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(54) **THREE-PHASE POWER-FREQUENCY DUAL-CIRCUIT ELECTROMAGNETIC INDUCTION AND SHORT-CIRCUIT HEATING DEVICE AND HEATING METHOD FOR LIQUID**

(57) The present invention relates to a three-phase power-frequency dual-circuit, electromagnetic induction and short-circuit heating device for liquid and a heating method. The heating device includes an EI-shaped core and three-phase primary windings wound on core legs. A metal housing is arranged along a closed three-phase magnetic circuit, to form a dual-circuit shell structure that surrounds the core and the three-phase primary windings and that has 10 secondary-side short-circuited metal rings. During operation, high short-circuit currents are inductively generated in the respective secondary-side short-circuited metal rings. Respective secondary sides are conducted through a same metal housing to generate high short-circuit between phases and among three phases. Inner and outer secondary-side short-circuit currents in the respective phases have a same direction, while adjacent magnetic flux leakages have opposite directions. A powerful and stable three-phase power-frequency alternating N-S magnetic field is formed. Hence, magnetic flux leakages are greatly reduced, and a temperature rise of a protective housing is correspondingly greatly decreased. When flowing through the present heating device, a liquid medium is magnetized by a powerful alternating magnetic field while being heated. The dual-circuit heating method of the present invention greatly reduces a surface load parameter, thereby effectively increasing a designed standalone power.

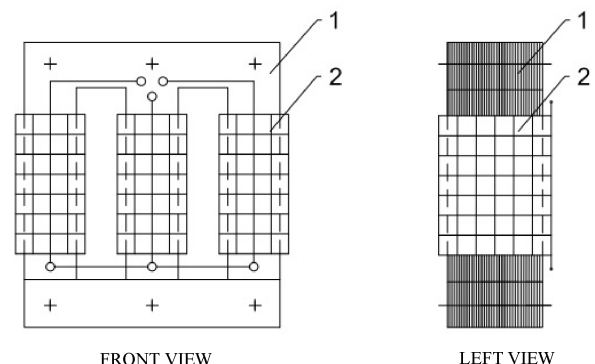


FIG. 1

EP 4 773 731 A1

Description

TECHNICAL FIELD

[0001] The present invention relates to a power-frequency electromagnetic induction and short-circuit heating device and a heating method, and more particularly, to a three-phase power-frequency dual-circuit, electromagnetic induction and short-circuit heating device and a heating method for heating a liquid.

BACKGROUND

[0002] In the power transformer manufacturing industry, there is a well-recognized "6-degree rule", which is for every 6°C rise above a rated temperature, the service life is halved, and for every 6°C drop below a rated temperature, the service life is doubled.

[0003] The Chinese patent document CN1142706C (Patent Application No. 01134187.4, hereinafter referred to as Patent Document 1) discloses a three-phase power-frequency electromagnetic induction and short-circuit heating device and method for liquid heating, whose operating principle is as follows: According to a primary-to-secondary turns ratio of a transformer, a low-voltage high current is obtained on a secondary side. In the foregoing patent, there is always one turn on the secondary side, and the second side is short-circuited to form a circuit, which, therefore, is referred to as short-circuit (single-circuit) heating. According to the professional terminology of the transformer, a part of a core on which a winding is arranged is referred to as a core leg, and a part of the core on which no winding is arranged and that only serves to form a closed magnetic circuit is referred to as a yoke. In the foregoing patent, a metal housing is creatively used as a secondary side, and surrounds a core and primary windings along a closed three-phase magnetic circuit. In this way, three short-circuited secondary-side metal rings are formed on a core leg section of the core, and four short-circuited secondary-side metal rings are formed on a yoke section of the core, leading to a heating device with a total of seven secondary short-circuits (hereinafter referred to as a 7-secondary-side short-circuit heating device).

[0004] When primary sides of the heating device are connected to a three-phase power-frequency power supply, all the secondary-side metal rings of the metal housing inductively generate high short-circuit currents. The secondary-side metal rings of all phases are conducted through a same metal housing to generate large short-circuit currents between phases and among three phases. The foregoing two different large short-circuit currents rapidly heat the metal housing, and then, the metal housing transfers Joule heat to a liquid medium surrounding the metal housing. A sum of vectors of the three-phase short-circuits formed by the respective secondary sides equals zero, resulting in zero potential during operation, leading to safety.

[0005] It is mentioned in the beneficial effects of the foregoing patent that: In thermal design, there is a surface load parameter, whose meaning is heat generation (dissipation) power per unit area. If a surface area is larger, a margin of a designed output power is larger. By applying the housing as a main heating body, a design with a maximized power should be obtained. Indeed, the foregoing patent has obtained the maximized design, but its output power is not proportional to a

surface area of the housing, which can be understood from a relational formula $S = K\sqrt{P}$ between a core cross-sectional area S and an output power P. It can be understood that when an output power is higher, a surface load parameter is higher, and a temperature rise of a primary winding is higher. When the temperature rise of the primary winding reaches a rated temperature rise, maximization of the designed output power is restricted. Further, temperature rises of respective sections of the metal housing are uneven. It can be learned from No. 2 of Test example 2 that after four secondary-side metal rings of the yoke section are cut off, it is measured that an output power of the housing with three secondary sides at the core leg section of the core accounts for 85.26% of that of the total device, but its surface area accounts for only 72.5% of the total device. In view of the above, a shell at the core leg section of the core has the largest heat generation amount and the highest surface load parameter.

[0006] Chinese patent document CN102384577A (Patent No. ZL201110340219.2, hereinafter referred to as Patent Document 2) discloses a three-phase power-frequency, electromagnetic double-induction heating device for liquid, and its working principle is as follows: By applying a mechanism that a metal plate made of a ferromagnetic material not only has good magnetic permeability, but also is prone to generating eddy currents and magnetic hysteresis, the metal plate is arranged around the foregoing 7-secondary-side short-circuit heating device to form a magnetic conductive frame. During operation, the magnetic conductive frame induces short-circuit magnetic flux leakages generated by the foregoing 7-secondary-side short-circuit heating device to form a circuit with the magnetic conductive frame, to inductively generate eddy currents and magnetic hysteresis inside the magnetic conductive frame, and cause the magnetic conductive frame to become an eddy current heating device. The eddy current heating device and the foregoing 7-secondary-side short-circuit heating device simultaneously heat a liquid medium flowing through them. That is, a 7-secondary-side short-circuit heating device is connected to a three-phase power-frequency power supply. Moreover, a liquid is heated by using a heating method with two induction heating devices, that is, the short-circuit heating device and the eddy current heating device, so

that the short-circuit magnetic flux leakages are confined within the magnetic conductive frame and are effectively controlled and used. It is mentioned in the beneficial effects of the foregoing patent that: When an output power is 131.09 kW, a temperature rise of a protective housing drops from 57 K to 15 K, which is indeed a great drop, but the temperature rise of the protective housing is approximately proportional to the output power. Since it is specified in the national standards that a temperature rise of a protective housing of a commercial heating device is not greater than 50 K, the designed output power is limited.

[0007] The single-circuit power-frequency short-circuit magnetic flux leakage in the foregoing two patents has significant adverse impact on the temperature-rise of the protective housing, but has a limited magnetization effect on the liquid medium flowing around it. As a result, mild scale is formed on the secondary-side housing during long-term operation. Although the mild scale will fall off itself, it is undoubted that the mild scale will affect heat dissipation of the secondary-side housing, affect the temperature rise of the primary winding, and affect a service life. However, although the foregoing two patents have defects, the basic technical solutions disclosed by them are also important components of this application.

SUMMARY OF THE INVENTION

Technical problems

[0008] Objectives of the present invention is to overcome shortcomings in the related art, under a condition that a winding temperature rise and a protective housing temperature rise meet related requirements in national standards, further increase a standalone output power and lower costs per kilowatt, and under a condition of a same total installed capacity, reduce a quantity of installed devices, reduce floor space that is expensive, and greatly lower initial investment costs, to provide a higher commercial value.

Technical solutions

[0009] To achieve the objectives of the present invention, a technical solution of a three-phase power-frequency dual-circuit, electromagnetic induction and short-circuit heating device for liquid is provided as follows: The three-phase power-frequency dual-circuit, electromagnetic induction and short-circuit heating device for liquid heating includes an EI-shaped core having a closed three-phase magnetic circuit entirely formed by laminating silicon steel sheets. Primary windings, that is, three-phase primary windings, are respectively wound on three core legs of the EI-shaped core. The three-phase primary windings from left to right are in a phase U, a phase V and a phase W respectively. Structural features thereof are as follows:

A metal housing is further included. The metal housing includes a first-circuit metal housing and a second-circuit metal housing. The first-circuit metal housing is arranged along the closed three-phase magnetic circuit, to form secondary-side metal rings surrounding the core and the respective primary windings. The second-circuit metal housing is arranged along outer sides of secondary sides of all phases of the three core legs of the core in a first circuit. In this way, the three-phase primary windings, three short-circuited secondary-side metal rings (referred to as Ua, Va, and Wa respectively corresponding to the phase U, phase V and phase W of the three-phase primary windings) of the first circuit, three short-circuited secondary-side metal rings (referred to as Ub, Vb, and Wb respectively corresponding to the phase U, phase V and phase W of the three-phase primary windings) of a second circuit, and four short-circuited secondary-side metal rings respectively surrounding left and right portions of upper and lower yokes of the core are sequentially arranged around the core legs of the EI-shaped core from inside to outside. Hence, the metal housing forms a dual-circuit shell structure having 10 short-circuited secondary-side metal rings on two main heating elements inside and outside a core leg section of the core.

[0010] In the foregoing three-phase power-frequency dual-circuit, electromagnetic induction and short-circuit heating device for liquid, the first-circuit metal housing includes a first shell and two rectangular tubes. The second-circuit metal housing includes a second shell and two flow guide members with folded fins at front and rear ends. A height of the second shell is higher than heights of the folded fins of the flow guide members but lower than a height of the first shell.

[0011] In the foregoing three-phase power-frequency dual-circuit, electromagnetic induction and short-circuit heating device for liquid, upper and lower surfaces of the flow guide member in an inner cavity of the rectangular tube are welded and fixed to upper and lower inwardly folded fins of the rectangular tube. A straight section of the flow guide member has a uniform clearance from all sides of an inner wall of rectangular tube, which is equal to net heights of the upper and lower inwardly folded fins of the rectangular tube. The front and rear folded fins of the flow guide member respectively extend out of front and rear end surfaces of the rectangular tube by a distance and are welded and fixed to the front and rear end surfaces of the rectangular tube.

[0012] In the three-phase power-frequency dual-circuit, electromagnetic induction and short-circuit heating device for liquid, there are two rectangular tubes, namely, a first rectangular tube and a second rectangular tube. Left and right

surfaces of the first rectangular tube and the second rectangular tube respectively form, together with the first shell, the three short-circuited secondary-side metal rings (Ua, Va, Wa) surrounding the respective primary windings. There are two flow guide members, namely, a first flow guide member and a second flow guide member. The first flow guide member and the second flow guide member respectively extend out of front and rear end surfaces of the corresponding first rectangular tube and second rectangular tube by a distance and run through front end rear surfaces of the second shell to be welded and fixed thereto, and the second shell (4-2) has a uniform clearance from all sides of the first shell. Hence, left and right surfaces of the two flow guide members and the second shell are respectively formed on outer sides of the three short-circuited secondary-side metal rings (Ua, Va, Wa), together with the three short-circuited secondary-side metal rings (Ub, Vb, Wb) parallel thereto, enclose the three-phase primary windings to be used as the second main heating element.

[0013] By applying a method of forming a dual-circuit structure by combining the flow guide members and the second shell of the three-phase power-frequency dual-circuit, electromagnetic induction and short-circuit heating device for liquid, a three-circuit or multi-circuit induction heating device with a higher standalone capacity can theoretically be formed on an outer side of the second shell.

[0014] In the foregoing three-phase power-frequency dual-circuit, electromagnetic induction and short-circuit heating device for liquid, the second shell and the flow guide member are made of stainless steel plates having a same thickness as those of the first shell and the rectangular tube.

[0015] The technical solution of a method for heating a liquid by a three-phase power-frequency dual-circuit, electromagnetic induction and short-circuit heating device for achieving the objectives of the present invention is: When three-phase primary windings of the three-phase power-frequency dual-circuit, electromagnetic induction and short-circuit heating device for liquid of the present invention are connected to a three-phase power-frequency power supply, high short-circuit currents are inductively generated in 10 short-circuited secondary-side metal rings of a dual-circuit metal housing. Secondary sides of all phases are conducted through a same metal housing to generate high phase-to-phase short-circuit currents and high three-phase short-circuit currents. Under a combined effect of the two types of high currents, the dual-circuit metal housing is rapidly heated, and generated Joule heat is transferred to a liquid medium surrounding the dual-circuit metal housing, and the metal housing is at zero potential, and is both a protective housing and a heat dissipator of the three-phase primary windings. Inner and outer secondary-side short-circuit currents of all phases of the two circuits of the dual-circuit have a same direction, while directions of adjacent magnetic flux leakages are opposite. In this way, under a condition of a short clearance between the inner and outer secondary sides of all phases of the dual-circuit, a powerful and stable three-phase power-frequency alternating N-S magnetic field circuit is formed. Hence, magnetic flux leakages are greatly reduced, and a temperature rise of the protective housing is correspondingly greatly decreased. When flowing through a channel between the inner and outer secondary sides of the dual-circuit, a liquid medium is magnetized by a powerful alternating magnetic field while being heated, where magnetized water is free from scaling, and magnetized oil is free from carbon deposition. Such a dual-circuit induction short-circuit heating method greatly reduces a surface load parameter and effectively increases a designed standalone power.

Beneficial Effects

[0016] The present invention has the following beneficial effects: (1) The heating device of the present invention has a shell structure with a dual-circuit structure, which greatly reduces a surface load parameter and decreases a winding temperature rise, so that a margin for a designed standalone output power can be greatly increased. (2) Inner and outer secondary-side short-circuit currents of all phases of the two circuits of the dual-circuit have a same direction, while directions of adjacent magnetic flux leakages are opposite. In this way, under a condition of a short clearance between the inner and outer secondary sides of all phases of the dual-circuit, a powerful and stable three-phase power-frequency alternating N-S magnetic field circuit is formed. Hence, magnetic flux leakages are greatly reduced, and a temperature rise of the protective housing is correspondingly greatly decreased. (3) When flowing through a channel between the inner and outer secondary sides of the dual-circuit, a liquid medium is magnetized by a powerful alternating magnetic field while being heated, where magnetized water is free from scaling, and magnetized oil is free from carbon deposition, which is beneficial to maintaining heat dissipation conditions of the secondary-side housing unchanged for a long term, and is beneficial to the winding temperature rise, leading to reliability, non-degraded long-term operation efficiency, maintenance-free operation, and greatly reduced operation costs. (4) With a total installed capacity unchanged, a standalone output power is doubled, and floor space is halved. In addition, a higher standalone output power indicates lower manufacturing costs per unit power, which helps reduce initial investment costs for construction of a thermal energy storage system.

BRIEF DESCRIPTION OF THE DRAWINGS

[0017]

FIG. 1 is a schematic structural diagram of a core and windings in a three-phase power-frequency dual-circuit, electromagnetic induction and short-circuit heating device for liquid according to the present invention;

FIG. 2 is a schematic structural diagram of a rectangular tube and a flow guide member in a three-phase power-frequency dual-circuit, electromagnetic induction and short-circuit heating device for liquid according to the present invention;

FIG. 3 is a schematic structural diagram of a three-phase power-frequency dual-circuit, electromagnetic induction and short-circuit heating device for liquid according to the present invention;

FIG. 4 is a structural schematic diagram of a circulating heating device using the three-phase power-frequency dual-circuit, electromagnetic induction and short-circuit heating device for liquid shown in FIG. 3; and

FIG. 5 is a schematic diagram of a commercial set of a three-phase power-frequency dual-circuit, electromagnetic induction and short-circuit heating device for liquid according to the present invention.

[0018] Reference signs in the foregoing accompanying drawings are as follows: core 1, three-phase primary winding 2, upper disc 3-1, lower disc 3-2, first shell 4-1, second shell 4-2, rectangular tube 5, first rectangular tube 5a, second rectangular tube 5b, terminal block 6, insulation plate 7, lead wire 8, insulation filler 9, flow guide member 10, first flow guide member 10a, second flow guide member 10b, inlet circular pipe 11, outlet 12, circulation tank 13, first base 14, circular hole 15, main inlet pipe 16, L-shaped branch pipe 17, magnetic conductive frame 18, protective housing 51, inlet temperature sensor 52, pressure sensor 53, frame 54, blowdown valve 55, second base 56, outlet temperature sensor 57, control cabinet 60; heating device 30A, circulating heating device 50A, commercial set 100A.

DETAILED DESCRIPTION OF THE EMBODIMENTS

[0019] Embodiments of this application are described below in detail, and examples of the embodiments are shown in the accompanying drawings, in which the same or similar elements or elements having same or similar functions are denoted by the same or similar reference signs throughout the description. The following embodiments described with reference to the accompanying drawings are exemplary, are intended to describe this application, and cannot be construed as limitations on this application.

[0020] In the description of this application, it should be understood that orientations or positional relationships indicated by terms, such as "center", "longitudinal", "transverse", "length", "width", "height", "upper", "lower", "front", "rear", "left", "right", "vertical", "horizontal", "top", "bottom", "inner", and "outer", are orientations or positional relationships shown based on the front view in FIG. 1 or the front view in FIG. 3, are used merely for conveniently describing this application and simplifying the description, rather than indicating or implying that the indicated devices or elements need to have specific orientations or be constructed and operated in specific orientations, and therefore, should not be construed as limitations on this application.

[0021] A three-phase power-frequency dual-circuit, electromagnetic induction and short-circuit heating device for liquid and a heating method according to the present invention are described below with reference to the accompanying drawings.

(Embodiment 1)

[0022] Referring to FIG. 1, two, front and side views of FIG. 1 show a relational structure between a core 1 and three-phase primary windings 2 of a three-phase power-frequency dual-circuit, electromagnetic induction and short-circuit heating device for liquid of the present invention. The core 1 is EI-shaped, and a closed three-phase magnetic-circuit is formed entirely by laminating silicon steel sheets. Primary windings, that is, the three-phase primary windings 2 are respectively wound on three core legs of the EI-shaped core 1. The three-phase primary windings 2 are arranged from left to right in a phase sequence, and are respectively represented by U, V, and W. The three-phase primary windings 2 may be connected according to a Wye (Y) connection or a delta (Δ) connection. A Wye (Y) connection is shown in the figure.

[0023] Referring to FIG. 2, FIG. 2 shows a rectangular tube 5 that is semi-closed at two ends and that has inwardly folded fins on its upper and lower surfaces in the three-phase power-frequency dual-circuit, electromagnetic induction and short-circuit heating device for liquid of the present invention. One end of the rectangular tube 5 is provided with at least four inlet circular pipes 11 as inlets thereof, and an other end thereof is provided five square holes as outlets thereof. A flow guide member 10 with folded fins at two ends is arranged in an inner cavity of the rectangular tube 5. A main body of the flow guide member 10 is a hollow tube, and a straight section of the hollow tube has a uniform clearance from all sides of an inner wall of the rectangular tube 5, which is equal to heights of the upper and lower inwardly folded fins of the rectangular tube. Upper and lower surfaces of the flow guide member 10 are welded and fixed to the upper and lower inwardly folded fins of the rectangular tube 5. Folded fins of the flow guide member 10 at two ends respectively extend out of front and rear ends of the rectangular tube 5 by a distance and are welded and fixed to front and rear end surfaces of the rectangular tube 5.

[0024] Referring to FIG. 3, three views of FIG. 3 show a three-phase power-frequency dual-circuit, electromagnetic induction and short-circuit heating device for liquid 30A according to the present invention. The three-phase power-frequency dual-circuit, electromagnetic induction and short-circuit heating device for liquid 30A has a first-circuit metal housing and a second-circuit metal housing. The first-circuit metal housing is arranged along a closed three-phase magnetic circuit. The core 1 and the primary windings 2 in FIG. 1 are all encapsulated in a metal housing formed by an upper disc 3-1, a lower disc 3-2, a first shell 4-1, a rectangular tube 5, and a terminal block 6. In FIG. 3, there are two rectangular tubes 5, which are a first rectangular tube 5a and a second rectangular tube 5b respectively. A lead wire 8 of the three-phase primary windings is led out from a terminal block 6 through an insulation plate 7. The first-circuit metal housing has insulation clearances from the core 1 and the primary windings 2. All space inside the metal housing is filled with an insulation filler 9, to form a fully closed entity. The second-circuit metal housing is formed by a second shell 4-2 and two flow guide members 10 with folded fins at two ends, and is arranged along an outer side of the first-circuit metal housing on the three core legs of the core 1.

[0025] Still referring to FIG. 3, in this embodiment, except that the terminal block 6 and an inlet circular pipe 11 are made of stainless steel pipes, all parts of the metal housing are formed by stamping, bending, and pressing stainless steel plates, and then, are assembled. A preferred thickness of the stainless steel plate is 1.0 to 4.0 millimeters.

[0026] The terminal block 6 is welded above a side of the first shell 4-1. The upper disc 3-1 is welded to an upper end of the first shell 4-1. The lower disc 3-2 is welded to a lower end of the first shell 4-1.

[0027] There are two rectangular tubes 5, namely, a first rectangular tube 5a and a second rectangular tube 5b. The first rectangular tube 5a and the second rectangular tube 5b are respectively arranged between two phases U and V and two phases V and W of the three-phase primary windings 2 and between upper and lower yokes. Moreover, the first rectangular tube 5a and second rectangular tube 5b run through front and rear surfaces of the first shell 4-1, and peripheries of their front and rear ends are welded and fixed to the front and rear surfaces of the first housing 4-1. In this way, upper surfaces of the two rectangular tubes 5 respectively form, together with the first shell 4-1 and the upper disc 3-1, two short-circuited secondary-side metal rings surrounding the upper yoke. Lower surfaces of the two rectangular tubes 5 respectively form, together with the first shell 4-1 and the lower disc 3-2, two short-circuited secondary-side metal rings surrounding the lower yoke. FIG. 3 shows two, upper and lower short-circuited secondary-side metal rings at a UV-phase section.

[0028] Referring to FIG. 3, left and right surfaces of the first rectangular tube 5a and the second rectangular tube 5b respectively form, together with the first shell 4-1, three short-circuited secondary-side metal rings surrounding the respective primary windings 2. The three short-circuited secondary-side metal rings are respectively Ua, Va, and Wa.

[0029] There are two flow guide members 10, namely, a first flow guide member 10a and a second flow guide member 10b. Folded fins at two ends of the first flow guide member 10a and the second flow guide member 10b respectively extend out of front and rear end surfaces of the corresponding first rectangular tube 5a and second rectangular tube 5b by a distance and run through front end rear surfaces of the second shell 4-2 to be welded and fixed thereto, and the second shell 4-2 has a uniform clearance from all sides of the first shell 4-1. Left and right surfaces of the two flow guide members 10 and the second shell 4-2 respectively form three short-circuited secondary-side metal rings that are in parallel to the first housing 4-1 and that surround the respective primary windings 2. The three secondary-side metal rings are respectively represented by Ub, Vb, and Wb according to their phases. The metal housing of the heating device 30A is a dual-circuit shell structure having 10 short-circuited secondary-side metal rings, which not only greatly reduces a surface load parameter and a primary winding temperature rise, but also effectively increases a designed standalone power.

[0030] Still referring to FIG. 3, the left surface of the first rectangular tube 5a of the first-circuit metal housing belongs to a U-phase short-circuited secondary-side metal ring, and the right surface thereof belongs to a V-phase short-circuited secondary-side metal ring. The short-circuited secondary-side metal rings of the two different phases are conducted through the upper, lower, front, and rear surfaces of the first rectangular tube 5a, to form a phase-to-phase short-circuit of the UV two-phase secondary sides. Moreover, the V-phase secondary-side short-circuited metal ring and the W-phase secondary-side short-circuited metal ring are conducted through the upper, lower, front, and rear surfaces of the second rectangular tube 5b, to form a phase-to-phase short-circuit of the VW two-phase secondary sides. The U-phase short-circuited secondary-side metal ring and the W-phase short-circuited secondary-side metal ring are conducted through the first shell 4-1, to form a phase-to-phase short-circuit of the UW two-phase secondary sides. Moreover, the foregoing short-circuited secondary-side metal rings are conducted through a same metal housing, to form three-phase short-circuits, a sum of vectors of the three-phase short-circuits is zero. That is, the first-circuit metal housing is at zero potential. In view of the above, the second shell 4-2 of the second circuit is higher than a height of a folded fin of the flow guide member 10, to reduce impact of electric and magnetic fields caused by UW two-phase and three-phase short-circuits.

[0031] A method for heating a liquid by a three-phase power-frequency dual-circuit, electromagnetic induction and short-circuit heating device for liquid 30A is as follows: Still referring to FIG. 3, other than a wire outlet of a terminal block, the three-phase power-frequency dual-circuit, electromagnetic induction and short-circuit heating device for liquid 30A is completely immersed in a liquid. When three-phase primary windings 2 of the three-phase power-frequency dual-circuit, electromagnetic induction and short-circuit heating device for liquid 30A are connected to a three-phase power-frequency power supply, high short-circuit currents are inductively generated in 10 short-circuited secondary-side metal rings of two,

inner and outer circuits. Secondary sides of all phases are conducted through a same metal housing to generate high phase-to-phase short-circuit currents and high three-phase short-circuit currents. Under a combined effect of the two types of high currents, the dual-circuit metal housing is rapidly heated, and generated Joule heat is transferred to a liquid medium surrounding the dual-circuit metal housing, and the metal housing is at zero potential, and is both a protective housing and a heat dissipator of the three-phase primary windings 2. Inner and outer secondary-side short-circuit currents of all phases of the two circuits of the dual-circuit have a same direction, while directions of adjacent magnetic flux leakages are opposite. Under a condition of a short clearance between the inner and outer secondary sides of all phases of the dual-circuit, a powerful and stable three-phase power-frequency alternating N-S magnetic field circuit is formed. Hence, magnetic flux leakages are greatly reduced, and a temperature rise of the protective housing is correspondingly greatly decreased. When flowing through a channel between the inner and outer secondary sides of the dual-circuit, a liquid medium is magnetized by a powerful alternating magnetic field while being heated. Magnetized water is free from scaling, and magnetized oil is free from carbon deposition. Such a dual-circuit heating method, compared with an existing single-circuit heating method, significantly increases a total output power and greatly reduces a winding temperature rise under a condition that a cross-section of the core remains unchanged.

(Application example 1)

[0032] Referring to FIG. 4, three views in FIG. 4 show a circulating heating device 50A assembled by applying the present invention. The three-phase power-frequency dual-circuit, electromagnetic induction, and short-circuit heating device for liquid 30A according to Embodiment 1 of the present invention is fixed onto a first base 14 inside a circulation tank 13 with a magnetic conductive frame 18. To-be-heated water from a water storage tank (not shown in the figure) is pumped into the circulation tank 13 through a main inlet pipe 16 by a circulation pump and then divided into three paths of outlet water. One path is spraying water downward through a circular hole 15, where the water moves upward after diffusion. The other two paths are that water passes through two L-shaped branch pipes 17, enters gaps between the two rectangular tubes 5 and their respective flow guide members 10 through eight inlet circular pipes 11 of the three-phase power-frequency dual-circuit, electromagnetic induction, and short-circuit heating device for liquid 30A of the present invention, and then is discharged from the other ends of the two rectangular tubes 5. Water in the foregoing three paths flows through inner and outer surfaces of the dual-circuit metal housing of the three-phase power-frequency dual-circuit, electromagnetic induction and short-circuit heating device for liquid 30A of the present invention to perform sufficient heat exchange, is discharged together with generated Joule heat from an outlet 12, and then returns to the water storage tank. This cycle is repeated, to heat water in the water storage tank to a required temperature, so that the circulating heating device 50A is formed.

(Application example 2)

[0033] Referring to FIG. 5, two views of FIG. 5 show a commercial set 100A using the three-phase power-frequency dual-circuit, electromagnetic induction and short-circuit heating device for liquid of the present invention. The circulating heating device 50A of Application example 1, together with a protective housing 51, is installed on a frame 54. The frame 54 and a control cabinet 60 are installed on a same second base 56, as a fixed structure. A thermal insulation layer (not shown in the figure) is arranged between the circulating heating device 50A and the protective housing 51. A blowdown valve 55 is arranged at a bottom of the circulating heating device 50A. An inlet temperature sensor 52 and a pressure sensor 53 are arranged on a pipeline of the main inlet pipe 16 of the circulating heating device 50A, and an outlet temperature sensor 57 is arranged on a pipeline of an outlet 12 of the circulating heating device 50A. Low-voltage electrical components selected for matching the control cabinet 60 can effectively detect failure signals, such as short-circuit, overcurrent, and leakage, in an electrical system. In addition, signals, such as an outlet water temperature, an inlet-outlet water temperature difference, and a pressure, detected by the foregoing sensors are all sent to a programmable logic controller (PLC). Then, according to a programmed program, the PLC issues a control or alarm signal, to implement unmanned, safe, and automated operation.

(Test example 1)

[0034] Winding temperature rise tests and protective housing temperature rise tests were respectively carried out by using the single-circuit heating device in Patent Document 2 involved in BACKGROUND and the three-phase power-frequency dual-circuit, electromagnetic induction and short-circuit heating device for liquid manufactured in the present invention. Main test data is shown in Table 1 and Table 2 respectively:

Table 1 (single-circuit)

Specification (kW)	350	420	500	600	800	1100
Winding temperature rise (K)	51.7	60.1	67.8	73.9	80.5	88.2
Protective housing temperature rise (K)	39.0	47.5	55.6	67.6	89.5	112.8

[0035] The protective housing refers to the protective housing 51 of the single-circuit heating device in Patent Document 2.

Table 2 (dual-circuit)

Specification (kW)			500	600	800	1100
Winding temperature rise (K)			61.5	66.3	71.7	73.8
Protective housing temperature rise (K)			26.6	27.1	29.8	32.5

[0036] The protective housing refers to the protective housing 51 of the dual-circuit heating device in Application example 2 of the present invention.

[0037] Winding temperature rise: measured by using the resistance method. Referring to the national standards GB1094.2 (Power Transformers, Part 2), an enterprise-specified temperature rise shall not exceed a rated temperature rise 75 K.

[0038] Protective housing temperature rise: measured by using a surface contact thermometer, where a temperature rise shall not exceed a rated temperature rise 50 K.

[0039] In view of Table 1, applying the single-circuit heating device disclosed in Patent Document 2, the specification for qualified operation reaches 420 kW. In view of Table 2, compared with Table 1, winding temperature rises at the same specifications all decrease significantly, which is basically consistent with reduction in the surface heat load of the dual-circuit. Therefore, the winding temperature rises all meet rated requirements, and the protective housing temperature rise is greatly reduced.

(Test example 2)

[0040] Scaling comparison tests were carried out on one single-circuit heating device described in Patent Document 2 and one three-phase power-frequency dual-circuit electromagnetic induction and short-circuit heating device for liquid heating manufactured according to the present invention. Under the condition of heating water in a same water storage tank from 45°C to 90°C, the two devices were disassembled after being in operation for 16 months. The relevant data is shown in Table 3:

Table 3 (Scaling test comparison)

Heating device	Specification (kW)	$\cos\varphi$	Reactive power (kVAR)	Visual scaling observation (on a surface of a secondary-side housing)
Single-circuit	1000	0.9805	38.7	Mild scale: light tan, the entire secondary-side housing is mottled and peeling
Dual-circuit	1000	0.9702	58.7	No scale: the entire secondary-side housing shows no sign of scaling

[0041] In table 3, $\cos\varphi$ is a measured value, and the power is calculated according to a rated value, which makes the output comparison for reactive power clearer. The tests have verified the descriptions of the aforementioned beneficial effects (2) and (3).

[0042] In this application, by applying a method of forming a basic dual-circuit structure by combining the flow guide members 10 and the second shell 4-2 of the three-phase power-frequency dual-circuit, electromagnetic induction and short-circuit heating device for liquid, a three-circuit or multi-circuit induction heating device with a higher standalone capacity can theoretically be formed on an outer side of the second shell 4-2, which are all extensions of this application and fall within the protection scope of this application.

[0043] In the description of this application, although the embodiments, application examples, and test examples of this application have been shown and described, a person of ordinary skill in the art can understand that various changes,

modifications, substitutions, and variations can be made to these technical solutions without departing from the principle and spirit of this application, the scope of this application is defined by the appended claims and their equivalents. For example, the description of "liquid" in this application relates to "water", but can also be replaced with "oil" or another liquid medium, which also falls within the protection scope of this application.

Claims

1. A three-phase power-frequency dual-circuit, electromagnetic induction and short-circuit heating device for liquid, comprising: an EI-shaped core (1) having a closed three-phase magnetic circuit entirely formed by laminating silicon steel sheets, wherein primary windings, that is, three-phase primary windings (2), are respectively wound on three core legs of the EI-shaped core (1), and

further comprising: a metal housing, the metal housing comprising a first-circuit metal housing and a second-circuit metal housing, wherein the first-circuit metal housing is arranged along the closed three-phase magnetic circuit, to form secondary-side metal rings surrounding the core (1) and the respective primary windings (2); the second-circuit metal housing is arranged along outer sides of secondary sides of all phases of the three core legs of the core (1) in a first circuit; the three-phase primary windings (2), three short-circuited secondary-side metal rings (Ua, Va, Wa) of the first circuit, three short-circuited secondary-side metal rings (Ub, Vb, Wb) of a second circuit, and four short-circuited secondary-side metal rings respectively surrounding left and right portions of upper and lower yokes of the core (1) are sequentially arranged around the core legs of the EI-shaped core (1) from inside to outside; the metal housing forms a dual-circuit shell structure having 10 short-circuited secondary-side metal rings on two main heating elements inside and outside a core leg section of the core (1); and the first-circuit metal housing and the second-circuit metal housing further comprise a first shell (4-1), a rectangular tube (5), a second shell (4-2) and a flow guide member (10); and the second shell (4-2) and flow guide member (10) are formed by stamping, bending, and pressing stainless steel plates with a same thickness as those of the first shell (4-1) and the rectangular tube (5).

2. The three-phase power-frequency dual-circuit, electromagnetic induction and short-circuit heating device for liquid according to claim 1, wherein the first-circuit metal housing comprises the first shell (4-1) and two rectangular tubes (5); the second-circuit metal housing comprises the second shell (4-2) and two flow guide members (10) with folded fins at front and rear ends; and a height of the second shell (4-2) is higher than heights of the folded fins of the flow guide members (10) but lower than a height of the first shell (4-1).

3. The three-phase power-frequency dual-circuit, electromagnetic induction and short-circuit heating device for liquid according to claim 2, wherein upper and lower surfaces of the flow guide member (10) in an inner cavity of the rectangular tube (5) are welded and fixed to upper and lower inwardly folded fins of the rectangular tube (5); a straight section of the flow guide member (10) has a uniform clearance from all sides of an inner wall of the rectangular tube (5), which is equal to net heights of the upper and lower inwardly folded fins of the rectangular tube (5); and the front and rear folded fins of the flow guide member (10) respectively extend out of front and rear end surfaces of the rectangular tube (5) by a distance and are welded and fixed to the front and rear end surfaces of the rectangular tube (5).

4. The three-phase power-frequency dual-circuit, electromagnetic induction and short-circuit heating device for liquid according to claim 2 or 3, wherein there are two rectangular tubes (5), namely, a first rectangular tube (5a) and a second rectangular tube (5b); left and right surfaces of the first rectangular tube (5a) and the second rectangular tube (5b) respectively form, together with the first shell (4-1), the three short-circuited secondary-side metal rings (Ua, Va, Wa) surrounding the respective primary windings (2); there are two flow guide members (10), namely, a first flow guide member (10a) and a second flow guide member (10b); the first flow guide member (10a) and the second flow guide member (10b) respectively extend out of front and rear end surfaces of the corresponding first rectangular tube (5a) and second rectangular tube (5b) by a distance and run through front end rear surfaces of the second shell (4-2) to be welded and fixed thereto, and the second shell (4-2) has a uniform clearance from all sides of the first shell (4-1); hence, left and right surfaces of the two flow guide members (10) and the second shell (4-2) are respectively formed on outer sides of the three short-circuited secondary-side metal rings (Ua, Va, Wa), and enclose, together with the three short-circuited secondary-side metal rings (Ub, Vb, Wb) parallel thereto, the three-phase primary windings (2) to be used as the second main heating element.

5. A method for heating a liquid by using a three-phase power-frequency dual-circuit, electromagnetic induction and short-circuit heating device, wherein when the three-phase primary windings (2) of the three-phase power-frequency

dual-circuit, electromagnetic induction and short-circuit heating device for liquid of claim 1 are connected to a three-phase power-frequency power supply, high short-circuit currents are inductively generated in 10 short-circuited secondary-side metal rings of a dual-circuit metal housing; secondary sides of all phases are conducted through a same metal housing to generate high phase-to-phase short-circuit currents and high three-phase short-circuit currents; under a combined effect of the two types of high currents, the dual-circuit metal housing is rapidly heated, and generated Joule heat is transferred to a liquid medium surrounding the dual-circuit metal housing, and the metal housing is at zero potential, and is both a protective housing and a heat dissipator of the three-phase primary windings (2); inner and outer secondary-side short-circuit currents of all phases of the two circuits of the dual-circuit have a same direction, while directions of adjacent magnetic flux leakages are opposite; under a condition of a short clearance between the inner and outer secondary sides of all phases of the dual-circuit, a powerful and stable three-phase power-frequency alternating N-S magnetic field circuit is formed; hence, magnetic flux leakages are greatly reduced, and a temperature rise of the protective housing is correspondingly greatly decreased; and when flowing through a channel between the inner and outer secondary sides of the dual-circuit, a liquid medium is magnetized by a powerful alternating magnetic field while being heated, wherein magnetized water is free from scaling, and magnetized oil is free from carbon deposition.

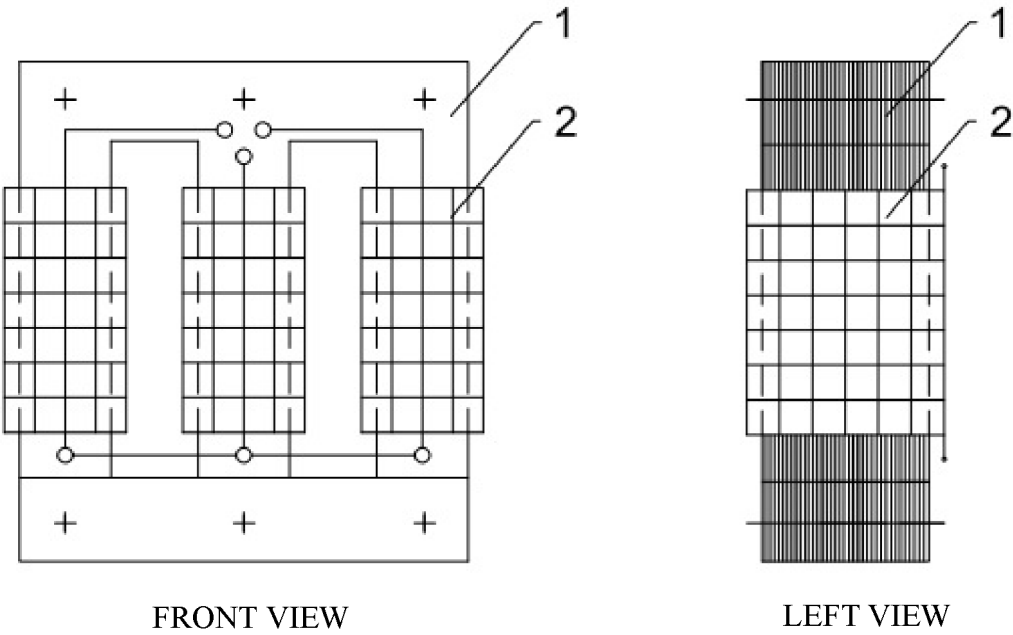


FIG. 1

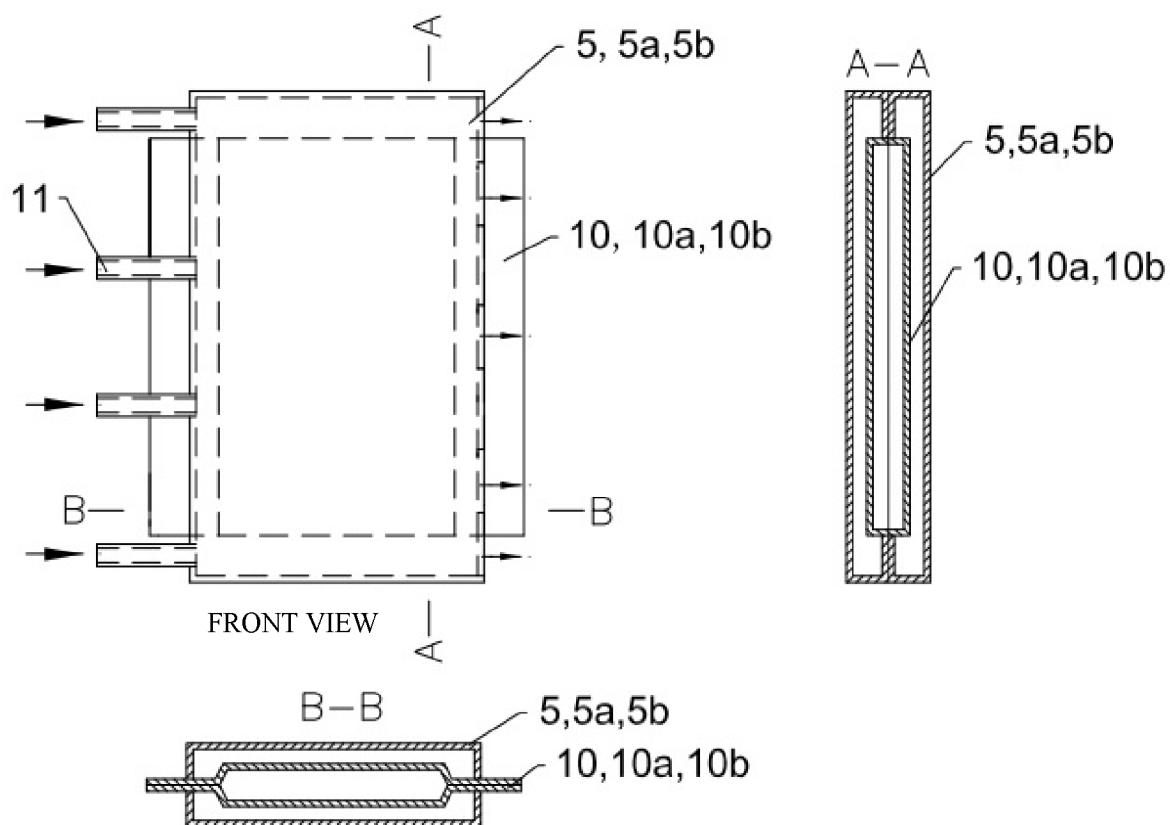


FIG. 2

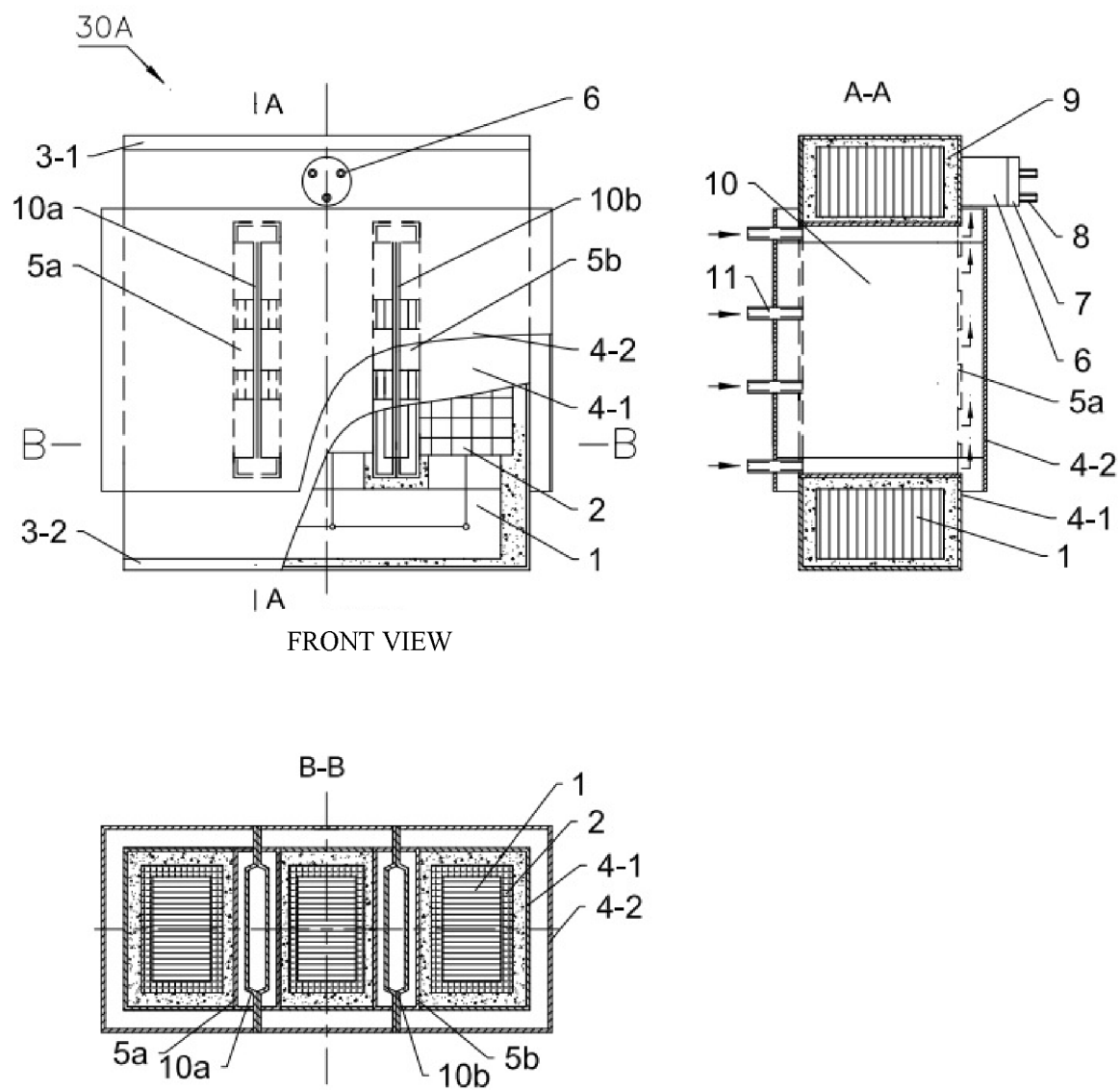


FIG. 3

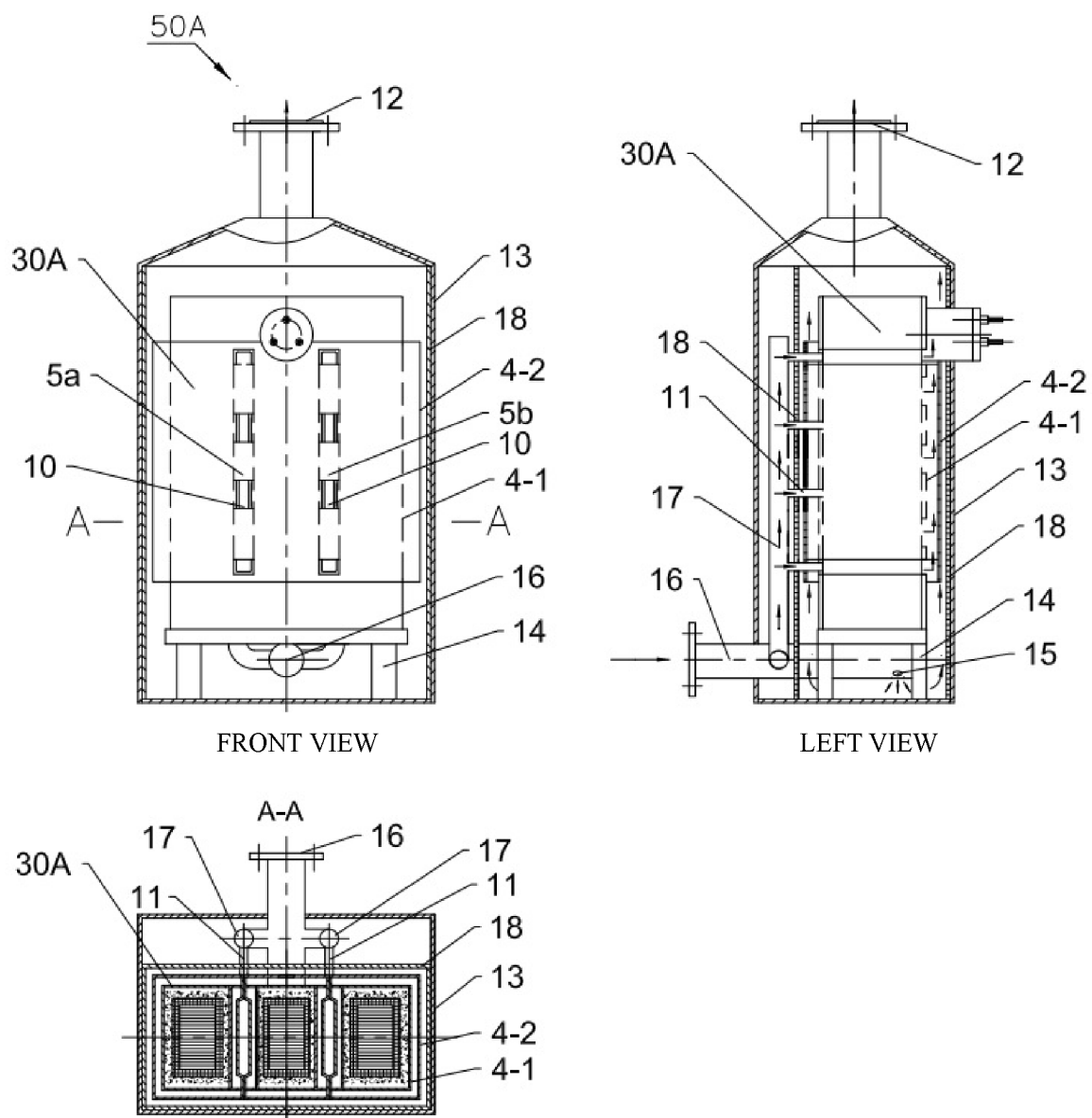


FIG. 4

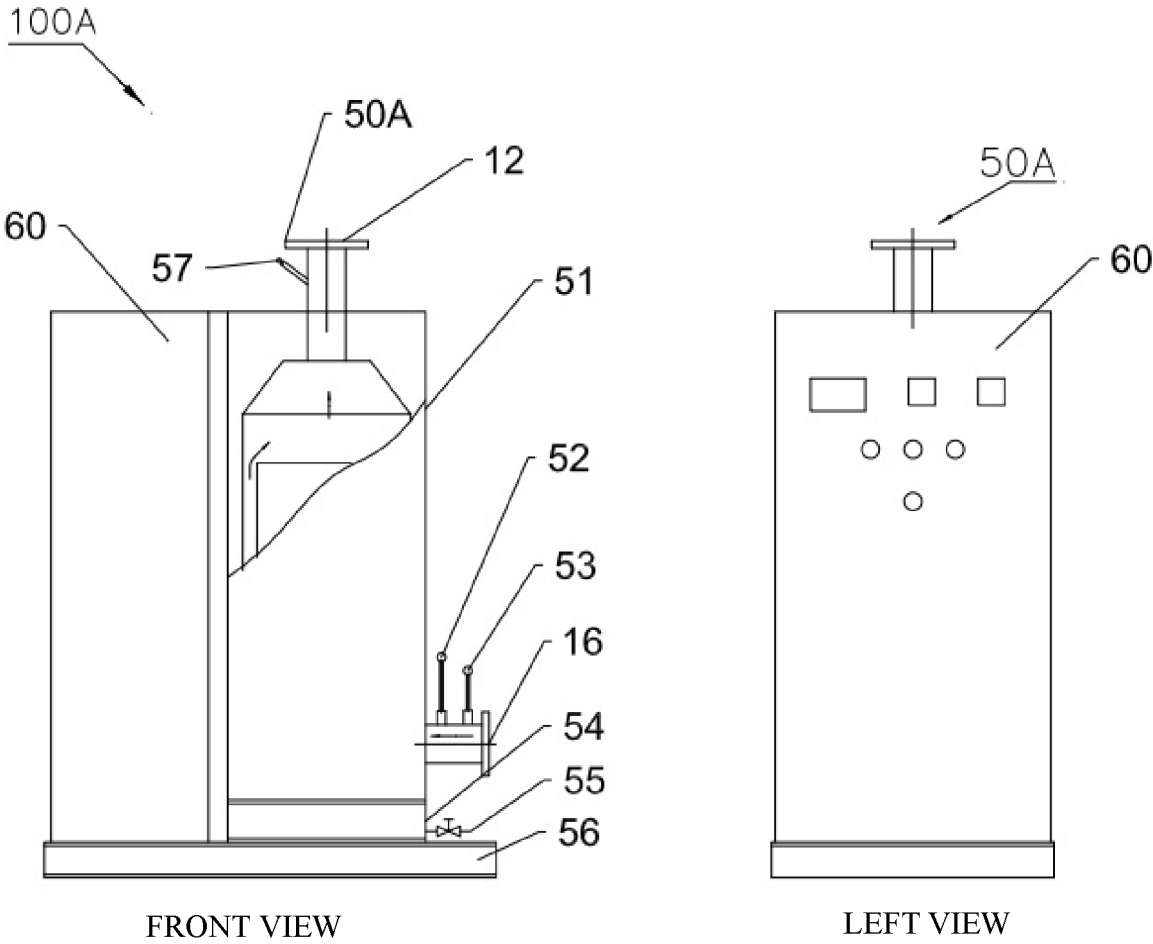


FIG. 5

INTERNATIONAL SEARCH REPORT

International application No.

PCT/CN2025/079690

A. CLASSIFICATION OF SUBJECT MATTER

H05B6/02(2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC: H05B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

CNABS: CNTXT; CNKI; WPABS; DWPI; USTXT; WOTXT; EPTXT: 电磁, 感应, 短路, 加热, 铁芯, 绕组, 外壳, 回路, 漏磁, electromagnetic, induction, short circuit, heat, core, winding, housing, loop, leakage

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	CN 200980177 Y (CHEN BINGYAN) 21 November 2007 (2007-11-21) description, page 2, line 1 to page 8, line 23, and figures 2A-3D	1, 5
A	CN 200980177 Y (CHEN BINGYAN) 21 November 2007 (2007-11-21) description, page 2, line 1 to page 8, line 23, and figures 2A-3D	2-4
A	CN 2508513 Y (WU RONGHUA) 28 August 2002 (2002-08-28) entire document	1-5
A	US 5350901 A (NIKKO K.K. et al.) 27 September 1994 (1994-09-27) entire document	1-5

☐ Further documents are listed in the continuation of Box C.☒ See patent family annex.

* Special categories of cited documents:	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"A" document defining the general state of the art which is not considered to be of particular relevance	"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
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"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	
"O" document referring to an oral disclosure, use, exhibition or other means	
"P" document published prior to the international filing date but later than the priority date claimed	

Date of the actual completion of the international search

13 March 2025

Date of mailing of the international search report

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Name and mailing address of the ISA/CN

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Telephone No.

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/CN2025/079690

Patent document cited in search report			Publication date (day/month/year)	Patent family member(s)			Publication date (day/month/year)
CN	200980177	Y	21 November 2007	None			
CN	2508513	Y	28 August 2002	None			
US	5350901	A	27 September 1994	EP	0580899	A1	02 February 1994
				JPH	06208887	A	26 July 1994

REFERENCES CITED IN THE DESCRIPTION

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- CN ZL201110340219 [0006]

Non-patent literature cited in the description

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