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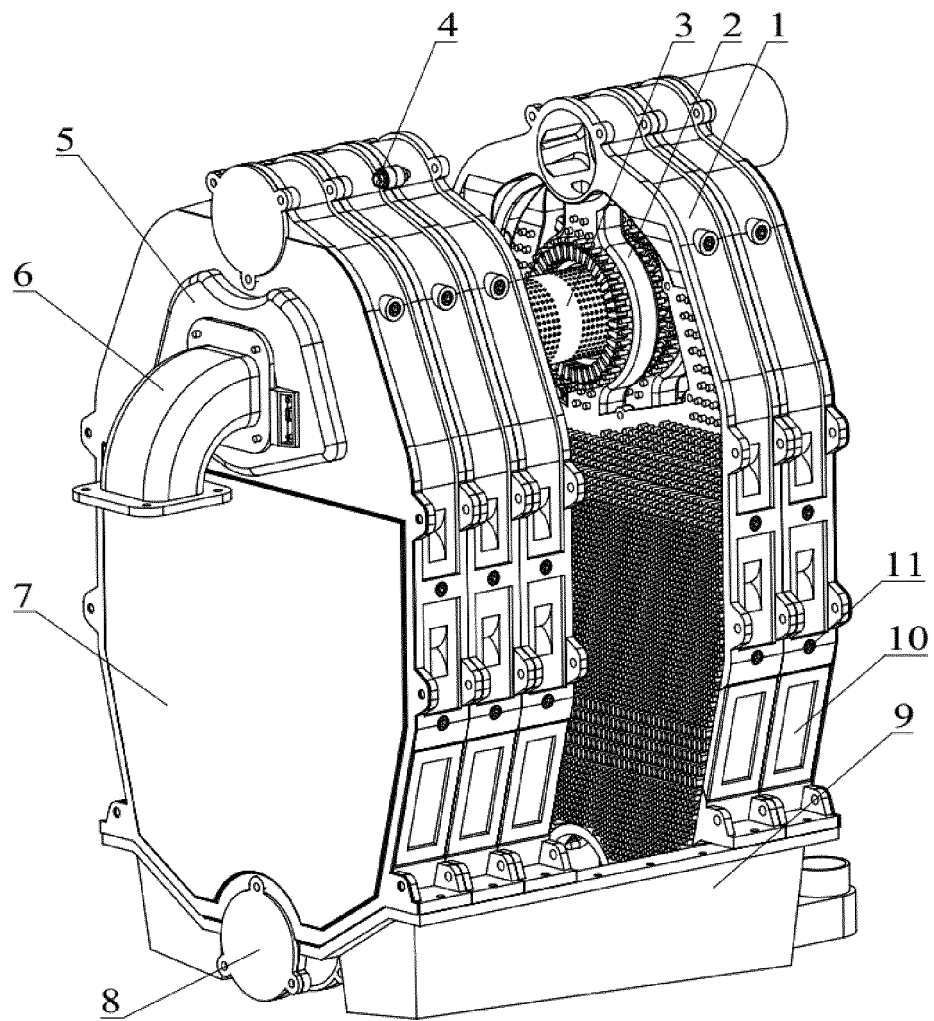
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(54) **SINGLE-BOILER-SHEET SERIES CAST ALUMINUM-SILICON WATER HEATER COUPLED TO PRE-MIXING WATER-COOLING COMBUSTOR**

(57) A premixed water-cooling combustion coupled cast-aluminum-silicon water boiler with series-connected boiler sections. A main structure is formed by axisymmetric series-connected boiler sections instead of three different boiler sections, including an upper radiation zone composed of a water-cooling combustion head, a front cover plate and a rear cover plate, a middle convection zone and condensation zone, and a lower special-shaped smoke box. A center of a combustion chamber of each boiler section is provided with a water-cooling combustion head including an annular water channel, two parallel ascending water channels or water channels respectively provided at two sides of an upper portion of a furnace. A flue gas-air mixture is ignited to burn after

passing through anti-backfire ribs and flame-stabilizing fins. The flue gas is allowed to flow downward through radiation zone, the convection zone and a pin-fin heating surface of the condensation zone, and is collected in the special-shaped smoke box. The flue gas is allowed to turn to be upwardly discharged. The boiler is provided with a header inside rather than connected to an external water channel, so as to simplify sealing, improve working efficiency, and make a boiler structure more compact. The water boiler integrates water cooling and heat exchange, reducing a temperature of the combustion area, restraining a generation of nitrogen oxides, and reducing nitrogen oxides.

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Description

TECHNICAL FIELD

[0001] This application relates to thermal engineering, and more particularly to a premixed water-cooling combustion coupled cast-aluminum-silicon water boiler with series-connected boiler sections, which has high production efficiency, low costs, reduced energy consumption and desirable reliability, and is environmentally friendly.

BACKGROUND

[0002] According to "Report on Energy and Chemical Industrial Development in China in 2020", the demand for natural gas in China will reach 329 billion cubic meters in 2020, which increases 8.8% year-on-year. Natural gas energy has become a directional energy for the adjustment of energy structure to head for, and a key alternative energy for the improvements the life qualities. Consequently, under the multiple influences of "energy conservation and emission reduction" policy, "utilization of renewable energy" policy and "coal-burning to gas-burning" policy in China, the entire industry of gas heating furnace has ushered in major development opportunities, but also challenged with more intense industry competition. In this case, the commercial gas heating furnaces that have been gradually applied in schools, hotels, hospitals must cope with two issues on both technology and development of how to effectively control costs and how to effectively save energy and reduce consumption in terms of technology and development.

[0003] Regarding the cost control, the current commercial condensing gas heating furnaces are mostly cast-aluminum-silicon condensing gas heating furnaces, which occupies a larger share due to the advantages of high thermal conductivity, simple installation and maintenance, relatively flexible design, and good corrosion resistance. Unfortunately, at present, most of the cast-aluminum-silicon condensing gas heating furnaces available on the market have a combined structure of a front boiler section, several middle boiler sections and a rear boiler section, where the front boiler section is connected to the burner head, the rear boiler section is configured to confine the flow of flue gas and support the rear part of the burner head, and the front boiler section is connected to the rear boiler section through 1-12 middle boiler sections with the same structure that are connected in series. In this case, during the production of the cast-aluminum-silicon gas heating furnace with a certain power range, it requires at least 3 sets of different molds to produce the front boiler section, the middle boiler section and the rear boiler section respectively, leading to high cost of extremely high cost of casting molds. Especially for the commercial cast-aluminum-silicon gas heating furnaces with high power and large scale, the weight of each boiler section is about 70-100 kg, and the cost of the mold corresponding to the boiler section is even more

expensive. Considering that the production quantity of the front boiler section and the rear boiler section that are connected to the burner is only 10-20% of that of the middle boiler section, in general, if the above three kinds of boiler sections can have the relatively unified structure, and the differences of non-critical details in the structures are negligible, the single boiler section enables to achieve the functions of the above three kinds of boiler sections at the same time, such that the cost of the casting molds can be lowered to one third of the cost of the casting molds of the above three kinds of casting molds, thereby not only effectively reducing the production costs, improving the production efficiency and reducing the scrap rate, but also augmenting the product series and significantly enhancing the product quality and reliability.

[0004] As for the reduction of energy consumption, considering that the commercial cast-aluminum-silicon gas heating furnaces have quite compact structures, the current gas burners generally select full-premixed metal-fiber surface burner with short flame lengths, but the smaller size of the furnace results in volumetric heat release rate of the full-premixed metal-fiber surface burner. Under the rated load, the emission of nitrogen oxides (NO_x) often exceeds 30mg/m³, which fails to meet the requirements of the pollutant emission indicators of major cities in China, such that the boiler operates at a reduced load. Unfortunately, the problems existing in the full-premixed surface combustion technology are as follows. With the increase of the air-fuel premixing ratio, the stable combustion range of the flame are narrowed, limiting the large size of the full-premixed burner. Moreover, due to the accurate proportion mixing in the full-premixed combustion, the complete combustion is performed, the combustion speed is fast, and the flame temperature is high. As a result, conventional full-premixed surface combustion technology often requires a large amount of excess air to cool the combustion area, so as reduce the generation of the nitrogen oxides (NO_x) in the combustion process. However, the higher excess air coefficient leads to increased exhaust heat loss, directly reducing the thermal efficiency of the boiler.

[0005] In order to improve the situation caused by the problems arouse by the combustion with high excess air coefficient and easy-to-flashback, technicians have developed a full-premixed water-cooling combustion technology based on the full-premixed surface combustion technology. The burner head is composed of a water-cooling tube bundle with a high heat transfer coefficient. After premixing, it is ejected through the slit between the water-cooling tube bundles and then ignited and burned. The water-cooling tube bundles will not only quickly take away the heat produced by the premixed flame at the root of the flame, effectively reducing the temperature of the combustion area, thereby suppressing the generation of thermal NO_x, but also renders flameout to protect due to the "cold wall effect" of the water-cooling tube bundles, effectively lowering the risk of the flame flash-

back of the burner head. Considering the advantages mentioned above, the full-premixed water-cooling combustion technology has been widely accepted and applied to many condensing boilers. In addition, almost all cast-aluminum-silicon condensing gas boilers available on the market are equipped with full-premixed metal fiber surface burners, where the fan equipped with the full-premixed metal fiber surface burner requires an antistatic draught fan with low power. It is necessary to choose the full premixed water-cooling burners to break through the power limitation. At present, it is unprecedented to combine the full-premixed water-cooling burner with cast-aluminum-silicon, not to mention the integrated product of the full-premixed water-cooling burner and cast-aluminum-silicon.

SUMMARY

[0006] This application provides a premixed water-cooling combustion coupled cast-aluminum-silicon water boiler with series-connected boiler sections, which combines water-cooling combustion head and axisymmetric heat exchange boiler sections. The boiler provided herein not only achieves objectives of cost control, energy saving and consumption reduction, and reduction of nitrogen oxides in the flue gas, but also lowers the unnecessary cost in the production of the cast aluminum-silicon condensing water boiler.

[0007] Technical solutions of this application are described as follows.

[0008] In a first aspect, this application provides a premixed water-cooling combustion coupled cast-aluminum-silicon water boiler with series-connected boiler sections, comprising:

a main structure;

wherein the main structure is formed by 2-12 axisymmetric boiler sections 1; for adjacent two axisymmetric boiler sections 1, a rear end surface of a former axisymmetric boiler section 1 is sealed with a front end surface of a later axisymmetric boiler section 1, and then the axisymmetric boiler sections 1 are connected in series through bolts 4 to form the main structure; the axisymmetric boiler sections 1 comprise a front boiler section, and a front cover plate 5 arranged on the front boiler section and aligned with a furnace center; the front cover plate 5 is inwardly connected to a cylindrical flow-equalizing orifice plate 3; the cylindrical flow-equalizing orifice plate 3 is supported on an annular inner wall of an annular water-cooling combustion head 2; the cylindrical flow-equalizing orifice plate 3 passes through the annular water-cooling combustion head 2 of each of the axisymmetric boiler sections 1; the front cover plate 5 is outwardly connected to a premixer through a connecting elbow 6; the axisymmetric boiler sections 1 further comprise a rear boiler section; a pin-fin portion of the front boiler section and a pin-fin

portion of the rear boiler section are respectively provided with a lined heat-insulating cover plate 7; a top end and a bottom end of the front boiler section are respectively provided with an end cap 8, wherein the end cap 8 is configured to seal a water-side header; a rear cover plate 12 is arranged on the rear boiler section and aligned with the furnace center, wherein the rear cover plate 12 is provided with a fireproof heat-insulation lining; a bottom end of the rear boiler section is provided with a water-side inlet header 13, and a top end of the rear boiler section is provided with a water-side outlet header 14, wherein the water-side inlet header 13 and the water-side outlet header 14 are configured to enable water circulation; both sides of the main structure are each provided with a detachable dust-cleaning baffle 10 and a residue discharging plug 11; a special-shaped smoke box 9 is provided at a bottom end of the main structure; and

an outer front side and an outer rear side of each of the axisymmetric boiler sections 1 are each divided into a radiation zone, a convection zone and a condensation zone in turn from top to bottom; a center of a combustion chamber in the radiation zone is provided with the annular water-cooling combustion head 2 which is integrated with or separated from the axisymmetric boiler sections 1; the annular water-cooling combustion head 2 comprises a first annular water-cooling channel 101; a plurality of first anti-backfire ribs 102 are centrosymmetrically provided on a surface of the first annular water-cooling channel 101, and a plurality of first flame holding fins 103 are centrosymmetrically provided on the surface of the first annular water-cooling channel 101; an outer side of the combustion chamber in the radiation zone, the convection zone and the condensation zone are regularly provided with circular columns 104 and waist-shaped columns 106; two sides of a bottom of each of the axisymmetric boiler sections 1 are respectively provided with a base 108, and the base 108 is connected to the special-shaped smoke box 9; a fuel gas-air mixture is allowed to enter the cylindrical flow-equalizing orifice plate 3 from the connecting elbow 6 and pass through the annular water-cooling combustion head 2, and then is uniformly ejected along an annular gap between two adjacent axisymmetric boiler sections 1 and ignited to burn at an axial interval along an annular cylindrical surface to generate flue gas; after filling the radiation zone around a furnace of the water boiler, the flue gas is allowed to flow downward through a pin-fin heating surface of the convection zone and the condensation zone and flow into the special-shaped smoke box 9 from the bottom end of the main structure; the flue gas is collected and turned to be upwardly discharged; an inside of each of the axisymmetric boiler sections 1 is configured as a hollow cavity; and return water is allowed to enter from a

first port 109 provided at the bottom of each of the axisymmetric boiler sections 1, and flows out through a second port 110 provided at a top of each of the axisymmetric boiler sections 1, wherein the first port 109 is configured for connection with the water-side inlet header 13, and the second port 110 is configured for connection with the water-side outlet header 14.

[0009] In an embodiment, the plurality of first anti-backfire ribs 102 each have a corn kernel-shaped cross section; the first anti-backfire ribs 102 are circumferentially arranged, wherein a distance between any adjacent two first anti-backfire ribs 102 is the same along a radial direction, and is 1-10 mm; a height of each of the first anti-backfire ribs 102 is set to 6-30 mm such that the fuel gas-air mixture is ejected through gaps between the adjacent two first anti-backfire ribs 102 at an average rate of 2-3 m/s;

the first flame holding fins 103 are located outside the first anti-backfire ribs 102, and are staggered with the first anti-backfire ribs 102 to stabilize a flame; the first flame holding fins 103 have the same height with the first anti-backfire ribs 102; circumferential base ribs 113 are arranged around a wall surface of the combustion chamber in the radiation zone, and each of the circumferential base ribs 113 is evenly provided with 4-8 hole seats 111 each provided with a threaded hole; and the front boiler section is connected to the front cover plate 5 through the hole seats 111, and the rear boiler section is connected to the rear cover plate 12 through the hole seats 111.

[0010] In an embodiment, the circular columns 104 and the waist-shaped columns 106 on each of the axisymmetric boiler sections 1 are arranged in different manners along a flow direction of the flue gas; with respect to the circular columns in the convection zone, a height of the circular columns 104 in the radiation zone has a smaller height but a larger diameter and larger transverse and longitudinal intercepts; as a temperature of the flue gas and radiation amount decline along the flow direction of the flue gas, the height of the circular columns 104 gradually increases; the circular columns 104 are in a close, staggered and regular triangle arrangement in the convection zone where the temperature of the flue gas is lower than 500°C, wherein a shortest distance between the circular columns 104 is 3-4 mm; in the convection zone, the circular columns 104 are of equal height, or designed in a high-low alternating manner with one or two rows of the circular columns 104 as a group, wherein a height difference is not larger than 1/3 of an average height of the circular columns 104; in the condensation zone where the temperature of the flue gas is lower than 65°C, the circular columns 104 and the waist-shaped columns 106 are arranged, wherein a longer diameter of the waist-shaped columns 106 is consistent with the flow direction of the flue gas, and a shorter diameter of the waist-shaped columns 106 is equal to a diameter of the

circular columns 104; parallel channels formed between the circular columns 104 and parallel channels formed between the waist-shaped columns 106 are configured to provide sufficient heat exchange zone for condensing the flue gas to allow continuous condensation of the flue gas; a width of the condensation zone is reduced gradually along the flow direction of the flue gas, such that a periphery of a lower portion of each of the axisymmetric boiler sections 1 is configured as U-shaped in a whole.

[0011] In an embodiment, the hollow cavity inside each of the axisymmetric boiler sections 1 is configured as a water channel space; the water channel space is divided by a longitudinal rib 115 along a vertical direction and a plurality of transverse ribs 116 along a horizontal direction; the longitudinal rib 115 is configured to divide the water channel space into two portions from left to right; a spacing between adjacent two transverse ribs 116 varies from 40 mm to 120 mm, and decreases from top to bottom; a water flow is allowed to turn upward to a bottom of the radiation zone along a serpentine curve in the water channel space within the condensation zone and the convection zone; the transverse ribs 116 provided at an upper portion of the convection zone have an inclination angle of 0-10° with the horizontal direction, and are each provided with a steam exhaust hole 114 at an end; the water channel space corresponding to the radiation zone has two kinds of structures, respectively a first structure and a second structure; the first structure is composed of the first annular water-cooling channel 101 at a furnace center of the radiation zone and water channels 112 provided at two sides of the furnace and outside a circumferential base rib 113, such that the water flow is divided at the bottom of the radiation zone, and divided water flows rise in parallel along the first annular water-cooling channel 101 and the water channels 112, respectively, join together at the second port 110; in the second structure, the water channels 112 is split by a split rib 118 into an ascending water channel 119 and a descending water channel 120, and thus the second structure is composed of the first annular water-cooling channel 101, the ascending water channel 119 and the descending water channel 120; in the second structure, the water flow is not divided at the bottom of the radiation zone, but is allowed to laterally flow to two sides of the furnace and turn 90° to enter the ascending water channel 119, ascend to the second port 110, inwardly turn 180° to flow downward to the descending water channel 120, flow to a bottom of the furnace, inwardly turn 90° to flow to the longitudinal rib 115, and upwardly turn 90° to join together and flow to the first annular water-cooling channel 101, and ascend to flow out through the second port 110.

[0012] In an embodiment, bolt holes 105, cleanout ports 107 and residue discharging holes 117 are arranged in pair at two sides of each of the axisymmetric boiler sections 1; the axisymmetric boiler sections 1 are aligned with each other, and then connected in series by inserting the bolts 4 into the bolt holes 105; an aperture of each of the cleanout ports 107 is designed to ensure

cleaning of 1/3-1/2 of the convection zone, so as to avoid opening the sealed furnace in a heating season, and the cleanout ports 107 are configured to be assembled with the detachable dust-cleaning baffle 10; the residue discharging port 117 is arranged directly opposite to a transverse rib 116, and directly penetrates through a water channel in depth; and the residue discharging port 117 is configured to be assembled with the residue discharging plug 11.

[0013] In an embodiment, the front cover plate 5 and the rear cover plate 12 are similar in structure, and are formed by the same set of molds through casting or stamping; the front cover plate 5 and the rear cover plate 12 both have a disk-like structure, and are each circumferentially provided with openings 501 at periphery for connection with circumferential base ribs 113; an inner side of the disk-like structure is centripetally provided with four supporting ribs 504 to support the cylindrical flow-equalizing orifice plate 3; a method for processing the rear cover plate 12 into the front cover plate 5 comprises: obtaining the rear cover plate 12 by casting or stamping; perforating a center of the rear cover plate 12, so as to allow installation of the cylindrical flow-equalizing orifice plate 3, and arranging threaded holes 502 at an outer end surface of the disk-like structure; and arranging an integrated monitoring system 503 comprising igniting holes, flame monitoring holes and pressure monitoring holes at the outer end surface of the disk-like structure.

[0014] In an embodiment, the axisymmetric boiler sections 1 are fabricated from ZL101 alloy, ZL102 alloy, ZL104 alloy or AlSi10Mg alloy through integrated casting molding; the condensation zone is provided with a superhydrophobic film to make the condensation zone superhydrophobic, self-cleaning and corrosion-resistant; the lined heat-insulating cover plate 7 is made from stainless steel by integrated stamping molding; the special-shaped smoke box 9 is made from polytetrafluoroethylene (PTFE), polyvinyl chloride (PVC), polypropylene (PP) or acrylonitrile butadiene styrene copolymers (ABS); the special-shaped smoke box 9 comprises a condensate receiving plate 901 and a smoke exhaust outlet 902; the condensate receiving plate 901 is a special-shaped polyhedron, whose partial cross-sectional area gradually decreases along a length direction, a width direction and a height direction to ensure that there is a lowest point therein.

[0015] In an embodiment, when the annular water-cooling combustion head 2 and the axisymmetric boiler sections 1 are in a separated structure, the annular water-cooling combustion head 2 is assembled by a plurality of water-cooling annular cavities 15, an independent inlet-outlet header 16 and an end flange 17; a main structure of each of the plurality of water-cooling annular cavities comprises a second annular water-cooling channel 1501, second anti-backfire ribs 1502 and second flame holding fins 1503; the number of the plurality of water-cooling annular cavities 15 is equal to the number of the axisymmetric boiler sections 1; two sides of an annular

inner wall of each of the plurality of water-cooling annular cavities 15 are respectively provided with a water inlet-outlet hole 1504 for butt assembly with the independent inlet-outlet header 16, so as to enable independent water circulation inside the separated structure; a front end of the annular water-cooling cavity 15 matched with the front boiler section is provided with the end flange 17 to connect the front cover plate 5 with the connecting elbow 6; at the same time, an inner wall of each of the plurality of water-cooling annular cavities 15 is provided with two arc-shaped flow-equalizing orifice plates 18; an orifice of the two arc-shaped flow-equalizing orifice plates is directly opposite to a gap between two adjacent second anti-backfire ribs 1502, and is circular, waist-shaped, elliptical or elongated; edges of the two arc-shaped flow-equalizing orifice plates 18 are respectively located on an upper side of the independent inlet-outlet header 16 and a lower side of the independent inlet-outlet header 16; the fuel gas-air mixture is fully mixed and then passes through the two arc-shaped flow-equalizing orifice plates 18, the second anti-backfire ribs 1502 and the second flame holding fins 1503, and is uniformly ejected and then ignited to burn at intervals along a circumferential gap of a cylindrical surface.

[0016] In an embodiment, when the annular water-cooling combustion head 2 and the axisymmetric boiler sections 1 are in a separated structure, the annular water-cooling combustion head 2 is cast independently as a whole; a main body of the annular water-cooling combustion head 2 comprises a plurality of annular water-cooling zones 201, anti-backfire columns 202, flame holding columns 203 and a header pipe 204, wherein the anti-backfire columns 202 and the flame holding columns 203 are evenly and centrometrically distributed on a surface of the annular water-cooling zones 201; the anti-backfire columns 202 each have a corn kernel-shaped cross section and are arranged circumferentially, wherein a distance between any two centrosymmetric anti-backfire columns 202 is equal in the radial direction, and the distance is 1-10 mm; a height of each of the anti-backfire columns 202 is 6-30 mm such that an average ejection rate of the fuel gas-air mixture through gaps between adjacent two anti-backfire columns 202 is 2-3 m/s; the flame holding columns 203 are located outside the anti-backfire columns 202 and are staggered with the anti-backfire columns 202 to stabilize the flame; the flame holding columns 203 have the same height with the anti-backfire columns 202; an outer section of the header pipe 204 is circular, oblong, elliptical or waist-shaped; the header pipe 204 is divided into a water inlet pipe 205 and a water outlet pipe 206 by a middle rib; after entering the annular water-cooling combustion head 2 from the water inlet pipe 205, cooling water is distributed to the annular water-cooling zones 201, and allowed to flow circumferentially to experience heat exchange, and then collected at the water outlet pipe 206 to complete an independent water circulation; at the same time, an inner wall of the annular water-cooling combustion head 2 is provided

with an arc-shaped flow-equalizing orifice plate 18; orifices of the arc-shaped flow-equalizing orifice plate 18 are just opposite to gaps between adjacent anti-backfire columns 202, and are circular, waist-shaped, elliptical or oblong; after being fully mixed, the fuel gas-air mixture is allowed to pass through the arc-shaped flow-equalizing orifice plate 18 to experience flow equalization, and then flow through the anti-backfire columns 202 and the flame holding columns 203, and is uniformly ejected and ignited to burn at intervals along a circumferential gap of a cylindrical surface.

[0017] In a second aspect, this application provides a premixed water-cooling combustion coupled cast-aluminum-silicon water boiler with series-connected boiler sections, comprising:

a main structure;

wherein the main structure is formed by 2-12 axisymmetric boiler sections 19; for adjacent two axisymmetric boiler sections 19, a rear end surface of a former axisymmetric boiler section 19 is sealed with a front end surface of a later axisymmetric boiler section 19, and then the axisymmetric boiler sections 19 are connected in series through bolts to form the main structure; the axisymmetric boiler sections 19 comprise a front boiler section, and a front-end cover plate 22 arranged on the front boiler section and aligned with a furnace center; the front-end cover plate 22 is inwardly connected to a rectangular flow-equalizing orifice plate 21; the rectangular flow-equalizing orifice plate 21 is supported on an inner wall of a parallel water-cooling combustion head 20; the rectangular flow-equalizing orifice plate 21 passes through the parallel water-cooling combustion head 20 of each of the axisymmetric boiler sections 19; the front-end cover plate 22 is outwardly connected to a premixer through an elbow 23; the axisymmetric boiler sections 19 further comprise a rear boiler section; a pin-fin portion of the front boiler section and a pin-fin portion of the rear boiler section are respectively provided with a heat-insulating cover plate 24; a top end and a bottom end of the front boiler section are respectively provided with an end cap 25, wherein the end cap 25 is configured to seal an inlet-outlet header; a rear-end cover plate 29 is arranged on the rear boiler section and aligned with the furnace center, wherein the rear-end cover plate 29 is provided with a fireproof heat-insulation lining; a bottom end of the rear boiler section is provided with a water inlet header pipe 30-1, and a top end of the rear boiler section is provided with a water outlet header pipe 30-2, wherein the water inlet header pipe 30-1 and the water outlet header pipe 30-2 are configured to enable water circulation; both sides of the main structure are each provided with a dust-cleaning baffle 27 and a plug 28; a smoke box 26 is provided at a bottom end of the main structure; an outer front side and an outer rear side of each of the

axisymmetric boiler sections 19 are each divided into a radiation zone, a convection zone and a condensation zone in turn from top to bottom; a center of a combustion chamber in the radiation zone is provided with the parallel water-cooling combustion head 20 which is integrated with the axisymmetric boiler sections 19; the parallel water-cooling combustion head 20 comprises two parallel water-cooling channels 1901 provided at two sides of a central rectangular sectional cavity 1904; a plurality of anti-backfire pin-fins 1902 are centrosymmetrically provided on a surface of the two parallel water-cooling channels 1901, and a plurality of flame holding fins 1903 are centrosymmetrically provided on the surface of the two parallel water-cooling channels 1901; an outer side of the combustion chamber in the radiation zone, the convection zone and the condensation zone are regularly provided with circular pin-fins 1905 and waist-shaped pin-fins 1907; two sides of a bottom of each of the axisymmetric boiler sections 19 are respectively provided with a base 1909, and the base 1909 is connected to the smoke box 26; a fuel gas-air mixture is allowed to enter the rectangular flow-equalizing orifice plate 21 from the elbow 23 and pass through the central rectangular sectional cavity 1904, and then is uniformly ejected along a gap between two adjacent axisymmetric boiler sections 19 and ignited to burn at an interval along a plane surface to generate flue gas; after filling the radiation zone around a furnace of the water boiler, the flue gas is allowed to flow downward through a pin-fin heating surface of the convection zone and the condensation zone and flow into the smoke box 26 from the bottom end of the main structure; the flue gas is collected and turned to be upwardly discharged; an inside of each of the axisymmetric boiler sections 19 is configured as a hollow cavity; and return water is allowed to enter from a first water channel port 1910 provided at the bottom of each of the axisymmetric boiler sections 19, and flows out through a second water channel port 1911 provided at a top of each of the axisymmetric boiler sections 19, wherein the first water channel port 1910 is configured for connection with the water inlet header pipe 30-1, and the second water channel port 1911 is configured for connection with the water outlet header pipe 30-2.

[0018] In an embodiment, the anti-backfire pin-fins 1902 and the flame holding fins 1903 are axisymmetrically and evenly distributed on a surface of the parallel water-cooling channels 1901, the anti-backfire pin-fins 1902 each have an oblong cross-section or a rectangular cross-section; a distance between any two adjacent anti-backfire pin-fins 1902 is 1-10 mm, a height of each of the anti-backfire pin-fins 1902 is 6-30 mm, such that an average ejection rate of the fuel gas-air mixture through gaps between adjacent two anti-backfire pin-fins 1902 is

2-3 m/s; the flame holding fins 1903 are arranged outside the anti-backfire pin-fins 1902, and are staggered with the anti-backfire pin-fins 1902 to stabilize a flame; circumferential ribs 1913 are arranged around a wall surface of the combustion chamber in the radiation zone, and each of the circumferential ribs 1913 is evenly provided with 4-8 hole seats 1914; and 4-8 hole seats 1914 are each provided with a threaded hole; and the front boiler section is connected to the front-end cover plate 22 through the hole seats 1914, and the rear boiler section is connected to the rear-end cover plate 29 through the hole seats 1914.

[0019] In an embodiment, the circular pin-fins 1905 and the waist-shaped pin-fins 1907 on each of the axisymmetric boiler sections 19 are arranged in different manners along a flow direction of the flue gas; with respect to the circular pin-fins in the convection zone, a height of the circular pin-fins 1905 in the radiation zone has a smaller height but a larger diameter and larger transverse and longitudinal intercepts; as a temperature of the flue gas and radiation amount decline along the flow direction of the flue gas, the height of the circular pin-fins 1905 gradually increases; the circular pin-fins 1905 are in a close, staggered and regular triangle arrangement in the convection zone where the temperature of the flue gas is lower than 500°C, wherein a shortest distance between the circular pin-fins 1905 is 3-4 mm; in the convection zone, the circular pin-fins 1905 are of equal height, or designed in a high-low alternating manner with one or two rows of the circular pin-fins 1905 as a group, wherein a height difference is not larger than 1/3 of an average height of the circular pin-fins 1905; in the condensation zone where the temperature of the flue gas is lower than 65°C, the circular pin-fins 1905 and the waist-shaped pin-fins 1907 are arranged, wherein a longer diameter of the waist-shaped pin-fins 1907 is consistent with the flow direction of the flue gas, and a shorter diameter of the waist-shaped pin-fins 1907 is equal to a diameter of the circular pin-fins 1905; parallel channels formed between the circular pin-fins 1905 and parallel channels formed between the waist-shaped pin-fins 1907 are configured to provide sufficient heat exchange zone for condensing the flue gas to allow continuous condensation of the flue gas; a width of the condensation zone is reduced gradually along the flow direction of the flue gas, such that a periphery of a lower portion of each of the axisymmetric boiler sections 19 is configured as U-shaped in a whole.

[0020] In an embodiment, the hollow cavity inside each of the axisymmetric boiler sections 19 is configured as a water channel space; the water channel space is divided by a longitudinal rib 1916 along a vertical direction and a plurality of transverse ribs 1917 along a horizontal direction; the longitudinal rib 1916 is configured to divide the water channel space into two portions from left to right; a spacing between adjacent two transverse ribs 1917 varies from 40 mm to 120 mm, and decreases from top to bottom; an outside water channel 1912 is provided outside the furnace of the radiation zone; a water flow is

allowed to turn upward to a bottom of the radiation zone along a serpentine curve in the water channel space within the condensation zone and the convection zone; the water flow is divided at the bottom of the radiation zone, and divided water flows rise in parallel along the parallel water-cooling channel 1901 and the outside water channel 1912, respectively, join together at the second water channel port 1911; the transverse ribs 1917 provided at an upper portion of the convection zone have an inclination angle of 0-10° with the horizontal direction, and are each provided with a steam exhaust hole at an end 1915.

[0021] In an embodiment, connecting holes 1906, cleanout grooves 1908 and residue discharging holes 1918 are arranged in pair at two sides of each of the axisymmetric boiler sections 19; the axisymmetric boiler sections 19 are aligned with each other, and then connected in series through the connecting holes 1906; a width of each of the cleanout grooves 1908 is designed to ensure cleaning of 1/3-1/2 of the convection zone, so as to avoid opening the sealed furnace in a heating season, and the cleanout grooves 1908 are configured to be assembled with the dust-cleaning baffle 27; the residue discharging hole 1918 is arranged directly opposite to a transverse rib 1917, and directly penetrates through a water channel in depth; and the residue discharging hole 1918 is configured to be assembled with the plug 28.

[0022] In an embodiment, the front-end cover plate 22 and the rear-end cover plate 29 are similar in structure, and are formed by the same set of molds through casting or stamping; the front-end cover plate 22 and the rear-end cover plate 29 both have a disk-like structure, and are each circumferentially provided with openings 2201 at periphery for connection with circumferential ribs 1913; an inner side of the disk-like structure is centripetally provided with four supporting ribs 2204 to support the rectangular flow-equalizing orifice plate 21; a method for processing the rear-end cover plate 29 into the front-end cover plate 22 comprises: obtaining the rear-end cover plate 29 by casting or stamping; perforating a center of the rear-end cover plate 29, so as to allow installation of the rectangular flow-equalizing orifice plate 21, and arranging threaded holes 2202 at an outer end surface of the disk-like structure; and arranging an integrated seat 2203 of monitoring system comprising igniting holes, flame monitoring holes and pressure monitoring holes at the outer end surface of the disk-like structure.

[0023] In a third aspect, this application provides a premixed water-cooling combustion coupled cast-aluminum-silicon water boiler with series-connected boiler sections, comprising:

a main structure;

wherein the main structure is formed by 2-12 symmetric boiler sections 31; for adjacent two symmetric boiler sections 31, a rear end surface of a former symmetric boiler section 31 is sealed with a front end surface of a later symmetric boiler section 31, and then the symmetric boiler sections 31 are connected

in series through bolts to form the main structure; two sides of a top of a furnace of each of the symmetric boiler sections 31 are respectively provided with an isobaric air blower distributor 32; the symmetric boiler sections 31 further comprise a rear boiler section; a pin-fin portion of the front boiler section and a pin-fin portion of the rear boiler section are respectively provided with a heat-insulating cover plate 33; a top end and a bottom end of the front boiler section are respectively provided with an end cap 34, wherein the end cap 34 is configured to seal a header; a bottom end of the rear boiler section is provided with a water-inlet header pipe 37-1, and a top end of the rear boiler section is provided with a water-outlet header pipe 37-2, wherein the water-inlet header pipe 37-1 and the water-outlet header pipe 37-2 are configured to enable water circulation; both sides of the main structure are each provided with a detachable dust-cleaning cover plate 35 and a sealed plug 36; a smoke discharging box 34 is provided at a bottom end of the main structure; and an outer front side and an outer rear side of each of the symmetric boiler sections 31 are each divided into a radiation zone, a convection zone and a condensation zone in turn from top to bottom; a fuel gas-air mixture is fully mixed and then divided to flow into the isobaric air blower distributors 32, and is uniformly ejected along a gap between two adjacent symmetric boiler sections 31; two sides of a top of the furnace are respectively provided with a first water channel 3101 to be configured as a water-cooling combustion head; the water-cooling combustion head is provided with anti-backfire fins 3102 and flame holding ribs 3103; an outer side of the combustion chamber in the radiation zone, the convection zone and the condensation zone are regularly provided with circular fins 3104 and waist-shaped fins 3106; two sides of a bottom of each of the symmetric boiler sections 31 are respectively provided with a base 3108, and the base 3108 is connected to the smoke discharging box 34; the radiation zone is configured as a radiation space of a flame; the flue gas is allowed to flow downward through a pin-fin heating surface of the convection zone and the condensation zone and flow into the smoke discharging box 34 from the bottom end of the main structure; the flue gas is collected and turned to be upwardly discharged; an inside of each of the symmetric boiler sections 31 is configured as a hollow cavity; and return water is allowed to enter from an inlet 3109 provided at the bottom of each of the symmetric boiler sections 31, and flows out through an outlet 3110 provided at a top of each of the symmetric boiler sections 31, wherein the inlet 3109 is configured for connection with the water-inlet header pipe 37-1, and the outlet 3110 is configured for connection with the water-outlet header pipe 37-2.

[0024] In an embodiment, the fuel gas-air mixture is ignited to burn after passing through the anti-backfire fins 3102 and the flame holding ribs 3103; the anti-backfire fins 3102 each have a rectangular cross-section or an oblong cross-section, wherein a distance between any two adjacent anti-backfire fins 3102 is 1-10 mm; a height of each of the anti-backfire fins 3102 is 6-30 mm such that an average ejection rate of the fuel gas-air mixture through gaps between adjacent two anti-backfire fins 3102 is 2-3 m/s; the flame holding ribs 3103 are located outside the anti-backfire fins 3102 and are staggered with the anti-backfire fins 3102 to stabilize the flame; the flame holding ribs 3103 have the same height with the anti-backfire fins 3102; a plurality of supporting hole seats 3111 are each provided with a threaded hole, and are arranged on two sides of a top of each of the symmetric boiler sections 31; and the plurality of supporting hole seats 3111 are connected to the isobaric air blower distributor 32.

[0025] In an embodiment, the circular fins 3104 and the waist-shaped fins 3106 on each of the symmetric boiler sections 31 are arranged in different manners along a flow direction of the flue gas; with respect to the circular fins in the convection zone, a height of the circular fins 3104 in the radiation zone has a smaller height but a larger diameter and larger transverse and longitudinal intercepts; as a temperature of the flue gas and radiation amount decline along the flow direction of the flue gas, the height of the circular fins 3104 gradually increases; the circular fins 3104 are in a close, staggered and regular triangle arrangement in the convection zone where the temperature of the flue gas is lower than 500°C, wherein a shortest distance between the circular fins 3104 is 3-4 mm; in the convection zone, the circular fins 3104 are of equal height, or designed in a high-low alternating manner with one or two rows of the circular fins 3104 as a group, wherein a height difference is not larger than 1/3 of an average height of the circular fins 3104; in the condensation zone where the temperature of the flue gas is lower than 65°C, the circular fins 3104 and the waist-shaped fins 3106 are arranged, wherein a longer diameter of the waist-shaped fins 3106 is consistent with the flow direction of the flue gas, and a shorter diameter of the waist-shaped fins 3106 is equal to a diameter of the circular fins 3104; parallel channels formed between the circular fins 3104 and parallel channels formed between the waist-shaped fins 3106 are configured to provide sufficient heat exchange zone for condensing the flue gas to allow continuous condensation of the flue gas; a width of the condensation zone is reduced gradually along the flow direction of the flue gas, such that a periphery of a lower portion of each of the symmetric boiler sections 31 is configured as U-shaped in a whole.

[0026] In an embodiment, the hollow cavity inside each of the symmetric boiler sections 31 is configured as a second water channel; the second water channel is divided by a center rib 3114 along a vertical direction and a plurality of straight ribs 3115 along a horizontal direc-

tion; the center rib 3114 is configured to divide the second water channel into two portions from left to right; a spacing between adjacent two straight ribs 3115 varies from 40 mm to 120 mm; as a height of the plurality of straight ribs increases, a height of a cross-section decreases, so as to ensure that the height of the cross-section around the radiation zone is about 1/2 of a highest height of the cross-section; the center rib 3114 and the plurality of the straight ribs 3115 form symmetrical serpentine water channels 3112 from left to right; the plurality of straight ribs 3115 provided at an upper portion of the convection zone has an inclination angle of 0-10°, and are processed with steam discharging holes 3113 at an end; return water is allowed to flow into the symmetric boiler sections 31, turn along the symmetrical serpentine water channels 3112, ascend to turn to the first water channels 3101 provided at two sides of the furnace, join together at the outlet 3110 provided at a top of each of the symmetric boiler sections 31, and then flow out.

[0027] In an embodiment, connecting holes 3105, dust cleanout ports 3107 and residue discharging holes 3116 are arranged in pair at two sides of each of the symmetric boiler sections 31; the symmetric boiler sections 31 are aligned with each other, and then connected in series; an aperture of each of the dust cleanout ports 3107 is designed to ensure cleaning of 1/3-1/2 of the convection zone, so as to avoid opening the sealed furnace in a heating season, and the dust cleanout ports 3107 are configured to be assembled with the dust-cleaning cover plate 35; the residue discharging port 3116 is arranged directly opposite to a transverse rib 3115, and directly penetrates through a water channel in depth; and the residue discharging port 3116 is configured to be assembled with the sealed plug 36.

[0028] Compared with the prior art, this application has the following beneficial effects.

1. The water-cooling premixed combustion technology and the structure of the series-connected boiler sections are applied to the cast aluminum silicon condensing water boiler to simplify the casting mold, lower cost and improve the product quality. The partial heat exchange structure of the boiler section acts as a combustion head of the full-premixed water-cooling combustor to integrate the combustor with the cast aluminum-silicon heat exchanger, so as to allow the heat exchanger to have the combustor and the combustor have the heat exchanger.

2. The boiler provided herein is designed based on the principle of water-cooling premixed combustion. The water-cooling channels are added in the combustion chamber in different forms to allow the high temperature caused by the flame generated by the full-premixed combustor reduces quickly, so as to restrict the generation of the thermal nitrogen oxides (NO_x), thereby reducing the nitrogen NO_x

3. The structure of the main body of the boiler provided herein is symmetrical. Considering that the

conventional cast aluminum-silicon condensing water boiler requires a set of symmetrical molds for molding front boiler sections, middle boiler sections and rear boiler sections to complete the design of the furnace design, the structure provided herein is optimized to be cast by only one general mold, not only simplifying the production process, but also controlling the casting cost, effectively.

4. According to the requirement of large capacity, this application provides a design of the left and right split water channels, such that the heat exchange unit is wider, and the maximum capacity of the condensing boiler of this application can be increased by about 30% compared with a traditional boiler. In addition, the working medium does not drop during the entire flow in each independent pipe, which not only ensures that the molding sand can be poured out and the flow distribution is uniform, but also prevents the deterioration of heat transfer caused by subcooled boiling, and improve the corrosion resulted from the retention of the cold working medium, which is caused by the long-time drying protection during the non-heating period. Rather than connected to an external water tank, the design is provided with a header inside, so as to simplify the assembly process, reduce the sealing workload, improve production efficiency, and allow the condensing boiler to be more compact.

5. This application provides the double-U-shaped outlet design with a gradual shortening of the local part of the flue gas convection heating surface and an elongation of the mainstream area in the flue gas convection heating surface, which improves the heat exchange intensity per unit area effectively reduces the redundant heat exchange zone with the flowing speed varying uniformly, so as to reduce the weight and cost of the condensing water boilers. In addition, the flue gas side is provided with uniform groups of one to three rows of pin-fins arranged in a high-low staggered manner. The latter half of the flue gas convection heating surface (condensation heat exchange zone) are mainly provided with downstream waist-shaped pin-fins. The parallel channels between each two waist-shaped pin-fins enable to provide sufficient and continuous condensation space for the flue gas, so that the condensate is allowed to be discharged more easily under the carrying of the mainstream flue gas, thereby improving the overall heat and mass transfer performance.

BRIEF DESCRIPTION OF THE DRAWINGS

[0029]

Fig. 1a is an axonometric drawing of a premixed water-cooling combustion coupled cast-aluminum-silicon water boiler with series-connected boiler sections according to an embodiment of this application;

Fig. 1b is a front view of the premixed water-cooling combustion coupled cast-aluminum-silicon water boiler with series-connected boiler sections according to an embodiment of this application;

Fig. 2a is an axonometric drawing of each of the axisymmetric boiler sections;

Fig. 2b is a front view of each of the axisymmetric boiler sections;

Fig. 2c is a right view of each of the axisymmetric boiler sections;

Fig. 2d is a cross-sectional view of each of the axisymmetric boiler sections;

Fig. 2e is a cross-sectional view of each of the axisymmetric boiler sections;

Fig. 3 is a schematic diagram of a water-cooling channel of an integrated axisymmetric boiler section;

Fig. 4a is an axonometric drawing of a structure of downstream waist-shaped pin-fins in a condensing heat exchange zone of each of the axisymmetric boiler sections;

Fig. 4b is a front view of the structure of the downstream waist-shaped pin-fins in the condensing heat exchange zone of each of the axisymmetric boiler sections;

Fig. 5a is a front view of a front cover plate;

Fig. 5b is a back view of the front cover plate;

Fig. 6a is a front view of the rear cover plate;

Fig. 6b is a back view of the rear cover plate;

Fig. 7a is a front view of a special-shaped smoke box;

Fig. 7b is a right view of the special-shaped smoke box;

Fig. 8a is an axonometric drawing of a water-cooling combustion head assembled by water-cooling annular cavities;

Fig. 8b is a front view of the water-cooling combustion head assembled by the water-cooling annular cavities;

Fig. 8c is an A-A sectional view of the water-cooling combustion head assembled by the water-cooling annular cavities;

Fig. 9a is a front view of each of the water-cooling annular cavities;

Fig. 9b is a right view of each of the water-cooling annular cavities;

Fig. 9c is a schematic diagram of a water flow in each of the annular cavities according to Fig. 8c;

Fig. 10a is an axonometric drawing of an annular water-cooling combustion head;

Fig. 10b is a front view of the annular water-cooling combustion head;

Fig. 10c is a left view of the annular water-cooling combustion head;

Fig. 10d is an A-A sectional view of the annular water-cooling combustion head;

Fig. 10e is a B-B cross-sectional view of a water flow process in the annular water-cooling combustion head;

Fig. 11a is an axonometric drawing of a premixed

water-cooling combustion coupled cast-aluminum-silicon water boiler with series-connected boiler sections according to another embodiment of this application;

Fig. 11b is a front view of the premixed water-cooling combustion coupled cast-aluminum-silicon water boiler according to another embodiment of this application;

Fig. 12a is a front view of each of the axisymmetric boiler sections;

Fig. 12b is a left view of each of the axisymmetric boiler sections;

Fig. 12c is a cross-sectional view of each of the axisymmetric boiler sections;

Fig. 13 is a schematic diagram of water-cooling channels of each of the axisymmetric boiler sections;

Fig. 14a is a front view of a front-end cover plate;

Fig. 14b is a back view of the front-end cover plate;

Fig. 15a is a front view of a rear-end cover plate;

Fig. 15b is a back view of the rear-end cover plate;

Fig. 16a is an axonometric drawing of a premixed water-cooling combustion coupled cast-aluminum-silicon water boiler with series-connected boiler sections assembled by a combination of the boiler sections and an isobaric air blower distributor according to an embodiment of this application;

Fig. 16b is a front view of the premixed water-cooling combustion coupled cast-aluminum-silicon water boiler with symmetrical series-connected boiler sections assembled by a combination of the boiler sections and the isobaric air blower distributor;

Fig. 17a is a front view of each of the symmetrical boiler sections;

Fig. 17b is a right view of each of the symmetrical boiler sections; and

Fig. 17c is a cross-sectional view of each of the symmetrical boiler sections.

DETAILED DESCRIPTION OF EMBODIMENTS

[0030] This application will be described in detail below with reference to the accompanying drawings and specific embodiments.

Embodiment 1

[0031] Referring to an embodiment shown in Figs. 1a and 1b, an X-axis is a first direction, a Y-axis is a second direction. A front provided in this description refers to a front along the first direction, and a rear provided in this description refers to a rear along the first direction. This application provides a premixed water-cooling combustion coupled cast-aluminum-silicon water boiler with series-connected boiler sections. The boiler includes a main structure. The main structure is formed by 2-12 axisymmetric boiler sections 1. For adjacent two axisymmetric boiler sections 1, a rear end surface of a former axisymmetric boiler section 1 is sealed with a front end

surface of a later axisymmetric boiler section 1, and then the axisymmetric boiler sections 1 are connected in series through bolts 4 to form the main structure. The axisymmetric boiler sections 1 comprise a front boiler section, and a front cover plate 5 is arranged at on the front boiler section and aligned with a furnace center. The front cover plate 5 is inwardly connected to a cylindrical flow-equalizing orifice plate 3. The cylindrical flow-equalizing orifice plate 3 is supported on an annular inner wall of an annular water-cooling combustion head 2. The cylindrical flow-equalizing orifice plate 3 passes through the annular water-cooling combustion head 2 of each of the axisymmetric boiler sections 1. The front cover plate 5 is outwardly connected to a premixer through a connecting elbow 6. A first boiler section of the axisymmetric boiler sections 1 along the first direction is the front boiler section, and a last boiler section of the axisymmetric boiler sections 1 along the first direction is a rear boiler section. The axisymmetric boiler sections 1 further comprise a rear boiler section. A pin-fin portion of the front boiler section and a pin-fin portion of the rear boiler section are respectively provided with a lined heat-insulating cover plate 7. Atop end and a bottom end of the front boiler section are respectively provided with an end cap 8, where the end cap 8 is configured to seal a water-side header. A rear cover plate 12 is arranged on the rear boiler section and aligned with the furnace center, where the rear cover plate 12 is provided with a fireproof heat-insulation lining. A bottom end of the rear boiler section is provided with a water-side inlet header 13, and a top end of the rear boiler section is provided with a water-side outlet header 14, where the water-side inlet header 13 and the water-side outlet header 14 are configured to enable water circulation. Two sides of the main structure along the second direction are respectively provided with a detachable dust-cleaning baffle 10 and a residue discharging plug 11. A special-shaped smoke box 9 is provided at a bottom end of the main structure.

[0032] As shown in Figs 2a, 2b and 2c, an outer front side and an outer rear side of each of the axisymmetric boiler sections 1 are each divided into a radiation zone, a convection zone and a condensation zone in turn from top to bottom. A center of a combustion chamber in the radiation zone is provided with the annular water-cooling combustion head 2, which is integrated with or separate from the axisymmetric boiler sections 1. The annular water-cooling combustion head 2 includes a first annular water-cooling channel 101. A plurality of first anti-backfire ribs 102 are centrosymmetrically provided on a surface of the first annular water-cooling channel 101, and a plurality of first flame holding fins 103 are centrosymmetrically provided on the surface of the first annular water-cooling channel 101. An outer side of the combustion chamber in the radiation zone, the convection zone and the condensation zone are regularly provided with circular columns 104 and waist-shaped columns 106. Two sides of the bottom of each of the axisymmetric boiler sections 1 are respectively provided with a base 108, and

the base 108 is connected to the special-shaped smoke box 9. A flue gas-air mixture is allowed to enter the cylindrical flow-equalizing orifice plate 3 from the connecting elbow 6, and pass through the annular water-cooling combustion head 2, and then is uniformly ejected along an annular gap between two adjacent axisymmetric boiler sections 1 and ignited to burn at an axial interval along an annular cylindrical surface to generate flue gas. After filling the radiation zone around a furnace of the water boiler, the flue gas is allowed to flow downward through a pin-fin heating surface of the convection zone and the pin-fin heating surface of the condensation zone and flow into the special-shaped smoke box 9 from the bottom end of the main structure. The flue gas is collected and turned to be upwardly discharged. An inside of each of the axisymmetric boiler sections 1 is configured as a hollow cavity. Return water is allowed to enter from a first port 109 provided at the bottom of each of the axisymmetric boiler sections 1, and flows out through a second port 110 provided at a top of each of the axisymmetric boiler sections 1, where the first port 109 is configured for connection with the water-side inlet header 13, and the second port 110 is configured for connection with the water-side outlet header 14.

[0033] Bolt holes 105, cleanout ports 107 and residue discharging holes 117 are arranged in pair at two sides of each of the axisymmetric boiler sections 1. The axisymmetric boiler sections 1 are aligned with each other, and then connected in series by inserting the bolts 4 into the bolt holes 105. An aperture of each of the cleanout ports 107 is designed to ensure cleaning of 1/3-1/2 of the convection zone, so as to avoid opening the sealed furnace in a heating season, and the cleanout ports 107 are configured to be assembled with the detachable dust-cleaning baffle 10. The residue discharging port 117 is arranged directly opposite to a transverse rib 116, and directly penetrates through a water channel in depth. The residue discharging port 117 is configured to be assembled with the residue discharging plug 11.

[0034] As shown in Figs. 2d and 3, the plurality of first anti-backfire ribs 102 each have a corn kernel-shaped cross section. The first anti-backfire ribs 102 are circumferentially arranged, where a distance between any adjacent two first anti-backfire ribs 102 is the same along a radial direction, and is 1-10 mm. A height of each of the first anti-backfire ribs 102 is set to 6-30 mm, such that the fuel gas-air mixture is ejected through gaps between the adjacent two first anti-backfire ribs 102 at an average rate of 2-3 m/s. The first flame holding fins 103 are located outside the first anti-backfire ribs 102, and are staggered with the first anti-backfire ribs 102 to stabilize a flame. The first flame holding fins 103 have the same height with the first anti-backfire ribs 102. Circumferential base ribs 113 are arranged around a wall surface of the combustion chamber in the radiation zone, and each of the circumferential base ribs 113 is evenly provided with 4-8 hole seats 111. Each of the 4-8 hole seats 111 is provided with a threaded hole. The front boiler section is connected

to the front cover plate 5 through the hole seats 111, and the rear boiler section is connected to the rear cover plate 12 through the hole seats 111.

[0035] In this embodiment, the hollow cavity inside each of the axisymmetric boiler sections 1 is configured as a water channel space. The water channel space is divided by a longitudinal rib 115 along a vertical direction and a plurality of transverse ribs 116 along a horizontal direction. The longitudinal rib 115 is configured to divide the water channel space into two portions from left to right. A spacing between each two transverse ribs 116 varies from 40 mm to 120 mm, and decreases from top to bottom. A water flow is allowed to turn upward to a bottom of the radiation zone along a serpentine curve in the water channel space within the condensation zone and the convection zone. The transverse ribs 116 provided at an upper portion of the convection zone have an inclination angle of 0-10° with the horizontal direction, and are each provided with a steam exhaust hole 114 at an end. A first structure of the water channel space corresponding to the radiation zone is composed of the first annular water-cooling channel 101 at a furnace center of the radiation zone and water channels 112 provided at two sides of the furnace and outside a circumferential base rib 113, such that the water flow is divided at the bottom of the radiation zone, and divided water flows rise in parallel along the first annular water-cooling channel 101 and the water channels 112, respectively, join together at the second port 110.

[0036] As shown in Figs. 4a and 4b, the circular columns 104 and the waist-shaped columns 106 on each of the axisymmetric boiler sections 1 are arranged in different manners along a flow direction of the flue gas. With respect to the circular columns in the convection zone, a height of the circular columns 104 in the radiation zone has a smaller height but a larger diameter and larger transverse and longitudinal intercepts. As a temperature of the flue gas and radiation amount decline along the flow direction of the flue gas, the height of the circular columns 104 gradually increases. The circular columns 104 are in a close, staggered and regular triangle arrangement in the convection zone where the temperature of the flue gas is lower than 500°C, and a shortest distance between the circular columns 104 is 3-4 mm. In the convection zone, the circular columns 104 are of equal height, or designed in a high-low alternating manner with one or two rows of the circular columns 104 as a group, where a height difference is no larger than 1/3 of an average height of the circular columns 104. In the condensation zone where the temperature of the flue gas is lower than 65°C, the circular columns 104 and the waist-shaped columns 106 are arranged, where a longer diameter of the waist-shaped columns 106 is consistent with the flow direction of the flue gas, and a shorter diameter of the waist-shaped columns 106 is equal to a diameter of the circular columns 104. Parallel channels between circular columns 104 and parallel channels between the waist-shaped columns 106 are configured to

provide a sufficient heat exchange zone for condensing the flue gas to allow continuous condensation of the flue gas.

[0037] As shown in Figs. 5a, 5b, 6a and 6b, the front cover plate 5 and the rear cover plate 12 are similar in structure, and are formed by the same set of molds through casting or stamping. The front cover plate 5 and the rear cover plate 12 both have a disk-like structure, and are each circumferentially provided with openings 501 at periphery for connection with circumferential base ribs 113. An inner side of the front cover plate 5 is centripetally provided with four supporting ribs 504 to support the cylindrical flow-equalizing orifice plate 3. A method for processing the rear cover plate 12 into the front cover plate 5 is specifically performed as follows. The rear cover plate 12 is obtained by casting or stamping. A center of the rear cover plate 12 is perforated, so as to allow installation of the cylindrical flow-equalizing orifice plate 3, and threaded holes 502 are provided at an outer end surface of the front cover plate 5. An integrated monitoring system 503 including igniting holes, flame monitoring holes and pressure monitoring holes is arranged on the outer end surface of the front cover plate 5.

[0038] As shown in Figs. 7a and 7b, the special-shaped smoke box 9 is made from polytetrafluoroethylene (PTFE), polyvinyl chloride (PVC), polypropylene (PP) or acrylonitrile butadiene styrene copolymers (ABS). The special-shaped smoke box includes a condensate receiving plate 901 and a smoke exhaust outlet 902. The condensate receiving plate 901 is a special-shaped polyhedron, whose partial cross-sectional area gradually decreases along a length direction, a width direction and a height direction to ensure that there is a lowest point therein.

Embodiment 2

[0039] In this embodiment, the same symbols are given to the same structures as those in **Embodiment 1**, and the same descriptions are omitted.

[0040] Referring to an embodiment shown in Figs 2d and 2e, a second structure of water channel space is provided, where the water channels 112 is split by a split rib 118 into an ascending water channel 119 and a descending water channel 120, and thus the second structure is composed of the first annular water-cooling channel 101, the ascending water channel 119 and the descending water channel 120. In the second structure, the water flow is not divided at the bottom of the radiation zone, but is allowed to laterally flow to two sides of the furnace and turn 90° to enter the ascending water channel 119, ascend to the second port 110, inwardly turn 180° to flow downward to the descending water channel 120, flow to a bottom of the furnace, inwardly turn 90° to flow to the longitudinal rib 115, and upwardly turn 90° to join together and flow to the first annular water-cooling channel 101, and ascend to flow out through the second port 110.

Embodiment 3

[0041] In this embodiment, the same symbols are given to the same structures as those in **Embodiments 1 and 2**, and the same descriptions are omitted.

[0042] Referring to an embodiment collectively shown in Figs 8a, 8b, 8c, 9a, 9b and 9c, a separated structure of the annular water-cooling combustion head 2 and the axisymmetric boiler sections 1 is provided, where the annular water-cooling combustion head 2 is assembled by a plurality of water-cooling annular cavities 15, an independent inlet-outlet header 16 and an end flange 17. A main structure of the plurality of water-cooling annular cavities 15 includes a second annular water-cooling channel 1501, second anti-backfire ribs 1502 and second flame holding fins 1503. The number of the plurality of water-cooling annular cavities 15 is equal to the number of the axisymmetric boiler sections 1. Two sides of an annular inner wall of each of the plurality of water-cooling annular cavities are respectively provided with a water inlet-outlet hole 1504 for butt assembly with the independent inlet-outlet header 16, so as to enable independent water circulation inside the separated structure. A front end of the plurality of annular water-cooling cavities 15 matched with the front boiler section is provided with the end flange 17 to connect the front cover plate 5 to the connecting elbow 6. At the same time, an inner wall of each of the plurality of water-cooling annular cavities 15 is provided with two arc-shaped flow-equalizing orifice plates 18. An orifice of the two arc-shaped flow-equalizing orifice plates 18 is directly opposite to a gap between two adjacent second anti-backfire ribs 1502, and is circular, waist-shaped, elliptical or elongated. Edges of the two arc-shaped flow-equalizing orifice plates 18 are respectively located on an upper side of the independent inlet-outlet header 16 and a lower side of the independent inlet-outlet header 16. The flue gas-air mixture is fully mixed and then passes through the two arc-shaped flow-equalizing orifice plates 18, the second anti-backfire ribs 1502 and the second flame holding fins 1503, and is uniformly ejected and then ignited to burn at intervals along a circumferential gap of a cylindrical surface.

Embodiment 4

[0043] In this embodiment, the same symbols are given to the same structures as those in **Embodiments 1-3**, and the same descriptions are omitted.

[0044] Referring to an embodiment shown in Figs. 10a, 10b, 10c, 10d and 10e, another separated structure of the annular water-cooling combustion head 2 and the axisymmetric boiler sections 1 is provided, where the annular water-cooling combustion head 2 is cast independently as a whole. A main body of the annular water-cooling combustion head 2 includes a plurality of annular water-cooling zones 201, anti-backfire columns 202, flame holding columns 203 and a header pipe 204, where the anti-backfire columns 202 and the second flame holding

columns 203 are evenly and centrometrically distributed on a surface of the plurality of annular water-cooling zones 201. The anti-backfire columns 202 each have a corn kernel-shaped cross section and are arranged circumferentially, where a distance between any two centrosymmetric anti-backfire columns 202 is equal in the radial direction, and the distance is 1-10mm. The height of each of the anti-backfire columns 202 is 6-30 mm, such that an average ejection rate of the fuel gas-air mixture through gaps between adjacent two anti-backfire columns 202 is 2-3 m/s. The flame holding columns 203 is located outside the anti-backfire columns 202 and is staggered with the anti-backfire columns 202 to stabilize the flame. The flame holding columns 203 have the same height with the anti-backfire columns 202. An outer sectional shape of the header pipe 204 is circular, oblong, elliptical or waist-shaped. The header pipe is divided into a water inlet pipe 205 and a water outlet pipe 206 by a middle rib. After entering the annular water-cooling combustion head 2 from the water inlet pipe 205, cooling water is distributed to the annular water-cooling zones 201, and allowed to flow circumferentially to experience a heat exchange, and then collected at the water outlet pipe 206 to complete an independent water circulation. At the same time, an inner wall of the annular water-cooling combustion head 2 is provided with an arc-shaped flow-equalizing orifice plate 18. Orifices of the arc-shaped flow-equalizing orifice plate 18 are just opposite to the gaps between each two adjacent anti-backfire columns 202, and are circular, waist-shaped, elliptical or oblong. After being fully mixed, the flue gas-air mixture is allowed to pass through the arc-shaped flow-equalizing orifice plate 18 to experience the flow equalization, and then flow through the anti-backfire columns 202 and the flame holding columns 203, and is uniformly ejected and then ignited to burn at intervals along a circumferential gap of a cylindrical surface.

Embodiment 5

[0045] In this embodiment, the same symbols are given to the same structures as those in **Embodiments 1-4**, and the same descriptions are omitted.

[0046] Referring to an embodiment shown in Figs. 11a and 11b, provided herein is a premixed water-cooling combustion coupled cast-aluminum-silicon water boiler with series-connected boiler sections. The boiler includes a main structure a main structure, where the main structure is formed by 2-12 axisymmetric boiler sections 19. For adjacent two axisymmetric boiler sections 19, a rear end surface of a former axisymmetric boiler section 19 is sealed with a front-end surface of a later axisymmetric boiler section 19, and then the axisymmetric boiler sections 19 are connected in series through bolts to form the main structure. The axisymmetric boiler sections 19 comprise a front boiler section, and a front-end cover plate 22 arranged on the front boiler section and aligned with a furnace center. The front-end cover plate 22 is

inwardly connected to a rectangular flow-equalizing orifice plate 21, and the rectangular flow-equalizing orifice plate 21 is supported on an inner wall surface of a parallel water-cooling combustion head 20. The rectangular flow-equalizing orifice plate 21 is configured to pass through the parallel water-cooling combustion head 20 of each of the axisymmetric boiler sections 19. The front-end cover plate 22 is outwardly connected to a premixer through an elbow 23. The axisymmetric boiler sections 19 further comprise a rear boiler section. A pin-fin portion of the front boiler section and a pin-fin portion of a rear boiler section of the axisymmetric boiler sections 19 are respectively provided with a heat insulating plate 24. A top end and a bottom end of the front boiler section are respectively provided with an end cap 25, where the end cap 25 is configured to seal an inlet-outlet header. A rear-end cover plate 29 is arranged at a center of a furnace of the rear boiler section, where the rear-end plate 29 is provided with a fireproof and heat-insulation lining. A bottom end of the rear boiler section is provided with a water inlet header pipe 30-1, and a top end of the rear boiler section is provided with a water outlet header pipe 30-2, where the water inlet header pipe 30-1 and the water outlet header pipe 30-2 are configured to enable water circulation. Both sides of the main structure along the second direction are respectively provided with a dust-cleaning baffle 27 and a plug 28. A smoke box 26 is provided at a bottom of the main structure.

[0047] As collectively shown in Figs. 12a, 12b and 12c, an outer front side and an outer rear side of each of the axisymmetric boiler sections 19 are each divided into a radiation zone, a convection zone and a condensation zone in turn from top to bottom. A center of a combustion chamber in the radiation zone is provided with the parallel water-cooling combustion head 20, which is integrated with the axisymmetric boiler sections 19. The parallel water-cooling combustion head 20 includes two parallel water-cooling channels 1901 provided at two sides of a central rectangular sectional cavity 1904. A plurality of anti-backfire pin-fins 1902 are centrosymmetrically provided on a surface of the two parallel water-cooling channels 1901, and a plurality of flame holding fins 1903 are centrosymmetrically provided on the surface of the two parallel water-cooling channels 1901. An outer side of the combustion chamber of the radiation zone, the convection zone and the condensation zone are regularly arranged with circular pin-fins 1905 and waist-shaped pin-fins 1907. Two sides of a bottom of each of the axisymmetric boiler sections 19 are respectively provided with a base 1909, and the base 1909 is connected to the smoke box 26. A flue gas-air mixture is allowed to enter the rectangular flow-equalizing orifice plate 21 from the elbow 23, pass through the central rectangular sectional cavity 1904, and then is uniformly ejected along a gap between each two adjacent axisymmetric boiler sections 19, and ignited to burn at intervals along a plane surface to generate flue gas. After filling a radiation zone around a furnace of the water boiler, a flue gas is allowed to flow

downward through a pin-fin heating surface of the convection zone and the condensation zone and flow into the smoke box 26 from the bottom of the main structure. The flue gas is collected and turned to be upwardly discharged. An inside of each of the axisymmetric boiler sections 19 is configured as a hollow cavity. The return water is allowed to enter from a first water channel port 1910 provided at a bottom of each of the axisymmetric boiler sections 19, and flows out through a second water channel port 1911 provided at a top of each of the axisymmetric boiler sections 19, where the first water channel port 1910 is configured for connection with the water inlet header pipe 30-1, and the second water channel port 1911 is configured for connection with the water outlet header pipe 30-2.

[0048] The hollow cavity inside each of the axisymmetric boiler sections 19 is configured as a water channel space. The water channel space is divided by a longitudinal rib 1916 along a vertical direction and a plurality of transverse ribs 1917 along a horizontal direction. The longitudinal rib 1916 is configured to divide the water channel space into two portions from left to right. A spacing between each two transverse ribs 1917 varies from 40 mm to 120 mm, and decreases from top to bottom. An outside water channel 1912 is provided outside the furnace of the radiation zone. A water flow is allowed to turn upward to a bottom of the radiation zone along a serpentine curve in the water channel space within the condensation zone and the convection zone. The water flow is divided at the bottom of the radiation zone, and divided water flows rise in parallel along the parallel water-cooling channel 1901 and the outside water channel 1912, respectively, and join together at the second water channel port 1911. The transverse ribs 1917 provided at an upper portion of the convection zone have an inclination angle of 0-10° with the horizontal direction, and are each provided with steam exhaust holes 1915 at an end.

[0049] Connecting holes 1906, cleanout grooves 1908 and residue discharging holes 1918 are arranged in pair at two sides of each of the axisymmetric boiler sections 19 along the second direction. The axisymmetric boiler sections 19 are aligned with each other, and then connected in series through the connecting holes 1906. A width of the deashing groove 1908 is designed to ensure cleaning of 1/3-1/2 of the convection zone, so as to avoid opening the sealed furnace in a heating season, and the cleanout grooves 1908 is assembled with the dust-cleaning baffle 27. The residue discharging hole 1918 is arranged directly opposite to a transverse rib 1917, and directly penetrates through a water channel in depth, and the residue discharging hole 1918 is configured to be assembled with the plug 28.

[0050] As shown in Fig. 13, the anti-backfire pin-fins 1902 and the flame holding fins 1903 are axisymmetrically and evenly distributed on a surface of the parallel water-cooling channels 1901, the anti-backfire pin-fins 1902 have an oblong cross-section structure or a rectangular cross-section structure. A distance between any

two adjacent anti-backfire pin-fins 1902 is 1-10 mm, a height of each of the anti-backfire pin-fins 1902 is 6-30 mm, such that an average ejection rate of the fuel gas-air mixture through gaps between adjacent two anti-backfire pin-fins 1902 is 2-3 m/s. The flame holding fins 1903 are arranged outside the anti-backfire pin-fins 1902, and are staggered with the anti-backfire pin-fins 1902 to stabilize a flame. Circumferential ribs 1913 are arranged around a wall surface of the combustion chamber in the radiation zone, and each of the circumferential ribs 1913 is evenly provided with 4-8 hole seats 1914; each of the 4-8 hole seats 1914 is provided with a threaded hole; and the front boiler section is connected to the front-end cover plate 22 through the hole seats 1914, and the rear boiler section is connected to the rear-end cover plate 29 through the hole seats 1914.

[0051] As shown in Figs. 14a, 14b, 15a and 15b, the front-end cover plate 22 and the rear-end cover plate 29 are similar in structure, and are formed by the same set of molds through casting or stamping. The front-end cover plate 22 and the rear-end cover plate 29 both have a disk-like structure 1. Openings 2201 are circumferentially provided at an outer boundary of the front-end cover plate 22 for connection with circumferential ribs 1913. An inner side of the front-end cover plate 22 is centripetally provided with four reinforcing ribs 2204 to support the rectangular flow-equalizing orifice plate 21. A method for processing the rear-end cover plate 29 into the front-end cover plate 22 is specifically performed as follows. The rear-end cover plate is obtained by casting or stamping. A rectangular hole is perforated a center of the rear-end cover plate 29, so as to allow installation of the rectangular flow-equalizing orifice plate 21, and threaded holes 2202 are arranged at an outer end surface of the rear-end cover plate 29. An integrated seat 2203 of monitoring system including igniting holes, flame monitoring holes and pressure monitoring holes is processed on the outer end surface of the rear-end cover plate 29.

Embodiment 6

[0052] In this embodiment, the same symbols are given to the same structures as those in **Embodiments 1-5**, and the same descriptions are omitted.

[0053] Referring to an embodiment shown in Figs 16a and 16b, provided herein is a premixed water-cooling combustion coupled cast-aluminum-silicon water boiler with series-connected boiler sections. The boiler includes a main structure, where the main structure is formed by 2-12 symmetric boiler sections 31. For adjacent two symmetric boiler sections 31, a rear end surface of a former symmetric boiler section 31 is sealed with a front-end surface of a later symmetric boiler section 31, and then the symmetric boiler sections 31 are connected in series through bolts to form the main structure. Two sides of a top of each of the symmetric boiler sections 31 are respectively provided with an isobaric air blower distributor 32. The symmetric boiler sections 31 further

comprise a rear boiler section. A pin-fin portion of the front boiler section and a pin-fin portion of a rear boiler section are respectively provided with a heat insulating cover plate 33. A top end and a bottom end of the front boiler section are respectively provided with an end cap 34, where the end cap 34 is configured to seal a header. A bottom end of the rear boiler section is provided with a water-inlet header pipe 37-1, and a top end of the rear boiler section is provided with a water-outlet header pipe 37-2 to enable water circulation. Both sides of the main structure are respectively provided with a detachable dust-cleaning cover plate 35 and a sealed plug 36 along the second direction. A smoke discharging box 34 is provided at a bottom of the main structure.

[0054] As shown in Fig. 17a, an outer front side and an outer rear side of each of the symmetric boiler sections 31 are divided into a radiation zone, a convection zone and a condensation zone in turn from top to bottom. A fuel gas-air mixture is fully mixed, and then divided to flow into the isobaric air blower distributor 32, and uniformly ejected along a gap between two adjacent symmetric boiler sections 31, and ignited to burn. Two sides of a top of the furnace are respectively provided with a first water channel 3101 to be configured as a water-cooling combustion head. The water-cooling combustion head is provided with anti-backfire fins 3102 and flame holding ribs 3103. An outer side of the combustion chamber in the radiation zone, the convection zone and the condensation zone are regularly provided with circular fins 3104 and waist-shaped fins 3106. Two sides of a bottom of each of the symmetric boiler sections 31 are respectively provided with a base 3108. The base 3108 is connected to the smoke discharging box 34. The radiation zone of the furnace is configured as a radiation space of the flame. After filling a radiation zone of a furnace, the flue gas is allowed to flow downward dash through a pin-fin heating surface of the convection zone and the condensation zone and flow into the smoke discharging box 34 from the bottom of the main structure. The flue gas is collected and turned to be upwardly discharged. An inside of each of the symmetric boiler sections 31 is configured as a hollow cavity. The return water is allowed to enter from an inlet 3109 provided at a bottom of each of the boiler sections 31, and flows out through an outlet 3110 provided at a top of each of the boiler sections 31, where the inlet 3109 is configured for connection with the water-inlet header pipe 37-1, and the outlet 3110 is configured for connection with the water-outlet header pipe 37-2.

[0055] The fuel gas-air mixture is ignited to burn after passing through the anti-backfire fins 3102 and the flame holding ribs 3103. The anti-backfire fins 3102 each have a rectangular cross section or an oblong structure cross section, where a distance between any two anti-backfire fins 3102 is 1-10 mm. A height of each of the anti-backfire fins 3102 is 6-30 mm, such that an average ejection rate of the fuel gas-air mixture through gaps between adjacent two anti-backfire fins 3102 is 2-3 m/s. The flame holding

ribs 3103 are located outside the anti-backfire fins 3102, and the flame holding ribs 3103 are staggered with the anti-backfire fins 3102 to stabilize the flame. The flame holding ribs 3103 have the same height with the anti-backfire fins 3102. A plurality of supporting hole seats 3111 are each provided with a threaded hole, and are arranged on two sides of a top of each of the symmetric boiler sections 31 along the second direction. The plurality of supporting hole seats 3111 are connected to the isobaric air blower distributor 32.

[0056] The circular fins 3104 and the waist-shaped fins 3106 on each of the symmetric boiler sections 31 are arranged in different manners along a flow direction of the flue gas. With respect to the circular fins in the convection zone, a height of the circular fins 3104 in the radiation zone has a smaller height but a larger diameter and larger transverse and longitudinal intercepts. As a temperature of the flue gas and radiation amount decline along the flow direction of the flue gas, the height of the circular fins 3104 gradually increases. The circular fins 3104 are in a close, staggered and regular triangle arrangement in the convection zone where the temperature of the flue gas is lower than 500°C, where a shortest distance between the circular fins 3104 is 3-4 mm. In the convection zone, the circular fins 3104 are of equal height, or designed in a high-low alternating manner with one or two rows of the circular fins 3104 as a group, where a height difference is not larger than 1/3 of an average height of the circular fins 3104. In the condensation zone where the temperature of the flue gas is lower than 65°C, the circular fins 3104 and the waist-shaped fins 3106 are arranged, where a longer diameter of the waist-shaped fins 3106 is consistent with the flow direction of the flue gas, and a shorter diameter of the waist-shaped fins 3106 is equal to a diameter of the circular fins 3104. Parallel channels formed between the circular fins 3104 and parallel channels formed between the waist-shaped fins 3106 are configured to provide sufficient heat exchange zone for condensing the flue gas to allow continuous condensation of the flue gas. A width of the condensation zone is reduced gradually along the flow direction of the flue gas, such that a periphery of a lower portion of each of the symmetric boiler sections 31 is configured as U-shaped in a whole.

[0057] As shown in Fig. 17b, connecting holes 3105, dust cleanout ports 3107 and residue discharging holes 3116 are arranged in pair at two sides of each of the symmetric boiler sections 31. The symmetric boiler sections 31 are aligned with each other, and then connected in series. An aperture of each of the dust cleanout ports 3107 is designed to ensure cleaning of 1/3-1/2 of the convection zone, so as to avoid opening the sealed furnace in a heating season, and the dust cleanout ports 3107 are configured to be assembled with the dust-cleaning cover plate 35. The residue discharging port 3116 is arranged directly opposite to a transverse rib 3115, and directly penetrates through a water channel in depth. The residue discharging port 3116 is configured to be assembled

with the sealed plug 36.

[0058] As shown in Fig. 17c, the hollow cavity inside each of the symmetric boiler sections 31 is configured as a second water channel. The second water channel is divided by a center rib 3114 along a vertical direction and a plurality of straight ribs 3115 along a horizontal direction. The center rib 3114 is configured to divide the second water channel into two portions from left to right. A spacing between adjacent two straight ribs 3115 varies from 40 mm to 120 mm; as a height of the plurality of straight ribs increases, a height of a cross-section decreases, so as to ensure that the height of the cross-section around the radiation zone is about 1/2 of a highest height of the cross-section; the center rib 3114 and the plurality of the straight ribs 3115 form symmetrical serpentine water channels 3112 from left to right; the plurality of straight ribs 3115 provided at an upper portion of the convection zone has an inclination angle of 0-10°, and are processed with steam discharging holes 3113 at an end; return water is allowed to flow into the symmetric boiler sections 31, turn along the symmetrical serpentine water channels 3112, ascend to turn to the first water channels 3101 provided at two sides of the furnace, join together at the outlet 3110 provided at a top of each of the symmetric boiler sections 31, and then flow out.

Claims

1. A premixed water-cooling combustion coupled cast-aluminum-silicon water boiler with series-connected boiler sections, comprising:

a main structure;

wherein the main structure is formed by 2-12 axisymmetric boiler sections (1); for adjacent two axisymmetric boiler sections (1), a rear end surface of a former axisymmetric boiler section (1) is sealed with a front end surface of a later axisymmetric boiler section (1), and then the axisymmetric boiler sections (1) are connected in series through bolts (4) to form the main structure; the axisymmetric boiler sections (1) comprise a front boiler section, and a front cover plate (5) arranged on the front boiler section and aligned with a furnace center; the front cover plate (5) is inwardly connected to a cylindrical flow-equalizing orifice plate (3); the cylindrical flow-equalizing orifice plate (3) is supported on an annular inner wall of an annular water-cooling combustion head (2); the cylindrical flow-equalizing orifice plate (3) passes through the annular water-cooling combustion head (2) of each of the axisymmetric boiler sections (1); the front cover plate (5) is outwardly connected to a premixer through a connecting elbow (6); the axisymmetric boiler sections (1) further comprise a rear boiler section; a pin-fin portion of the

front boiler section and a pin-fin portion of the rear boiler section are respectively provided with a lined heat-insulating cover plate (7); a top end and a bottom end of the front boiler section are respectively provided with an end cap (8), wherein the end cap (8) is configured to seal a water-side header; a rear cover plate (12) is arranged on the rear boiler section and aligned with the furnace center, wherein the rear cover plate (12) is provided with a fireproof heat-insulation lining; a bottom end of the rear boiler section is provided with a water-side inlet header (13), and a top end of the rear boiler section is provided with a water-side outlet header (14), wherein the water-side inlet header (13) and the water-side outlet header (14) are configured to enable water circulation; both sides of the main structure are each provided with a detachable dust-cleaning baffle (10) and a residue discharging plug (11); a special-shaped smoke box (9) is provided at a bottom end of the main structure; and

an outer front side and an outer rear side of each of the axisymmetric boiler sections (1) are each divided into a radiation zone, a convection zone and a condensation zone in turn from top to bottom; a center of a combustion chamber in the radiation zone is provided with the annular water-cooling combustion head (2) which is integrated with or separated from the axisymmetric boiler sections (1); the annular water-cooling combustion head (2) comprises a first annular water-cooling channel (101); a plurality of first anti-backfire ribs (102) are centrosymmetrically provided on a surface of the first annular water-cooling channel (101), and a plurality of first flame holding fins (103) are centrosymmetrically provided on the surface of the first annular water-cooling channel (101); an outer side of the combustion chamber in the radiation zone, the convection zone and the condensation zone are regularly provided with circular columns (104) and waist-shaped columns (106); two sides of a bottom of each of the axisymmetric boiler sections (1) are respectively provided with a base (108), and the base (108) is connected to the special-shaped smoke box (9); a fuel gas-air mixture is allowed to enter the cylindrical flow-equalizing orifice plate (3) from the connecting elbow (6) and pass through the annular water-cooling combustion head (2), and then is uniformly ejected along an annular gap between two adjacent axisymmetric boiler sections (1) and ignited to burn at an axial interval along an annular cylindrical surface to generate flue gas; after filling the radiation zone around a furnace of the water boiler, the flue gas is allowed to flow downward through a pin-fin heating surface of

the convection zone and the condensation zone and flow into the special-shaped smoke box (9) from the bottom end of the main structure; the flue gas is collected and turned to be upwardly discharged; an inside of each of the axisymmetric boiler sections (1) is configured as a hollow cavity; and return water is allowed to enter from a first port (109) provided at the bottom of each of the axisymmetric boiler sections (1), and flows out through a second port (110) provided at a top of each of the axisymmetric boiler sections (1), wherein the first port (109) is configured for connection with the water-side inlet header (13), and the second port (110) is configured for connection with the water-side outlet header (14).

2. The premixed water-cooling combustion coupled cast-aluminum-silicon water boiler according to claim 1, **characterized in that** the plurality of first anti-backfire ribs (102) each have a corn kernel-shaped cross section; the first anti-backfire ribs (102) are circumferentially arranged, wherein a distance between any adjacent two first anti-backfire ribs (102) is the same along a radial direction, and is 1-10 mm; a height of each of the first anti-backfire ribs (102) is set to 6-30 mm such that the fuel gas-air mixture is ejected at an average rate of 2-3 m/s through gaps between the adjacent two first anti-backfire ribs (102); the first flame holding fins (103) are located outside the first anti-backfire ribs (102), and are staggered with the first anti-backfire ribs (102) to stabilize a flame; the first flame holding fins (103) have the same height with the first anti-backfire ribs (102); circumferential base ribs (113) are arranged around a wall surface of the combustion chamber in the radiation zone, and each of the circumferential base ribs (113) is evenly provided with 4-8 hole seats (111) each provided with a threaded hole; and the front boiler section is connected to the front cover plate (5) through the hole seats (111), and the rear boiler section is connected to the rear cover plate (12) through the hole seats (111).
3. The premixed water-cooling combustion coupled cast-aluminum-silicon water boiler according to claim 1, **characterized in that** the circular columns (104) and the waist-shaped columns (106) on each of the axisymmetric boiler sections (1) are arranged in different manners along a flow direction of the flue gas; with respect to the circular columns in the convection zone, a height of the circular columns (104) in the radiation zone has a smaller height but a larger diameter and larger transverse and longitudinal intercepts; as a temperature of the flue gas and radiation amount decline along the flow direction of the flue gas, the height of the circular columns (104) gradually increases; the circular columns (104) are in a close, staggered and regular triangle arrange-

ment in the convection zone where the temperature of the flue gas is lower than 500°C, wherein a shortest distance between the circular columns (104) is 3-4 mm; in the convection zone, the circular columns (104) are of equal height, or designed in a high-low alternating manner with one or two rows of the circular columns (104) as a group, wherein a height difference is not larger than 1/3 of an average height of the circular columns (104); in the condensation zone where the temperature of the flue gas is lower than 65°C, the circular columns (104) and the waist-shaped columns (106) are arranged, wherein a longer diameter of the waist-shaped columns (106) is consistent with the flow direction of the flue gas, and a shorter diameter of the waist-shaped columns (106) is equal to a diameter of the circular columns (104); parallel channels formed between the circular columns (104) and parallel channels formed between the waist-shaped columns (106) are configured to provide sufficient heat exchange zone for condensing the flue gas to allow continuous condensation of the flue gas; a width of the condensation zone is reduced gradually along the flow direction of the flue gas, such that a periphery of a lower portion of each of the axisymmetric boiler sections (1) is configured as U-shaped in a whole.

4. The premixed water-cooling combustion coupled cast-aluminum-silicon water boiler according to claim 1, **characterized in that** the hollow cavity inside each of the axisymmetric boiler sections (1) is configured as a water channel space; the water channel space is divided by a longitudinal rib (115) along a vertical direction and a plurality of transverse ribs (116) along a horizontal direction; the longitudinal rib (115) is configured to divide the water channel space into two portions from left to right; a spacing between adjacent two transverse ribs (116) varies from 40 mm to 120 mm, and decreases from top to bottom; a water flow is allowed to turn upward to a bottom of the radiation zone along a serpentine curve in the water channel space within the condensation zone and the convection zone; the transverse ribs (116) provided at an upper portion of the convection zone have an inclination angle of 0-10° with the horizontal direction, and are each provided with a steam exhaust hole (114) at an end; the water channel space corresponding to the radiation zone has two kinds of structures, respectively a first structure and a second structure; the first structure is composed of the first annular water-cooling channel (101) at a furnace center of the radiation zone and water channels (112) provided at two sides of the furnace and outside a circumferential base rib (113), such that the water flow is divided at the bottom of the radiation zone, and divided water flows rise in parallel along the first annular water-cooling channel (101) and the water channels (112), respectively, join together at

the second port (110); in the second structure, the water channels (112) is split by a split rib (118) into an ascending water channel (119) and a descending water channel (120), and thus the second structure is composed of the first annular water-cooling channel (101), the ascending water channel (119) and the descending water channel (120); in the second structure, the water flow is not divided at the bottom of the radiation zone, but is allowed to laterally flow to two sides of the furnace and turn 90° to enter the ascending water channel (119), ascend to the second port (110), inwardly turn 180° to flow downward to the descending water channel (120), flow to a bottom of the furnace, inwardly turn 90° to flow to the longitudinal rib (115), and upwardly turn 90° to join together and flow to the first annular water-cooling channel (101), and ascend to flow out through the second port (110).

5. The premixed water-cooling combustion coupled cast-aluminum-silicon water boiler according to claim 1, **characterized in that** bolt holes (105), cleanout ports (107) and residue discharging holes (117) are arranged in pair at two sides of each of the axisymmetric boiler sections (1); the axisymmetric boiler sections (1) are aligned with each other, and then connected in series by inserting the bolts (4) into the bolt holes (105); an aperture of each of the cleanout ports (107) is designed to ensure cleaning of 1/3-1/2 of the convection zone, so as to avoid opening the sealed furnace in a heating season, and the cleanout ports (107) are configured to be assembled with the detachable dust-cleaning baffle (10); the residue discharging port (117) is arranged directly opposite to a transverse rib (116), and directly penetrates through a water channel in depth; and the residue discharging port (117) is configured to be assembled with the residue discharging plug (11).
6. The premixed water-cooling combustion coupled cast-aluminum-silicon water boiler according to claim 1, **characterized in that** the front cover plate (5) and the rear cover plate (12) are similar in structure, and are formed by the same set of molds through casting or stamping; the front cover plate (5) and the rear cover plate (12) both have a disk-like structure, and are each circumferentially provided with openings (501) at periphery for connection with circumferential base ribs (113); an inner side of the disk-like structure is centripetally provided with four supporting ribs (504) to support the cylindrical flow-equalizing orifice plate (3); a method for processing the rear cover plate (12) into the front cover plate (5) comprises: obtaining the rear cover plate (12) by casting or stamping; perforating a center of the rear cover plate (12), so as to allow installation of the cylindrical flow-equalizing orifice plate (3), and arranging threaded holes (502) at an outer end surface

of the disk-like structure; and arranging an integrated monitoring system (503) comprising igniting holes, flame monitoring holes and pressure monitoring holes at the outer end surface of the disk-like structure.

7. The premixed water-cooling combustion coupled cast-aluminum-silicon water boiler according to claim 1, **characterized in that** the axisymmetric boiler sections (1) are fabricated from ZL101 alloy, ZL102 alloy, ZL104 alloy or AlSi10Mg alloy through integrated casting molding; the condensation zone is provided with a super-hydrophobic film to make the condensation zone super-hydrophobic, self-cleaning and corrosion-resistant; the lined heat-insulating cover plate (7) is made from stainless steel by integrated stamping molding; the special-shaped smoke box (9) is made from polytetrafluoroethylene (PTFE), polyvinyl chloride (PVC), polypropylene (PP) or acrylonitrile butadiene styrene copolymers (ABS); the special-shaped smoke box (9) comprises a condensate receiving plate (901) and a smoke exhaust outlet (902); the condensate receiving plate (901) is a special-shaped polyhedron, whose partial cross-sectional area gradually decreases along a length direction, a width direction and a height direction to ensure that there is a lowest point therein.
8. The premixed water-cooling combustion coupled cast-aluminum-silicon water boiler according to claim 1, **characterized in that** when the annular water-cooling combustion head (2) and the axisymmetric boiler sections (1) are in a separated structure, the annular water-cooling combustion head (2) is assembled by a plurality of water-cooling annular cavities (15), an independent inlet-outlet header (16) and an end flange (17); a main structure of each of the plurality of water-cooling annular cavities comprises a second annular water-cooling channel (1501), second anti-backfire ribs (1502) and second flame holding fins (1503); the number of the plurality of water-cooling annular cavities (15) is equal to the number of the axisymmetric boiler sections (1); two sides of an annular inner wall of each of the plurality of water-cooling annular cavities (15) are respectively provided with a water inlet-outlet hole (1504) for butt assembly with the independent inlet-outlet header (16), so as to enable independent water circulation inside the separated structure; a front end of the annular water-cooling cavity (15) matched with the front boiler section is provided with the end flange (17) to connect the front cover plate (5) with the connecting elbow (6); at the same time, an inner wall of each of the plurality of water-cooling annular cavities (15) is provided with two arc-shaped flow-equalizing orifice plates (18); an orifice of the two arc-shaped flow-equalizing orifice plates is directly opposite to a gap between two adjacent second anti-backfire ribs

(1502), and is circular, waist-shaped, elliptical or elongated; edges of the two arc-shaped flow-equalizing orifice plates (18) are respectively located on an upper side of the independent inlet-outlet header (16) and a lower side of the independent inlet-outlet header (16); the fuel gas-air mixture is fully mixed and then passes through the two arc-shaped flow-equalizing orifice plates (18), the second anti-backfire ribs (1502) and the second flame holding fins (1503), and is uniformly ejected and then ignited to burn at intervals along a circumferential gap of a cylindrical surface.

9. The premixed water-cooling combustion coupled cast-aluminum-silicon water boiler according to claim 1, **characterized in that** when the annular water-cooling combustion head (2) and the axisymmetric boiler sections (1) are in a separated structure, the annular water-cooling combustion head (2) is cast independently as a whole; a main body of the annular water-cooling combustion head (2) comprises a plurality of annular water-cooling zones (201), anti-backfire columns (202), flame holding columns (203) and a header pipe (204), wherein the anti-backfire columns (202) and the flame holding columns (203) are evenly and centrometrically distributed on a surface of the annular water-cooling zones (201); the anti-backfire columns (202) each have a corn kernel-shaped cross section and are arranged circumferentially, wherein a distance between any two centrosymmetric anti-backfire columns (202) is equal in the radial direction, and the distance is 1-10 mm; a height of each of the anti-backfire columns (202) is 6-30 mm such that an average ejection rate of the fuel gas-air mixture through gaps between adjacent two anti-backfire columns (202) is 2-3 m/s; the flame holding columns (203) are located outside the anti-backfire columns (202) and are staggered with the anti-backfire columns (202) to stabilize the flame; the flame holding columns (203) have the same height with the anti-backfire columns (202); an outer section of the header pipe (204) is circular, oblong, elliptical or waist-shaped; the header pipe (204) is divided into a water inlet pipe (205) and a water outlet pipe (206) by a middle rib; after entering the annular water-cooling combustion head (2) from the water inlet pipe (205), cooling water is distributed to the annular water-cooling zones (201), and allowed to flow circumferentially to experience heat exchange, and then collected at the water outlet pipe (206) to complete an independent water circulation; at the same time, an inner wall of the annular water-cooling combustion head (2) is provided with an arc-shaped flow-equalizing orifice plate (18); orifices of the arc-shaped flow-equalizing orifice plate (18) are just opposite to gaps between adjacent anti-backfire columns (202), and are circular, waist-shaped, elliptical or oblong; after being fully mixed, the fuel gas-

air mixture is allowed to pass through the arc-shaped flow-equalizing orifice plate (18) to experience flow equalization, and then flow through the anti-backfire columns (202) and the flame holding columns (203), and is uniformly ejected and ignited to burn at intervals along a circumferential gap of a cylindrical surface.

10. A premixed water-cooling combustion coupled cast-aluminum-silicon water boiler with series-connected boiler sections, comprising:

a main structure;

wherein the main structure is formed by 2-12 axisymmetric boiler sections (19); for adjacent two axisymmetric boiler sections (19), a rear end surface of a former axisymmetric boiler section (19) is sealed with a front end surface of a later axisymmetric boiler section (19), and then the axisymmetric boiler sections (19) are connected in series through bolts to form the main structure; the axisymmetric boiler sections (19) comprise a front boiler section, and a front-end cover plate (22) arranged on the front boiler section and aligned with a furnace center; the front-end cover plate (22) is inwardly connected to a rectangular flow-equalizing orifice plate (21); the rectangular flow-equalizing orifice plate (21) is supported on an inner wall of a parallel water-cooling combustion head (20); the rectangular flow-equalizing orifice plate (21) passes through the parallel water-cooling combustion head (20) of each of the axisymmetric boiler sections (19); the front-end cover plate (22) is outwardly connected to a premixer through an elbow (23); the axisymmetric boiler sections (19) further comprise a rear boiler section; a pin-fin portion of the front boiler section and a pin-fin portion of the rear boiler section are respectively provided with a heat-insulating cover plate (24); a top end and a bottom end of the front boiler section are respectively provided with an end cap (25), wherein the end cap (25) is configured to seal an inlet-outlet header; a rear-end cover plate (29) is arranged on the front boiler section and aligned with the furnace center, wherein the rear-end cover plate (29) is provided with a fireproof heat-insulation lining; a bottom end of the rear boiler section is provided with a water inlet header pipe (30-1), and a top end of the rear boiler section is provided with a water outlet header pipe (30-2), wherein the water inlet header pipe (30-1) and the water outlet header pipe (30-2) are configured to enable water circulation; both sides of the main structure are each provided with a dust-cleaning baffle (27) and a plug (28); a smoke box (26) is provided at a bottom end of the main structure; an outer front side and an

outer rear side of each of the axisymmetric boiler sections (19) are each divided into a radiation zone, a convection zone and a condensation zone in turn from top to bottom; a center of a combustion chamber in the radiation zone is provided with the parallel water-cooling combustion head (20) which is integrated with the axisymmetric boiler sections (19); the parallel water-cooling combustion head (20) comprises two parallel water-cooling channels (1901) provided at two sides of a central rectangular sectional cavity (1904); a plurality of anti-backfire pin-fins (1902) are centrosymmetrically provided on a surface of the two parallel water-cooling channels (1901), and a plurality of flame holding fins (1903) are centrosymmetrically provided on the surface of the two parallel water-cooling channels (1901); an outer side of the combustion chamber in the radiation zone, the convection zone and the condensation zone are regularly provided with circular pin-fins (1905) and waist-shaped pin-fins (1907); two sides of a bottom of each of the axisymmetric boiler sections (19) are respectively provided with a base (1909), and the base (1909) is connected to the smoke box (26); a fuel gas-air mixture is allowed to enter the rectangular flow-equalizing orifice plate (21) from the elbow (23) and pass through the central rectangular sectional cavity (1904), and then is uniformly ejected along a gap between two adjacent axisymmetric boiler sections (19) and ignited to burn at an interval along a plane surface to generate flue gas; after filling the radiation zone around a furnace of the water boiler, the flue gas is allowed to flow downward through a pin-fin heating surface of the convection zone and the condensation zone and flow into the smoke box (26) from the bottom end of the main structure; the flue gas is collected and turned to be upwardly discharged; an inside of each of the axisymmetric boiler sections (19) is configured as a hollow cavity; and return water is allowed to enter from a first water channel port (1910) provided at the bottom of each of the axisymmetric boiler sections (19), and flows out through a second water channel port (1911) provided at a top of each of the axisymmetric boiler sections (19), wherein the first water channel port (1910) is configured for connection with the water inlet header pipe (30-1), and the second water channel port (1911) is configured for connection with the water outlet header pipe (30-2).

11. The premixed water-cooling combustion coupled cast-aluminum-silicon water boiler of claim 10, **characterized in that** the anti-backfire pin-fins (1902) and the flame holding fins (1903) are axisymmetrically and evenly distributed on a surface of the par-

allel water-cooling channels (1901), the anti-backfire pin-fins (1902) each have an oblong cross-section or a rectangular cross-section; a distance between any two adjacent anti-backfire pin-fins (1902) is 1-10 mm, a height of each of the anti-backfire pin-fins (1902) is 6-30 mm, such that an average ejection rate of the fuel gas-air mixture through gaps between adjacent two anti-backfire pin-fins (1902) is 2-3 m/s; the flame holding fins (1903) are arranged outside the anti-backfire pin-fins (1902), and are staggered with the anti-backfire pin-fins (1902) to stabilize a flame; circumferential ribs (1913) are arranged around a wall surface of the combustion chamber in the radiation zone, and each of the circumferential ribs (1913) is evenly provided with 4-8 hole seats (1914); and 4-8 hole seats (1914) are each provided with a threaded hole; and the front boiler section is connected to the front-end cover plate (22) through the hole seats (1914), and the rear boiler section is connected to the rear-end cover plate (29) through the hole seats (1914).

12. The premixed water-cooling combustion coupled cast-aluminum-silicon water boiler according to claim 10, **characterized in that** the circular pin-fins (1905) and the waist-shaped pin-fins (1907) on each of the axisymmetric boiler sections (19) are arranged in different manners along a flow direction of the flue gas; with respect to the circular pin-fins in the convection zone, a height of the circular pin-fins (1905) in the radiation zone has a smaller height but a larger diameter and larger transverse and longitudinal intercepts; as a temperature of the flue gas and radiation amount decline along the flow direction of the flue gas, the height of the circular pin-fins (1905) gradually increases; the circular pin-fins (1905) are in a close, staggered and regular triangle arrangement in the convection zone where the temperature of the flue gas is lower than 500°C, wherein a shortest distance between the circular pin-fins (1905) is 3-4 mm; in the convection zone, the circular pin-fins (1905) are of equal height, or designed in a high-low alternating manner with one or two rows of the circular pin-fins (1905) as a group, wherein a height difference is not larger than 1/3 of an average height of the circular pin-fins (1905); in the condensation zone where the temperature of the flue gas is lower than 65°C, the circular pin-fins (1905) and the waist-shaped pin-fins (1907) are arranged, wherein a longer diameter of the waist-shaped pin-fins (1907) is consistent with the flow direction of the flue gas, and a shorter diameter of the waist-shaped pin-fins (1907) is equal to a diameter of the circular pin-fins (1905); parallel channels formed between the circular pin-fins (1905) and parallel channels formed between the waist-shaped pin-fins (1907) are configured to provide sufficient heat exchange zone for condensing the flue gas to allow continuous conden-

sation of the flue gas; a width of the condensation zone is reduced gradually along the flow direction of the flue gas, such that a periphery of a lower portion of each of the axisymmetric boiler sections (19) is configured as U-shaped in a whole.

13. The premixed water-cooling combustion coupled cast-aluminum-silicon water boiler according to claim 10, **characterized in that** the hollow cavity inside each of the axisymmetric boiler sections (19) is configured as a water channel space; the water channel space is divided by a longitudinal rib (1916) along a vertical direction and a plurality of transverse ribs (1917) along a horizontal direction; the longitudinal rib (1916) is configured to divide the water channel space into two portions from left to right; a spacing between adjacent two transverse ribs (1917) varies from 40 mm to 120 mm, and decreases from top to bottom; an outside water channel (1912) is provided outside the furnace of the radiation zone; a water flow is allowed to turn upward to a bottom of the radiation zone along a serpentine curve in the water channel space within the condensation zone and the convection zone; the water flow is divided at the bottom of the radiation zone, and divided water flows rise in parallel along the parallel water-cooling channel (1901) and the outside water channel (1912), respectively, join together at the second water channel port (1911); the transverse ribs (1917) provided at an upper portion of the convection zone have an inclination angle of 0-10° with the horizontal direction, and are each provided with a steam exhaust hole at an end (1915).
14. The premixed water-cooling combustion coupled cast-aluminum-silicon water boiler according to claim 10, **characterized in that** connecting holes (1906), cleanout grooves (1908) and residue discharging holes (1918) are arranged in pair at two sides of each of the axisymmetric boiler sections (19); the axisymmetric boiler sections (19) are aligned with each other, and then connected in series through the connecting holes 1906; a width of each of the cleanout grooves (1908) is designed to ensure cleaning of 1/3-1/2 of the convection zone, so as to avoid opening the sealed furnace in a heating season, and the cleanout grooves (1908) are configured to be assembled with the dust-cleaning baffle (27); the residue discharging hole (1918) is arranged directly opposite to a transverse rib (1917), and directly penetrates through a water channel in depth; and the residue discharging hole (1918) is configured to be assembled with the plug (28).
15. The premixed water-cooling combustion coupled cast-aluminum-silicon water boiler according to claim 10, **characterized in that** the front-end cover plate (22) and the rear-end cover plate (29) are sim-

ilar in structure, and are formed by the same set of molds through casting or stamping; the front-end cover plate (22) and the rear-end cover plate (29) both have a disk-like structure, and are each circumferentially provided with openings (2201) at periphery for connection with circumferential ribs (1913); an inner side of the disk-like structure is centripetally provided with four supporting ribs (2204) to support the rectangular flow-equalizing orifice plate (21); a method for processing the rear-end cover plate (29) into the front-end cover plate (22) comprises: obtaining the rear-end cover plate (29) by casting or stamping; perforating a center of the rear-end cover plate (29), so as to allow installation of the rectangular flow-equalizing orifice plate (21), and arranging threaded holes (2202) at an outer end surface of the disk-like structure; and arranging an integrated seat (2203) of monitoring system comprising igniting holes, flame monitoring holes and pressure monitoring holes at the outer end surface of the disk-like structure.

16. A premixed water-cooling combustion coupled cast-aluminum-silicon water boiler with series-connected boiler sections, comprising:

a main structure;

wherein the main structure is formed by 2-12 symmetric boiler sections (31); for adjacent two symmetric boiler sections (31), a rear end surface of a former symmetric boiler section (31) is sealed with a front end surface of a later symmetric boiler section (31), and then the symmetric boiler sections (31) are connected in series through bolts to form the main structure; two sides of a top of a furnace of each of the symmetric boiler sections (31) are respectively provided with an isobaric air blower distributor (32); the symmetric boiler sections (31) further comprise a rear boiler section; a pin-fin portion of the front boiler section and a pin-fin portion of the rear boiler section are respectively provided with a heat-insulating cover plate (33); a top end and a bottom end of the front boiler section are respectively provided with an end cap (34), wherein the end cap (34) is configured to seal a header; a bottom end of the rear boiler section is provided with a water-inlet header pipe (37-1), and a top end of the rear boiler section is provided with a water-outlet header pipe (37-2), wherein the water-inlet header pipe (37-1) and the water-outlet header pipe (37-2) are configured to enable water circulation; both sides of the main structure are each provided with a detachable dust-cleaning cover plate (35) and a sealed plug (36); a smoke discharging box (34) is provided at a bottom end of the main structure; and an outer front side and an outer rear side of each

of the symmetric boiler sections (31) are each divided into a radiation zone, a convection zone and a condensation zone in turn from top to bottom; a fuel gas-air mixture is fully mixed and then divided to flow into the isobaric air blower distributors (32), and is uniformly ejected along a gap between two adjacent symmetric boiler sections (31); two sides of a top of the furnace are respectively provided with a first water channel (3101) to be configured as a water-cooling combustion head; the water-cooling combustion head is provided with anti-backfire fins (3102) and flame holding ribs (3103); an outer side of the combustion chamber in the radiation zone, the convection zone and the condensation zone are regularly provided with circular fins (3104) and waist-shaped fins (3106); two sides of a bottom of each of the symmetric boiler sections (31) are respectively provided with a base (3108), and the base (3108) is connected to the smoke discharging box (34); the radiation zone is configured as a radiation space of a flame; the flue gas is allowed to flow downward through a pin-fin heating surface of the convection zone and the condensation zone and flow into the smoke discharging box (34) from the bottom end of the main structure; the flue gas is collected and turned to be upwardly discharged; an inside of each of the symmetric boiler sections (31) is configured as a hollow cavity; and return water is allowed to enter from an inlet (3109) provided at the bottom of each of the symmetric boiler sections (31), and flows out through an outlet (3110) provided at a top of each of the symmetric boiler sections (31), wherein the inlet (3109) is configured for connection with the water-inlet header pipe (37-1), and the outlet (3110) is configured for connection with the water-outlet header pipe (37-2).

17. The premixed water-cooling combustion coupled cast-aluminum-silicon water boiler according to claim 16, **characterized in that** the fuel gas-air mixture is ignited to burn after passing through the anti-backfire fins (3102) and the flame holding ribs (3103); the anti-backfire fins (3102) each have a rectangular cross-section or an oblong cross-section, wherein a distance between any two adjacent anti-backfire fins (3102) is 1-10 mm; a height of each of the anti-backfire fins (3102) is 6-30 mm such that an average ejection rate of the fuel gas-air mixture through gaps between adjacent two anti-backfire fins (3102) is 2-3 m/s; the flame holding ribs (3103) are located outside the anti-backfire fins (3102) and are staggered with the anti-backfire fins (3102) to stabilize the flame; the flame holding ribs (3103) have the same height with the anti-backfire fins (3102); a plurality of supporting hole seats (3111) are each pro-

vided with a threaded hole, and are arranged on two sides of a top of each of the symmetric boiler sections (31); and the plurality of supporting hole seats (3111) are connected to the isobaric air blower distributor (32).

18. The premixed water-cooling combustion coupled cast-aluminum-silicon water boiler according to claim 16, **characterized in that** the circular fins (3104) and the waist-shaped fins (3106) on each of the symmetric boiler sections (31) are arranged in different manners along a flow direction of the flue gas; with respect to the circular fins in the convection zone, a height of the circular fins (3104) in the radiation zone has a smaller height but a larger diameter and larger transverse and longitudinal intercepts; as a temperature of the flue gas and radiation amount decline along the flow direction of the flue gas, the height of the circular fins (3104) gradually increases; the circular fins (3104) are in a close, staggered and regular triangle arrangement in the convection zone where the temperature of the flue gas is lower than 500°C, wherein a shortest distance between the circular fins (3104) is 3-4 mm; in the convection zone, the circular fins (3104) are of equal height, or designed in a high-low alternating manner with one or two rows of the circular fins (3104) as a group, wherein a height difference is not larger than 1/3 of an average height of the circular fins (3104); in the condensation zone where the temperature of the flue gas is lower than 65°C, the circular fins (3104) and the waist-shaped fins (3106) are arranged, wherein a longer diameter of the waist-shaped fins (3106) is consistent with the flow direction of the flue gas, and a shorter diameter of the waist-shaped fins (3106) is equal to a diameter of the circular fins (3104); parallel channels formed between the circular fins (3104) and parallel channels formed between the waist-shaped fins (3106) are configured to provide sufficient heat exchange zone for condensing the flue gas to allow continuous condensation of the flue gas; a width of the condensation zone is reduced gradually along the flow direction of the flue gas, such that a periphery of a lower portion of each of the symmetric boiler sections (31) is configured as U-shaped in a whole.
19. The premixed water-cooling combustion coupled cast-aluminum-silicon water boiler according to claim 16, **characterized in that** the hollow cavity inside each of the symmetric boiler sections (31) is configured as a second water channel; the second water channel is divided by a center rib (3114) along a vertical direction and a plurality of straight ribs (3115) along a horizontal direction; the center rib (3114) is configured to divide the second water channel into two portions from left to right; a spacing between adjacent two straight ribs (3115) varies from

40 mm to 120 mm; as a height of the plurality of straight ribs increases, a height of a cross-section decreases, so as to ensure that the height of the cross-section around the radiation zone is about 1/2 of a highest height of the cross-section; the center rib (3114) and the plurality of the straight ribs (3115) form symmetrical serpentine water channels (3112) from left to right; the plurality of straight ribs (3115) provided at an upper portion of the convection zone has an inclination angle of 0-10°, and are processed with steam discharging holes (3113) at an end; return water is allowed to flow into the symmetric boiler sections (31), turn along the symmetrical serpentine water channels (3112), ascend to turn to the first water channels (3101) provided at two sides of the furnace, join together at the outlet (3110) provided at a top of each of the symmetric boiler sections (31), and then flow out.

20. The premixed water-cooling combustion coupled cast-aluminum-silicon water boiler according to claim 16, **characterized in that** connecting holes (3105), dust cleanout ports (3107) and residue discharging holes (3116) are arranged in pair at two sides of each of the symmetric boiler sections (31); the symmetric boiler sections (31) are aligned with each other, and then connected in series; an aperture of each of the dust cleanout ports (3107) is designed to ensure cleaning of 1/3-1/2 of the convection zone, so as to avoid opening the sealed furnace in a heating season, and the dust cleanout ports (3107) are configured to be assembled with the dust-cleaning cover plate (35); the residue discharging port (3116) is arranged directly opposite to a transverse rib (3115), and directly penetrates through a water channel in depth; and the residue discharging port (3116) is configured to be assembled with the sealed plug (36).

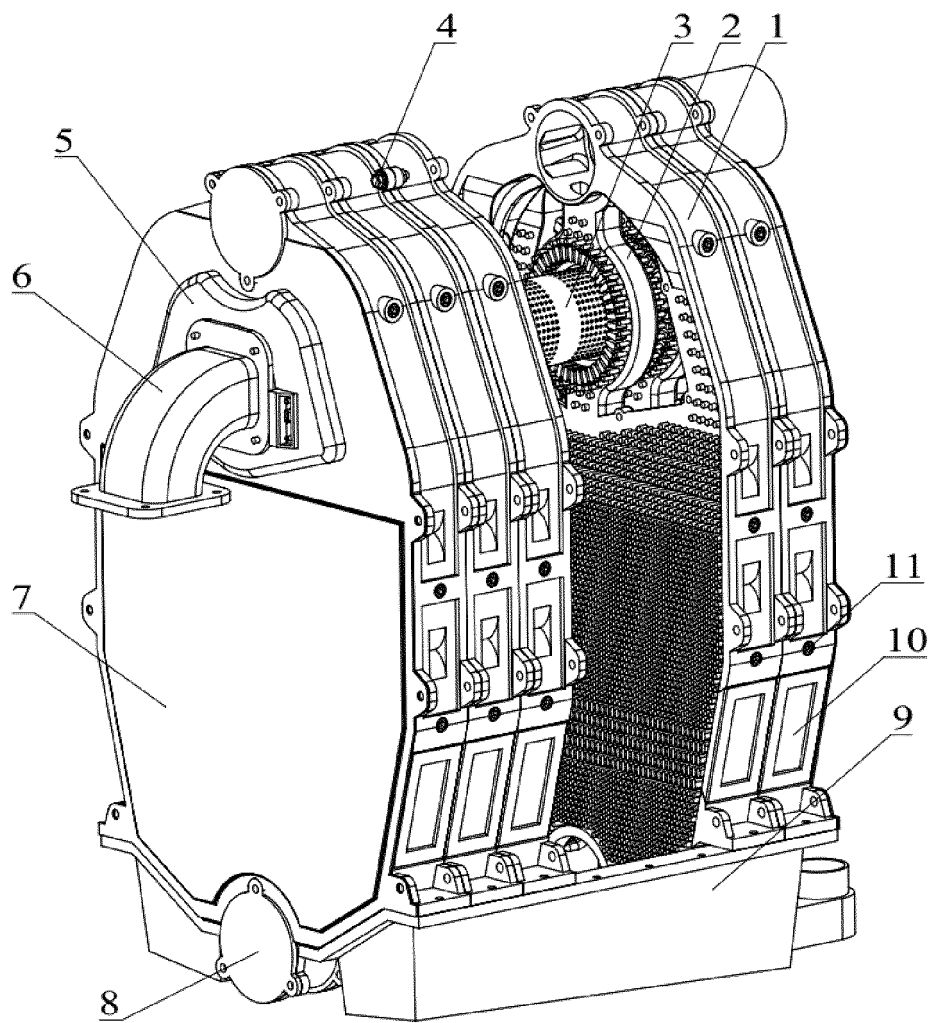


Fig. 1a

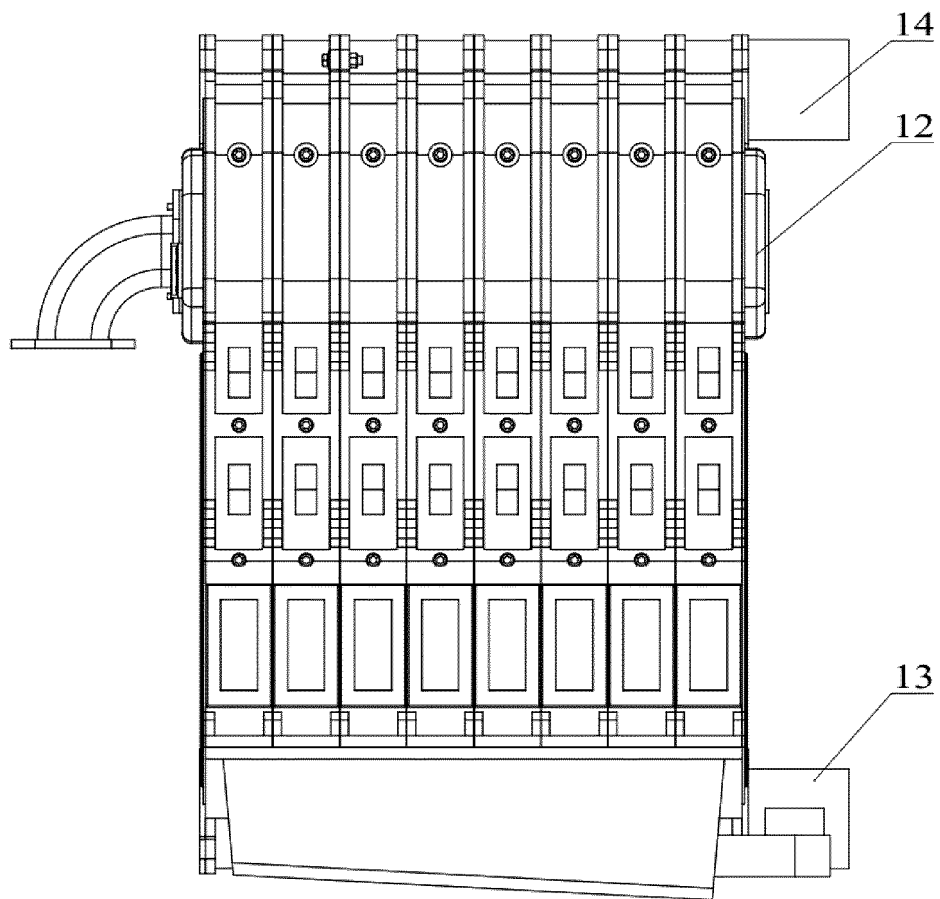


Fig. 1b

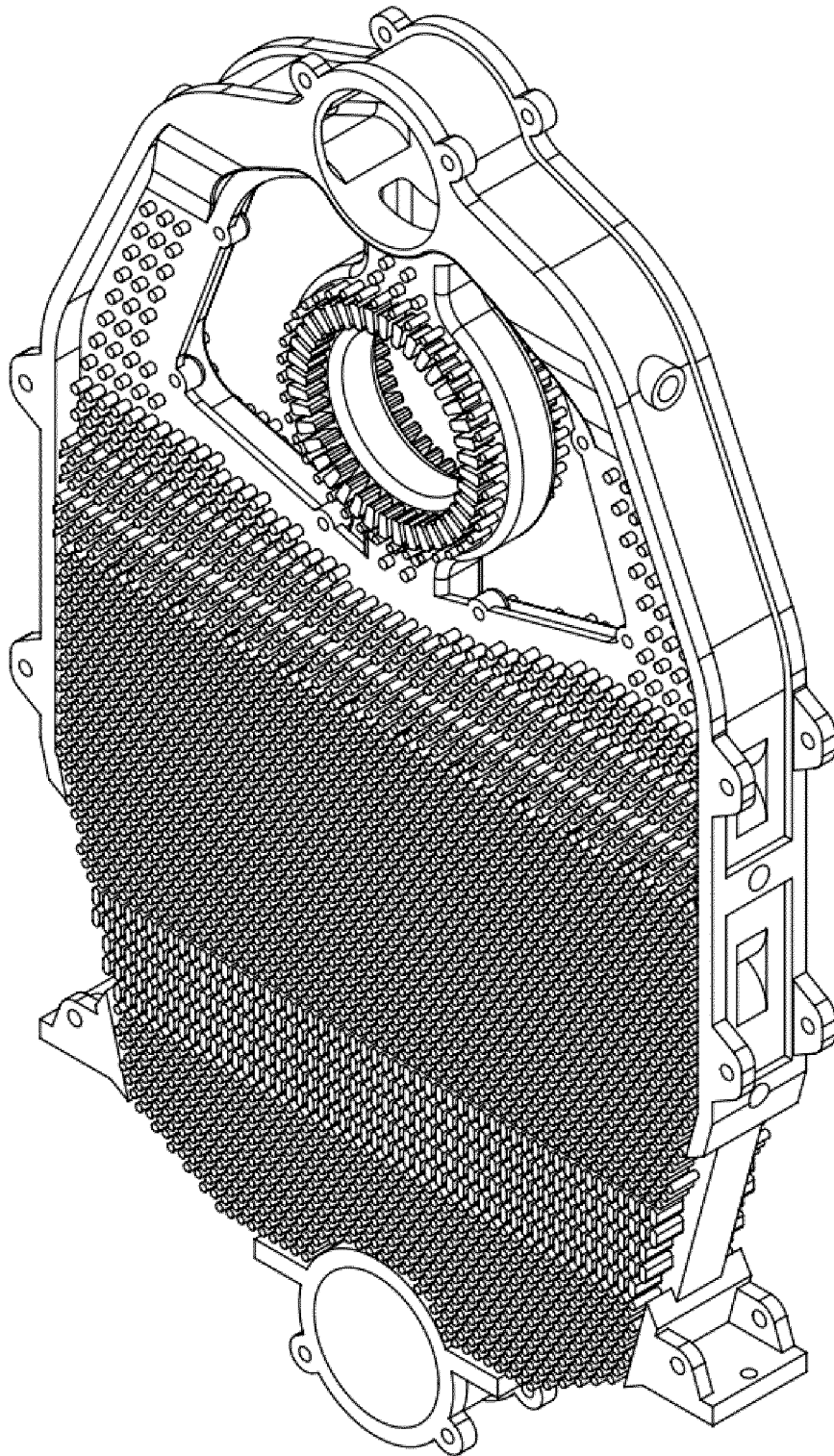


Fig. 2a

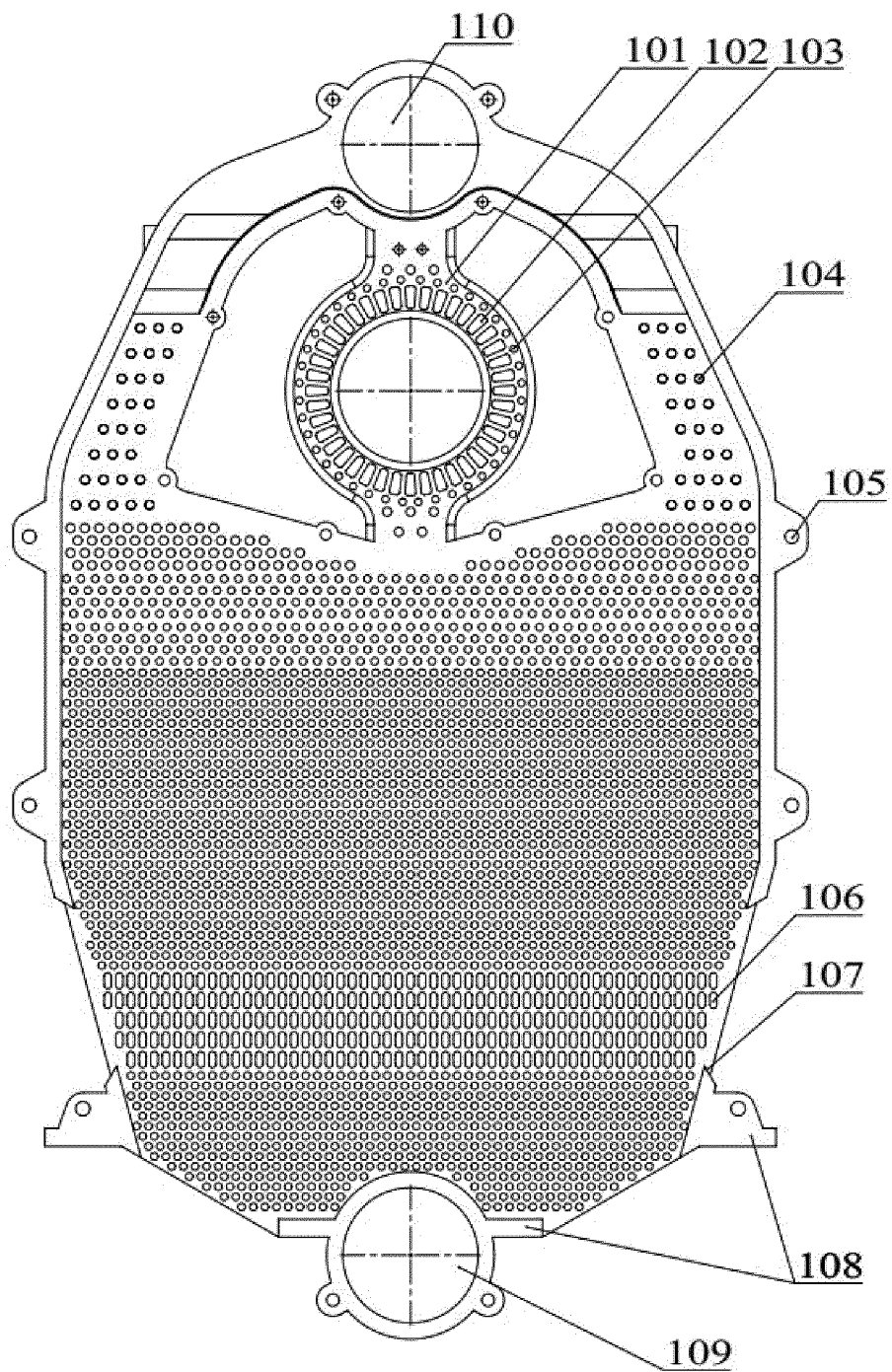


Fig. 2b

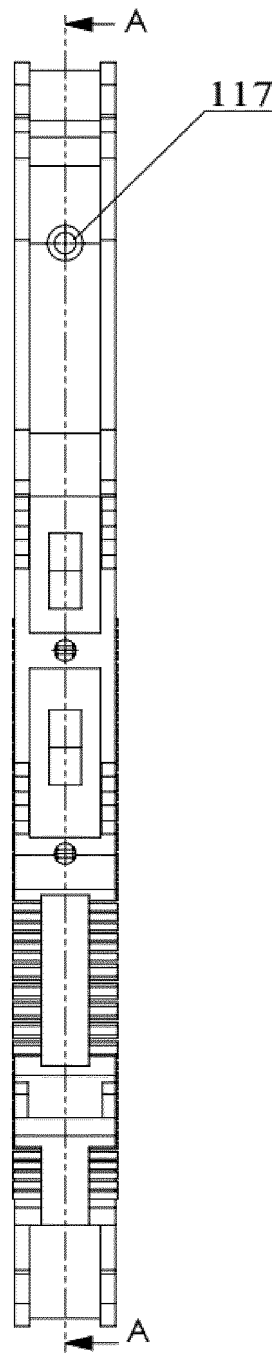


Fig. 2c

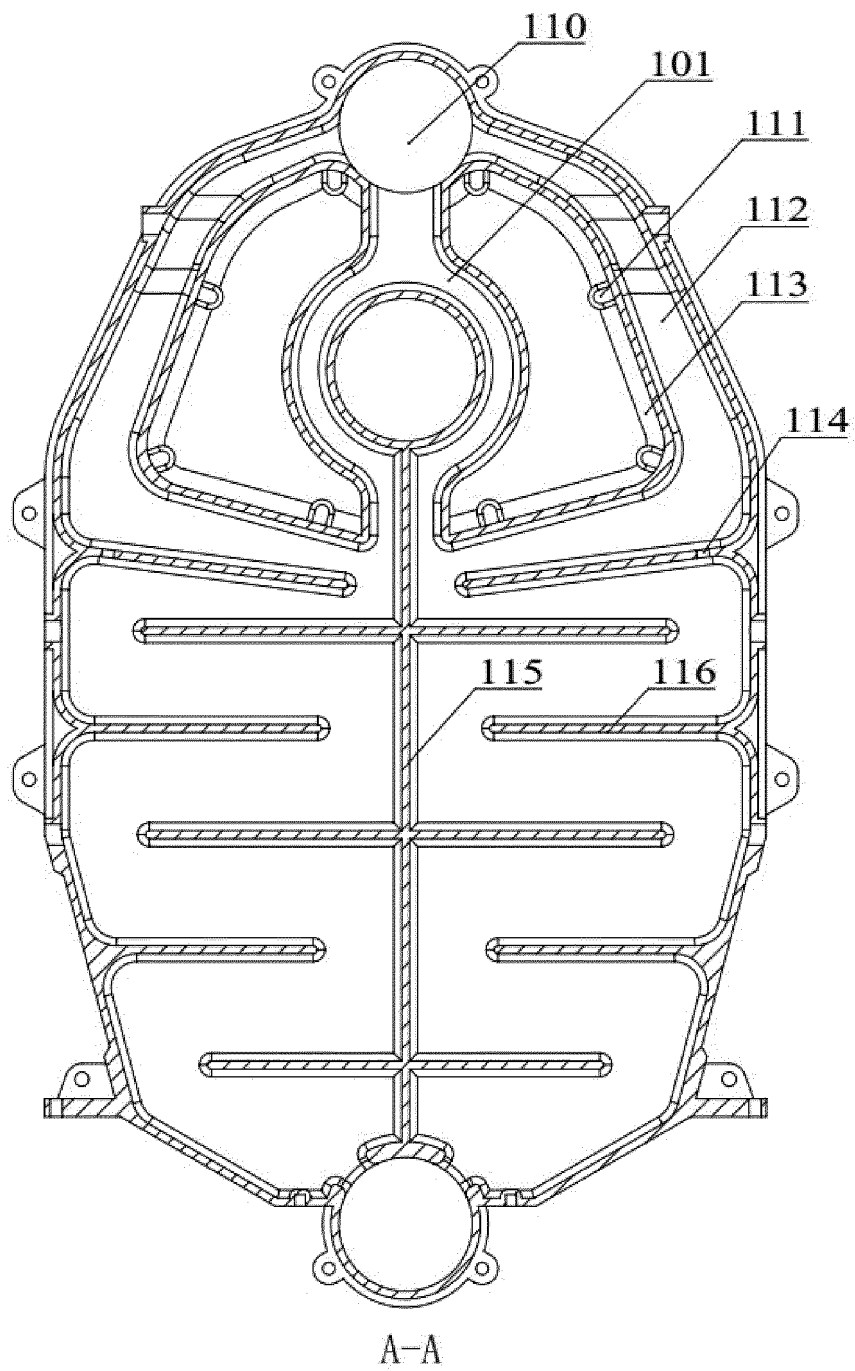


Fig. 2d

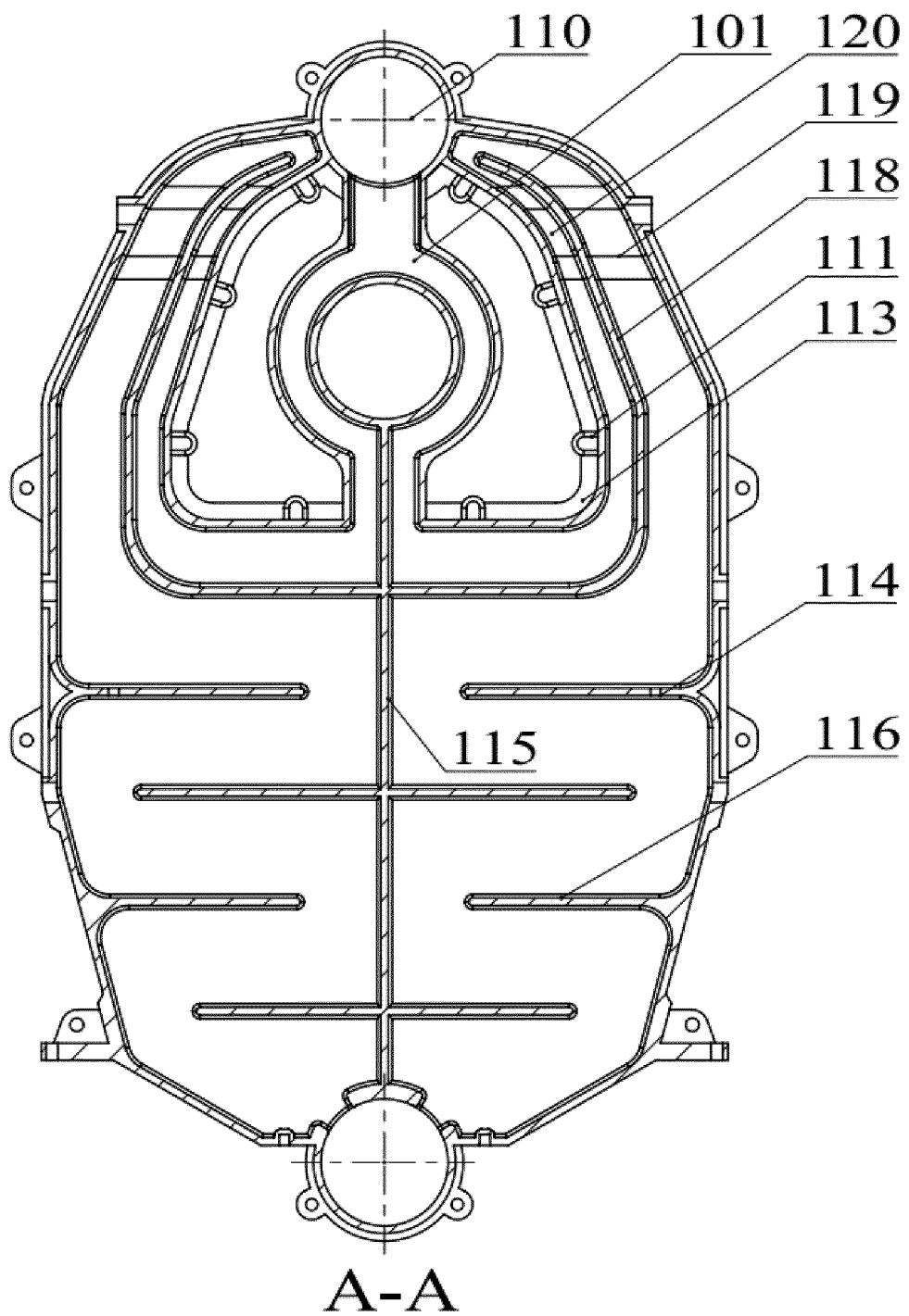


Fig. 2e

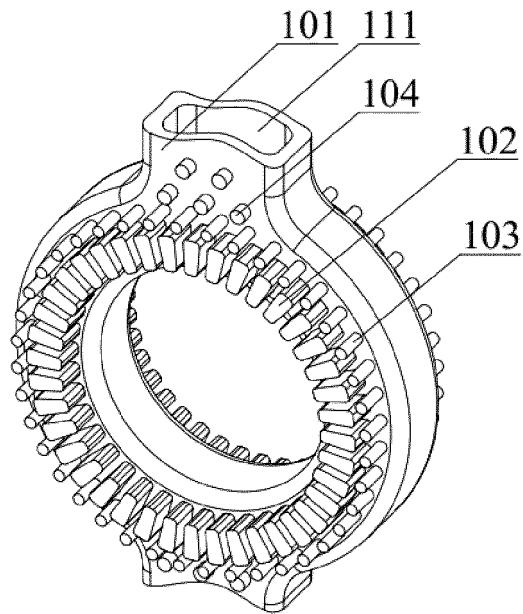


Fig. 3

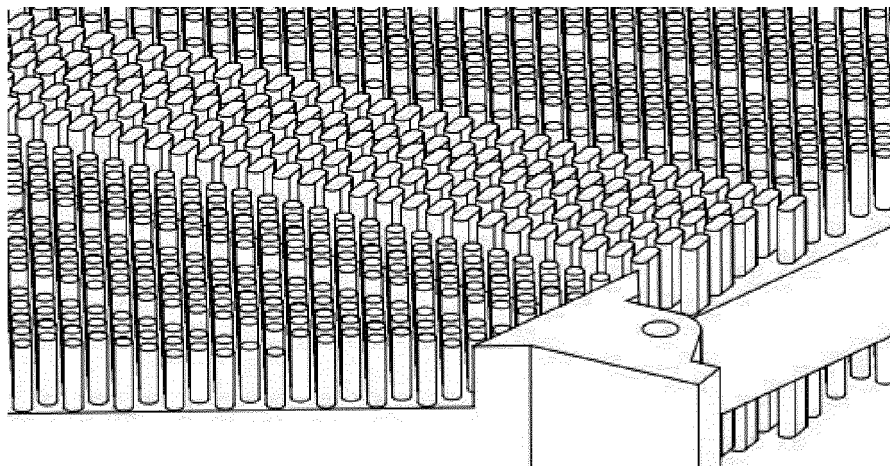


Fig. 4a

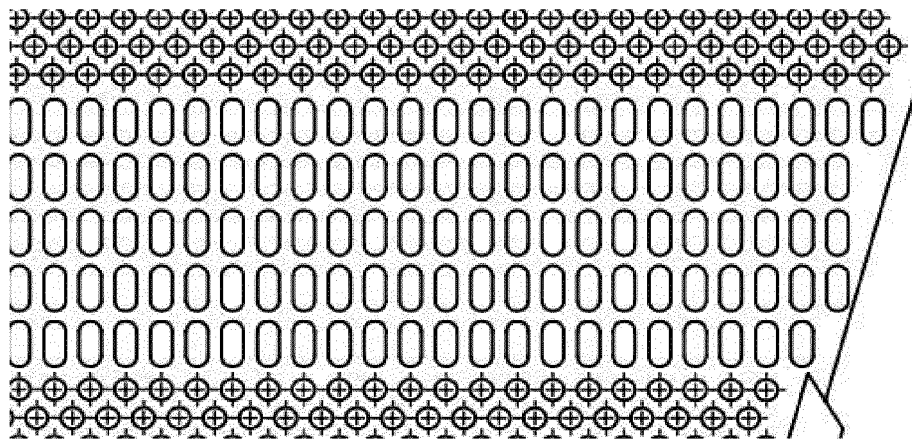


Fig. 4b

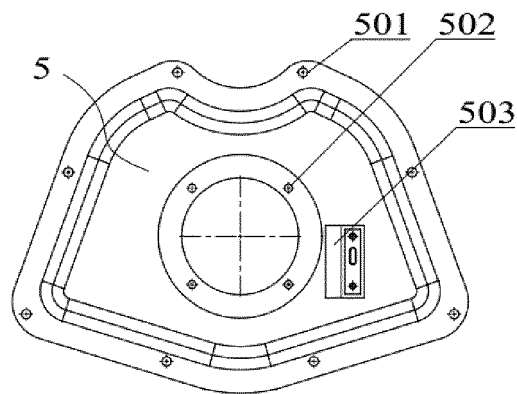


Fig. 5a

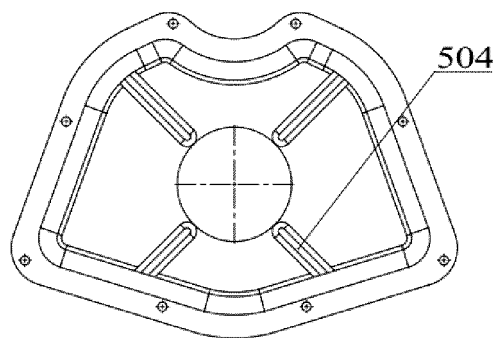


Fig. 5b

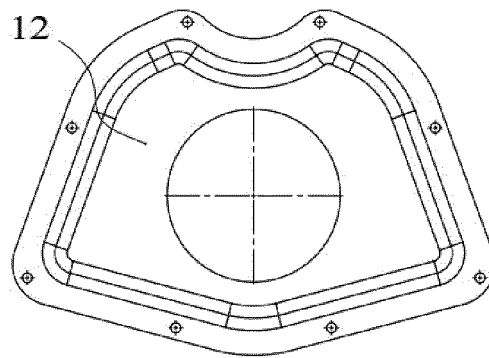


Fig. 6a

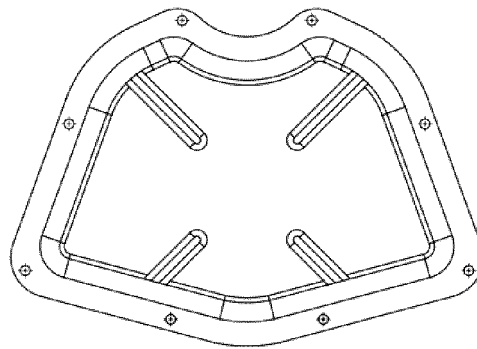


Fig. 6b

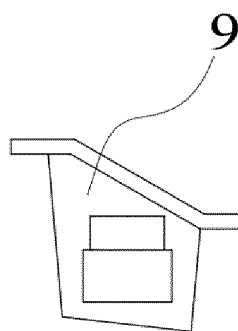


Fig. 7a

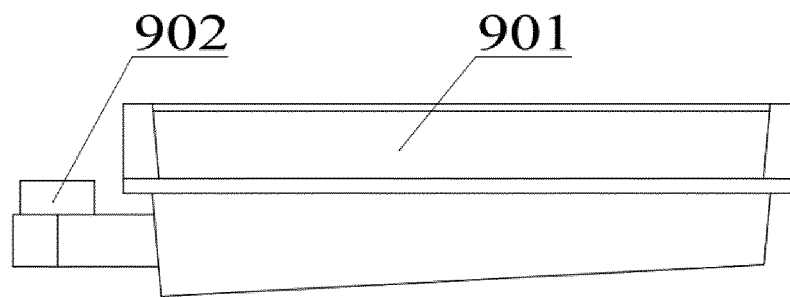


Fig. 7b

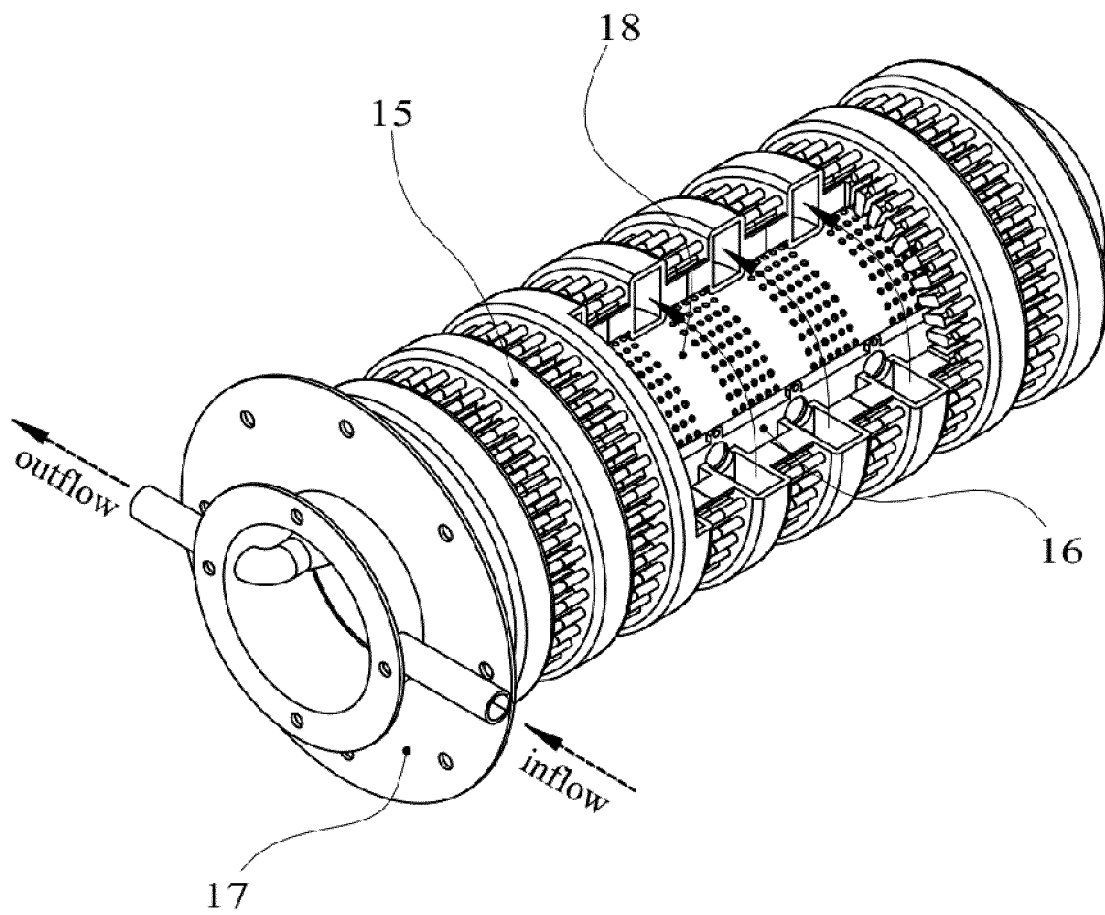


Fig. 8a

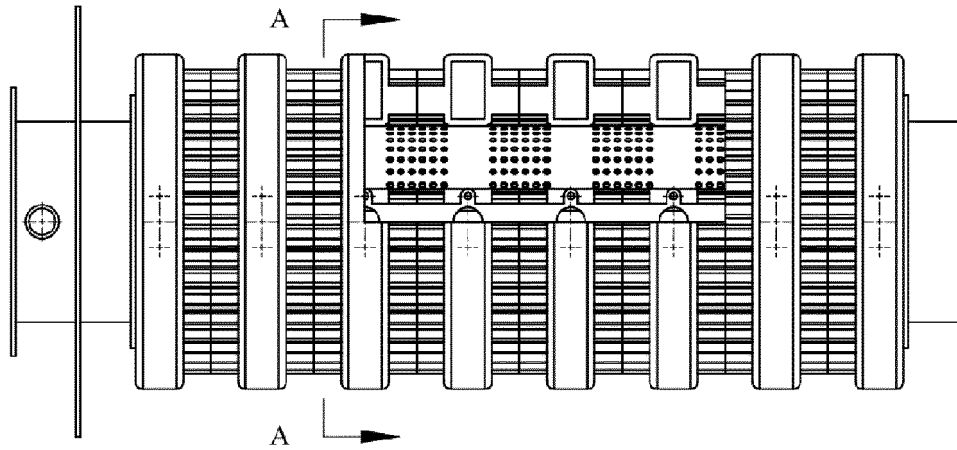


Fig. 8b

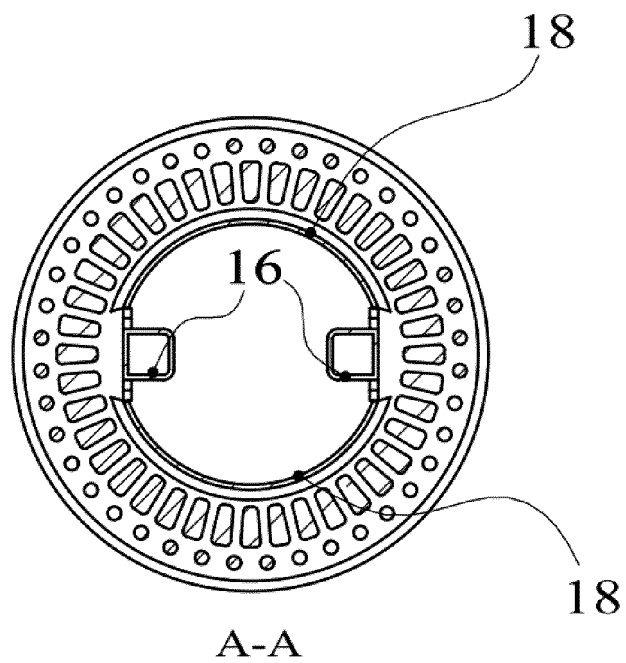


Fig. 8c

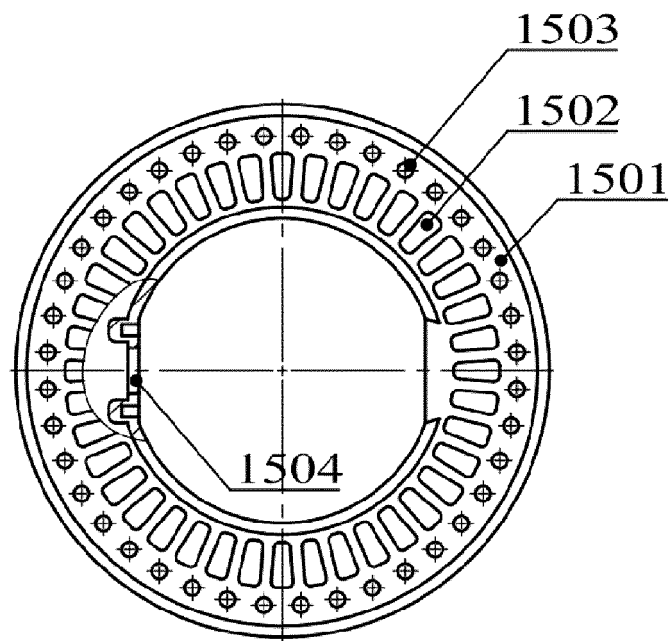


Fig. 9a

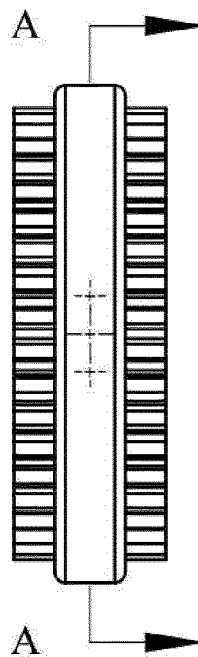
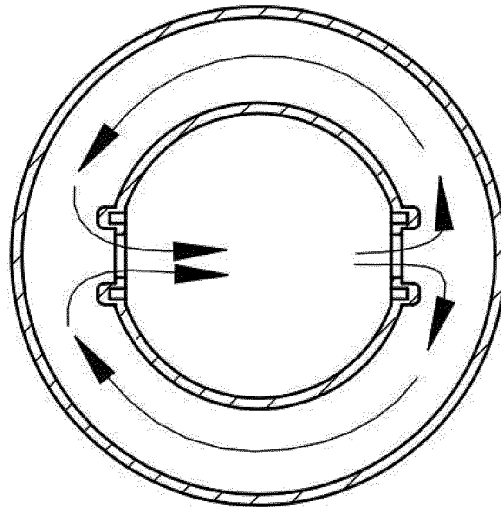


Fig. 9b



A-A

Fig. 9c

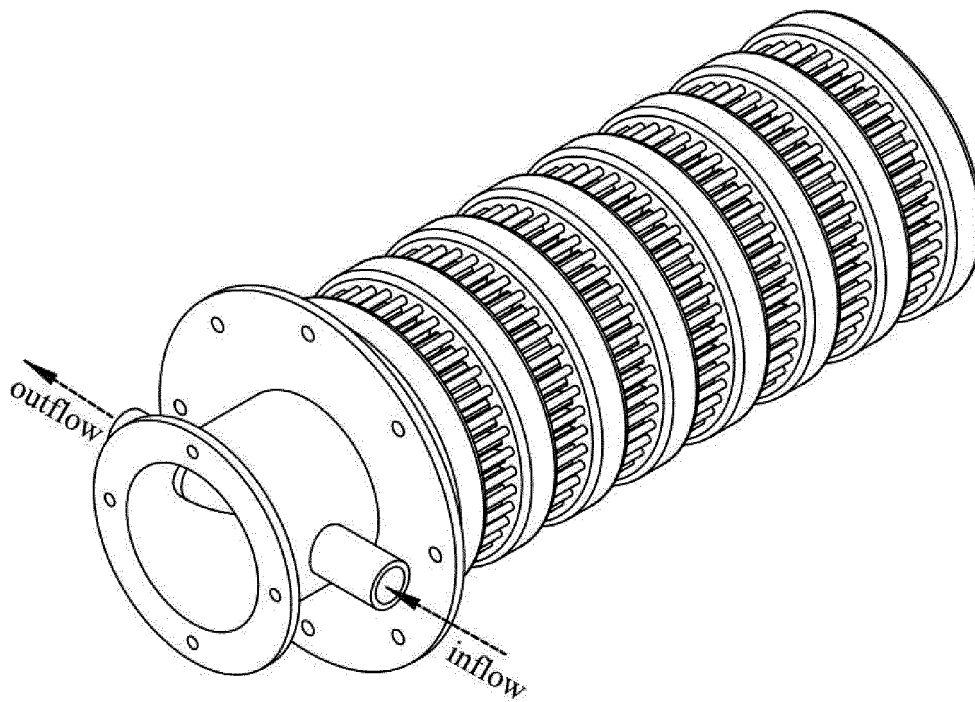


Fig. 10a

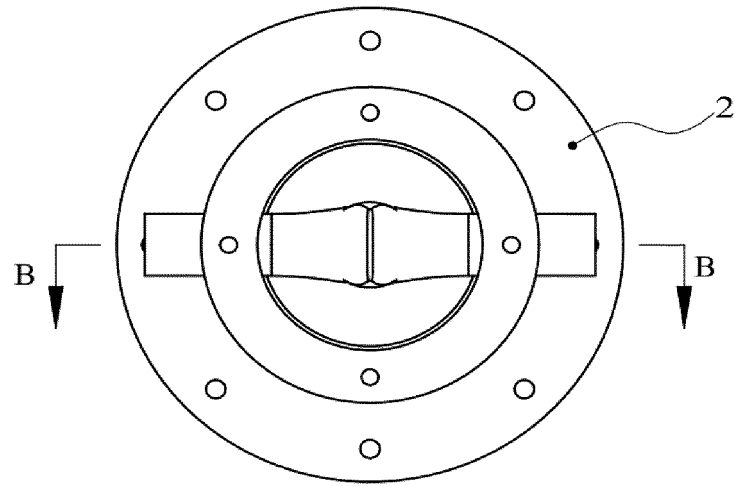


Fig. 10b

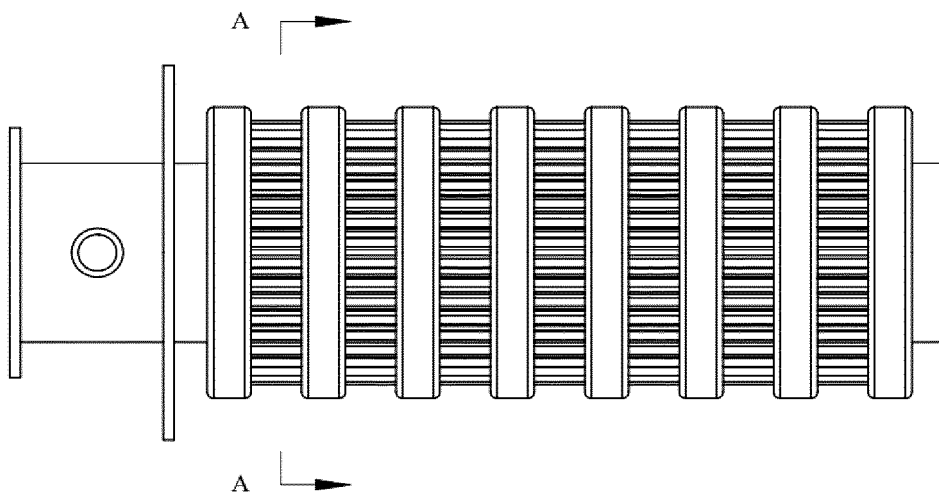


Fig. 10c

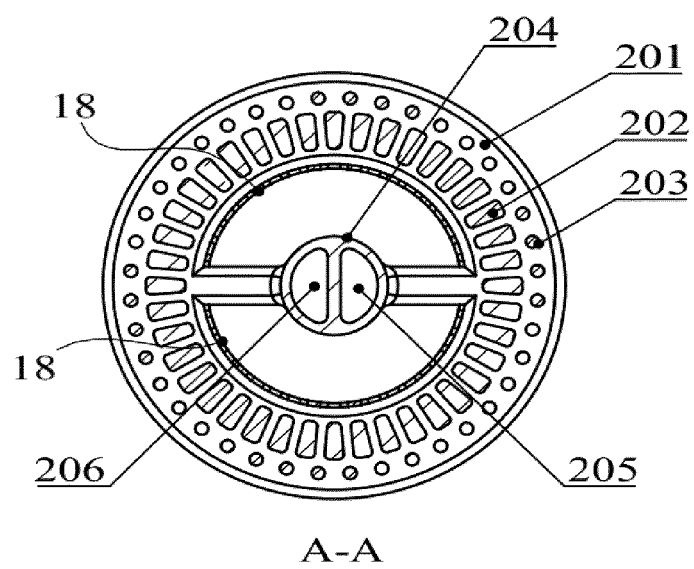


Fig. 10d

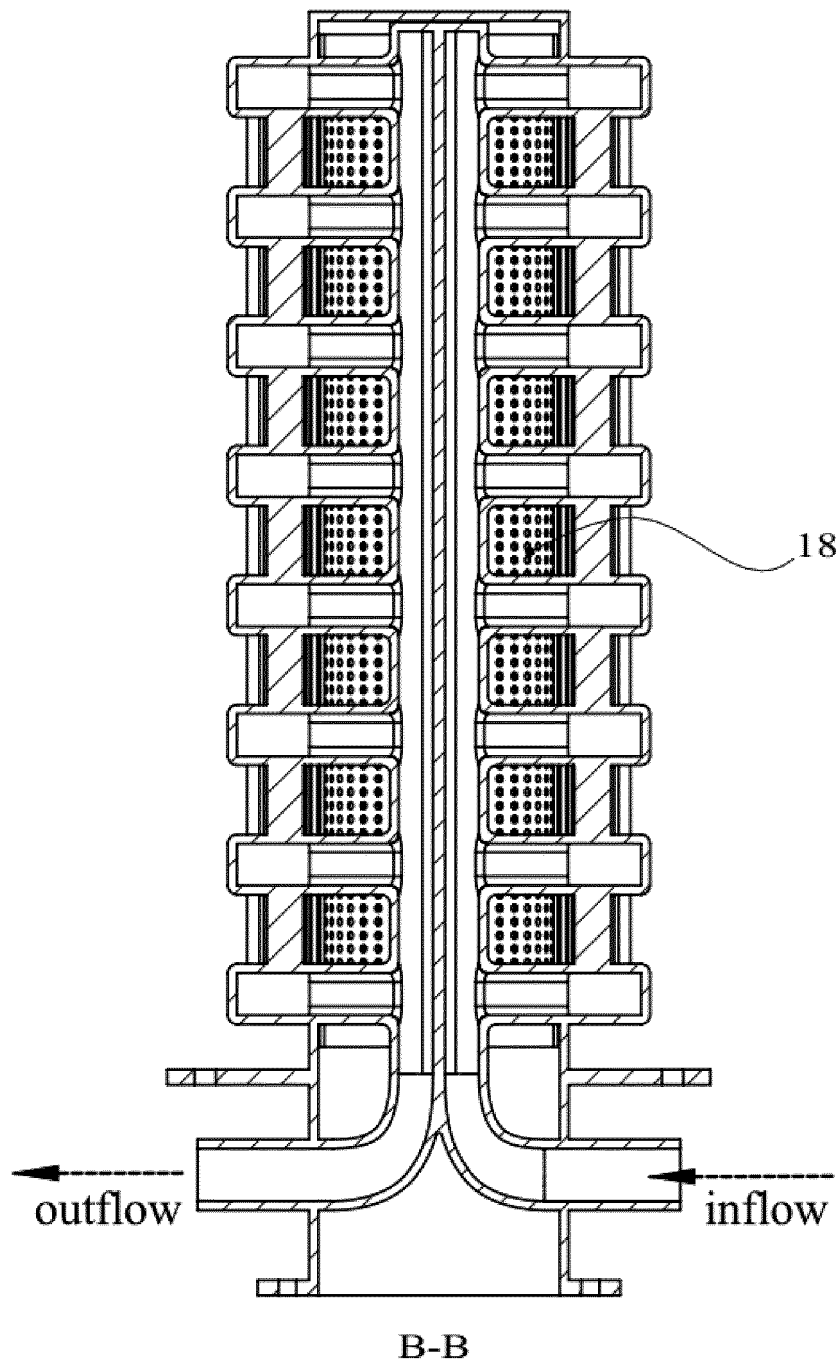


Fig. 10e

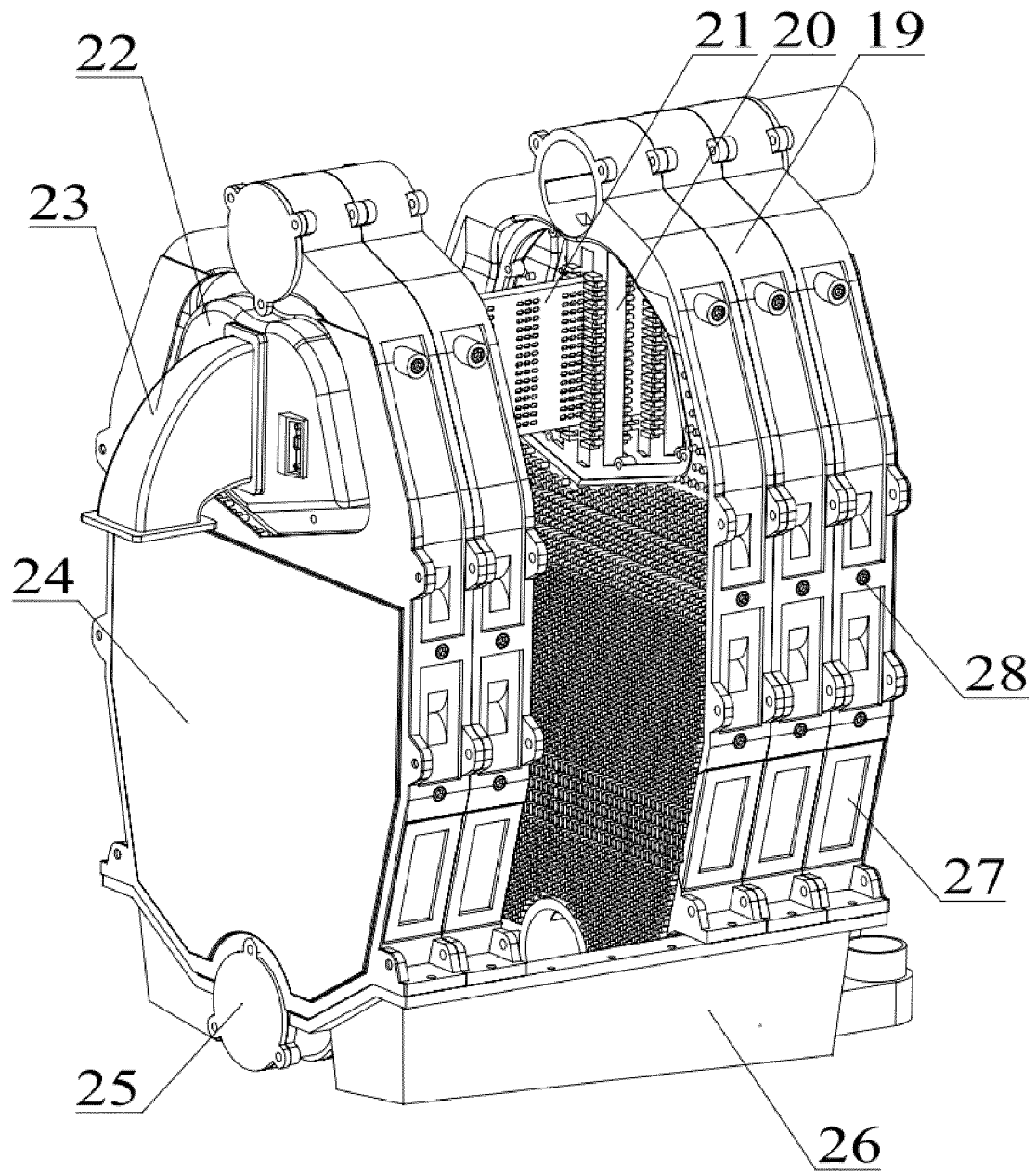


Fig. 11a

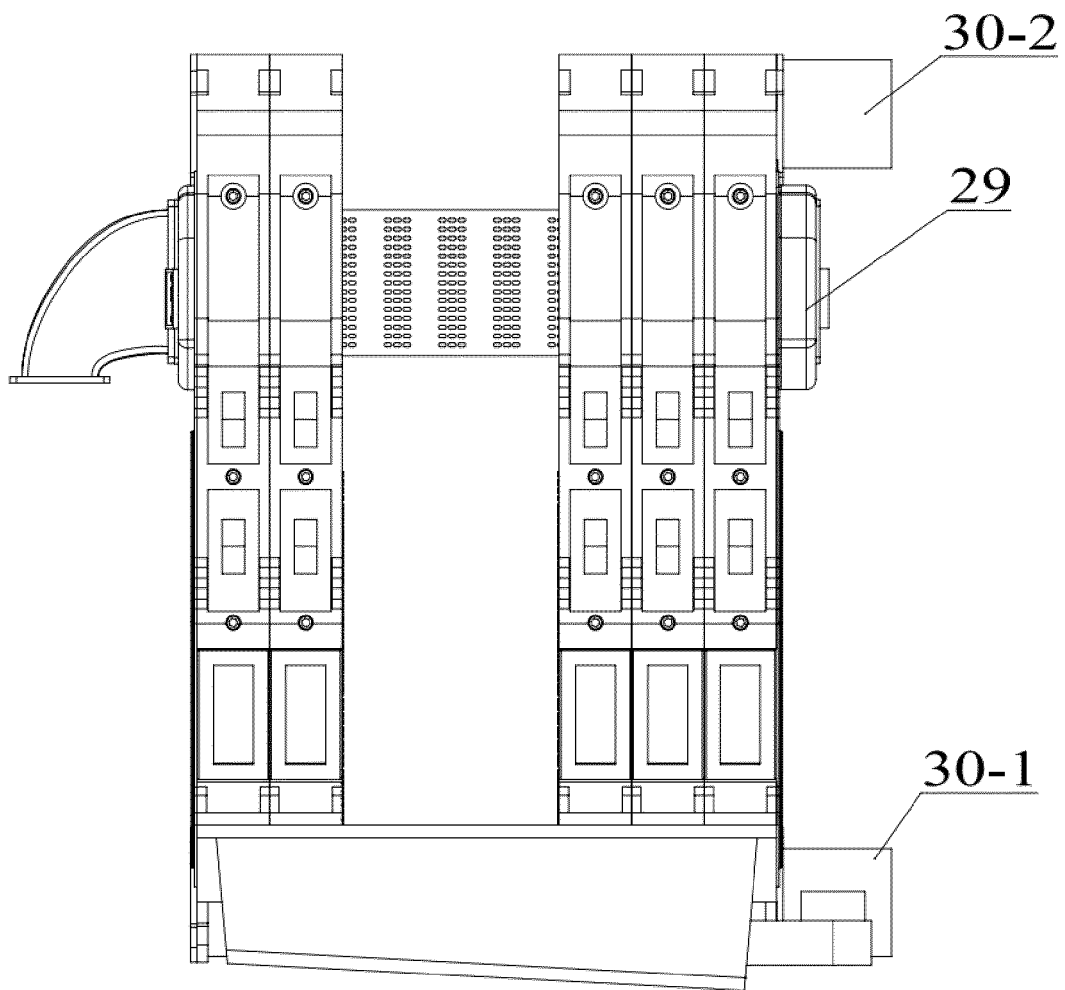


Fig. 11b

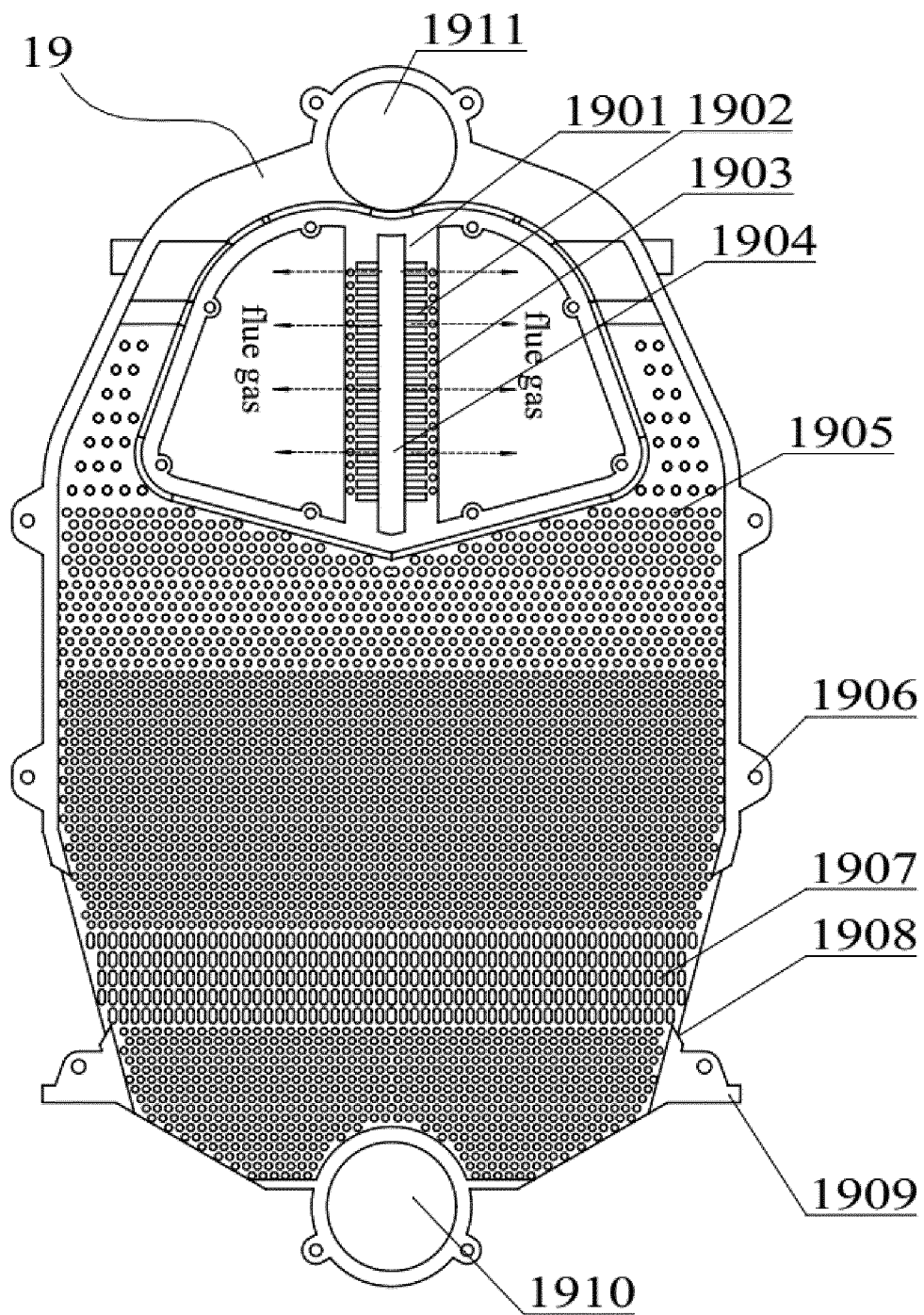


Fig. 12a

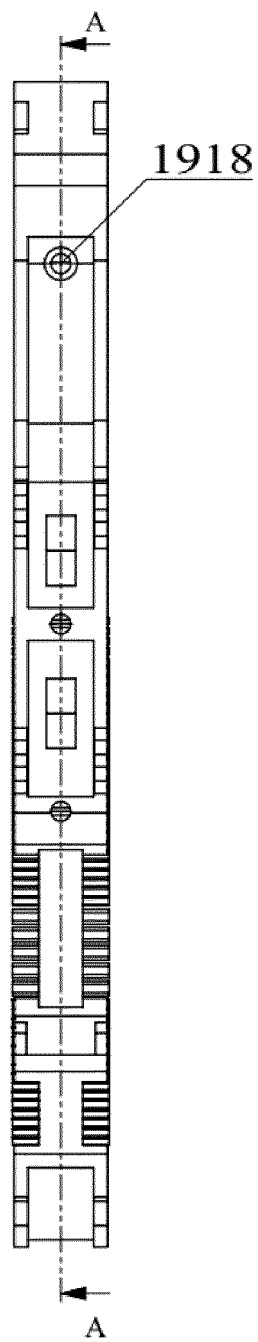
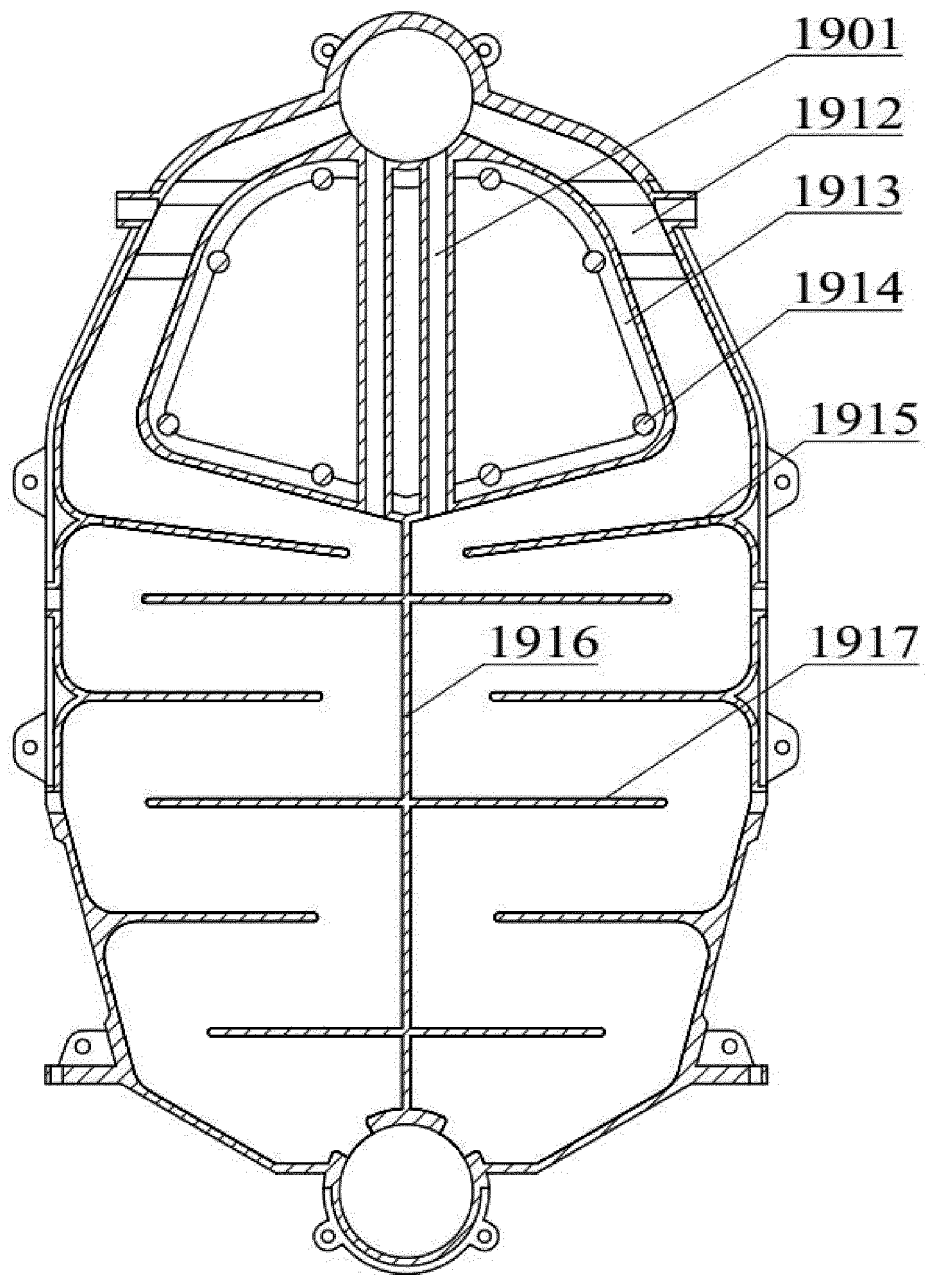


Fig. 12b



A-A

Fig. 12c

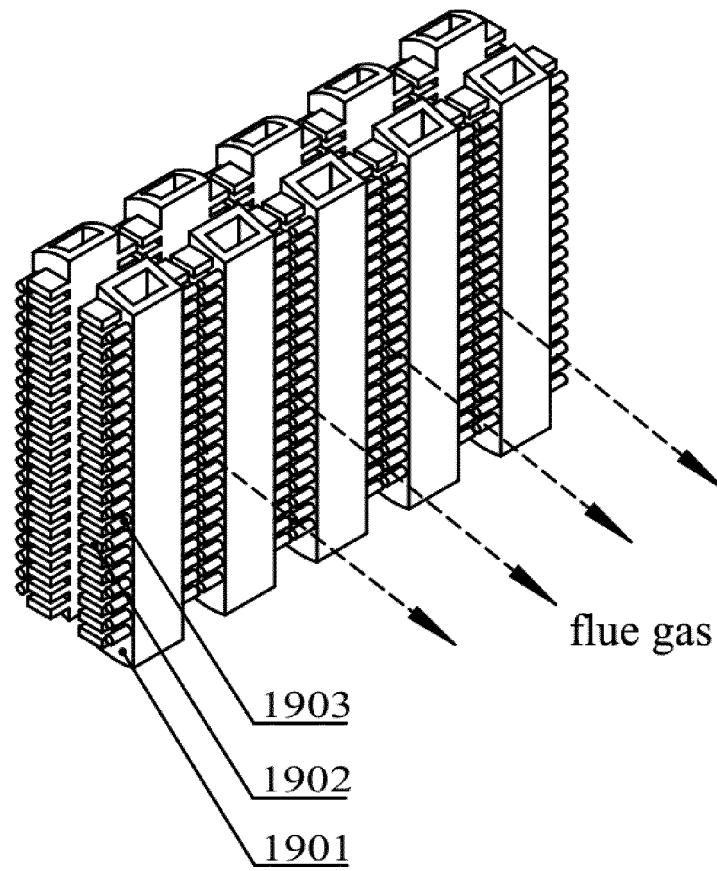


Fig. 13

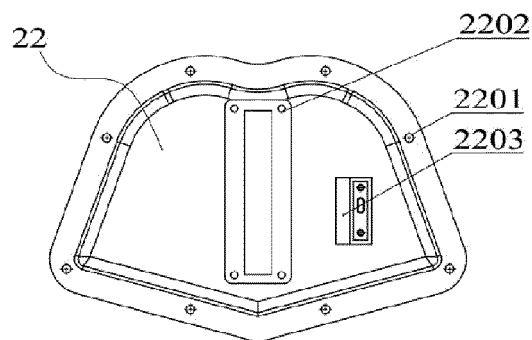


Fig. 14a

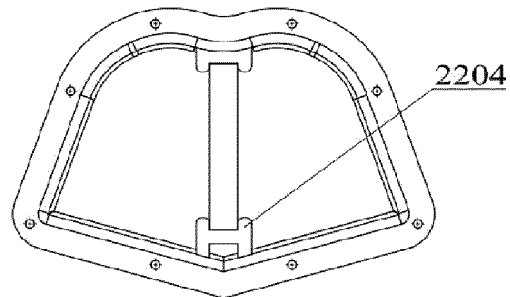


Fig. 14b

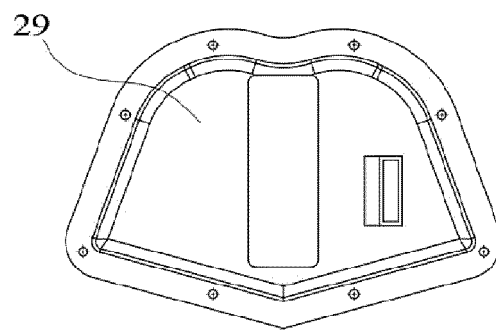


Fig. 15a

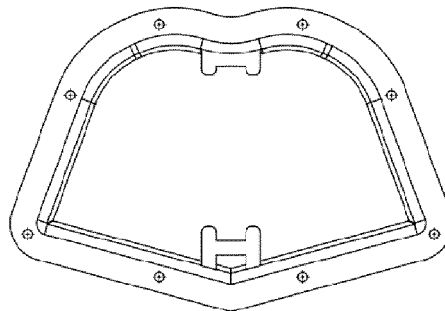


Fig. 15b

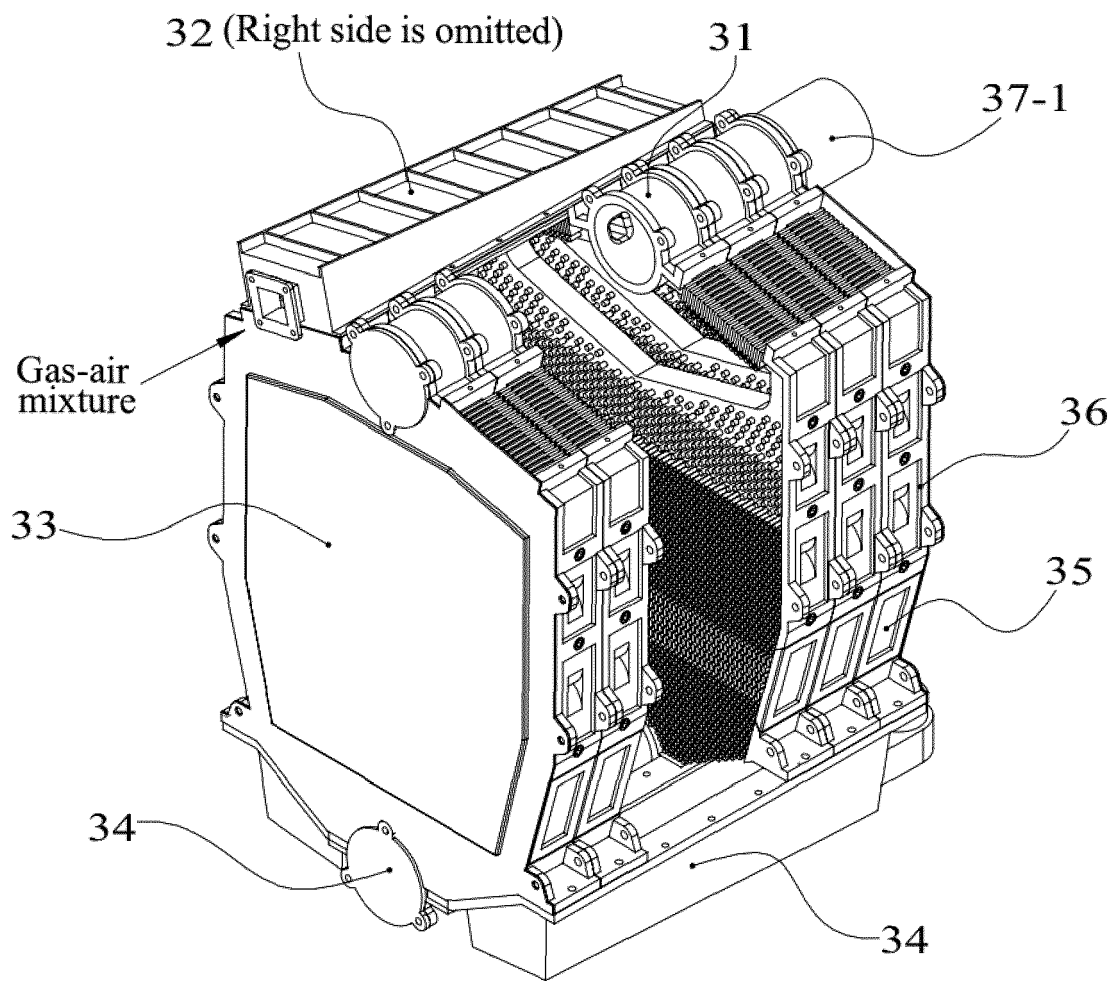


Fig. 16a

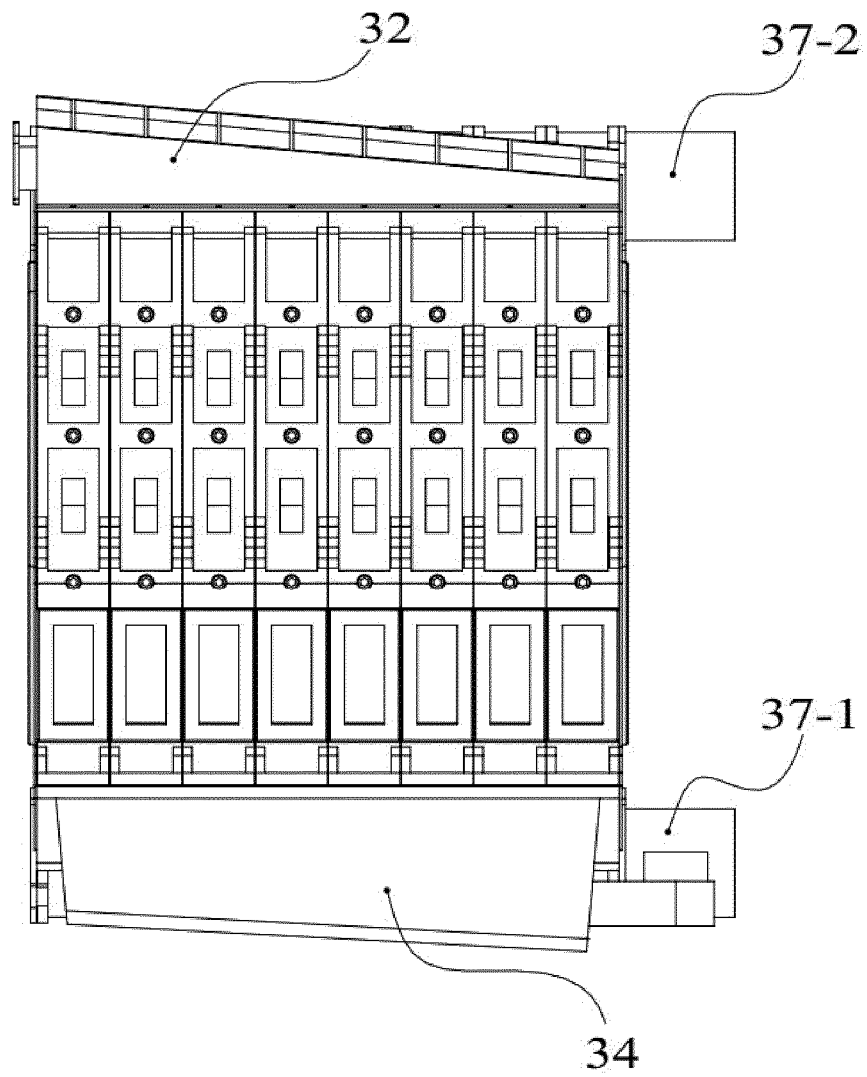


Fig. 16b

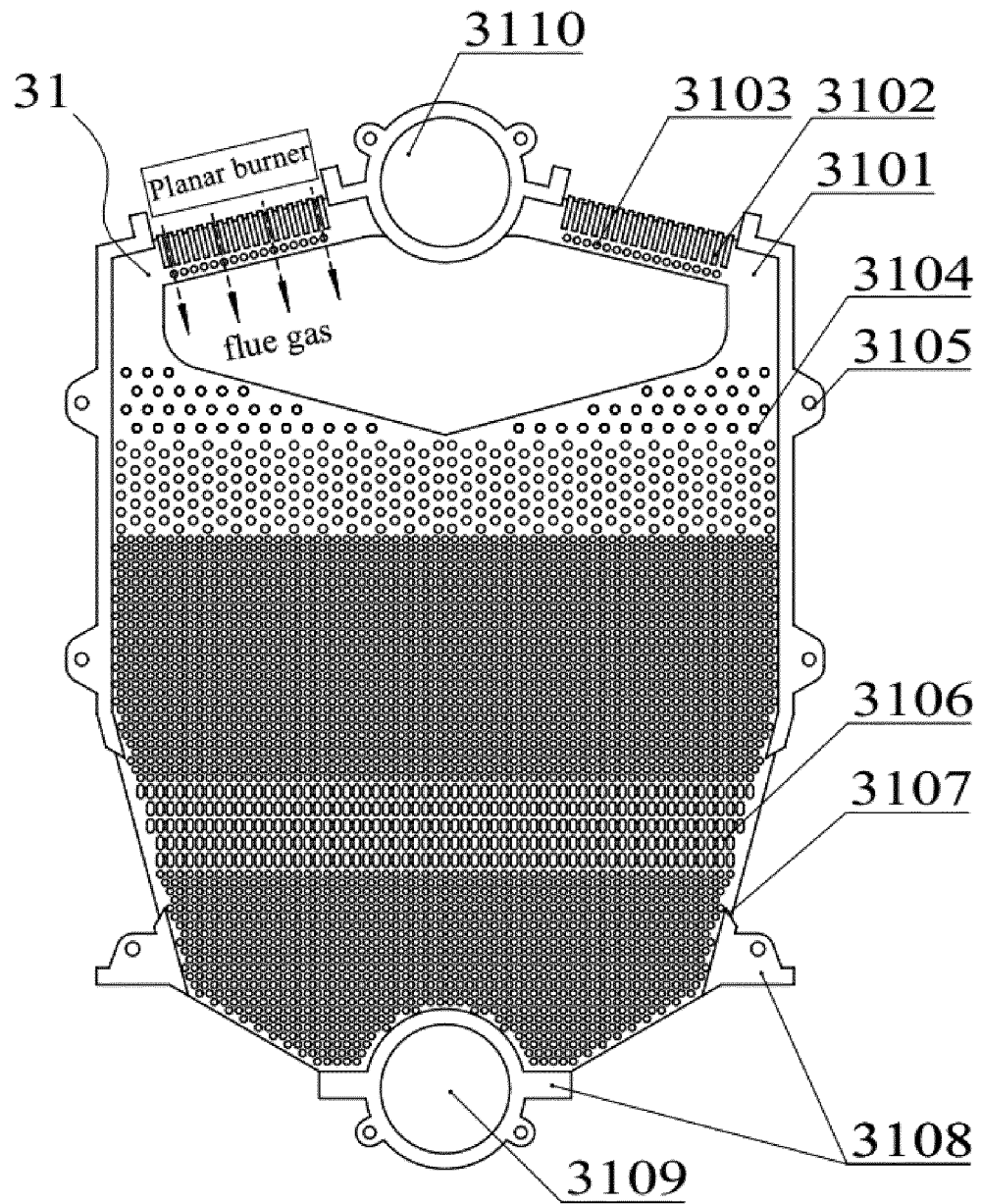


Fig. 17a

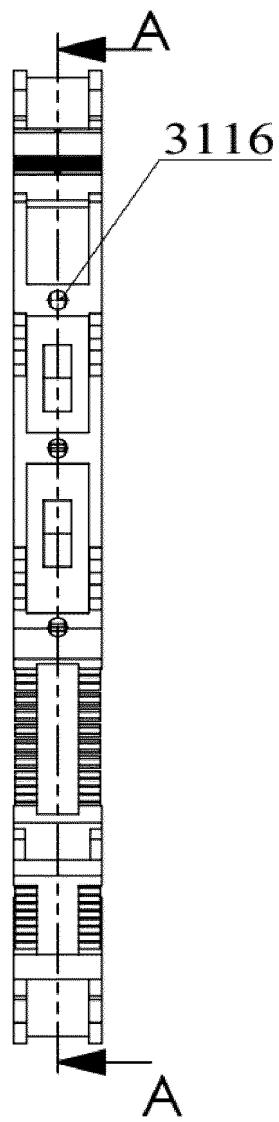
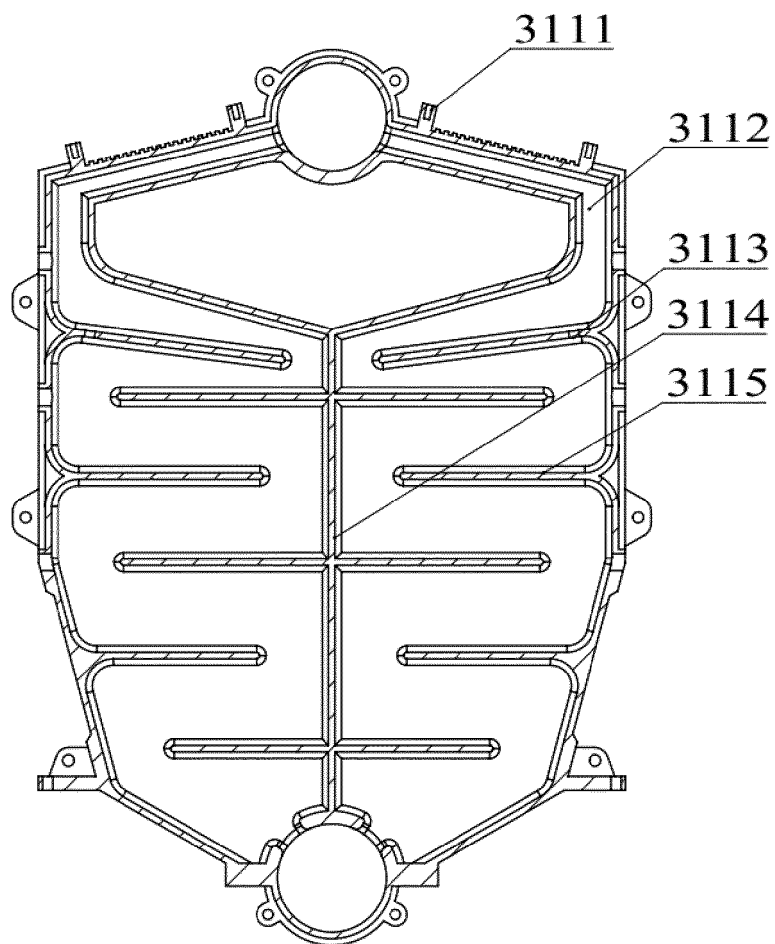


Fig. 17b



A-A

Fig. 17c

INTERNATIONAL SEARCH REPORT

International application No.

PCT/CN2021/105092

5	A. CLASSIFICATION OF SUBJECT MATTER F24H 8/00(2006.01)i; F24H 9/00(2006.01)i; F24H 9/02(2006.01)i; F24H 9/18(2006.01)i According to International Patent Classification (IPC) or to both national classification and IPC		
10	B. FIELDS SEARCHED Minimum documentation searched (classification system followed by classification symbols) F24H Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched		
15	Electronic data base consulted during the international search (name of data base and, where practicable, search terms used) CNABS, CNKI, DWPI, VEN: 耦合, 单锅片, 铸铝硅, 热水炉, 预混, 水冷, 轴对称, 均流孔板, 燃烧头, 烟箱, 辐射, 对流, 冷凝, coupling type, single boiler sheet, cast aluminum silicon, water heater, pre-mixing, water cooling, axial symmetry, equalizing orifice, combustion head, smoke box, radiation, convection, condensation		
20	C. DOCUMENTS CONSIDERED TO BE RELEVANT		
25	Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
30	PX	CN 111829179 A (XI'AN JIAOTONG UNIVERSITY) 27 October 2020 (2020-10-27) claims 1-20	1-20
35	A	CN 109883051 A (XI'AN JIAOTONG UNIVERSITY) 14 June 2019 (2019-06-14) see description, paragraphs [0034]-[0063], figures 1-9	1-20
40	A	CN 109855286 A (XI'AN JIAOTONG UNIVERSITY) 07 June 2019 (2019-06-07) entire document	1-20
45	A	CN 109099588 A (XI'AN JIAOTONG UNIVERSITY) 28 December 2018 (2018-12-28) entire document	1-20
50	A	CN 110220305 A (SHAO, Longsheng) 10 September 2019 (2019-09-10) entire document	1-20
55	A	CN 210831977 U (HANGZHOU CAWAT THERMAL TECHNOLOGY CO., LTD.) 23 June 2020 (2020-06-23) entire document	1-20
	A	CN 208058822 U (BEIJING ZHONGLI CHUANGYE MECHANICAL ELECTRONICAL EQUIPMENT CO., LTD.) 06 November 2018 (2018-11-06) entire document	1-20
	☒ Further documents are listed in the continuation of Box C. ☒ See patent family annex.		
	* Special categories of cited documents: "A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier application or patent but published on or after the international filing date "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 "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 "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 "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art "&" document member of the same patent family		
	Date of the actual completion of the international search		Date of mailing of the international search report
	27 September 2021		11 October 2021
	Name and mailing address of the ISA/CN		Authorized officer
	China National Intellectual Property Administration (ISA/CN) No. 6, Xitucheng Road, Jimenqiao, Haidian District, Beijing 100088 China		
	Facsimile No. (86-10)62019451		Telephone No.

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International application No.

PCT/CN2021/105092

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	FR 2907539 B1 (DIETRICH THERMIQUE) 26 April 2013 (2013-04-26) entire document	1-20

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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.

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Patent document cited in search report			Publication date (day/month/year)	Patent family member(s)		Publication date (day/month/year)
CN	111829179	A	27 October 2020	None		
CN	109883051	A	14 June 2019	None		
CN	109855286	A	07 June 2019	None		
CN	109099588	A	28 December 2018	None		
CN	110220305	A	10 September 2019	None		
CN	210831977	U	23 June 2020	None		
CN	208058822	U	06 November 2018	None		
FR	2907539	B1	26 April 2013	FR	2907539 A1	25 April 2008

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