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HEAT EXCHANGER

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2 Sheets-Sheet 1

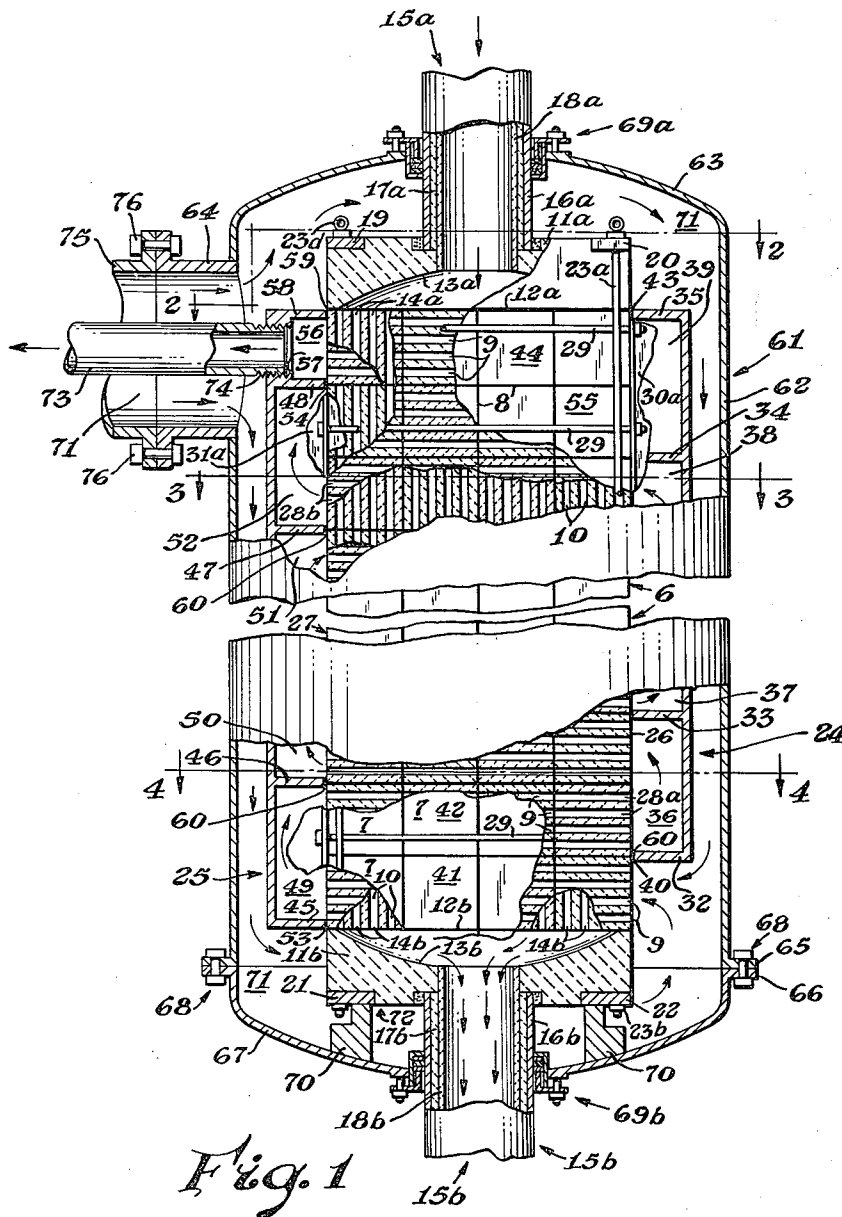


Fig. 1

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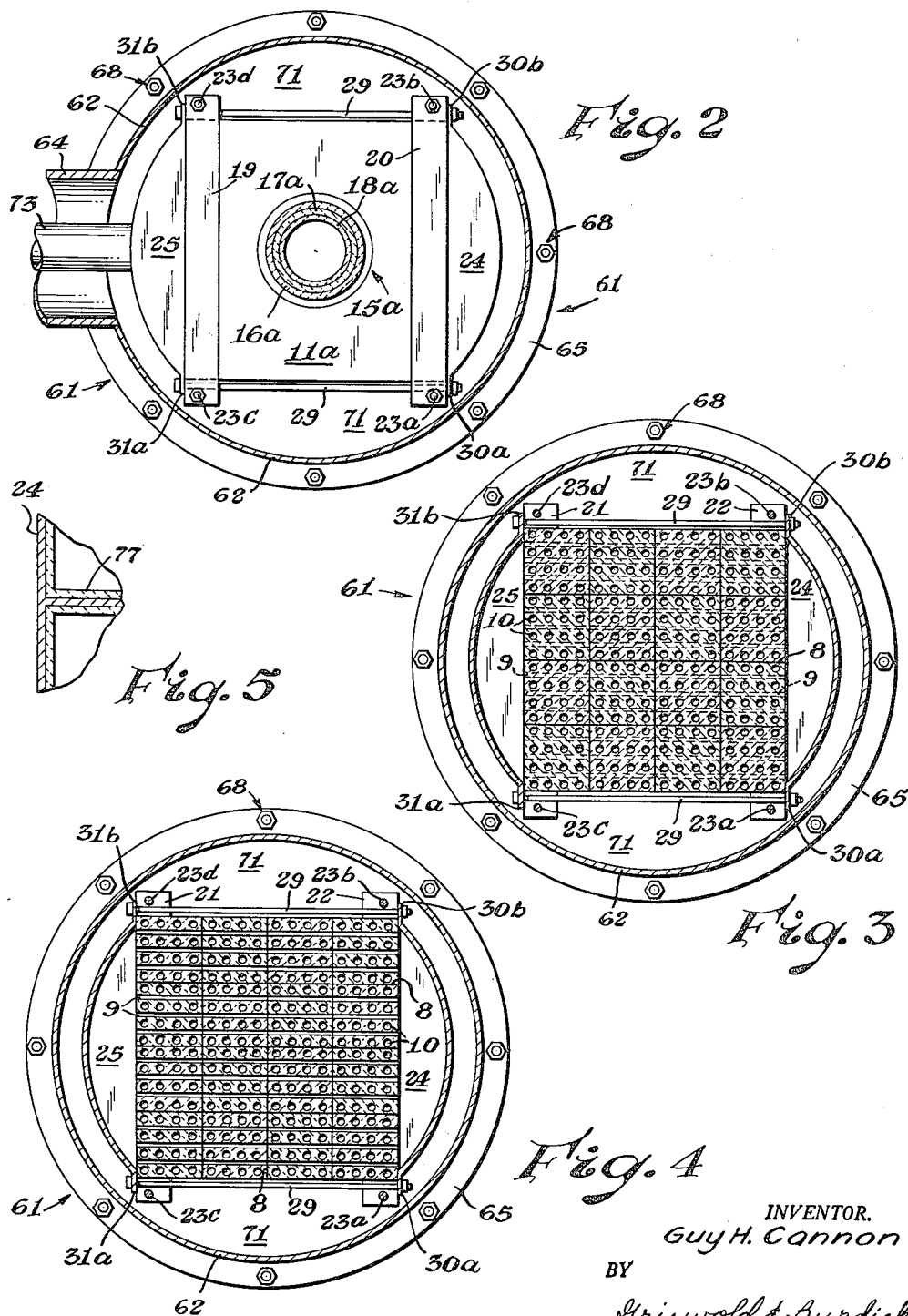
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HEAT EXCHANGER

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This invention relates to a heat exchanger. It more particularly relates to a heat exchanger having a graphite core assembly for use with high temperature liquid metal and gas coolants.

Liquid metals which, in general, have high boiling points and high freezing points, as compared to the conventionally used liquid organic and aqueous heat transfer media, are very useful for transporting heat at high temperatures and low pressures. Commercial utility of metals such as bismuth, bismuth-lead, sodium, lead, lead-magnesium, sodium-potassium alloys and the like in their liquid state as heat transfer media has become increasingly important with the advent of high-pressure, high-temperature gas driven turbines. The liquid metal heat transfer media are particularly useful in connection with nuclear energy based power generating reactors. Conventional heat exchangers made from normal structural metals are not generally satisfactory for use with liquid metal heat transfer media because of the tendency of the various structural metals to be dissolved by the liquid metallic heat transfer media on the hot side of the system followed by reprecipitation of this dissolved metal on other parts of the system that have colder wall surfaces (mass transport effect). In addition to the mass transport effect, the structural metals undergo considerable degradation of physical properties when subjected to high temperatures. These undesirable phenomena which accompany the use of liquid metal heat exchange media in conventional structural metal heat exchanger now unexpectedly have been overcome in accordance with the invention by use of a heat exchanger having among its essential components a graphite core. It is the principal purpose of this invention, therefore, to provide a heat exchanger having a graphite core for transfer of heat from a low-pressure high-temperature liquid metal to a high-pressure secondary fluid to be heated. An advantage of the use of graphite in this core is that graphite is not wetted by liquid metals and also can be made essentially impervious both to liquid metals and gases. Additionally graphite has good thermal conductivity, is easily machined, is very resistant to thermal shock, and has a very low coefficient of thermal expansion. Furthermore, graphite has good compressive strength, which strength increases with increases in temperature up to temperatures of about 2500° centigrade. A further object of this invention is to provide a heat exchanger configuration which maintains compressive stresses on the graphite core by surrounding this core with the high-pressure secondary fluid to be heated. Another object of the invention is to provide a heat exchanger configuration wherein no metal structural members come into contact with the high-temperature liquid metal thereby avoiding mass transport effects. Still another object of the invention is to provide a heat exchanger configuration wherein minimum pressure induced stresses are maintained in the structural metal parts of the heat exchanger. Other objects and advantages will be apparent to one skilled in the art from the drawings and description which follow.

The heat exchanger of the present invention comprises in combination, a monolithic graphite core assembly made up of cross-bored graphite blocks stacked together in layers of rows in such a manner that there is provided a series of alternate vertical and horizontal passages

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through the core assembly. Attached to the top and bottom of this monolithic core are graphite header domes opposite the open ends of the vertical passageways. These header domes have outwardly projecting low-pressure fluid carrying conduit means for the low-pressure, high-temperature liquid metal heat exchanger medium. This portion of the assembly permits a single pass of the liquid metal heat transfer medium from one header to the other through the vertical passageways of the core. Attached to opposite sides of the core and enclosing the exposed open ends of the horizontal through passages are internally walled side headers which form, when abutted to the core, compartments, these compartments enclosing a series of continuous passageways horizontally through two adjacent ascending layers of blocks. One of the headers additionally has an exhaust port at the top. The side headers are fastened to the opposite vertical faces of the core in such a manner that the secondary high-pressure fluid must first enter the horizontal passages of the bottom layer of blocks, then pass through a compartment of a side header to the next above layer of blocks thence through their horizontal passages in the opposite direction, thence similarly through the other layers of blocks sequentially, finally exiting from the top layer of blocks into the exhaust port.

The unitized assembly of core complete with graphite header domes and internally walled side headers is positioned inside an enveloping external tank member in such a manner as to leave an annulus between the unitized core assembly and the tank. The low pressure fluid carrying conduit means project respectively through the top and bottom of the tank. The high-pressure secondary fluid exhaust port of the internally compartmented side header faces a side opening in the tank. This side opening serves as an annular entrance port for the introduction of the high pressure-low temperature secondary fluid.

The shape of the heat transfer core, fittings, headers, external tank, high- and low-pressure fluid carrying conduit means and the like can be of a variety of forms and can be assembled by diverse means, but one embodiment of the invention, using blocks of cubical form, is shown in the drawings and explained by the accompanying detailed description.

In the drawings:

FIGURE 1 is a side elevation, partly in section, of the heat exchanger with parts cut-away to show internal structure.

FIGURE 2 is a horizontal sectional view of the heat exchanger taken along line 2—2 of FIGURE 1.

FIGURE 3 is a horizontal sectional view of the heat exchanger taken along line 3—3 of FIGURE 1.

FIGURE 4 is a horizontal sectional view of the heat exchanger taken along lines 4—4 of FIGURE 1.

FIGURE 5 is a fragmentary view of a modification of the apparatus of FIGURE 1 showing thermal insulation affixed to the inner wall of a compartmented or walled side header.

The heat exchanger as shown in the figures has a graphite core 6. This core is made from cubical, cross-bored graphite blocks 7 cemented together at their butting faces into a monolithic structure with cement 8. The blocks are oriented in such a fashion that the cross bores provide parallel rows of passageways in each layer of blocks which align with each other and form layers of continuous passageways 9 in the horizontal direction and at the same time a similar series of passageways 10 in the vertical direction.

Graphite header domes, 11a and 11b, are cemented to the top and bottom of the monolithic graphite core, with cement 12a and 12b. These header domes are concavely hollowed on their insides 13a and 13b which face the

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openings 14a and 14b of the vertical passageways of the core. Additionally, each of the two graphite header domes is fitted with low-pressure liquid metal conduit carrying means 15a and 15b projecting vertically outward from the center of each dome. These conduits have steel shells 16a and 16b, refractory insulation 17a and 17b and graphite linings 18a and 18b.

The graphite header domes and monolithic core are held together in compression by four steel beams 19, 20, 21, and 22, the opposite ends of the upper pair 19 and 20 being fitted with tie bolts 23a, 23b, 23c and 23d to the corresponding ends of the lower pair of beams 21 and 22.

Side headers 24 and 25, usually made of metal, are attached to the sides 26 and 27 respectively of the monolithic core and enclose the openings 28a and 28b of the horizontal passageways. These headers are held in contact with the monolithic core by a series of tie bolts 29 passing through the flanged edges 30a and 30b of header 24 and 31a and 31b of header 25 at intervals along the vertical length of the header and running horizontally across the outside of the core. The header 24 has a number of walls or partitions, e.g. 33 and 34, spaced substantially at intervals equal to about the thickness of two horizontal layers of blocks, along its length. These partitions project inwardly and contact the monolithic core at the junction of adjacent layers of blocks in such a manner that there is formed a series of compartments 36, 37, 38, and 39, each of which has a height sufficient to encompass the openings of the horizontal passageway on one side of two adjoining horizontal layers of blocks.

The header 24 is blind at both its top 35 and bottom 32 and is of such a length that the edge of its bottom wall 32 fits against the monolithic graphite core at the junction 40 of the bottom-most horizontal layer 41 and the next above layer 42 of blocks and the edge of its top 35 fits against the core at the junction 43 of the top layer of blocks 44 and the graphite header dome 11a.

The second side header 25 has walls, or partitions, 46, 47, and 48 which, project inwardly and fit against the monolithic core at the junction of adjacent layers of blocks to form a series of compartments, e.g. 49, 50, 51, 52 and 56 essentially identical in size to those formed correspondingly by the core and header 24 except for the exit compartment 56. Header 25 has its bottom edge 45 fitting against the monolithic core at the junction 53 of the bottom graphite header 10b and the bottom most layer 41 of graphite blocks and the edge of its top wall 48 fitting against the core at the junction 54 of the top layer 44 of blocks and those of the layer 55 next below. Additionally, header 25 has an exhaust port or compartment 56 having an inside threaded opening 57. Wall 48, which is the top of the compartment 52, also is the bottom of the exit or exhaust compartment 56. The edge of the top 58 of the side header 25 fits against the monolithic core at the junction 59 of the graphite header dome 11a and the top layer 44 of blocks. As shown, a sealant 60 is inserted between the edges of the side headers and the partitions where they abut the core to render the header contacts with the core pressure tight.

The unitized core assembly of the monolithic graphite core with attached top and bottom graphite header domes and side headers is placed in an enveloping tank 61. This tank has a cylindrical body portion 62, an integral domed top 63, and an outwardly projecting flanged conduit 64 on one side near the top communicating with the interior. The lower end of the cylindrical body member has an outwardly projecting flange 65 which mates with a similar flange 66 of the bottom member 67. By the flanges 65 and 66 the two members 62 and 67 are joined using conventional bolt and nut assemblies 68. The top and bottom tank members 63 and 67 have conventional packing gland assemblies 69a and 69b in their centers as shown. Additionally, the inside of the bottom member

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67 has supporting lugs 70 on which rests the beams 21 and 22 of the core assembly and thereby supports the bottom 72 of the core in the tank.

As shown, the unitized core assembly is positioned inside the exterior tank body member 62 in such a manner that an annulus 71 is provided between the unitized core assembly and the exterior tank body, the low-pressure liquid metal carrying conduit 15a projects through the packing gland assembly 69a, and the exhaust port 56 faces the flanged conduit 64 in the side of the tank.

A high-pressure heated secondary fluid carrying conduit 73 having external threads 74 is fitted into the threaded exhaust port 57. An outwardly flanged high pressure secondary fluid inlet conduit carrying means 75 surrounding the conduit 73 is coupled to the mating flanged conduit 64 by conventional bolt and nut assemblies 76. The annulus 71 formed between the conduits 75 and 73 and the unitized core assembly and the closed exterior tank is rendered pressure tight where the graphite lined, low-pressure fluid conduits projects through the top and bottom of the tank by the conventional packing gland sealing assemblies 69a and 69b.

The graphite used in constructing the core, top and bottom header domes and liquid metal carrying means is commercially available so-called, impervious graphite.

The metal tank, side headers, bolt and nut assemblies and the like which are subjected to only minimum temperature and pressure induced stresses during operation may be constructed in a conventional manner from common structural metals having properties permitting the safe transport of the secondary high pressure fluid.

In actual operation of the heat exchanger, low-pressure high-temperature liquid metal to be cooled is carried into one end of the heat exchanger by the graphite lined fluid carrying conduit means 15a, which liquid metal then is distributed by the header dome 11a and conducted in a single pass through the length of the monolithic graphite core by means of the vertical passages 10, the metal thereby transferring heat to the graphite core. The liquid metal, so cooled, is collected in the lower graphite header dome 11b, and exits from the dome through the conduit 15b. Simultaneously, a low-temperature high-pressure inert fluid which is to be heated, such as nitrogen, argon, helium and the like is carried to the heat exchanger by conduit 75 and introduced into the annulus 71, between the exterior tank member and unitized core assembly, through conduit 64. This high pressure fluid surrounds the unitized core assembly before entering the horizontal passages 9 of the core at the bottom layer 41 of blocks and subjects the core assembly to external fluid pressure tending to hold the headers against the core. This second fluid passes through the core by passing from the annulus 71 into the horizontal passages in the lower-most layer of blocks thence through compartment 49 into the horizontal passages of the next above layer of blocks. From these passages, the fluid passes into compartment 36 and thence into the passages of the next above layer of blocks and so forth to the top-most layer from which the fluid exits into compartment 56 and thence through conduit 73. By so traversing the core, the fluid is heated and may be made to do useful work as in a turbine.

In this apparatus, it can be recognized during normal operations that by surrounding the graphite core structure with the fluid to be heated, which has a pressure always higher than the primary liquid metal from which heat is to be extracted the graphite structure will be always kept under compression stresses. As a result, high strength will be imparted to the core. It is further recognized that side headers 24 and 25 are subjected to essentially no pressure induced stresses because the pressure on the inside and outside of these headers is substantially the same. Although these headers will be heated on their insides as the second fluid passes up

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through the core and becomes heated, the actual header temperature is always somewhat lower than the heated fluid itself. However, if desired, alternatively, heat insulation 77 as shown in FIGURE 5 can be applied to the inner walls of the headers to reduce the heating thereof.

The actual amount of heat transfer obtained is determined by the total amount of surface area presented to the two fluids. This surface area in turn can be varied by the size of the core, number and size of the cross borings, the number of passes back and forth of the secondary fluid through the core and the difference in temperature of the fluids entering the system.

Various modifications can be made in the present invention without departing from the spirit or scope thereof for it is understood that I limit myself only as defined in the appended claims.

I claim:

1. A heat exchanger comprising in combination a monolithic graphite core of graphite blocks each block having a series of passages extending perpendicularly therethrough from one face to the opposite face and another series of passages at right angles to the first extending perpendicularly therethrough from an adjacent face to the one opposite, said blocks being stacked in horizontal layers to form the core, the blocks in each layer being aligned with each other to provide vertical and horizontal passages through the core, a graphite header dome attached to the top and another to the bottom of said graphite core, one of said header domes encompassing the upper ends and the other the lower ends of said vertical passages, outwardly projecting conduit means affixed to said graphite header domes and communicating with the interior thereof, a first internally partitioned side header attached to one side of said monolithic core and encompassing all the openings of the horizontal passages excluding those of the bottom-most horizontal layer of blocks on one side of the core, a second internally partitioned side header attached to the opposite side of the core and encompassing all the other openings of the horizontal passages on the opposite side of the core, a tank enveloping the assembly of the graphite core, graphite header domes and internally partitioned headers whereby an annulus is formed between said assembly and said external tank member, a packing gland in each of the top and bottom of said external tank member, said outwardly projecting conduit means projecting through said packing glands in the top and bottom of said external tank, said exhaust port facing a flanged conduit projecting outward from the side of said external tank.

2. A heat exchanger comprising in combination a monolithic graphite core of cross-bored cubical graphite blocks each block having a series of passages extending perpendicularly therethrough from one face to the opposite face and another series of passages at right angles

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to the first extending perpendicularly therethrough from an adjacent face to the one opposite, said blocks cemented together in superimposed, horizontal layers to form the core, the blocks in each layer being aligned with each other to provide vertical and horizontal passages through the core, a graphite header dome attached to the top and another to the bottom of said graphite core, one of said header domes encompassing the upper ends and the other of said header domes encompassing the lower ends of said vertical passages, outwardly projecting graphite-lined, low pressure fluid carrying conduit means affixed to said graphite header domes and communicating with the interior thereof, a side header cemented to one side of said monolithic core and encompassing all the openings of said horizontal passages excluding those of the bottom-most horizontal layer of blocks on one side of the core, said header having a series of inwardly projecting walls, the distance between said walls being equal about to the thickness of two horizontal layers of blocks, said walls contacting said core at the junctions of said horizontal layers of blocks, the bottom of said side header contacting said graphite core at the junction of the bottom-most horizontal layer and the next above layer of blocks and the top of said side header contacting said graphite core at the junction of the top layer of said graphite blocks and said top graphite header dome, a second side header cemented to the opposite side of the core and encompassing all the other openings of the horizontal passages on the opposite side of the core, said second header having a series of inwardly projecting walls and an exhaust port, said walls being similar in size and placement to those of said first side header, the bottom edge of said second side header contacting said graphite core at the junction of said bottom graphite header dome and said bottom-most layer of blocks and its top wall contacting the graphite core at the junction of the top layer of blocks and the layer next below, the top of said exhaust port contacting the core at the junction of the top graphite header dome and the top layer of blocks, a tank enveloping the assembly of monolithic graphite core, graphite header domes and side headers said tank having a packing gland in its top and bottom a flanged conduit in one side near the top, so that an annulus remains between said assembly and said external tank and the low-pressure fluid carrying conduit means project one through the packing gland in the top and one through the packing gland in the bottom of said external tank, said exhaust port facing said flanged conduit of said external tank.

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