

[54] HEAT EXCHANGER AND METHOD OF OPERATION THEREOF

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[63] Continuation-in-part of Ser. No. 78,688, Oct. 7, 1970, abandoned.

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[58] Field of Search 165/84, 95, 156, 179, 184, 165/163, 162, 159; 138/121, 122

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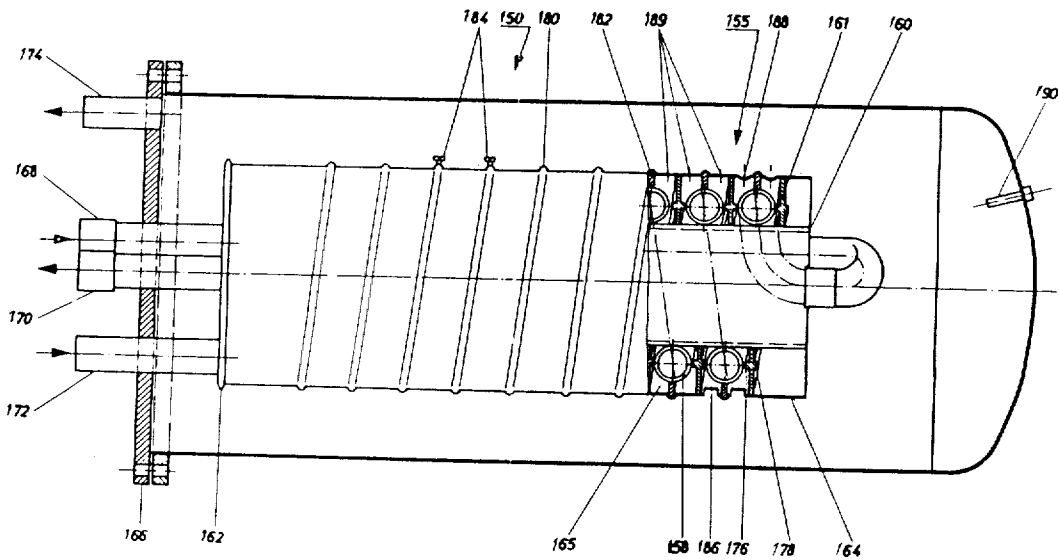
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[57] ABSTRACT

A heat exchanger wherein the element under internal pressure is a thin walled flexible tube whose inner and outer surfaces have the form of corrugations with supporting means which act to limit the expansion of the flexible tube to prevent deflection from the longitudinal axis.

9 Claims, 9 Drawing Figures



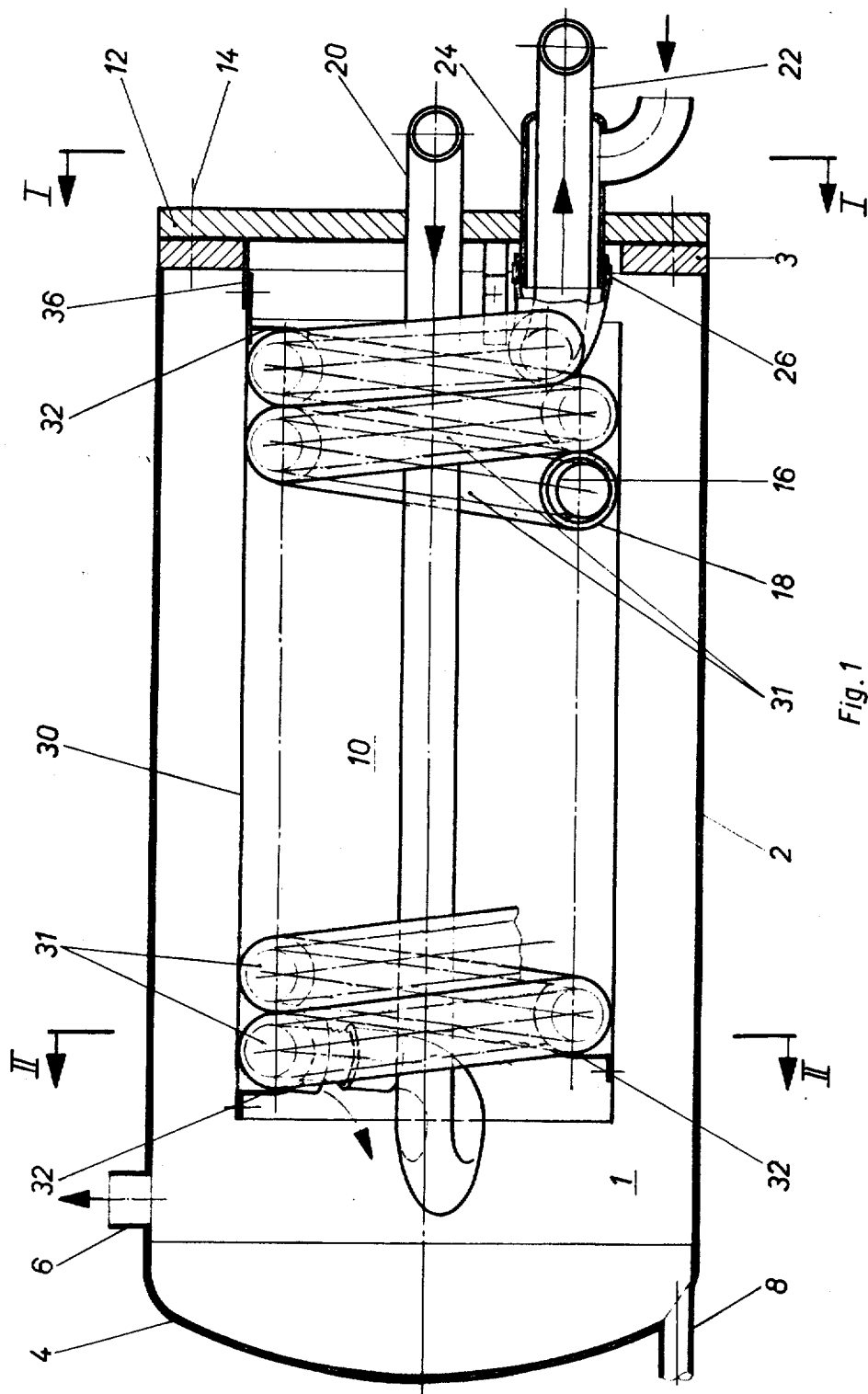


Fig. 1

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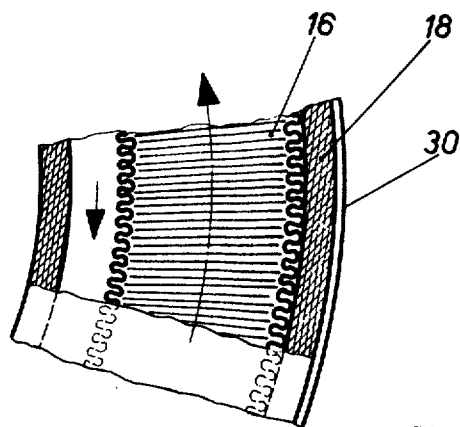


Fig. 2

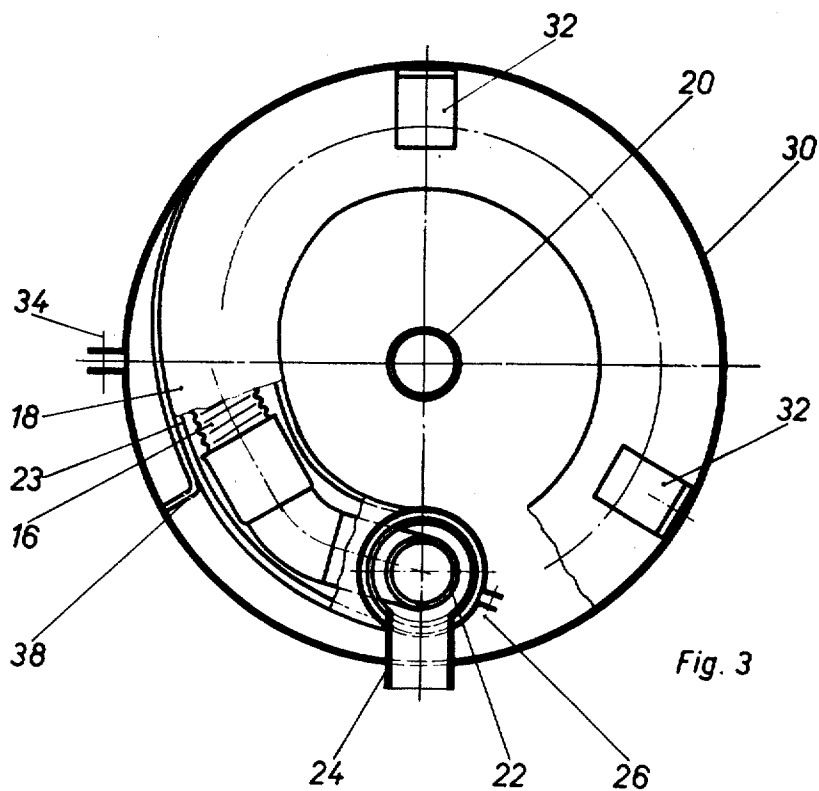


Fig. 3

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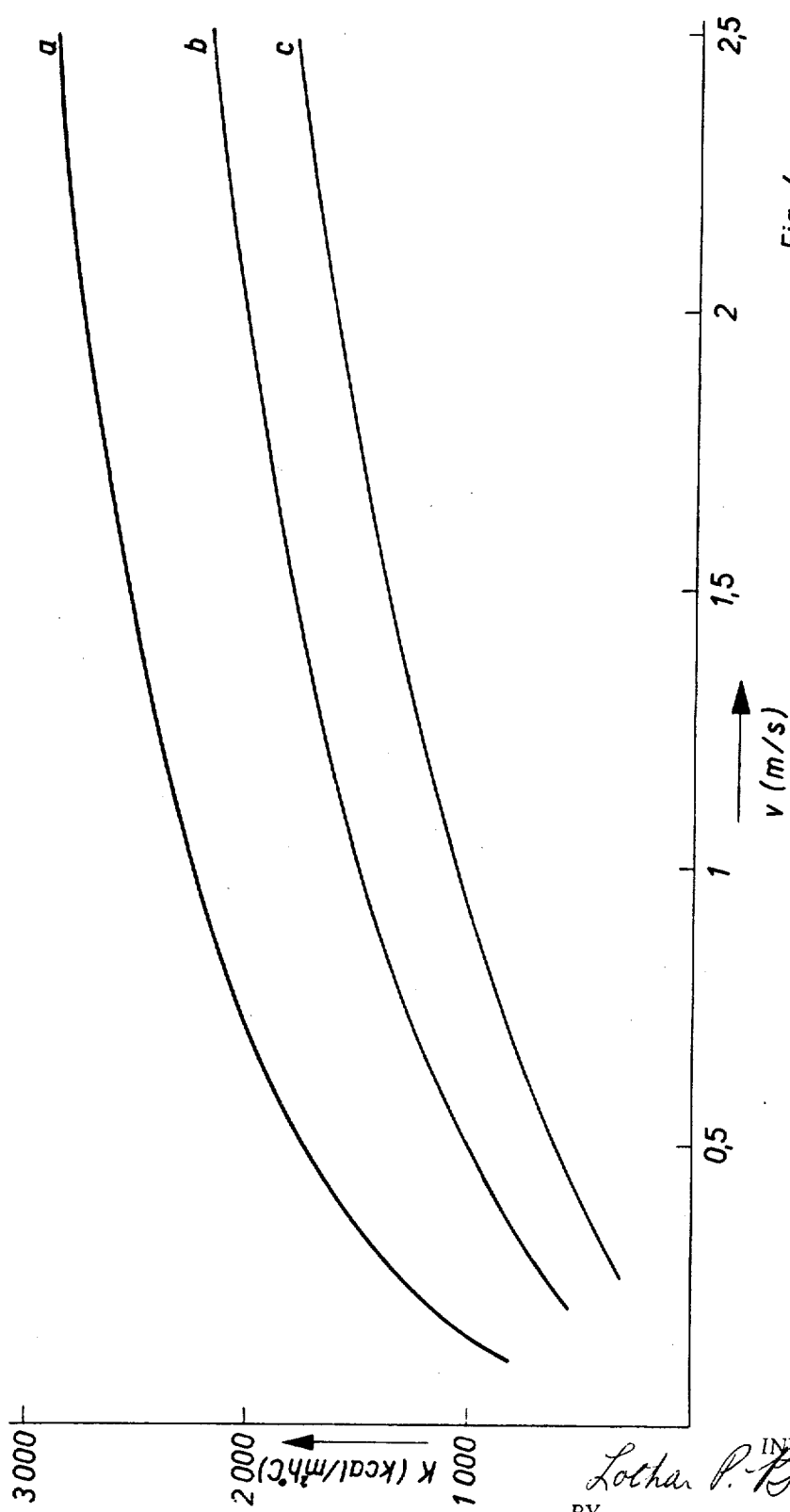
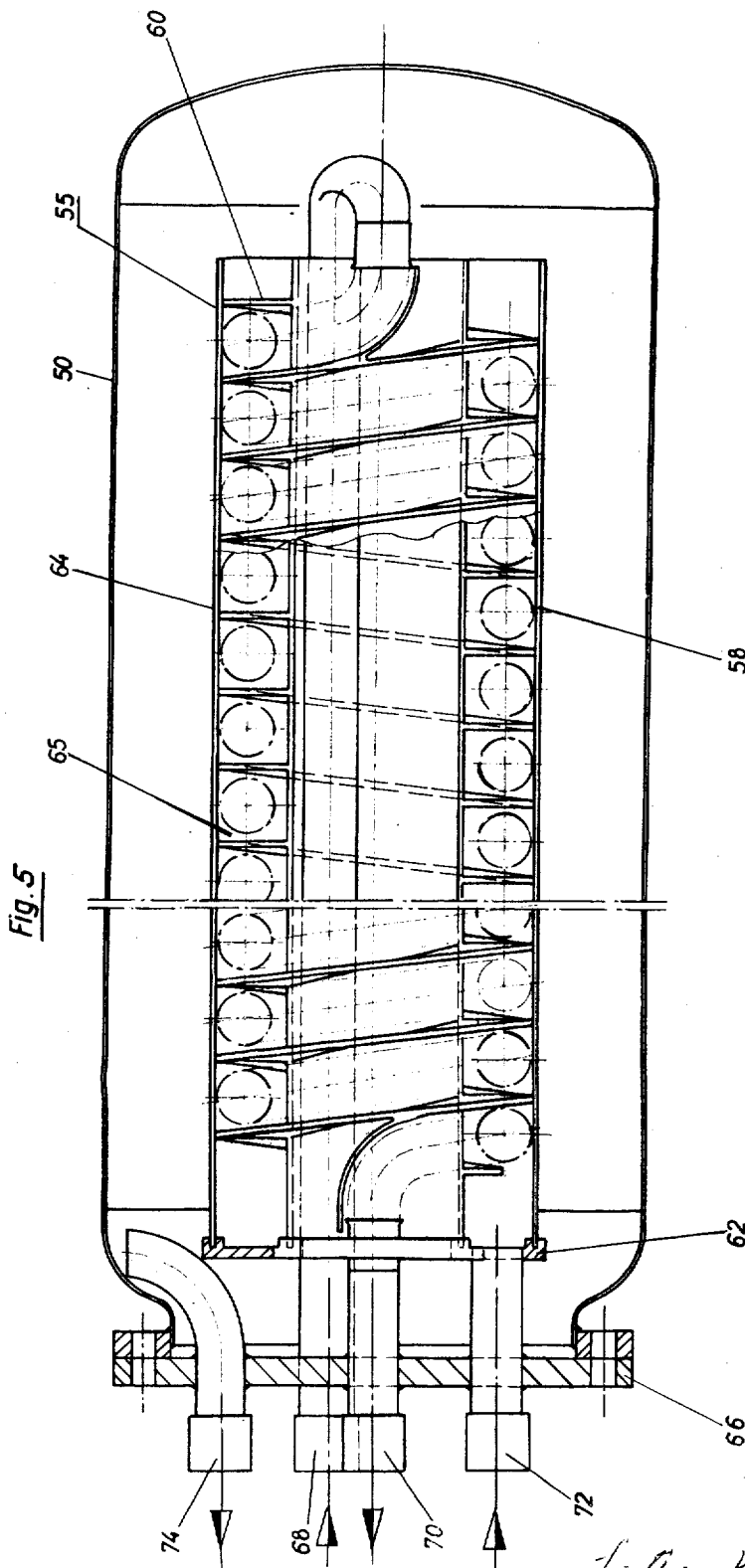
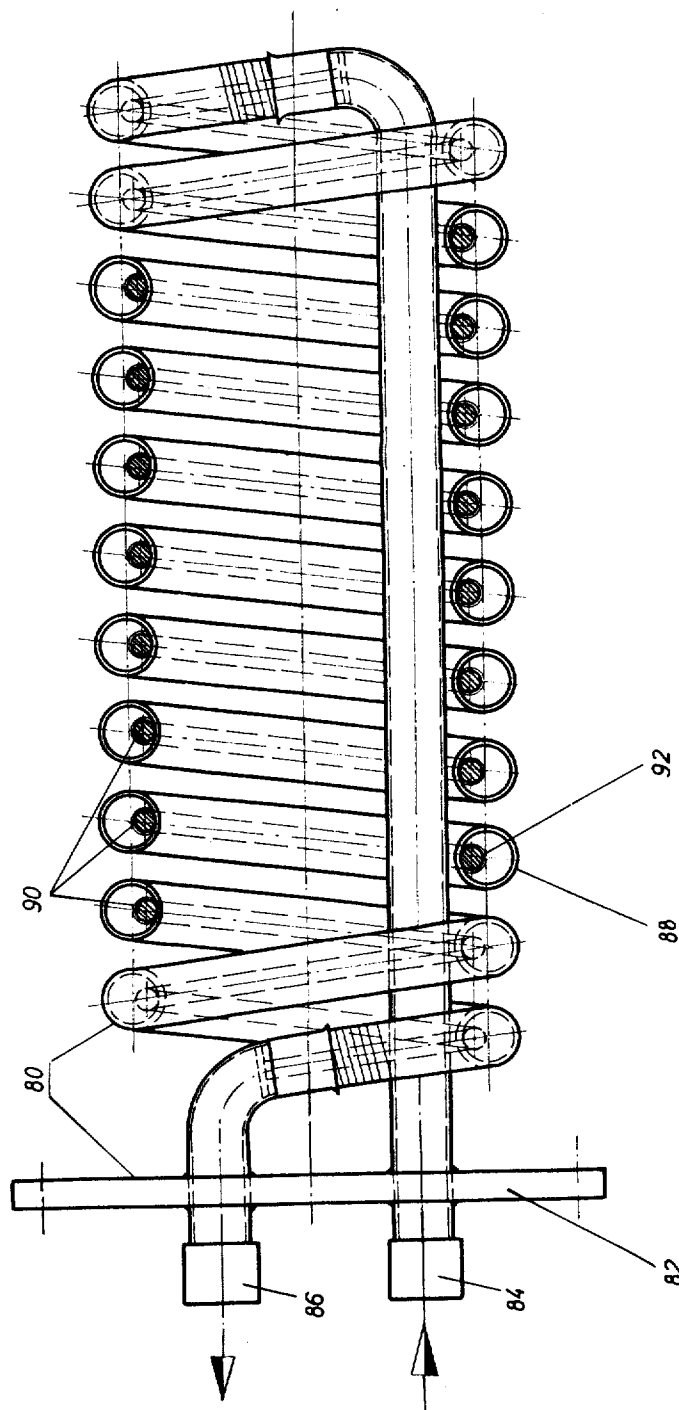


Fig. 4

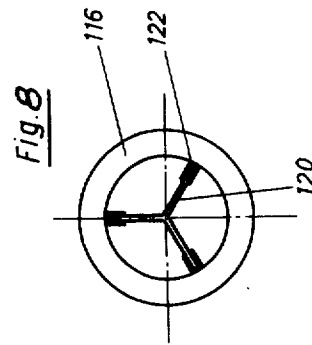
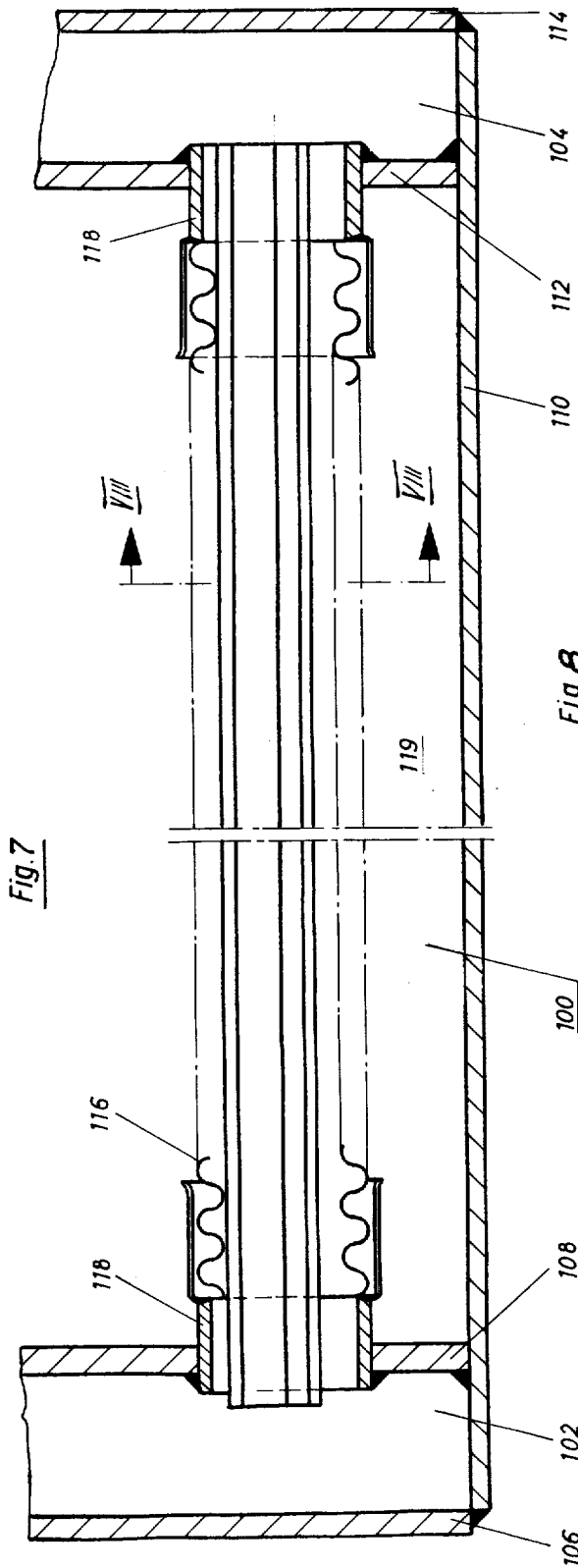
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Fig. 6

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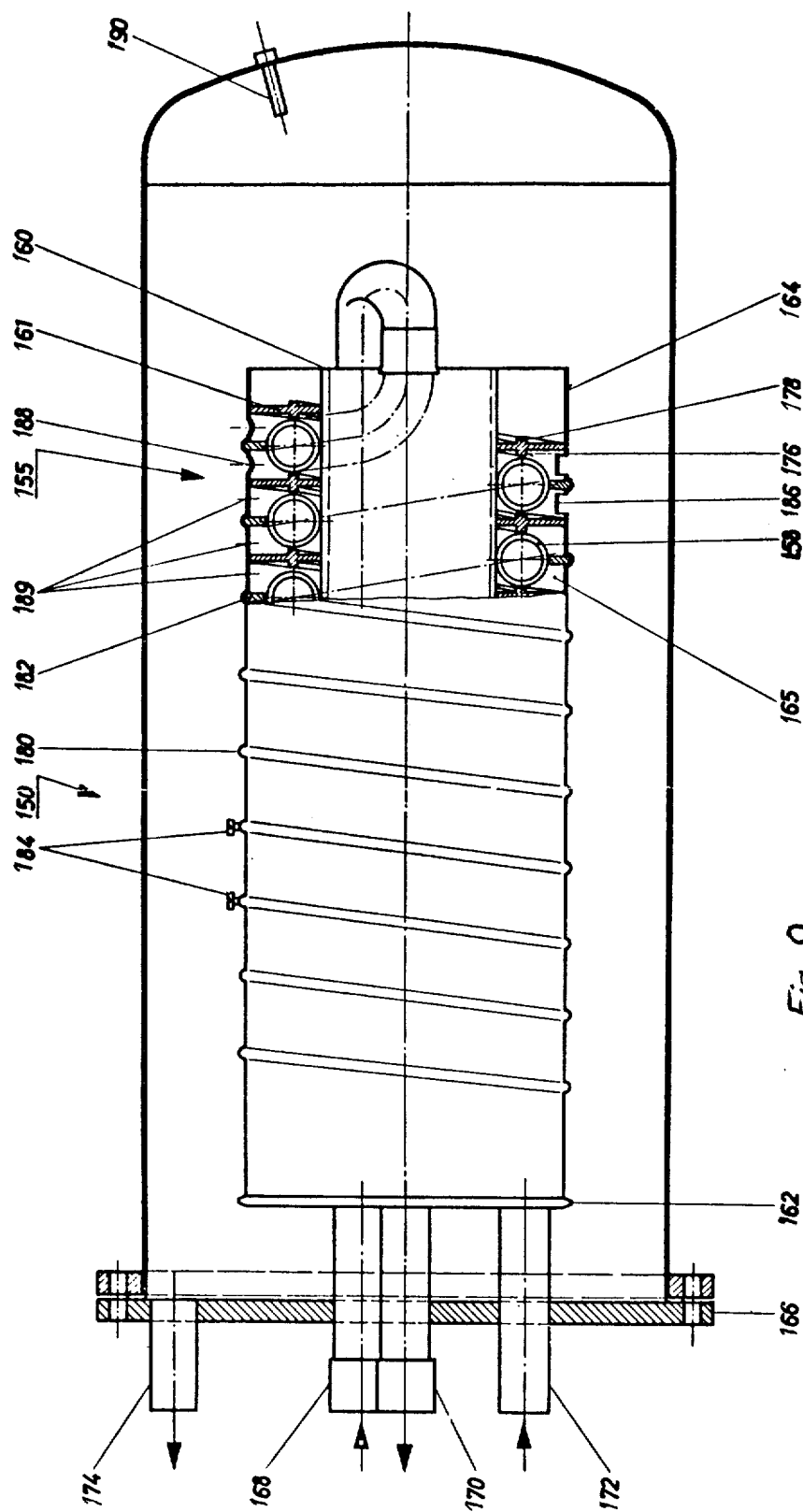


Fig. 9

HEAT EXCHANGER AND METHOD OF OPERATION THEREOF

The present application is a continuation-in-part of U.S. Ser. No. 78,688 filed Oct. 7, 1970, now abandoned, which is hereby incorporated by reference.

This present invention concerns a heat exchanger with a heat-exchanging element and further, a method of operation thereof. Its object is to provide a heat exchanger which, owing to its favorable heat transfer pattern, has relatively small outside dimensions and which also presents better resistance to corrosion.

The heat exchanger claimed hereunder is characterized in that the element under internal pressure comprises a thin-walled flexible tube whose inner and outer surfaces have the form of corrugations or hollow ribs and are approximately equal in size, and that supporting means are provided for the purpose of limiting the expansion of the flexible tube to ensure that under longitudinal expansion stress the tube is held without any deflection from the longitudinal axis and can only undergo deformation within the elastic range.

Several embodiments of the invention are illustrated by way of example in the accompanying drawings, in which:

FIG. 1 shows a heat exchanger in longitudinal section;

FIG. 2 shows part of the heat exchanger on the scale of 1:1;

FIG. 3 shows a cross-section of the heat exchanger along line I—I in FIG. 1, with the flange cover removed;

FIG. 4 is a graph of the heat transmission coefficient K plotted against the water velocity around the exchanger tube, for three different tubes;

FIG. 5 shows a longitudinal section through a heat exchanger with a helical water-bearing part and a plastic supporting jacket;

FIG. 6 shows a longitudinal section through another embodiment;

FIG. 7 shows a longitudinal section and a partial view of a third embodiment;

FIG. 8 shows a cross-section of the heat-exchanging element along line VIII—VIII in FIG. 7;

FIG. 9 shows a lengthwise section through a heat exchanger with the insert shown in cross-section, the outer covering of said insert being partially removed.

A container 1 to whose outer jacket 2 are welded a flange 3 at one end and a domed plate 4 with an outlet stub 6 and a drain stub 8 at the other end contains a heating element 10, connected to a flange cover 12, and secured to the flange 3 by screws 14. The heating element 10 comprises a thin helical metal tube 16 with corrugated inner and outer surfaces, which resembles a metal hose or a spring tube, for instance, and which is loosely jacketed by a plastic tube 18. The tube 16 is firmly connected to a hot water inlet stub 20 at one end and a hot water outlet stub 22 at the other.

The metal tube 16 further presents an inlet stub 24 for a second heat exchange medium to which the plastic tube 18 is secured by a clamp 26. A supporting jacket 30, having the form of a tube, for instance, and clamps 32 have the function of limiting the expansion scope of the metal tube 16. The supporting jacket 30 is preferably split and held together by screws 34 evenly spaced along it, so that the jacket is pressed against the tube turns 31. The jacket 30 is attached at its circumference by fishplates 36 weld-joined to the flange 3.

The end 23 of the plastic tube 18 rests on a supporting plate 38 (FIG. 3).

The above-described heat exchanger with its highly effective heating element 10, which is coiled from a metal tube in the form of a spring tube or a metal hose, has not only the function of indirect heat exchange between two media in closed circuits, but also that of producing warm service water, with the consumption water side passing into a storage tank. The heat exchange surfaces of the tubes or hoses are practically the same size inside and out, as their wall thickness is small. Such thin, preferably alloyed metal tubes, which have corrugations or hollow ribs inside and out, are used for compensators and, when provided with wire meshing, for flexible piping subject to internal pressure, wherein the wire meshing has the function of preventing longitudinal expansion and thus any undue stress on the thin metal tube. As such a metal tube of useful diameter can, unless supported by wire meshing, only stand up to an operating pressure of a few tenths of an atmosphere without undergoing longitudinal deformation, and as a metal tube provided with close-fitting wire meshing is useless as a heat-exchanging element, the metal tube must have a helical form of the smallest pitch possible and be arranged in an expansion limiter in the form of a supporting jacket firmly embracing the individual turns. This arrangement prevents any longitudinal expansion and also prevents any buckling, i.e. any deflection from the longitudinal axis (self-checking pitch). Accordingly, any deformation of the tube can only occur within the elastic range.

Tests have shown that starting and stopping of the hot water pump or opening and closing of the tap valves gives rise to pressure shocks which move individual corrugations of the thin metal tube. This involves the risk that the friction between the jacket wall 30 and the radially outermost corrugation point of the metal tube 16 may in time damage the thin metal tube. Also, there is the possibility of chemical reaction between the two materials. For this reason, it is expedient to arrange a plastic layer on the inner surface of the supporting jacket facing the metal tube or, as shown in the drawing, to arrange a plastic tube 18 between metal tube and jacket; the tube 18 also serves to conduct the medium to be heated, while not impairing the circulation of the medium on the outside of the tube 16.

On the other hand, the pressure shocks mentioned have a cleaning action, as any lime coatings and contaminations are dislodged by the movements produced and are flushed away by the medium.

As the tube 18 is not exposed to any pressure by the media, the tube, if made of plastic, can be heated up to the softening point of the plastic without involving any damage.

FIG. 4 shows the heat transmission coefficient K in $\text{kcal/m}^2\text{h}^\circ\text{C}$ plotted against the water velocity around a tube, for a constant velocity of the water inside the tube.

The curve (a) applies to a tube having corrugations inside and out and being in stretched condition and having the following:

Dimensions: $o/d = 31.5 \text{ mm}$, $i/d = 25 \text{ mm}$, $th. = 0.15 \text{ mm}$
 $A = 0.26 \text{ m}^2$
 Material: Cr Ni Mo steel (18/8/2.5)

The curve (b) applies to a straight solid-rib tube of the following:

Dimensions: $o/d = 31.5$ mm, $i/d = 22$ mm, body dia. = 24.5 mm
 (= smallest o/d at root of ribs)
 $A = 0.27$ m², $th. = 1.25$ mm
 Material: Cu Ni 10 Fe

The curve (c) applies to an ordinary tube of the following:

Dimensions: $o/d = 26.9$ mm, $i/d = 21.6$ mm, $A = 0.26$ m²
 $th. = 2.65$ mm
 Material: ST 35
 Symbols: o/d = outside diameter
 i/d = inside diameter (clear dia.)
 $th.$ = wall thickness
 A = heat exchange area
 Abscissa: Velocity of water around tube, for constant velocity of water in tube, viz. 1.12 meter/sec.

Temperature of water around and in tube, averaging delta t_m 35°C,

i.e. Heating water:	Inlet $t_i = 90^\circ\text{C}$ Outlet $t_o = 55^\circ\text{C}$
Service water:	Inlet $\theta_{a_i} = 10^\circ\text{C}$ Outlet $\theta_{a_o} = 60^\circ\text{C}$

As shown in FIG. 5, a container 50 contains a heating element 55. This element 55 essentially comprises a heat-transferring thin resilient metal tube 58, a helical ribbed plastic tube 60, a plastic flange 62, a plastic tube 64 shrunk on to the ribbed or helical tube 60, and a securing flange 66 with the necessary connection stubs for the heating water 68 and 70 and the service water 72 and 74. The shrunk-on plastic tube 64, in conjunction with the ribbed tube 60, forms a helical channel 65 for the conduction of the medium to be heated. The plastic tube 64 concurrently has the function of outwardly and laterally supporting the flexible heating tube 58 arranged inside the channel 65. Plastic tube 64 and ribbed tube 60 form an expansion limiter ensuring that the flexible heating tube cannot deflect sideways, i.e. off the helical path, and that it can only expand or become deformed within its elastic range.

The heating element 80 shown in FIG. 6 comprises a securing flange 82, service-water stubs 84 and 86, a heat-transferring resilient metal tube 88 and a plastic-jacketed steel coil spring 90, which may have a circular cross-section, for instance. The function of the coil spring 90 is to support the resilient metal tube 88, which is subject to internal pressure and therefore radially unstable. To prevent any metallic friction when the pressure load changes, the coil spring 90 is jacketed with plastic, as by a shrunk-on plastic tube 92. This arrangement also rules out any formation of electrochemical elements.

FIGS. 7 and 8 show a partial view of a heat exchanger 100 with water chambers 102 and 104, composed of limiting walls 106, 108, 110, 112, 114, and a heat-exchanging resilient metal tube 116. The thin-walled resilient metal tube 116 is connected to the water chambers 102 and 104 by two welding nipples 118. The heating medium is in the chamber 119. To prevent with certainty any lateral deflection of the thin-walled metal tube 116 subject to elevated pressure, a star-shaped element 120 is inserted into each tube 116. Fitted along the edges of the element 120 is a U-shaped piece 122 of rubber or plastic, preventing any metallic contact with the tube 116.

The expansion limiters in the form of tubes 60, 64, a spring 90, elements 120 or the like make it possible to use flexible thin-walled tubes and hoses capable of sustaining the internal pressures arising in particular in heat exchangers for hot service water.

The embodiment of FIG. 9 is an improvement over the previous embodiments which combine the expansion-limiting means of an outer tube and an inner tube, said inner tube having a helical outer surface. The embodiment of FIG. 9 is characterized by the fact that the thin-walled flexible tube is limited in its freedom of movement by spacing elements.

According to FIG. 9, a heating insert 155 is located inside a housing 150. This insert 155 incorporates as important structural elements a heat-conducting, thin, flexible, helically wound metal tube 158, said tube having corrugated inner and outer surfaces (not shown) and an inner tube 160 made of plastic, said inner tube having attached to it a helically wound rib 161. The outer end of the helical rib 161 is an outer tube 164, preferably of stainless steel. Inner tube 160 and outer tube 164 are butt-mounted in a plastic flange 162. The entire housing 150 is mounted on a flange 166, said flange being provided with the appropriate connecting stubs 168 for hot-water input and 170 for hot-water exhaust, as well as a stub 172 for admitting service water and a stub 174 for exhausting service water. Together with inner tube 160 and helical rib 161, outer tube 164 forms a helical channel 165 to conduct the medium to be heated (in the present instance, service water). As can be seen from the cutaway section of heater insert 155, channel 165 is dimensioned in cross section so that metal tube 158 can move diagonally in all directions.

Experience has now shown that an excessive degree of freedom of movement of metal tube 158 may mean that a constant flow rate through the cross section of channel 165 can no longer be ensured and the result is a deposition of previously chipped off lime particles (in areas of stagnant flow), which cut down the transmission of heat.

In order to limit this freedom of movement and thus attain as constant a flow cross section as possible, bar or pinshaped spacing elements 176 and 178 are provided on both sides of helical rib 161 as well as spacing elements 182 in the form of ribs which are secured in a corrugation 180 made in outer tube 164, said corrugation also being made helical. Furthermore, set screws made of plastic 180 are provided which make it possible to adjust or adapt the desired radial play of metal tube 158 with respect to outer tube 164 and inner tube 160 by shifting element 182.

The last or last two turns of the service water channel 165 of outer tube 164 are provided with circulation openings 186 and 188. Said openings are preferably located in the lower half of the heater insert 155 in a horizontally mounted heat exchanger according to the figure, while gas-escape openings 189 are correspondingly located at the highest point on the outer tube 164. Housing 150 is also provided with a thermostat 190.

In contrast to known heat exchangers of this kind, in which the outer tube 164 is made of plastic, in this case an outer tube 164 of nonferrous metal or steel covered with a protective coating is employed, said outer tube 164 being capable of withstanding a pressure of more than 6 atm. The spacing elements 182 in corrugation 180 and the set screws 184 also prevent metal tube 158, in the shape of a tube with hollow ribs, from com-

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ing in direct contact with the steel jacket of outer tube 164. Spacing elements 176 and 178 in the form of ribs serve, in conjunction with element 182 and set screws 184, as mentioned above, to limit the freedom of movement of metal tube 158 and create constant flow conditions for the service water to be heated in channel 165. This will ensure that the lime particles that chip off the heater insert will be carried away.

The circulation openings 186 and 188 serve to accelerate the reheating process after the hot water has been drawn off, wherein a thermal flow occurs over the last winding of heater insert 155, intensifying the heat exchange. The gas-escape openings 189, which extend over most of the length of metal tube 158, release the gas expelled during degassing of the service water being heated. This eliminates the impediment to flow constituted by gas bubbles in the latter. At a certain minimum temperature, thermostat 190 closes the control circuit or supply circuit of the hot-water circulating pump and shuts off this pump again when an adjustable maximum temperature is reached. In the interest of producing small lime particles, it is advisable for this circulating pump to be turned on and off as often as possible for short operating times, with the heating water being given a sudden push each time the pump is turned on. The metal tube 158 "breathes" each time the pump is switched on, thus knocking adhering lime particles loose from the outer walls. The frequency with which the pump is turned on and off makes it possible to keep the dislodged small particles at predetermined sizes that can easily be carried away by the service water as it flows through.

The spacing elements are preferably made of an electrochemically neutral material, preferably plastic. The distance of the spacing elements 176, 178 and 182 as well as 184 from the outer covering of the metal tube 158 must be large enough so that no areas of stagnant flow are produced, yet small enough so that tube 158 cannot shift at random within the area of the cross section of channel 165.

The foregoing description of the specific embodiments of the present invention will so fully reveal the general nature of the invention that others can, by applying current knowledge, readily modify and/or adapt for various applications such specific embodiments without departing from the generic concept, and therefore, such adaptations and modifications should and are intended to be comprehended within the meaning and range of equivalents of the disclosed embodiments. It is to be understood that the phraseology or terminology employed herein is for the purpose of description and not of limitation.

What is claimed is:

1. A heat exchanger for transferring heat between a medium inside an element and a medium outside the element comprising:

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a heat exchange element in the form of a tube whose inner and outer surfaces have the form of corrugations, said tube having a wall thickness thin enough to allow flexibility of the tube upon the occurrence of pressure differentials in either medium; and supporting means for limiting the freedom of movement in all directions and for allowing deformation of the tube to an extent sufficient to permit cleaning of the surfaces of the flexible tube upon the occurrence of pressure differentials in either medium, said supporting means only allowing deformation of said tube within the elastic range of the tube material;

wherein said supporting means comprises:

- 15 an outer cylinder;
- an inner cylinder;
- a helical rib connected between said outer cylinder and said inner cylinder to form a helical passageway therewith, wherein said heat exchange element passes through, said passageway; and
- 20 spacing elements connected to said rib and said outer cylinder for limiting the degree of freedom of movement of the heat exchange element.

2. A hot water heater in accordance with claim 1 wherein said spacing elements include continuous projections on both sides of said helical rib, between the portion thereof connected to said inner and outer cylinders.

3. A hot water heater in accordance with claim 1 wherein said spacing elements include projections connected to said outer cylinder and inwardly projecting therefrom.

4. A hot water heater in accordance with claim 3 wherein said outer cylinder has a continuous helical corrugation therearound and said spacing element projections are held in said corrugation.

5. A hot water heater in accordance with claim 1 wherein said spacing elements secure said heat exchange element within said passageway with sufficient play to allow water to also pass through said passageway.

6. A hot water heater in accordance with claim 1 wherein said spacing elements are electrochemically neutral.

7. A hot water heater in accordance with claim 1 wherein said outer cylinder, at least in the vicinity of one of its ends, is provided with openings therein for allowing gas to escape and for producing an additional thermal flow.

8. A hot water heater in accordance with claim 3 wherein said spacing elements further include set screw means for adjusting the distance said projections project inwardly from said outer cylinder.

9. A hot water heater in accordance with claim 1 wherein said outer cylinder is made of a material with good heat conducting properties.

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