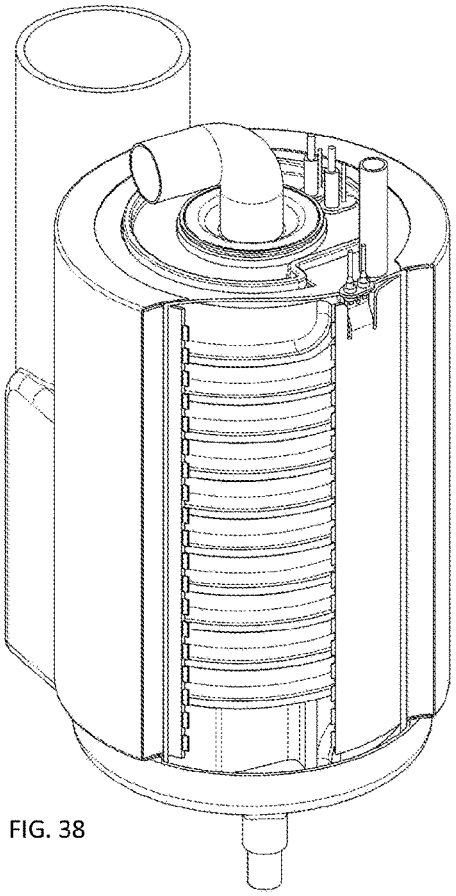


FIG. 38

FIG. 39

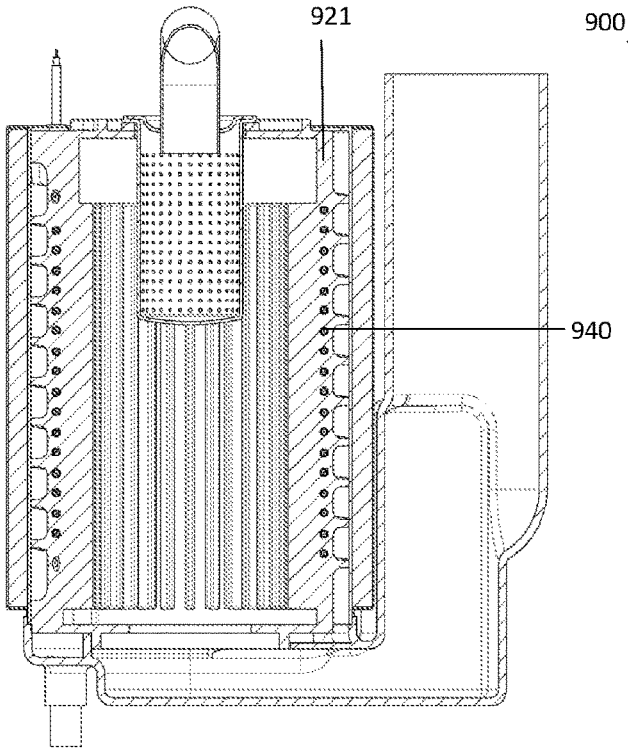
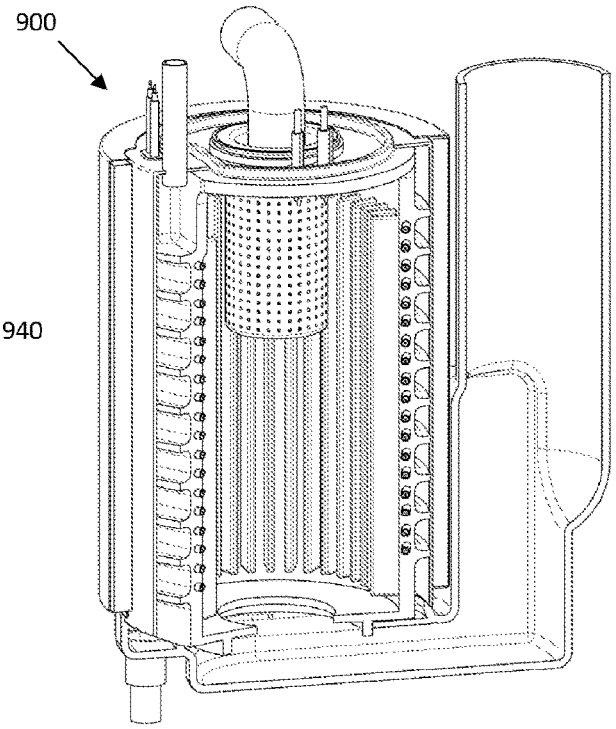
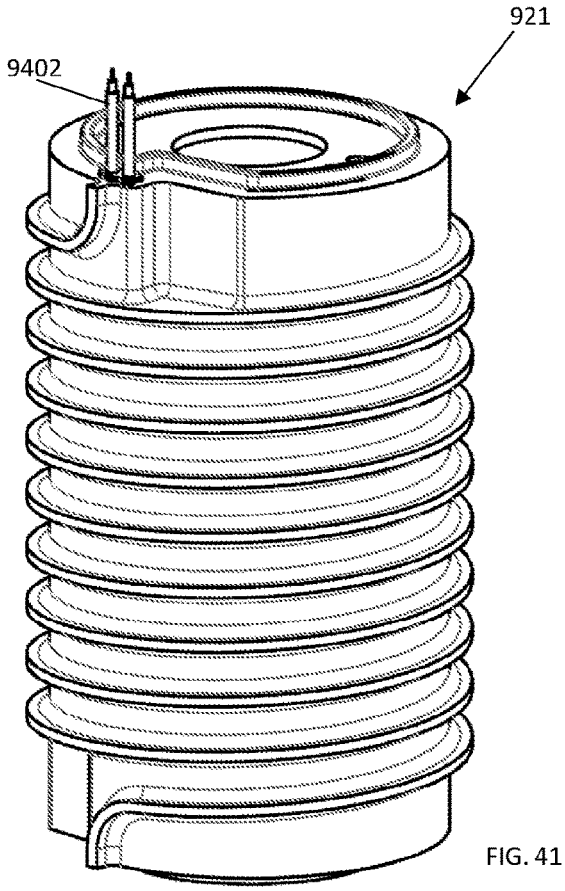


FIG. 40





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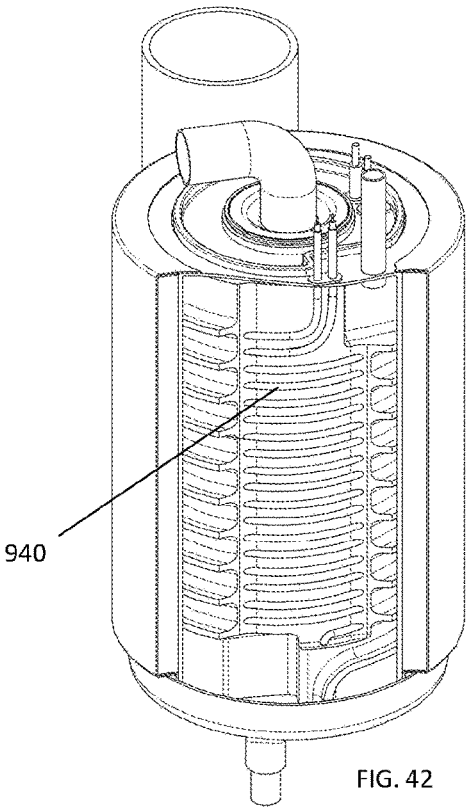

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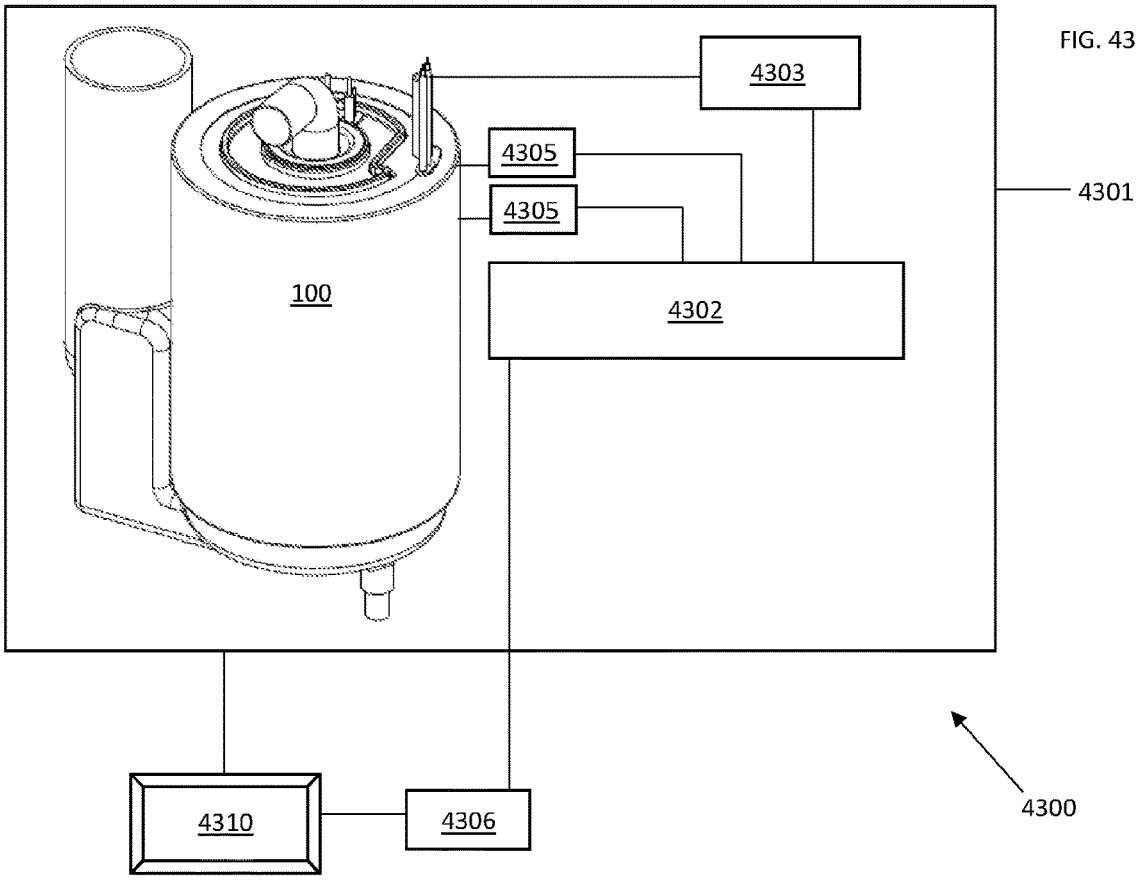
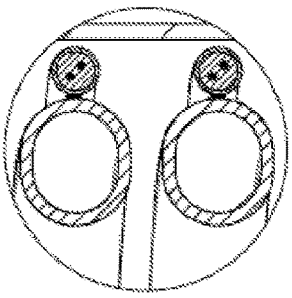


FIG. 43



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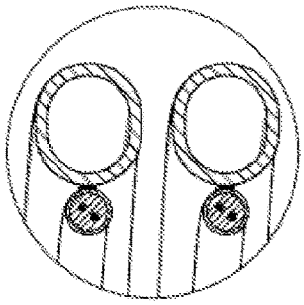


FIG. 50

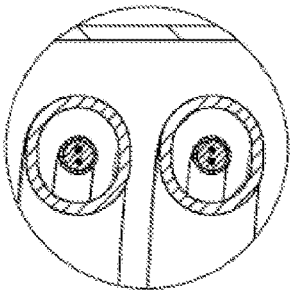


FIG. 51

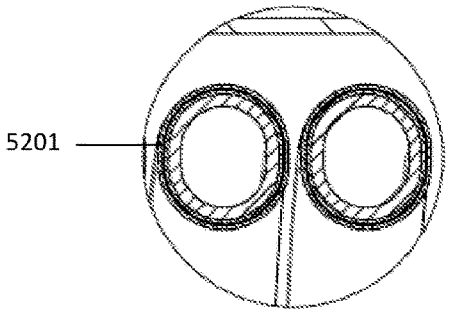


FIG. 52

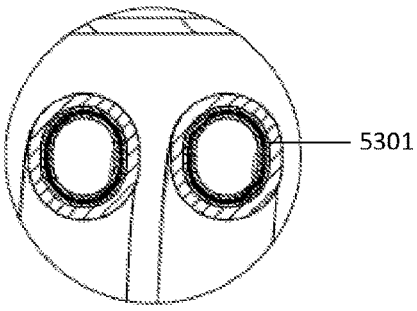


FIG. 53

FIG. 44

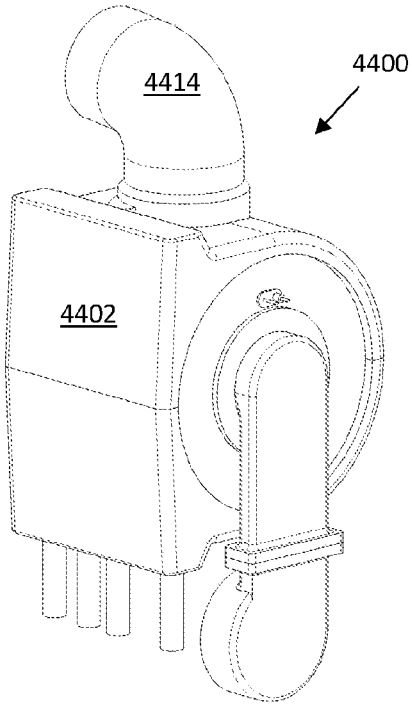


FIG. 45

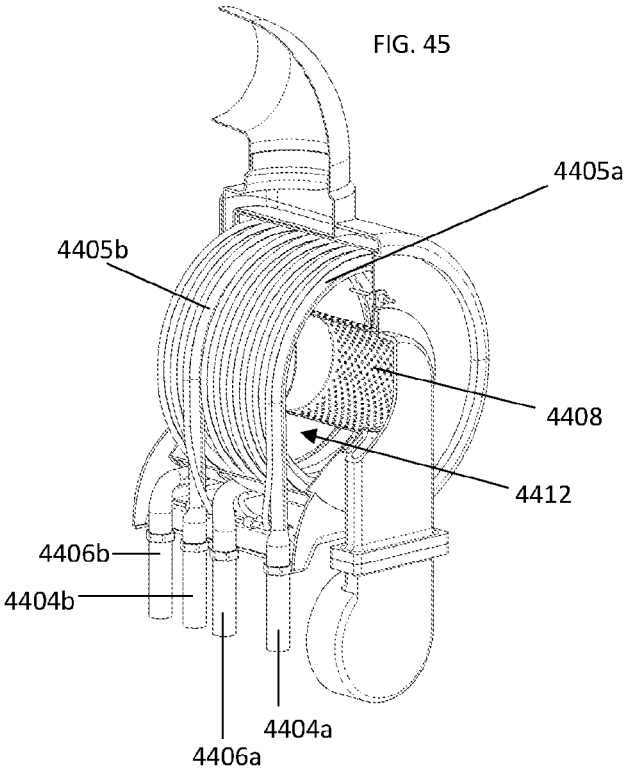
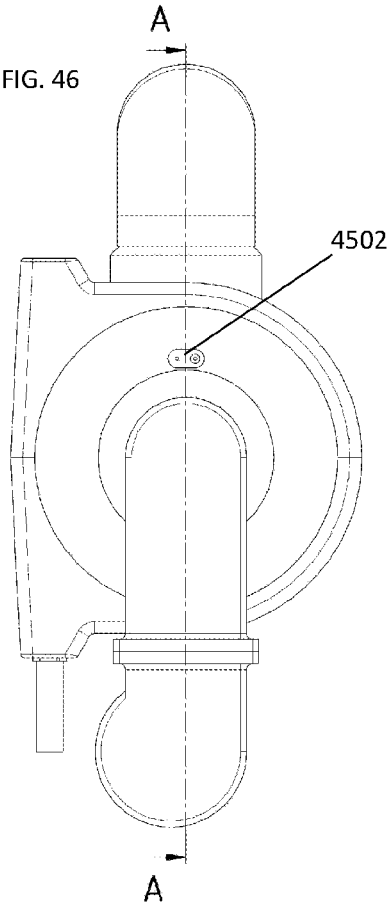


FIG. 46



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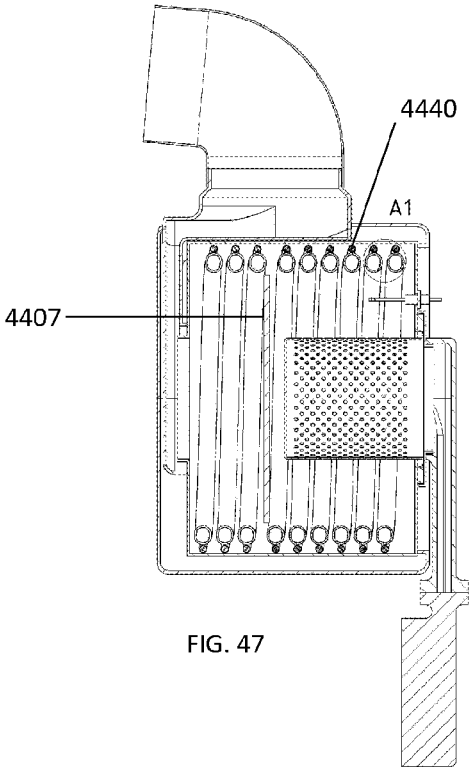
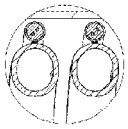
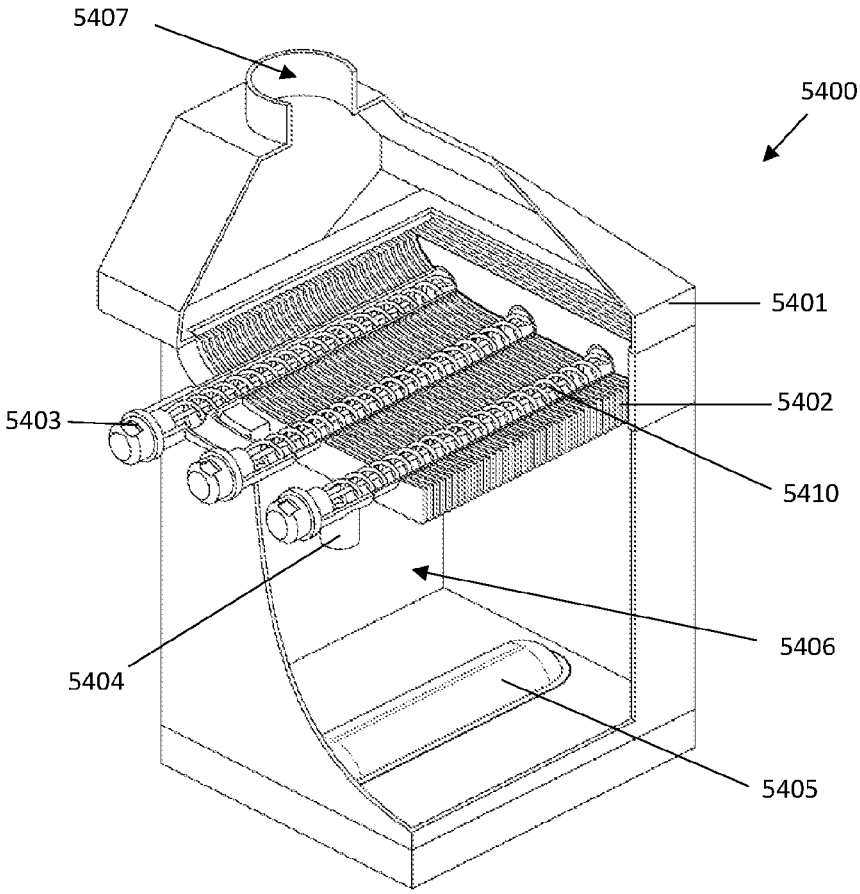


SECTION A-A

FIG. 48



DETAIL A1
SCALE 1 : 1


5407
5400
5401
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5405

FIG. 54

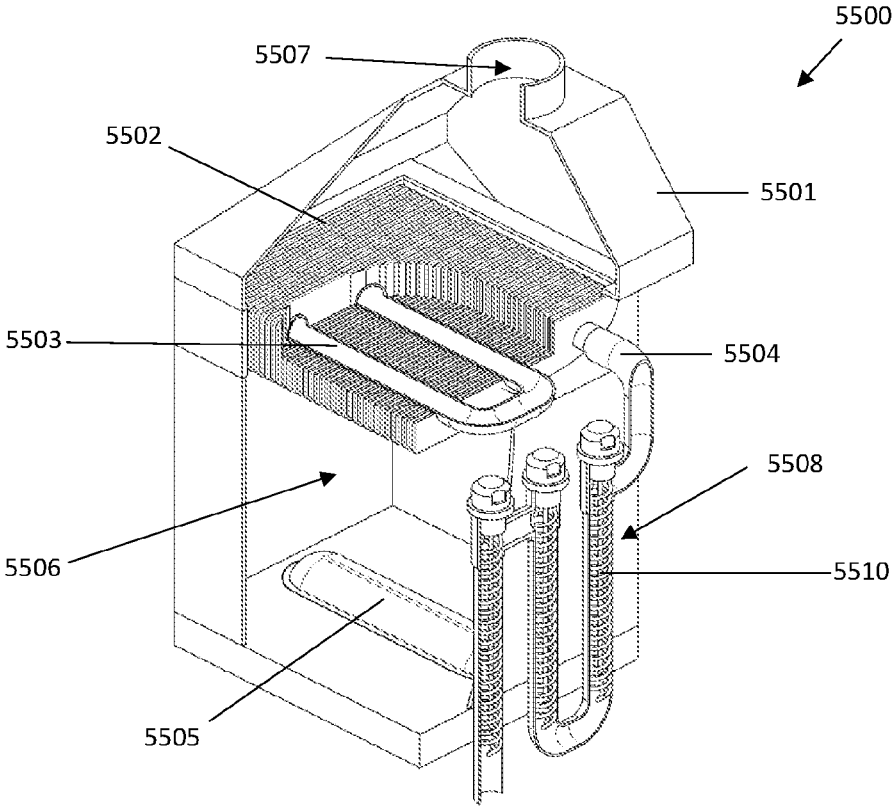
5500
5507
5502
5501
5503
5504
5508
5506
5510
5505

FIG. 55

BURNER VESSEL AND FLUID HEATER

FIELD

[0001] This invention relates to heaters for fluid heating systems. In particular, but not exclusively, the invention relates to boilers for wet heating systems or furnaces for air heating systems, both of which can supply heated fluid for heating spaces (such as via radiators) or heated tap water or both.

BACKGROUND

[0002] Gas boilers can provide wet heating solutions for hot water and heating needs. For example, a domestic gas boiler will often supply hot water for heating radiators within a heating system and also provide on-demand hot water to taps (e.g. for drinking, cleaning, washing). The two supplies (heating and tap) are kept separate since the heating water can become dirty as it passes through a radiator circuit, whereas tap water must be clean. Combination ("combi") boilers are popular as they provide all of this functionality within a sealed, high pressure environment within a single boiler housing with a relatively small physical footprint. Other types of boilers having separate tanks or cylinders are also used.

[0003] Gas boilers burn fossil fuel. As a result, electric boilers are now emerging as an environmentally friendly alternative. An electric boiler will pass the water via an electric heating element.

[0004] An electric combi boiler uses similar technology to an electric kettle. The electric boiler is connected to the mains electricity supply and is supplied with cold water from the mains. When hot water is requested (e.g. when a hot water tap is opened or the heating is switched on), the heating element inside the electric boiler heats up and passes this heat to the cold water. The heated water is then pumped to the tap or radiator where it is needed.

[0005] Storage electric boilers include a hot water tank (either an internal tank within the unit or an external tank). This enables heating and storage of water at times when energy costs are lower (e.g. overnight) for subsequent use at times when energy costs are higher (e.g. the next day). Such systems take up more space.

[0006] Along the same theme, but offering some of the advantages of a combi boiler, a combined primary storage unit (CPSU) has the central heating boiler and hot water cylinder combined in one big housing—this provides large amounts of hot water whenever required. However, a lot of space is required to house this system.

[0007] All of these electric boiler systems use heating elements powered by the AC (alternating current) mains supply.

[0008] The inventors have realised that a better fluid heater and heater vessel can be produced and have created the claimed solution.

SUMMARY

[0009] According to a first aspect of the present invention, there is provided a burner vessel as claimed in claim **1**. According to another aspect of the invention, there is provided a fluid heater as claimed in claim **21**. Advantageously, a hybrid electric-combustible fuel burner vessel/fluid heater arranged to heat fluid in one or more fluid circuits that can efficiently heat a fluid based on either or both of multiple energy sources is provided. This type of heater is eco-friendly relative to pure gas burning (or other combustible fossil fuel burning) boilers. Fluid heating resource (from the electric source or the combustible fuel source) can be supplied intelligently based on a number of desired supply and demand factors.

[0010] Optional features of the invention are as claimed in the dependent claims—various advantages are thereby provided as discussed in the detailed description. These optional features add efficiency and intelligence to the inventive heater setup. Any of these optional features may be combined with any other of the optional features as will be appreciated by those skilled in this art.

BRIEF DESCRIPTION OF DRAWINGS

[0011] Embodiments will now be described by way of example only with reference to the accompanying drawings, in which:

[0012] FIGS. **1** to **9** are schematic views, some with sections partially cutaway, of a burner vessel of a first embodiment of the invention; FIG. **5** is a cross-section view through the line A-A in FIG. **4**; FIG. **6** is a magnified view of section D in FIG. **5**; FIG. **7** is an exploded view showing components of the vessel of the first embodiment; FIGS. **10** to **12** are schematic views of a burner vessel of a second embodiment of the invention; FIG. **11** is a cross-section view through the line B-B in FIG. **10**;

[0013] FIG. **12** is a magnified view of section E in FIG. **11**;

[0014] FIGS. **13** to **15** are schematic views of a burner vessel of a third embodiment of the invention; FIG. **14** is a cross-section view through the line C-C in FIG. **13**; FIG. **15** is a magnified view of section F in FIG. **14**;

[0015] FIG. **16** is an exploded view showing components of a burner vessel of a fourth embodiment of the invention;

[0016] FIG. **17** is a schematic view, with a section partially cutaway, of the burner vessel of FIG. **16**;

[0017] FIGS. **18** to **20** are magnified versions of FIGS. **6**, **12** and **15** respectively;

[0018] FIG. **21** is a closeup view of part of a cross-section view through the burner vessel of FIG. **16**;

[0019] FIG. **22** is a closeup view of part of a cross-section view through a burner vessel according to a fifth embodiment of the invention;

[0020] FIGS. **24** to **28** are schematic views, some with sections partially cutaway, of a burner vessel of a sixth embodiment of the invention; FIG. **27** is a magnified view of section A in FIG. **28**; FIG. **24** is a closeup view of FIG. **27**;

[0021] FIGS. **23**, **29** and **20** are schematic views of a heating element or parts thereof that forms part of the vessel of FIGS. **24** to **28**;

[0022] FIGS. **32** to **34** are schematic views, some with sections partially cutaway, of a burner vessel of a seventh embodiment of the invention; FIG. **32** is a closeup view of part of a cross-section view through the burner vessel of FIGS. **33** and **34**;

[0023] FIG. **31** is a schematic view of a heating element that forms part of the vessel of FIGS. **32** to **34**;

[0024] FIGS. **36** to **38** are schematic views, some with sections partially cutaway, of a burner vessel of an eighth embodiment of the invention; FIG. **36** is a closeup view of part of a cross-section view through the burner vessel of FIGS. **37** and **38**;

[0025] FIG. **35** is a schematic view of a heating element that forms part of the vessel of FIGS. **36** to **38**;

[0026] FIGS. **39** to **42** are schematic views, some with sections partially cutaway or components removed, of a burner vessel of a ninth embodiment of the invention; FIG. **39** is a cross-section view through the burner vessel;

[0027] FIG. **43** shows a schematic view of a fluid heater according to another aspect of the invention including the burner vessel of FIGS. **1** to **9**;

[0028] FIGS. **44** to **49** show schematic views, some with sections partially cutaway or components removed, of a burner vessel of a further embodiment of the invention; FIG. **47** is a cross-section view through the line A-A in FIG. **46**; FIG. **48** is a magnified view of section A**1** in FIG. **47**; FIG. **49** is a close-up view of FIG. **48**;

[0029] FIGS. **49** to **53** are close-up cross-sectional views (equivalent to FIG. **49**) of other embodiments of the invention;

[0030] FIG. **54** is a schematic view, with sections partially cutaway or components removed, of another embodiment of the invention; and

[0031] FIG. **55** is a schematic view, with sections partially cutaway or components removed, of another embodiment of the invention.

[0032] For clarity, some components may be omitted in some of the drawings for ease of viewing other components or features.

DESCRIPTION OF EMBODIMENTS

[0033] The exemplary embodiments described in the detailed description and claims are not meant to be limiting. Other embodiments may be used, and other changes may be made, without departing from the scope of the invention. Various embodiments are described. The specific embodiments are not intended as an exhaustive description or as a limitation to the broader discussed and claimed aspects. Features described in conjunction with a particular embodiment are not necessarily limited to that embodiment and can be incorporated into any other embodiment(s). Protection afforded by any applicable doctrine of equivalents is retained to its fullest extent.

[0034] Terms such as up, down, top, bottom, left, right, inner, outer, vertical, upstanding etc. have been used to describe the invention simply and clearly. These terms are not to be interpreted in a manner that would be limiting. The person skilled in the art will envisage other suitable embodiments within the scope of the invention.

[0035] Referring to FIG. **1**, there is shown an inventive burner vessel **100**, according to a first embodiment of the invention, that is part of a fluid heater used to heat water for use in a standard fluid circuit, such as a radiator heating water circuit. Various aspects of the burner vessel and fluid heater will be described in detail with reference to non-limiting examples. Other details will be apparent to the skilled person. In particular, known boilers have burner vessels that are arranged to burn fuel and efficiently transfer heat (via a heat exchanger) to a fluid, such as water-aspects (including undescribed aspects) of known burner vessels and fluid heater systems can be incorporated and used with this invention by a person of ordinary skill in this field.

[0036] Generally, the fluid heater may be a tank-type boiler (known also as a system boiler), or a combi boiler, or any other known boiler type, or a furnace heater, such as a furnace air heater. The skilled person will be able to adapt the described embodiments to boiler types other than those described. As is known, these boiler types can be used to supply heating water (e.g. to a radiator circuit) or potable water (e.g. to a circuit of taps) or both. In other examples, instead of heating radiator water, there may be another type of heating fluid flowing through the heating system, e.g. another liquid, another gas (e.g. air) or oil or any combination thereof.

[0037] Such fluid circuits are well known in the field. The, any or each fluid circuit may be a substantially sealed fluid circuit in use and optionally may be pressurised. In a potable water circuit, pressure from the mains or gravity fed source drives water such that when a faucet/tap is opened, water flows out of tap in normal use. Typically, a radiator circuit is substantially sealed in normal use. Bleed points or pressure release points may be provided at convenient locations to allow inspection or pressure release or fluid release for maintenance and repair. It is known to use expansion tanks or expansion vessels (which are small tanks used to protect closed (not open to atmospheric pressure) fluid heating systems and domestic hot water systems from excessive pressure). Typically, expansion tanks are partially filled with air, whose compressibility dampens shock caused by water hammer and absorbs excess water pressure caused by thermal expansion. In an air heater, the fluid circuit usually comprises at least one vent through which heated air exits to the space to be heated. In such circuits, the air within the circuit is not sealed from the environment—it is typically at atmospheric or ambient pressure. In some such systems, air is drawn into the furnace during normal operation, heated and then blown around the heated network.

[0038] In this example (see FIGS. **1** to **9** and **18**), the burner vessel **100** is part of a water heater that is a system boiler. The burner vessel **100** comprises a vessel housing **102** to house its components. A feature of this burner vessel **100** is that it is compact and able to fit in a small space. In many examples, this invention includes features that make the burner vessel **100** compact to allow the burner vessel to fit within the same housing or space footprint as a typical known burner vessel, even though the inventive burner vessel comprises new components (as will be described in more detail below).

[0039] The burner vessel **100** is arranged to heat water in a first circuit, wherein the first circuit is a heating water circuit. The heating water circuit comprises multiple components, including standard domestic radiators (not shown) in addition to the burner vessel **100**. Water is used as the heating fluid within the first circuit in this example; other known heating fluids can be used in other examples.

[0040] The burner vessel **100** comprises a hybrid electric-combustible fuel vessel, i.e. as well as providing heating using a traditional combustion technique, the vessel also provides heating via an electric source. Within the same sealed, boiler vessel chamber are provided multiple heating mechanisms. One is an electric heating mechanism; the other is a gas burner mechanism in this example. The gas burner mechanism is substantially of a known type. Other examples may use other fuels—e.g., suitable combustible fuel may be a combustible fluid such as natural gas, hydrogen gas, or propane gas or methane gas, or ethane gas, or butane gas, or a suitable combustible oil or a combustible solid or mulch, such as woodchip or wood pellet, or any combination thereof. In this way, some of the heating power

is provided by the electric component and some of it is provided by more traditional burnt fuel.

[0041] The electric heating mechanism can be in any suitable form. In this example, it is in the form of electric heating elements powered by a DC power supply, which is sufficiently large to provide power to the electrical heating element sufficient to provide all or most of the required heated fluid/water (in other examples, it may not be so large). This can help to add redundancy within the system, or can be used to operate efficiently in an environment where one or other power source is scarce.

[0042] Relatively cold water from the first circuit enters the burner vessel **100** via a cold water input pipe **104**, is heated and then relatively hot water exits the burner vessel **100** to the first circuit via a hot water output pipe **106**. A first water duct **105** extends between the cold water input pipe **104** and the hot water output pipe **106**. The burner vessel **100** is a closed, sealed vessel and has a combustion zone **112** therein, in which fuel is burnt to supply heat to water flowing in the first water duct **105**. The housing also contains a burnt fuel heat exchanger **120** arranged to assist with transferring heat from fuel being burnt in the combustion zone to the water in the water circuit.

[0043] Within its housing **102**, the vessel **100** contains a combustible fuel burner **110** of a known type. The vessel **100** further comprises a fuel inlet pipe **108** in communication with the fuel burner **110** and arranged to convey an air-fuel mixture safely and efficiently to the burner in a known manner. The vessel **100** also comprises a flue **114** arranged to convey waste combustion gas away from the combustion zone and the vessel. In this example, the vessel **100** comprises a base frame **116**, with which the flue and hot water output pipe **106** are integrally formed.

[0044] In this example, the burner **110** comprises a perforated burner bar **1101** with jet holes that allow for even burning around the combustion zone. A sealing ring **1102** is arranged to seal the bottom of the burner bar **1101** to minimise uncontrolled fuel burning, e.g. by preventing hot air and uncombusted gas leakage from the combustion assembly other than through the flue. A pair of igniters **1103** is configured to ignite the air-fuel mixture on demand. The igniters **1103** are arranged to protrude from an upper end of the housing in use, for convenient access. In some examples, multiple burners may be provided.

[0045] The burner **110** is arranged to provide efficient heating in the combustion zone and to thereby transfer heat via the burnt fuel heat exchanger **120** to the fluid in the first water duct **105**. The burnt fuel heat exchanger increases efficiency of heat transfer from the burning fuel in a known manner. In particular, in this example, the heat exchanger is arranged to focus heat from the burning gas (or other fuel in other examples) on the fluid duct.

[0046] In other embodiments, instead of a water duct, a different fluid duct may be provided—e.g., in some embodiments, the fluid being heated may not be a liquid, e.g., it may be air in an air heating furnace and a typical air heater duct is provided; in other examples, the water may be potable water for use in a potable water circuit; in other examples, the fluid may be oil in an oil heater circuit.

[0047] In this example (see FIG. **7**), the burnt fuel heat exchanger comprises a generally cylindrical metal cast heat exchanger body **121** of a known type. The heat exchanger body substantially surrounds the combustion zone to efficiently capture heat therefrom. The cylindrical wall of the heat exchanger body is about 6 mm thick in this example. In other similar examples, dependent on materials used for construction, it may be about 3 mm to about 15 mm thick. The upper limit is chosen to avoid thermal mass issues and potentially also casting issues; although it is possible to construct a heat exchanger beyond these limits, it may not be ideal. In this example, the heat exchanger body is about the same thickness as the duct, i.e., the thickness of the wall of the heat exchanger body is about the same as the depth of the duct-different configurations will be apparent to the skilled reader; in general, efficient heat transfer at speed from the body to the fluid in the duct is provided. The base frame **116** is configured to seat the cylindrical heat exchanger body such that exhaust gases from within the body exit through the flue **114** and heated water from the first water duct **105** exits through the hot water outlet pipe **106**. In this example (see FIG. **7**), the housing comprises a multi-layer cover **130**, arranged to substantially surround the burnt fuel heat exchanger. The multi-layer cover comprises a heat insulant layer **131** (made of a suitable material, such as ceramic wool or brick)) sandwiched between an inner skin layer **132** and an outer skin layer **133**. The multi-layer cover is generally cylindrical to efficiently cover the generally cylindrical burnt fuel heat exchanger body **121**. In another example, the housing comprises a single layer cover including a combined skin and insulating layer.

[0048] As seen in FIG. **7**, components of the vessel are designed for easy assembly by placing (by sliding in this example) them in a desired order over one another around the heat exchanger body **121**.

[0049] In this example, the first water duct **105** comprises a channel **1050** defined between an outside wall of the heat exchanger body **121** and an inner surface of the inner skin layer **132**. The inner skin layer **132** has a section of the cold water input pipe **104** formed therewith and arranged to feed relatively cold water to the first water duct **105**.

[0050] In other examples, other configurations for the duct and the cold water feed are described below and yet further examples will be apparent to a person skilled in this field. For example, in some other embodiments, the duct may comprise a sealed pipe arranged to pass through a space or channel between a wall of the heat exchanger and the cover; or a channel defined entirely within the heat exchanger, such as within the body of the heat exchanger; or a sealed pipe arranged to pass through a space or channel entirely within the heat exchanger; or a sealed pipe passing through the housing, optionally through the combustion zone, and optionally spaced from the heat exchanger.

[0051] In this example, the outer wall of the heat exchanger body **121** comprises a continuous open, C-shaped recess in its outer surface, and the channel **1050** is defined between the surface of the recess and the cover (see FIGS. **3**, **6**, **8** and **9**). The channel extends in a spiral configuration around the outer wall of the heat exchanger from the first cold fluid inlet to the first hot fluid outlet, downwardly in an in-use configuration. The flow of water through the channel may be facilitated by a pump (not shown), or an otherwise pressurized fluid supply (e.g. mains water) or a gravity fed supply. Water flows from top to bottom and heats up as it flows along the spiral, in use.

[0052] The surface of the inner skin abuts and seals the open part of the channel (see FIGS. **6**, **8** and **9**) such that water flows only along a desired circuitous path—this

encourages efficient heat transfer as the time and distance for the flowing water to absorb heat is increased/maximised.

[0053] In this example, the heat exchanger further comprises multiple heat exchanger protuberances, in the form of heat exchanger fins **122**, arranged to efficiently transfer heat from the burning fuel by increasing the area and time available for interaction between the burning fuel and the heat exchanger material. The fins **122** extend from the heat exchanger body towards the combustion zone and are in thermal communication with the heat exchanger body **121**—the fins may be formed integrally or separately from the body **121**. In this example, vertical fins **1221** are arranged concentrically at regular intervals around the combustion zone (extending from the heat exchanger body **121** near the perimeter of the housing **102**), and lateral fins **1222** are arranged at the base of the combustion zone (towards the bottom of the heat exchanger body **121**). In this example, the fins are about 16 mm deep (i.e. from tip to base). In other examples, the fins may be any suitable depth, e.g. 1 cm to 4 cm. in other examples, the fin depth may be different depending on factors such as vessel size, materials, power etc. In combination with the wall of the heat exchanger body, efficient heat transfer to a fluid in the duct is thereby provided.

[0054] A compact, efficient burner assembly for transferring heat from burnt fuel to the fluid (in this case, heating water) is thereby provided. The skilled reader will understand that other burner assemblies may be configured differently and that the invention can be adapted to work with such other assemblies.

[0055] This invention further provides one or more electric heating elements **140** arranged to heat water in the first water duct **105**. In this example, the one or more electric heating elements **140** are contained in the housing **102**.

[0056] In this example, the electric heating element **140** comprises a continuous spiral shaped element **1401** configured to fit in the spiral water channel **1050**. The electric heating element **1401** is located in the channel **1050**, near a base of its open recess, and is also (in this example) spaced from the heat exchanger body **121** such that it does not touch the walls of the heat exchanger-advantages include: all of the heat passes directly to the fluid to be heated without passing via the heat exchanger; ease of assembly/repair/servicing etc.; allows space for movement in case of expansion/contraction caused by heating. In this example, the heating element **140** is a metal sheathed, ceramic powder insulated cable with a high-power nichrome element. In other examples, ceramic preform beads may be used instead of powder. Such preform beads are often ground into powder during rolling/die-drawing operations on the cable. Electrical connectors **1402** extend from the element **1401** and protrude from an upper end of the housing in use, for convenient access. The electrical connectors **1402** are suitable for connecting the element **1401** to a suitable power source.

[0057] In this example, the power source is a DC power supply, in this example a DC power supply in the form of a battery pack (not shown), which is located outside the burner vessel **100**.

[0058] In this example, the DC power supply has a capacity of 0.5 kWh. In another example, for a small gas-electric hybrid boiler system setup, the battery capacity may be about 1 kWh—this might be useful in a small dwelling, such as a small apartment or it may be useful in a larger dwelling as a boost to the usual hot water supply. In another example, for a larger gas-electric hybrid boiler system setup, the battery capacity may be about 3 to 5 kWh—this might be useful in a larger dwelling. In another example, for a large or industrial hybrid system setup, the battery capacity may be about 5 kWh or above. In some examples, the battery capacity may be about 90 kWh, e.g. to supply heating fluid and heated potable water to larger buildings. The skilled person will understand that different battery capacities may be appropriate for different uses—there is no upper limit to the battery capacity that may be required/useful.

[0059] In this example, the peak power output of the DC power supply is between 10 kW and 20 kW in some examples, and up to 200 kW in some examples. In low peak demand circuits, the peak power output may be 1 kW or 2 kW. Suitable peak power output provisions can be made according to specific circuit requirements and will be apparent to the skilled person. E.g. in one example scenario, a 90 kWh battery might provide 350 kW for 10 minutes.

[0060] In other examples, the power source is an AC power supply (e.g. mains AC). In yet further examples, the power source may be a combination of an AC and a DC power supply.

[0061] A computer implemented controller (not shown) is arranged to control the amount of heating supplied to the fluid by the combustible fuel burner and by the first heating element. The control may be based on one or more control factors, the control factors comprising: amount of heating required; fluid input temperature at an input point in the one or more fluid circuits; fluid output temperature at an output point in the one or more fluid circuits; fluid temperature at any predetermined point in the one or more fluid circuits; amount of heating capacity available from the first heating element; amount of heating capacity available from the combustible fuel burner; instantaneous demand for heating fluid or potable water; forecasted demand for heating fluid or potable water; and flow rate of fluid to be heated.

[0062] One or more sensors (not shown) may be provided to sense information relating to the one or more control factors and to provide said control factor information to the controller. In one example, for efficiency, the controller may be configured to heat fluid primarily using the electric heating element(s), such as primarily via the DC power supply, when a demand for hot fluid is first detected.

[0063] In general, the electric heating element of this invention can be wrapped around pipes or components of the first fluid circuit within the vessel-benefits include ease of manufacture, ease of reconfiguration/replacement/upgrade/repair, if needed (because the heating element is located externally of the pipe/component (and the wet side need not be touched). The heating element is easily visibly and so it is convenient to inspect (e.g. during regular servicing) whether it is degraded. Such heating elements are also easier to clean. Such heating elements are not affected by sludge and/or calcification within the water circuit (this problem is common in radiator water circuits). In air furnace circuits, similar problems arise from build up of dirt, dust, other detritus.

[0064] In other embodiments, the electric heating element can be placed inside a first circuit conduit/pipe-benefits include compactness, less heat loss to the environment (heat is retained almost entirely in the desired water circuit during normal heating operation).

[0065] In other embodiments, the electric heating element can be built into the walls of water circuit conduits of the first circuit-benefits are that these elements are robust, less susceptible to damage by dirty water, suffer less heat loss (than equivalent wrapped heating elements).

[0066] In other embodiments, the heating may occur in a chamber (rather than in a pipe or channel). In such embodiments, pipes of the first circuit may lead to and from the chamber and one or more electric heating elements may be provided within the chamber at any location or embedded within walls of the chamber or wound around the chamber walls or any combination thereof. An advantage of using such a chamber rather than just heating the water/heating fluid as it passes through a fluid pipe of the circuit is that a longer or more circuitous path may be provided and may allow the heating fluid to remain in proximity to the heating element(s) for a longer time during which more heat can be transferred (relative to a direct path through a straight pipe section).

[0067] In yet further examples, dependent upon the specific application, there may be a combination of types and arrangements of electric heating elements used.

[0068] The, any or each electrical heating element can be located anywhere in or around the burner vessel such that water can be heated by either or both of the gas and the electric heating mechanisms.

[0069] The heating elements can be electrical wires that can be heated by passing electric current therethrough and arranged suitably to deliver heat where needed. (E.g. wrapped around a water pipe, or a baffle (or any other component within the burner vessel).

[0070] In this specific example (see FIGS. **6** and **18**), the continuous spiral shaped element **1401** is configured to fit in the spiral water channel **1050** without touching the wall of the heat exchanger. The element **1401** is formed continuously as a double spiral profile which doubles back on itself from top to bottom, in use corresponding to the profile of the spiral water channel **1050** such that each pocket of the channel **1050** contains two strands of the element, in use, when the element is placed in the channel. As can be seen from the figures, the element is located near an inner side of the channel **1050** in this example. Not touching the wall of the heat exchanger results in an easy-to-assemble arrangement and ensures that the cable element **1401** can easily transfer heat to the water on all its surfaces. In other examples, the cable element may be located elsewhere in, e.g. in the middle of, the channel. The cable element may be configured with a spacer (such as a metallic spacer) to keep it in a desired position. In the present example, rigidity of the element **1401** maintains its desired position. Furthermore, in some examples, there may be a mechanism to increase surface area for heat transfer. For example, the heating element may have a non-circular cross-section, e.g. may be a fin cross-section.

[0071] In this example (and in many other described examples), the electric and combustible fuel heat sources are arranged to heat the fluid in the duct at the same location (or overlapping locations in some examples) in the fluid duct. In other words, fluid at a single location can be heated by either the electric heating element or the combustible fuel heat source or both simultaneously. In this example, the electric heating element and the gas burner are arranged to heat along substantially all/most of the length of the fluid duct that passes through the vessel. An effect of this feature is to allow (in some examples) the entire heating demand of a typical domestic water heater to be supplied by an electric source if needed (and to still have the option to use a gas source to heat the same fluid in the same location too). Another effect is to efficiently provide a more powerful instant response (e.g., when potable water is first requested from cold, and a quick/instant response is desirable). Furthermore, as a result of being configured to heat fluid at the same location via combustible fuel or electric or both simultaneously, another effect of some embodiments is that the electric heating elements can be used on their own initially, without any water flow, to pre-heat water in the duct. Then, heating via combustible fuel can be activated in the usual way along with fluid flow. As a result, an initial period of cold water when first turning on a tap can be reduced/avoided altogether (in an efficient way that avoids wasting water and/or burnt fuel). As previously described, in this example, combustible fuel heating occurs via the heat exchanger, and electric elements heat water directly in the duct. In other similar embodiments, the electric element may instead/additionally provide heating via the duct walls (e.g. if the elements are not completely located within the fluid (e.g. if they are located outside the duct nearby, e.g., on its surface)) or via the heat exchanger (e.g. if the elements are arranged to heat the heat exchanger).

[0072] A burner vessel **200** according to another embodiment (see FIGS. **10** to **12** and **19**) of the invention contains elements similar to those of the first described embodiment. For conciseness, elements that are identical/similar to their counterparts in the first embodiment will not be described again in detail, and are labelled with reference numerals in the format "2xx"/"2xxx" instead of "1xx"/"1 xxx".

[0073] The burner vessel **200** includes a cold water input **204**, a hot water output **206**, and a first water duct **205** therebetween. The vessel has a housing **202** containing a fuel burner **210**, a burnt fuel heat exchanger **220** and a multi-layer cover **230**.

[0074] The body **221** of the heat exchanger differs from the body **121** of the first embodiment in that the outer wall of the heat exchanger body **221** comprises a continuous open, C-shaped recess in its outer surface, and the channel **2050** is defined between the surface of the recess and the cover, but the channel **2050** does not have a smooth base. Instead (see FIGS. **11**, **12** and **19**), the base of the channel **2050** has a pair of grooves **2051** formed therein. The pair of grooves is formed in a spiral configuration corresponding to the shape and direction of the channel. The pair of grooves is configured to receive and retain the two strands of the heating element **2401**. The grooves are sized and shaped to receive the heating element cable **2401** as a tight fit such that the element will not be dislodged by flowing fluid during normal use. However, in this example, the element can be forcefully removed for servicing, repair or replacement.

[0075] In this example, the element is supported in the heat exchanger body **221** at the base of the channel. In other examples, the grooves may be formed elsewhere, e.g. at the sides of the channel.

[0076] As a result of the heating element being partially embedded in the heat exchanger, compared to the first embodiment, better heat transfer to the heat exchanger body from the electric heating element is provided-more gradual heat transfer to the fluid can be provided. The heating element is still partially exposed directly to the fluid.

[0077] A burner vessel **300** according to another embodiment (see FIGS. **13** to **15** and **20**) of the invention contains elements similar to those of the first described embodiment. For conciseness, elements that are identical/similar to their counterparts in the first embodiment will not be described again in detail, and are labelled with reference numerals in the format "3xx"/"3xxx" instead of "1xx"/"1 xxx". The burner vessel **300** includes a cold water input **304**, a hot water output **306**, and a first water duct **305** therebetween. The vessel has a housing **302** containing a fuel burner **310**, a burnt fuel heat exchanger **320** and a multi-layer cover **330**.

[0078] In this embodiment, the positioning of the spiral cable element **3401** in the channel **3050** is different to the positioning of the spiral cable element **1401** in the channel **1050** of the first embodiment. The cable element **3401** is wound to fit against the insulated cover **330** (see FIGS. **15** and **20**). As a result, the heating effect is spread across the breadth of the channel, more so than in the first embodiment.

[0079] In this example, since the cover **330** is a multi-layer cover, the element abuts against the inner skin layer **333**. The cable element **3401** is located completely in the fluid channel, i.e. not at all embedded in the heat exchanger or cover in this example. In other examples, the cable element may be partially or fully embedded in the cover.

[0080] A burner vessel **400** according to another embodiment (see FIGS. **16**, **17** and **21**) of the invention contains elements similar to those of the first described embodiment. For conciseness, elements that are identical/similar to their counterparts in the first embodiment will not be described again in detail, and are labelled with reference numerals in the format "4xx"/"4xxx" instead of "1xx"/"1 xxx". The burner vessel **400** includes a cold water input **404**, a hot water output **406**, and a first water duct **405** therebetween. The vessel has a housing **402** containing a fuel burner **410**, a burnt fuel heat exchanger **420** and a multi-layer cover **430**.

[0081] In this embodiment, the electric heating element **440** is of a different form to the electric heating element **140**. Instead of a cable heating element **1401**, the electric heating element **440** comprises a spiraled wire element **4401** (as seen clearly in see FIGS. **16**, **17** and **21**). The spiraled element **4401** has an enamel coating for electrical insulation. The spiraled element **4401** fits loosely in the channel **4050**. As a result, this arrangement is easy to assemble, repair and replace. In some examples, one or more spacers may be provided to locate the element **4401** in a desired position in the channel.

[0082] A burner vessel **500** according to another embodiment (see FIG. **22**) of the invention contains elements similar to those of the previously described embodiment. For conciseness, elements that are identical/similar to their counterparts in the first embodiment will not be described again in detail, and are labelled with reference numerals in the format "5xx"/"5xxx" instead of "4xx"/"4xxx".

[0083] The burner vessel **500** includes a cold water input **504**, a hot water output **506**, and a first water duct **505** therebetween. The vessel has a housing **502** containing a fuel burner **510**, a burnt fuel heat exchanger **520** and a multi-layer cover **530**.

[0084] In this embodiment, the electric heating element **540** comprises a spiraled wire element **5401** that is partially embedded in a pair of grooves **5051**. The base of the channel **5050** has a pair of grooves **5051** formed therein. The pair of grooves is formed in a spiral configuration corresponding to the shape and direction of the channel. The pair of grooves is configured to receive and retain the two strands of the spiraled wire heating element **5401**. The grooves are sized and shaped to retain the heating element cable **5401** such that the element will not be dislodged by flowing fluid during normal use. However, in this example, the element can be forcefully removed for servicing, repair or replacement.

[0085] In this example, the element is supported in the heat exchanger body **521** at the base of the channel. In other examples, the grooves may be formed elsewhere, e.g. at the sides of the channel.

[0086] As a result of the heating element being partially embedded in the heat exchanger, compared to the first embodiment, better heat transfer to the heat exchanger body from the electric heating element is provided-more gradual heat transfer to the fluid can be provided. The heating element is still partially exposed directly to the fluid.

[0087] A burner vessel **600** according to another embodiment (see FIGS. **23** to **30**) of the invention contains elements similar to those of the first described embodiment. For conciseness, elements that are identical/similar to their counterparts in the first embodiment will not be described again in detail, and are labelled with reference numerals in the format "6xx"/"6xxx" instead of "1xx"/"1 xxx".

[0088] The burner vessel **600** includes a cold water input **604**, a hot water output **606**, and a first water duct **605** therebetween. The vessel has a housing **602** containing a fuel burner **610**, a burnt fuel heat exchanger **620** and a multi-layer cover **630**. The burnt fuel heat exchanger **620** has vertical fins **6221**.

[0089] In this embodiment, the electric heating element **640** is preformed and configured to wrap around the heat exchanger fins **6221** (as seen clearly in see FIGS. **24** to **26**). The preformed element **6401** has an enamel coating for electrical insulation. The preformed element **6401** comprises a continuous thin wire element that is arranged in a preconfigured flat pattern (pre-wound/formed into flat or pyramidal spirals) and is configured to be easily pushed (telescopically) into place on a fin during assembly and fixed in position, to achieve the desired coverage of the fin by the heating element.

[0090] In other examples, different types of heating element may be wrapped around or partially or completely embedded in the heat exchanger fins **6221**. Similar heating element arrangements may be provided for lateral fins **6222** (not shown).

[0091] A burner vessel **700** according to another embodiment (see FIGS. **31** to **34**) of the invention contains elements similar to those of the first described embodiment. For conciseness, elements that are identical/similar to their counterparts in the first embodiment will not be described again in detail, and are labelled with reference numerals in the format "7xx"/"7xxx" instead of "1xx"/"1xxx".

[0092] The burner vessel **700** includes a cold water input **704**, a hot water output **706**, and a first water duct **705** therebetween. The vessel has a housing **702** containing a fuel burner **710**, a burnt fuel heat exchanger **720** and a multi-layer cover **730**.

[0093] In this embodiment, the electric heating element **740** comprises a thick film heating element **7401**. As seen in FIG. **32**, the heating element **7401** comprises a flat conductor **7403** encapsulated by an encapsulating film **7404**. The encapsulating film **7404** is a high temperature film (i.e. arranged to withstand high temperatures). The thick film

heating element **7401** is not at all embedded in the heat exchanger or the cover in this example (but might be in other examples). Reduced direct contact with the fluid to be heated and with the heat exchanger leads to a higher life expectancy for the heating element. Furthermore, heat provided by heating the conductor **7403** is efficiently and consistently dispersed across a relatively large area (the surface area of the encapsulating film **7404**).

[0094] A burner vessel **800** according to another embodiment (see FIGS. **35** to **38**) of the invention contains elements similar to those of the first described embodiment. For conciseness, elements that are identical/similar to their counterparts in the first embodiment will not be described again in detail, and are labelled with reference numerals in the format "8xx"/"8xxx" instead of "1xx"/"1 xxx".

[0095] The burner vessel **800** includes a cold water input **804**, a hot water output **806**, and a first water duct **805** therebetween. The vessel has a housing **802** containing a fuel burner **810**, a burnt fuel heat exchanger **820** and a multi-layer cover **830**.

[0096] In this embodiment, the electric heating element **840** comprises a cylindrical sleeve thick film heating element **8401**. The sleeve heating element **8401** can be made by spiralling (e.g. like a cardboard tube) or rolling and joining together a flat sheet. The heating element **8401** comprises a flat conductor **8403** encapsulated by an encapsulating film **8404** in the form of a sleeve. The encapsulating film **7404** is a high temperature film (i.e. arranged to withstand high temperatures). The cylindrical sleeve thick film heating element **8401** is placed around the generally cylindrical heat exchanger body **821**. In this example, the sleeve element **8401** is sandwiched between the cover **830** and the heat exchanger body **821**.

[0097] A burner vessel **900** according to another embodiment (see FIGS. **39** to **42**) of the invention contains elements similar to those of the first described embodiment. For conciseness, elements that are identical/similar to their counterparts in the first embodiment will not be described again in detail, and are labelled with reference numerals in the format "9xx"/"9xxx" instead of "1xx"/"1 xxx".

[0098] The burner vessel **900** includes a cold water input **904**, a hot water output **906**, and a first water duct **905** therebetween. The vessel has a housing **902** containing a fuel burner **910**, a burnt fuel heat exchanger **920** and a multi-layer cover **930**.

[0099] In this embodiment, the heat exchanger body **921** and the heating element **940** are formed together as a single inseparable unit. The heating element **940** comprises a metal-sheathed, ceramic powder insulated cable with a high power nichrome element (e.g. Kanthal (RTM)). The cable is cast into the metal of the heat exchanger during manufacture. The material of the sheath is able to withstand the molten metal of the casting during manufacture. The cable is immune to calcification since it is remote from the fluid being heated. In another similar example, the electric heating assembly can be overmoulded, e.g., with die cast aluminium. In this example, the cylindrical wall of the heat exchanger body is thicker than in similar examples without a heating element cast therein (perhaps about 140% to 200% thicker in some cases); in this example, the cylindrical wall of the heat exchanger body is about 10 mm thick.

[0100] The features of any of the described embodiments can be used with the features of any other of the described embodiments-disclosure is made of any such combinations and protection is sought for any such combinations. In particular, different types of element (e.g. cable or spiraled wire or flat encapsulated or sleeved) may be used together. In particular, electric heating elements can be embedded in the heat exchanger or cover or both, whether partially, completely or not at all or in any combination within the same embodiment. In particular, heating element(s) can interact as previously described in any combination with the heat exchanger fin(s) or the heat exchanger body or within the fluid channel or any combination thereof.

[0101] According to another embodiment of the invention, referring to FIG. **43**, there is shown a fluid heater **4300** arranged to heat fluid in a fluid circuit. The fluid circuit comprises a radiator circuit comprising at least one radiator **4310**. In this example, the fluid heater comprises a system boiler **4300** having a boiler housing **4301**. Within the boiler housing **4301**, the boiler comprises the burner vessel **100** of the first embodiment and a controller **4302** in communication with the vessel **100** and arranged to control the amount of heating supplied to the water in the fluid circuit of by the combustible fuel burner **110** and by the heating element **140**. The controller controls operation of the burner via suitable control circuitry in a known manner, and operation of the heating element **140** by controlling the current flowing therethrough with suitable control circuitry.

[0102] The fluid heater comprises a DC power supply (of the type previously described) in the form of a battery pack **4303** arranged to power the heating element **140**.

[0103] The fluid heater also has an AC connection (not shown) in order to power small electronic components (these have a relatively low power demand compared to the power required to heat water during normal boiler operation) such as switching circuitry, boiler display screen, boiler user interface, sensors, Wi-Fi, Bluetooth, sub 1 GHz comes etc, led lighting and other standard boiler components. Other such components include: igniter or spark generator; ignition electrode/ionisation electrode; pressure sensor/transmitter (water), also water pressure switch, flow sensor/switch (makes sure that the gas/air mix is flowing correctly before allowing ignition); combustion sensor (thermal switch-sometimes stated separately to temperature sensors by manufacturers); thermostat; thermocouple/PRT; control PCB; multi-media interface; power electronics for power-packs; pumps (simple electrical or possibly more complex with drive electronics) for water & gas. In some examples, this power may be provided by renewable heat sources too, such as solar or wind or a heat pump or any other suitable source. In some examples, these small electronic components are powered directly from the DC power supply—there is no AC connection to the boiler in this case.

[0104] In other examples, the fluid heater (and its electric heating element) is arranged to be powered, instead or in addition, by an AC power supply, such as mains AC.

[0105] In this example, the boiler also comprises an electric control unit (not shown) arranged to control any one or more of: heating, battery charging, battery discharging, system requirements, switching of the DC or AC power supply. In this example, the boiler also comprises a thermal beak or heat shield (not shown) located between the DC power supply and the vessel. The thermal break or heat shield may comprise any one or any combination of: an air gap; a gap filled (partly or fully) by a thermal insulation material; a gap filled (partly or fully) by an infrared-

reflective material; a gap filled (partly or fully) by an insulator or low thermal conductivity material.

[0106] In some examples, the heat shield may include an associated heat shield cooling mechanism arranged to transfer heat from the heat shield area towards another area in which it is safer to dissipate heat and comprising any one or more of:

[0107] a fluid material that takes heat away from the area (e.g., from the heat shield area to a dissipation area (i.e. another area in which it is safer to dissipate heat than in the heat shield area));

[0108] an active cooling mechanism, such as a Peltier device (that actively moves heat from one side to the other, e.g. towards another area in which it is safer to dissipate heat than in the heat shield area);

[0109] a chilled cabinet located inside the boiler housing (similar to a typical refrigerator) and arranged to substantially enclose the DC power supply; and

[0110] an air flow mechanism, such as a blower, arranged to draw air in from outside the housing, or from inside the housing, to provide the required cooling effect.

[0111] The boiler of this embodiment also comprises a cooling system (not shown). The electronics can get hotter than on a normal boiler because of the extra switching because of operation of the controller and its related circuitry aimed at using DC-v-AC intelligently.

[0112] In some examples, the heater comprises a high-power switching module arranged to efficiently switch high currents such that power can be varied in the same resistant electric heating element and smoothly change fluid temperatures. This is especially important in the potable water circuit. This features allows pulse width modulation within the control circuitry. The high-power switching module may be arranged to switch 30 amps or more.

[0113] In examples containing a battery charging mechanism, the inventor further found that heat generation within the battery charging system can be a problem-specifically in an AC-DC converter battery charging system, which allows a voltage to charge the DC battery packs/cells. This type of battery charging system does not exist within any boiler systems or boiler housings yet, and generates heat. A further advantage of some examples of the present invention is therefore to use the cooling system (or to provide a further separate cooling system) as a heat sink to cool the battery charging mechanism too. The battery charging mechanism cooling system can be particularly useful since charging can (and should) also occur when the system is not heating a building or providing hot potable water (e.g., in the middle of the night). The present invention's cooling system allows for running the heating system to leach heat away during charging. The controller may be arranged to run fluid through the fluid heater system to cool the battery charging mechanism even when heated fluid is not required, e.g., the controller may act in response to predicting or being informed or sensing that the battery charging system should be cooled (e.g., via feedback from a temperature sensor located near the battery charger or after the battery has been continuously charging for a threshold minimum time period). This battery charging mechanism cooling feature can be implemented with any of the described embodiments containing a battery charger to create a new embodiment of the invention.

[0114] In some examples (e.g., in which flow of the heating fluid/potable water is participating in the cooling), when the heating system is running (e.g., potable water or heated radiator fluid is being demanded), then cooling occurs via flow of the heating fluid/potable water past the controller/battery/battery charger. However, when the heating system is not running, this invention allows for operation of the charger cooling system (whether via flow of the heating fluid/potable water or via its own dedicated coolant within its own dedicated coolant circuit) specifically for the purpose of cooling the battery charger.

[0115] In some examples, the cooling system uses some of the water output from the radiators, which arrives at the cold input pipe (typically at about 35-40 deg C.) for cooling the electronics, which are much hotter (ideally, the intention is to keep the electronic components well below 100 deg C.). In some examples, an element of the cooling system comprises locating the first circuit pipework from the input within the boiler adjacent or near to the components that require cooling. As a result, overall efficiency of the fluid heater is enhanced, and its electronics can be made more compact/simpler due to a reduced need for perfect electronic efficiency with switching power.

[0116] The cooling system of this example also includes a coolant circuit having a closed coolant pipe system (not shown) through which coolant is pumped. The closed coolant pipe system is configured to encourage heat transfer between the coolant and the boiler's cold water input so as to transfer heat away thereto as well as to encourage heat transfer between the coolant and the DC battery cells (if present in any particular embodiment) or other components so as to transfer heat away therefrom. This is achieved by routing the pipe system close to any one or more of the boiler components, battery cells and cold water input at appropriate locations.

[0117] In some such examples, e.g. in examples where an air intake is used to aid the combustion process (e.g. when burning a gas or other combustible fuel), the cooling system can include using the air intake to cool the battery pack and/or electronic components since the air taken in will be relatively cool; at the same time, the air will become heated and will make the combustion process more efficient. This can be achieved by locating the air intake path near to the battery pack or components that need cooling.

[0118] In this example, the boiler **4300** is configured to be compact. The boiler housing **4301** has dimensions 400 cm width by 300 cm depth by 700 cm height and houses the vessel **100** and any required control circuitry. In other embodiments, the housing may have different dimensions, e.g.: W390 mm, D270 mm, H600 mm; or W400 mm, D300 mm, H724 mm; or W400 mm, D310 mm, H724 mm; or W440 mm, D365 mm, H780 mm; or W440 mm, D364 mm, H825 mm; or W440 mm, D365 mm, H780 mm; or any other suitable dimensions that will be apparent to the skilled person.

[0119] Providing further compactness, the DC power supply is located at a front side, in use, of the boiler housing, substantially fills the space between front and back ends of the housing, and also substantially fills the space between left and right sides of the housing. The boiler has walls on its left and right sides that are relatively inaccessible in use. The front side is relatively accessible and is usually used to access internal components when servicing.

[0120] In some examples, the fluid heater housing comprises an access door arranged to allow access to internal components of the heater (such as for servicing or repair) and the DC power supply is arranged within or integrally with the access door. This also adds to the overall compactness and also ensures that the DC battery does not need to be further removed or manipulated to access the internal boiler components (e.g. for repair/servicing).

[0121] One or more electric heating element(s) can be wrapped around pipes or components of the first circuit outside of the vessel **100**, and inside the boiler housing **4301**—benefits include ease of manufacture, ease of reconfiguration/replacement/upgrade/repair, if needed (because the heating element is located externally of the pipe/component (and the wet side need not be touched). The heating element is easily visibly and so it is convenient to inspect (e.g. during regular servicing) whether it is degraded.

[0122] Such heating elements are also easier to clean. Such heating elements are not affected by sludge within the water circuit (this problem is common in radiator water circuits).

[0123] In some examples, the vessel contains at least one baffle arranged to divert air heated by the fuel burner and arranged to increase thermal communication between the heated air and the heat exchanger. The, any or each electric element may be partially or completely embedded within the at least one baffle or wrapped around the at least one baffle.

[0124] In other embodiments, the electric heating element can be placed inside a first circuit conduit/pipe (outside the vessel **100** and inside the boiler housing **4301**)—benefits include compactness, less heat loss to the environment (heat is retained almost entirely in the desired water circuit during normal heating operation).

[0125] In other embodiments, the electric heating element can be built into the walls of water circuit conduits of the first circuit (outside the vessel **100** and inside the boiler housing **4301**)—benefits are that these are robust, less susceptible to damage by dirty water, suffer less heat loss (than equivalent wrapped heating elements).

[0126] The controller **4302** is arranged to control the amount of heating supplied to the fluid based on or in response to any one or more control factors, the control factors comprising: amount of heating required; fluid input temperature at an input point in the one or more fluid circuits; fluid output temperature at an output point in the one or more fluid circuits; fluid temperature at any predetermined point in the one or more fluid circuits; amount of heating capacity available from the first heating element; amount of heating capacity available from the combustible fuel burner; instantaneous demand for heating fluid or potable water; forecasted demand for heating fluid or potable water; and flow rate of fluid to be heated. Furthermore, the fluid heater comprises one or more sensors arranged to sense information relating to the one or more control factors and to provide said control factor information to the controller **4302**. Some of the sensors **4305** are located inside the boiler housing **4301** (e.g. to measure water temperature or flow rates within the boiler). Some of the sensors **4306** are located outside the boiler housing **4301** (e.g. to measure water temperature or flow rates at a desired location in the first circuit outside the boiler, such as in a room of a building). The controller acts in response to information from such sensors to instruct heating of the fluid by the fuel burner and electric heating element.

[0127] The controller may have a memory (not shown) associated therewith (either integrally or separately), the memory being arranged to store information about any one or more aspects of the system, such as historic or sensed information relating to any of the control factors, control factor information, sensed information from any of the sensors, desired output information (e.g. desired room temperature). The controller is able to access information from the memory in a known manner. The controller and memory may be implemented in a standard computerised network and system.

[0128] FIGS. **44** to **49** show a burner vessel **4400** according to another embodiment. In this example, the burner vessel **4400** is part of a water heater that is a combi boiler supplying heated fluid to two fluid circuits, a first circuit containing radiator fluid and a second circuit containing potable water. The burner vessel **4400** comprises a vessel housing **4402** to house its components. A feature of this burner vessel **4400** is that it is compact and able to fit in a small space. In many examples, this invention includes features that make the burner vessel **4400** compact to allow the burner vessel to fit within the same housing or space footprint as a typical known burner vessel, even though the inventive burner vessel comprises new components.

[0129] The first circuit is a heating fluid circuit, and comprises multiple components, including standard domestic radiators (not shown) in addition to the burner vessel **4400**. Water is used as the heating fluid within the first circuit in this example; other known heating fluids can be used in other examples. The second circuit, a potable water circuit, comprises multiple components, including standard hot water taps (not shown) in addition to the burner vessel **4400**.

[0130] The burner vessel comprises a hybrid electric-combustible fuel vessel, i.e. as well as providing heating using a traditional combustion technique, the vessel also provides heating via an electric source. Within the same sealed, boiler vessel chamber are provided multiple heating mechanisms. One is an electric heating mechanism; the other is a gas burner mechanism in this example. The gas burner mechanism is substantially of a known type. Other examples may use other fuels—e.g., as specified earlier in relation to other embodiments. In this way, some of the heating power is provided by the electric component and some of it is provided by more traditional burnt fuel.

[0131] The electric heating mechanism can be in any suitable form. In this example, it is in the form of electric heating elements powered by a DC power supply, which is sufficiently large to provide power to the electrical heating element sufficient to provide all or most of the required heated fluid/water (in other examples, it may not be so large). This can help to add redundancy within the system, or can be used to operate efficiently in an environment where one or other power source (gas/electric) is scarce.

[0132] Relatively cold water from the first circuit enters the burner vessel **4400** via a first cold radiator water input pipe **4404***a*, is heated and then relatively hot water exits the burner vessel **4400***a* to the first circuit via a first hot radiator water output pipe **4406***a*. A first water duct **4405***a* extends between the cold water input pipe **4404***a* and the hot water output pipe **4406***a*.

[0133] Relatively cold water from the second circuit enters the burner vessel via a second cold radiator water input pipe **4404***b* (via a mains water feed in this example), is heated and

then relatively hot water exits the burner vessel **4400** to the second circuit via a second hot potable water output pipe **4406***b*. A second water duct **4405***b* extends between the second cold water input pipe **4404***b* and the second hot water output pipe **4406***b*.

[0134] The burner vessel **4400** is a closed, sealed vessel and has a combustion zone **4412** therein, in which fuel is burnt to supply heat to water flowing in the water ducts **4405***a*, **4405***b*.

[0135] Within its housing **4402**, the vessel **4400** contains a combustible fuel burner of a known type. The vessel further comprises a fuel inlet pipe in communication with the fuel burner and arranged to convey an air-fuel mixture safely and efficiently to the burner in a known manner. The vessel also comprises a flue **4414** arranged to convey waste combustion gas away from the combustion zone and the vessel. In this example, the fuel burner is arranged horizontally in use.

[0136] In this example, the burner comprises a perforated burner bar **4408** (similar to that described in relation to previous examples) with jet holes that allow for even burning around the combustion zone. A sealing ring is arranged to seal the bottom of the burner bar **4408** to minimise uncontrolled fuel burning, e.g. by preventing hot air and uncombusted gas leakage from the combustion assembly other than through the flue. A pair of igniters is configured to ignite the air-fuel mixture on demand.

[0137] The burner is arranged to provide efficient heating in the combustion zone and to thereby transfer heat to the fluid in the first and second water duct **4405***a*, **4405***b*. In this example, heat is transferred from the hot gas in the combustion zone to the fluid in the ducts via the duct walls, which are configured to efficiently transfer heat in a known way.

[0138] In this example, but not in all examples, the vessel housing further contains a baffle **4407** located in the combustion zone and arranged to divert gas heated therein along desired routes to increase thermal communication between the heated air and the duct walls. In particular, the baffle encourages movement of hot gas towards radially outer regions of the generally cylindrical combustion zone, which is where the ducts are located.

[0139] In other embodiments, instead of a water duct, a different fluid duct may be provided—e.g., in some embodiments, the fluid being heated may not be a liquid, e.g., it may be air in an air heating furnace and a typical air heater duct is provided; in other examples, the water may be potable water for use in a potable water circuit; in other examples, the fluid may be oil in an oil heater circuit.

[0140] In this example, the combustion zone, housing and ducts comprise a generally cylindrical configuration of a known type. The ducts **4405***a*, **4405***b* substantially surround the combustion zone in a spiral arrangement to efficiently capture heat therefrom. The duct pipes spiral around near the perimeter of the housing to efficiently capture generated heat. There are gaps between adjacent parts of the duct to allow hot gas to flow therethrough, and thereby to transfer heat to the fluid in the duct and to efficiently travel to the flue thereafter.

[0141] Exhaust gases from within the combustion zone exit through the flue **4414** and heated water from the ducts **4405***a*, **4405***b* exits through the hot water outlet pipes **4406***a*, **4406***b*. The baffle guides hot gas movement along desired paths.

[0142] In this example, the first water duct pipe **4405***a* is spirally arranged near a mouth of the combustion chamber and adjacent to the burner bar. The second water duct pipe **4405***b* is spirally arranged at a distal end the combustion chamber away from the burner bar. Hot air still reaches and effectively flows over and around the second water duct pipe **4405***b* encouraged by the baffle **4407**. Other specific configurations will be apparent to the skilled reader.

[0143] In this example, each duct **4405***a*, **4405***b* has an elongated oval shaped cross profile extending in a direction radially away from the centre of the combustion zone—this can be seen schematically in FIG. **48** and FIGS. **49** to **53**. This feature allows for a longer contact time between the hot gas and the duct.

[0144] The ducts extend in a spiral configuration around the outer wall of the housing from their respective cold fluid inlets to their hot fluid outlets, from right to left, in use, as viewed in FIG. **47**. The flow of water through each duct may be facilitated by a pump (not shown), or an otherwise pressurized fluid supply (e.g. mains water) or a gravity fed supply.

[0145] A compact, efficient burner assembly for transferring heat from burnt fuel to the fluid (in this case, radiator fluid and potable water in different circuits) is thereby provided. The skilled reader will understand that other burner assemblies may be configured differently and that the invention can be adapted to work with such other assemblies. For example, the invention can be easily adapted to work with only a single fluid circuit, e.g. in a system boiler arrangement.

[0146] This invention further provides one or more electric heating elements **4440** arranged to heat water in the first and second ducts **4405***a*, **4405***b*. In this example, the one or more electric heating elements **4440** are contained in the housing **4402**.

[0147] In this example, the electric heating element **4440** comprises a continuous spiral shaped element configured to fit around, and follow closely the spiral path of, the ducts **4405***a*, **4405***b*. The element **4440** is held in place relative to the ducts, by spot welding in this example.

[0148] The electric heating element **4440** is located externally of the ducts and radially spaced further from the centre of the combustion zone than the ducts.

[0149] In this example, the heating element **4440** is a metal sheathed, ceramic powder insulated cable with multiple high power nichrome elements therein (2 elements are shown in the figures; there may be up to 7 elements in the example shown). Electrical connectors **4502** extend from the element and protrude from an upper end of the housing in use, for convenient access. The electrical connectors **4502** are suitable for connecting the element to a suitable power source.

[0150] In this example, the power source is a DC power supply, in this example a DC power supply in the form of a battery pack (not shown), which is located outside the burner vessel.

[0151] In this example, the DC power supply has a capacity of 0.5 kWh. In another examples, capacity may be similar to that previously described for other examples.

[0152] In this example, the peak power output of the DC power supply is between 10 kW. In another examples, peak power output may be similar to that previously described for other examples. E.g. in one example scenario, a 90 kWh battery might provide 350 kW for 10 minutes.

[0153] In other examples, the power source is an AC power supply (e.g. mains AC). In yet further examples, the power source may be a combination of an AC and a DC power supply.

[0154] A computer implemented controller (not shown) is arranged to control the amount of heating supplied to the fluid by the combustible fuel burner and by the first heating element. The control may be based on one or more control factors, the control factors comprising: amount of heating required; fluid input temperature at an input point in the one or more fluid circuits; fluid output temperature at an output point in the one or more fluid circuits; fluid temperature at any predetermined point in the one or more fluid circuits; amount of heating capacity available from the first heating element; amount of heating capacity available from the combustible fuel burner; instantaneous demand for heating fluid or potable water; forecasted demand for heating fluid or potable water; and flow rate of fluid to be heated.

[0155] In some multiple fluid circuit (e.g. combi boiler) examples, the controller is arranged to instruct exclusively using combustible fuel for heating purposes (e.g. heating radiator fluid) and exclusively using electric for heating potable water.

[0156] One or more sensors (not shown) may be provided to sense information relating to the one or more control factors and to provide said control factor information to the controller. In one example, for efficiency, the controller may be configured to heat fluid primarily using the electric heating element(s), such as primarily via the DC power supply, when a demand for hot fluid is first detected.

[0157] In general, the electric heating element of this invention can be wrapped around pipes or components of the first and/or second fluid circuit within the vessel-benefits include ease of manufacture, ease of reconfiguration/replacement/upgrade/repair, if needed (because the heating element is located externally of the pipe/component (and the wet side need not be touched). The heating element is easily visibly and so it is convenient to inspect (e.g. during regular servicing) whether it is degraded. Such heating elements are also easier to clean. Such heating elements are not affected by sludge within the water circuit (this problem is common in radiator water circuits).

[0158] FIGS. **49** to **53** show close-up views of pairs of heating element and duct arrangements from different embodiments. Features of these embodiments are similar to those of the previously described embodiment unless otherwise stated.

[0159] In the example of FIG. **50**, the heating element is in the form of a metal sheathed, ceramic powder insulated cable with multiple high power nichrome elements therein. The cable is welded to the duct in a similar manner to that of the embodiment of FIGS. **44** to **49**, but is radially closer to the centre of the combustion zone than the duct, i.e. it is on an inner side, or flame side, of the duct. In other examples, instead of being welded, the cable may be (vacuum) brazed to the duct.

[0160] In the example of FIG. **51**, the electric heating element is placed inside the duct pipe-benefits include compactness, less heat loss to the environment (heat is retained almost entirely in the desired water circuit during normal heating operation).

[0161] In the example of FIG. **52**, the electric heating element is in the form of a conductive coating **5201** around the outside of each duct. The conductive coating is arranged to heat up when an electric current is passed therethrough, and thereby to efficiently transfer heat to fluid in the duct. The conductive coating can be applied by spraying. Insulating layers are provided inside and outside of the conductive coating—the conductive coating is sandwiched between these insulating layers. The insulating layers are plasma sprayed or applied by dipping, in this example. Other techniques for applying these layers will be apparent to the skilled reader. In some examples in which the heating element is to be provided in distinct zones (not continuously along the entire length of the duct), gaps between the distinct zones can be formed by masking gap sections of the duct (e.g. with a spray mask) during the coating/spraying process.

[0162] In the example of FIG. **53**, the electric heating element is in the form of a conductive coating **5301** on the inside of each duct. The conductive coating is arranged to heat up when an electric current is passed therethrough, and thereby to efficiently transfer heat to fluid in the duct. The conductive coating can be applied by spraying. Insulating layers are provided inside and outside of the conductive coating—the conductive coating is sandwiched between these insulating layers. The insulating layers are plasma sprayed or applied by dipping, in this example. Other techniques for applying these layers will be apparent to the skilled reader.

[0163] In other embodiments, the electric heating element can be built into the walls of ducts of the first and second circuits-benefits are that these elements are robust, less susceptible to damage by dirty water, suffer less heat loss (than equivalent wrapped heating elements).

[0164] In yet further examples, dependent upon the specific application, there may be a combination of types and arrangements of electric heating elements used.

[0165] The, any or each electrical heating element can be located anywhere in or around the burner vessel such that water can be heated by either or both of the gas and the electric heating mechanisms.

[0166] The heating elements can be electrical wires that can be heated by passing electric current therethrough and arranged suitably to deliver heat where needed. (E.g. wrapped around a water pipe, or a baffle (or any other component within the burner vessel).

[0167] In another embodiment (see FIG. **54**), a burner vessel **5400** comprises a generally rectangular box-like housing **5401** and a rectangular block-like heat exchanger **5402** towards an upper end (in use) of the housing. Many features of this example are functionally similar to that of the first-described example, and so will not be described again for conciseness. In this example, a water duct **5403** is completely embedded in the heat exchanger (shown cut away in FIG. **54**). The water duct is fed from a cold inlet **5404** and doubles back on itself twice within the exchanger (to enhance heat transfer). Heated water exits from a hot water outlet (not visible in FIG. **54**, as it is on the other side of the housing). A burner **5405** heats gas in a combustion zone **5406** within the housing to heat the heat exchanger and thereby the embedded duct and fluid conveyed within the duct. A flue **5407** is provided at the top of the housing for exhaust gases.

[0168] In yet another embodiment (see FIG. **55**), a burner vessel **5500** comprises a generally rectangular box-like housing **5501** and a rectangular block-like heat exchanger **5502** towards an upper end (in use) of the housing. Many features of this example are functionally similar to that of the

previously described example, and so will not be described again for conciseness. In this example, a water duct **5503** is completely embedded in the heat exchanger (shown cut away in FIG. **55**). The water duct is fed from a cold inlet (not shown) and doubles back on itself twice within the exchanger (to enhance heat transfer). Heated water exits the vessel housing **5501** from a hot water outlet **5504**. A burner **5505** burns gas in a combustion zone **5506** within the housing to heat the heat exchanger and thereby the embedded duct **5503**, and the fluid conveyed within the duct. A flue **5507** is provided at the top of the housing for exhaust gases.

[0169] The burner vessel housing **5501** is contained within a larger boiler housing (not shown), which houses the vessel **5501** along with other boiler components (such as electrical boiler components, a computer control system comprising switches and valves for controlling operation of gas and electric heating power in a standard manner).

[0170] The outlet **5504** leads to a nearby further duct section **5508**. The further duct section **5508** is located within the boiler housing. Electric heating elements **5410** are arranged to heat fluid conveyed within the further duct section **5508**. In this example, the electric heating elements **5510** are located within the further duct section **5408**. In this example, the further duct section **5508** comprises a duct section that is doubled back on itself twice in order to provide a compact arrangement to enhance efficiency of heat transfer to the fluid in a small space. In this example, heating elements **5510** are located in each of the three branches of the further duct section **5508**—in other examples, heating elements are located only in some branches.

[0171] In the examples of FIGS. **54** and **55**, heat may be supplied to the fluid being conveyed through the burner vessel either by electric heating or by burning gas or both. Hardware or software (or a combination thereof) computer control may be used to intelligently decide when to use either or both fuel sources.

[0172] In yet further examples (not shown), heating elements may be associated both with the duct section in the burner vessel and the further duct section outside the vessel.

[0173] These examples help illustrate that the skilled reader may find multiple example configurations within the scope of this invention.

[0174] Various modifications may be made to this invention without departing from its scope.

[0175] The heat exchanger may be configured to focus heat not only from the burning fuel, but also from the, any or each electric heating element onto the fluid duct containing the fluid to be heated.

[0176] The heat exchanger can be made of any suitable material, e.g. metal or ceramic. In some examples, the heat exchanger may be in the form of one or more plates (e.g. metal plates) arranged partially or completely around the water pipe. Electric heating elements can be arranged between the plates. In another example, the heat exchanger may comprise a block of suitable material (e.g. a ceramic block) arranged around the water pipe.

[0177] For example, although examples of the invention have been described in relation to water boilers, the same inventive concepts can be applied to other (partially or wholly) electric fluid heaters, for example, air heaters (also known as furnaces) are common in North America. Such systems usually include a fan to blow the heated air—this is not shown in any drawings for clarity. Systems that heat other fluids will be apparent to those skilled in this field.

[0178] In some embodiments, a or the heating element can be powered by both the DC power supply and an AC power supply. In such embodiments, the DC power supply is arranged to at least partially power the heating element. In some such embodiments, the DC power supply may power the heating element completely at some times and partially at other times (depending on factors such as time of day, or availability of electricity from a renewable source etc.).

[0179] In some examples, fluid in multiple, independent fluid circuits is heated, e.g. a first circuit for radiator water and a second circuit for potable water as in a combi boiler. In such examples, the second circuit has a different conduit arrangement, i.e. different ducts/pipework to the first circuit so that the fluids within the two circuits do not meet (e.g. so that the potable water is not contaminated by the radiator water). The person skilled in this field will have knowledge of how to construct suitable vessels to accommodate independent fluid circuits. For example, a suitable vessel may include a second fluid inlet and a second fluid outlet with a second fluid pipe therebetween, wherein the burning of fuel in the combustion zone or heating of the electrical element or both is/are arranged to heat fluid in the second fluid pipe.

[0180] One or more or all of the heating elements may be located outside of the burner vessel (but still inside a larger boiler (or other fluid heater, e.g. air furnace) housing). Such examples may be particular suitable for retro-fitting electrical heating capability to existing gas boilers. For example, electric heating elements may be coated on, coated within, sprayed, contained in, wrapped around, partially or totally embedded in, or otherwise associated with, a duct section at or near: its exit from the burner vessel: its entrance to the burner vessel; or both. The heating element(s) may be powered by DC, AC or a combination thereof. In some examples, a battery, such as a large battery of the type previously described, may be attached to the burner vessel along with a control mechanism (e.g. control electronics and/or software) to control the amount of heating provided by the electric heating element(s) compared to the combustible fuel source. The control mechanism may also control the amount of heating provided by DC, AC or a combination thereof.

[0181] In most of the examples described above, the heating element extends along substantially the whole of the fluid duct. In other examples, one or more heating element (s) is provided only in some parts of the fluid duct; in other parts, there is no significant heating caused by the heating element(s). As a result, a more resource-efficient system that is easier to assemble may be provided.

[0182] In the described examples, the heating element(s) are powered by passing a current therethrough. In other examples, the heating elements may have a different configuration, e.g. such that they can be powered by induction (without direct contact).

[0183] In some examples, multiple distinct sections of heating element are provided within the fluid duct, and each section may be controlled together or separately, e.g. to provide different levels of heating at different section locations. This is efficient in situations where combustion heating levels are different in different locations of the burner vessel—the electric heating element(s) may provide less heating in sections where the burner is able to provide more heating and the electric heating element(s) may provide more heating in sections where the burner is able to provide less heating. In another use case, it may be desirable to

provide different heating levels at different sections of the fluid path, such as upon initial heating start-up when a fluid is first heated from cold, such as when a tap is first turned on, more intense heating may be provided at the beginning of the fluid path than at the end because the initial input fluid is particularly cold.

[0184] In some of these examples, the elements may be completely embedded in the fluid duct such that no part of them emerges or protrudes from the duct (e.g. there is no external electrical connection point).

[0185] In examples with multiple fluid circuits, e.g. combi boiler examples, the first heating element (powered by a DC power supply or an AC supply or a combination thereof) may be arranged to heat fluid only in one of the first and second circuits, and the combustion heater may be arranged to heat fluid only in the other of the first and second circuits, e.g. the tap water is heated only by the electric source and the heating water is heated by the combustible fuel source. In some examples, the controller is arranged to control the heater such that gas (or other combustible fuel) and electric hybrid heating is used only for heating fluid (e.g. radiator water) in the first fluid circuit and only electric heating is used for heating potable water in the second fluid circuit.

[0186] More than one heating element may be provided per vessel.

[0187] Any of the examples may include a DC power supply interface arranged to receive the DC power supply, wherein the DC power supply interface is configured to receive more than one type of DC power supply, such as any combination of an Ni-MH battery cell pack, an Ni—Cd battery cell pack and a lithium battery cell pack or a mixed pack containing a mixture of any of these types of cells.

[0188] Any of the examples that include DC power supply cells may include a safety shut-off mechanism arranged to disconnect the cells from powering the electric heating element. The safety shut-off mechanism may comprise a master switch or automatic master switch; in some examples the safety shut-off mechanism comprises a contactor. Advantageously, a safe, simple DC switching mechanism is thereby provided.

[0189] Within the examples in which the circuit comprises a heating water circuit such as a radiator circuit, the boiler/heater also comprises a pump such as a water pump (not shown for clarity in any of the drawings) as is known in the field.

[0190] Within the examples in which the circuit comprises a potable water circuit, the input is usually from a mains water input, which is pressurised and so no pump is required. In some examples, where the input is from an unpressurised clean water source, then a pump may be provided.

[0191] In some examples, the DC power supply is located within a top portion of the boiler housing. In such examples, wet components (such as pipes or chambers containing fluid) are located underneath the DC power supply only. The DC power supply may occupy about the top 80% of the space within the housing in some examples.

[0192] In some embodiments, the heating element is arranged to provide heating exclusively in the first fluid circuit, and the second heating element is arranged to provide heating exclusively in the second fluid circuit, or vice versa. E.g. one heating element may be dedicated to providing heating for a radiator circuit whilst another heating element may be dedicated to providing heating for a potable water circuit. Suitable bespoke, dedicated elements can thereby be used for different circuits with different needs.

[0193] In any of the described examples, the, any or each heating element may be any element that emits heat when an electric current is passed therethrough, such as any resistive wire, or arrangement of wires, that emits heat when a current is passed therethrough, such as (but not limited to):

[0194] Thin film (polyimide over conductive metal);

[0195] Ceramic (ceramic sheath with embedded nickel chrome aluminium etc.) wire;

[0196] Bare wire (nickel, nichrome, Kanthal, stellites etc. Tungsten);

[0197] Encapsulated wire—e.g. silicone jacketed nichrome;

[0198] Mineral insulated wire-copper sheath/nichrome, cupronickel/Inconel, steel sheath/nickel,

[0199] Inconel sheath/nickel allow wire and all sorts of mixtures of these. Elements may be drawn to size or manufactured at finish size etc. Insulation generally Al2O3 or MgO;

[0200] Plain wires, spiraled (helical) wires, busbar wires with wound elements between.

[0201] In any example where a single heating element is described, it may be replaced by one or more different heating elements as will be apparent to the skilled reader.

[0202] Embodiments of the invention have been described in relation to vessels having a spiral fluid channel defined between the heat exchanger body and the cover. Other configurations, e.g. without such a channel, are within the scope of the invention. For example, in other embodiments, instead of (or in addition to) such a fluid channel, a sealed fluid pipe (e.g. carrying potable water in a potable water circuit) may pass through the vessel and be heated by fuel burning in the combustion zone.

[0203] In some embodiments, the fluid heater may have a DC connection or an AC connection or both (combined AC and DC) through which power is transferred to the electric heating element(s). In any embodiments with a battery pack, the battery pack may be inside the fluid heater, or may be outside of the fluid heater.

[0204] In some embodiments, the heat exchanger and the duct are not separate components. The heat exchanger and duct are formed by a common element. For examples, the duct may comprise a pipe of a suitable construction such that its wall(s) transfer heat from its surrounding (e.g. from the combustion zone) to the fluid, inside the pipe, that is to be heated. The pipe may have a heating element(s) wrapped around, or embedded (partially or completely) in its wall(s) or located therein (e.g. in direct contact with the flowing fluid.

[0205] In other embodiments, the heat exchanger and the duct are separate components.

[0206] In many embodiments, the one or more electric heating elements are able to provide sufficient heat in isolation to supply all of the heating requirement (without burning fuel), including potable water. In that regard, for the purpose of this specification, the heating elements may be high-power heating elements, e.g., powered by a large battery (e.g. the DC power supply having a capacity of at least 0.5 kWh, or at least 1 kWh, or at least 5 kWh or at least 20 kWh), or via similarly powerful AC power supply, e.g. via a national grid. In such examples, the peak power output

of the DC power supply is between 10 kW and 20 kW in some examples, and up to 200 kW in some examples.

[0207] The combustible fuel is able to provide sufficient heat in isolation to supply all of the heating requirement. The combustible fuel and electric heating elements heat fluid at the same location within the single chamber at least in some areas (i.e. they completely or partially overlap with regards to heat supply along the extent of the fluid duct). The combustible fuel and electric heating elements can also be used in combination, if desired, to provide the heating requirement.

[0208] As previously described, in some examples, combustible fuel heating occurs via the heat exchanger, and one or more electric element heats water directly in the duct. In other embodiments, the one or more electric elements may instead/additionally provide heating via the duct walls (e.g. if the elements are not completely located within the fluid (e.g. if they are located outside the duct nearby, e.g., on its surface)) or via the heat exchanger (e.g. if the elements are arranged to heat the heat exchanger) or any other suitable configuration as will be apparent from the teachings in this specification.

[0209] In some examples (including most of the above-described examples), the electric and combustible fuel heat sources are arranged to heat the fluid in the duct at the same location (or overlapping locations in some examples) in the fluid duct. In other words, fluid at a single location can be heated by either the electric heating element or the combustible fuel heat source or both simultaneously. In some such examples, the electric heating element and the gas burner are arranged to heat along substantially all/most of the length of the fluid duct that passes through the vessel. An effect of this feature is to allow (in some examples) the entire heating demand of a typical domestic water heater to be supplied by an electric source if needed (and to still have the option to use a gas source to heat the same fluid in the same location too). Another effect is to efficiently provide a more powerful instant response (e.g., when potable water is first requested from cold, and a quick/instant response is desirable). Furthermore, as a result of being configured to heat fluid at the same location via combustible fuel or electric or both simultaneously, another effect of some embodiments is that the electric heating elements can be used on their own initially, without any water flow, to pre-heat water in the duct. Then, heating via combustible fuel can be activated in the usual way along with fluid flow. As a result, an initial period of cold water when first turning on a tap can be reduced/avoided altogether (in an efficient way that avoids wasting water and/or burnt fuel).

[0210] In many of the described embodiments, the combustible fuel and electric heating elements are arranged to heat the fluid in the fluid duct with a single sealed fluid heater vessel chamber. An advantageous effect is the lack of need for a main burner chamber and a supplementary heating chamber (such as a buffer tank, which may be heated electrically). This is especially true for air furnaces.

[0211] In some examples, the cooling system might be a passive cooling system (instead of or in addition to the previously-described cooling systems) arranged to transfer heat away from components to be cooled (such as the boiler electronics or DC power supply or battery charger or any combination thereof). The passive cooling system may not comprise a flowing fluid. The passive cooling system may comprise a thermal heatsink (e.g. an aluminium block, such as a 20 mm×40 mm×80 mm aluminium block, with natural convection fins for heat dissipation into the environment. The passive cooling system may comprise a large thermal mass, such as the heater housing.

1-33. (canceled)

34. A burner vessel for a hybrid electric-combustible fuel fluid heater arranged to heat fluid in one or more fluid circuits, the vessel comprising a vessel housing containing:

a combustible fuel burner arranged to burn combustible fuel;

one or more electric heating elements arranged to generate heat and transfer the heat to said fluid in one or more fluid circuits;

the vessel further comprising:

a first cold fluid inlet arranged to input relatively cold fluid to the vessel;

a first hot fluid outlet arranged to output relatively hot fluid to the one or more fluid circuits from the vessel;

a first fluid duct extending between the first cold fluid inlet and the first hot fluid outlet and arranged to convey fluid through the vessel;

a flue arranged to convey waste combustion gas from the vessel; and

wherein both the combustible fuel burner and the one or more electric heating elements are arranged to heat fluid in the first fluid duct.

35. The burner vessel of claim **34** wherein the housing further contains a burnt fuel heat exchanger arranged to transfer heat from the burnt fuel to said fluid in one or more fluid circuits.

36. The burner vessel of claim **34** wherein the duct comprises at least one duct wall through which heat is transferred from the burnt fuel to said fluid in one or more fluid circuits.

37. The burner vessel of claim **34** further comprising:

a second cold fluid inlet arranged to input relatively cold fluid to the vessel;

a second hot fluid outlet arranged to output relatively hot fluid from the vessel;

a second fluid duct extending between the second cold fluid inlet and the second hot fluid outlet and arranged to convey fluid through the vessel;

wherein either or both of the combustible fuel burner and the one or more electric heating elements are arranged to heat fluid in the second duct.

38. The burner vessel of any of claim **35** wherein one or more of the electric heating elements is partially or completely embedded in: the burnt fuel heat exchanger; the at least one duct wall; or both.

39. The burner vessel of any of claim **35** comprising multiple distinct electric heating elements arranged to heat fluid in distinct sections of the first fluid duct.

40. The burner vessel of any of claim **35** wherein the heat exchanger, or the at least one duct wall, or both has a groove or grooves formed therein, the groove or grooves being arranged to locate the one or more electric heating elements.

41. The burner vessel of any of claim **35** wherein one or more of the electric heating elements is completely or partially located in the, any or each duct, and optionally spaced from the burnt fuel heat exchanger.

42. The burner vessel of claim **34** wherein one or more of the electric heating elements comprises a conductive heating element coating on any one or more of: an interior surface of an at least one duct wall; an exterior surface of the at least one duct wall; and a surface of the burnt fuel heat exchanger.

43. The burner vessel of any of claim **35** wherein the combustible fuel burner is arranged to burn fuel in a combustion zone, and the burnt fuel heat exchanger comprises a heat exchanger body, such as a cast heat exchanger body, and optionally wherein the heat exchanger body either:

a) substantially surrounds the combustion zone;

b) comprises a block within or adjacent to the combustion zone, optionally near an upper part of the combustion zone; or

c) a combination of both a) and b).

44. The burner vessel of any of claim **35** wherein the burnt fuel heat exchanger comprises at least one heat exchanger protuberance, such as a heat exchanger fin, arranged to efficiently transfer heat from the burning fuel, and wherein optionally the at least one protuberance extends from the heat exchanger body towards the combustion zone and is in thermal communication with the heat exchanger body.

45. The burner vessel of any of claim **35** wherein the housing further comprises a cover, optionally a multi-layer cover, arranged to substantially surround the burnt fuel heat exchanger, and optionally the first fluid duct is defined between the cover and the burnt fuel heat exchanger.

46. The burner vessel of claim **45** wherein the multi-layer cover comprises at least one skin layer and at least one insulant layer.

47. The burner vessel of any claim **34** wherein the, any or each duct comprises:

a channel defined between a wall of the heat exchanger and the cover, such as between an outer wall of the heat exchanger body and an inner surface of the cover; or

a sealed pipe arranged to pass through a space or channel between a wall of the heat exchanger and the cover; or

a channel defined entirely within the heat exchanger; or

a sealed pipe arranged to pass through a space or channel entirely within the heat exchanger; or

a sealed pipe passing through the housing, optionally through the combustion zone, and spaced from the heat exchanger; or

a sealed pipe passing through the housing, optionally through the combustion zone.

48. The burner vessel of claim **47** wherein the outer wall of the heat exchanger comprises a continuous open, optionally U-shaped or C-shaped, recess in its outer surface, wherein the channel is defined between the surface of the recess and the cover, and optionally wherein the channel extends in a spiral configuration around the outer wall of the heat exchanger from the first cold fluid inlet to the first hot fluid outlet, optionally downwardly in an in-use configuration.

49. The burner vessel of claim **47** wherein the, any or each of the electric heating elements is:

located in or coated on or coated within the channel, optionally located near a base of the open recess, and further optionally spaced from the heat exchanger; or

partially or completely embedded in or coated on or coated within the heat exchanger near a base of the open recess; or

located in or coated on or coated within the channel, optionally located in contact with, or near to, the cover and spaced from a base of the open recess; or

partially or completely embedded in, or wrapped around, or coated on or coated within the at least one heat exchanger fin; or

integrally cast within or coated on or coated within the heat exchanger, such as within a channel, such as a spiral channel, defined entirely within the heat exchanger; or

wrapped around or coated on or coated within the, any or each duct; or

any combination thereof.

50. The burner vessel of claim **34** wherein the, any or each of the electric heating elements comprises any one or more of:

a metal-sheathed, ceramic powder insulated cable with a nichrome element;

a spiraled wire element;

an encapsulated metal etched element, such as a silicone encapsulated metal etched element;

a pre-formed element having a desired shape profile;

an enamel coated element;

a conductive coating.

51. The burner vessel of claim **34** wherein the vessel housing further contains at least one baffle arranged to divert air heated by the fuel burner and arranged to increase thermal communication between the heated air and the at least one duct wall or the heat exchanger or both, and optionally wherein the, any or each electric element is partially or completely embedded within or coated on or coated within the at least one baffle or wrapped around the at least one baffle.

52. The burner vessel of claim **34** being arranged to heat water in first and second independent water circuits, the first circuit being arranged to provide heating water for a radiator circuit and the second circuit arranged to provide potable water, wherein the burner vessel is arranged to heat water for both circuits.

53. The burner vessel of claim **34** wherein the or each electric heating element is configured to be powered by any one or a combination of a DC power supply and an AC power supply.

54. A fluid heater arranged to heat fluid in one or more fluid circuits, wherein the heater comprises:

a burner vessel for a hybrid electric-combustible fuel fluid heater arranged to heat fluid in one or more fluid circuits, the vessel comprising a vessel housing containing:

a combustible fuel burner arranged to burn combustible fuel;

one or more electric heating elements arranged to generate heat and transfer the heat to said fluid in one or more fluid circuits;

the vessel further comprising:

a first cold fluid inlet arranged to input relatively cold fluid to the vessel;

a first hot fluid outlet arranged to output relatively hot fluid to the one or more fluid circuits from the vessel;

a first fluid duct extending between the first cold fluid inlet and the first hot fluid outlet and arranged to convey fluid through the vessel;

a flue arranged to convey waste combustion gas from the vessel; and

wherein both the combustible fuel burner and the one or more electric heating elements are arranged to heat fluid in the first fluid duct; and wherein the fluid heater further comprises a controller arranged to control the amount of heating supplied to said fluid in one or more fluid circuits by the combustible fuel burner and by the first heating element.

55. The fluid heater of claim **54** further comprising one or more of:

a DC power supply, such as a battery pack, arranged to power the, any or each heating element, and optionally the DC power supply having a capacity of at least 0.5 kWh, further optionally at least 1 kWh, and yet further optionally at least 5 kWh or at least 20 k Wh; and

an AC power supply arranged to power the, any or each heating element.

56. The fluid heater of claim **55** wherein the controller is arranged to control supply of power to the electric heating element from the DC power supply, the AC power supply or both.

57. The fluid heater of claim **54**, wherein the controller is arranged to control the amount of heating supplied to the fluid based on or in response to any one or more control factors, the control factors comprising:

amount of heating required;

fluid input temperature at an input point in the one or more fluid circuits;

fluid output temperature at an output point in the one or more fluid circuits;

fluid temperature at any predetermined point in the one or more fluid circuits;

amount of heating capacity available from the first heating element;

amount of heating capacity available from the combustible fuel burner;

instantaneous demand for heating fluid or potable water;

forecasted demand for heating fluid or potable water; and

flow rate of fluid to be heated; and optionally

wherein the fluid heater further comprises one or more sensors arranged to sense information relating to the one or more control factors and to provide said control factor information to the controller, and further optionally wherein the controller is configured to heat fluid primarily using the one or more electric heating elements, such as primarily via the DC power supply, when a demand for hot fluid is first detected.

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