Jan. 16, 1968 R. L. BAKER 3,363,680

PLASTIC TUBE HEAT EXCHANGER WITH NOVEL HEADER CONSTRUCTION

Filed July 21, 1966

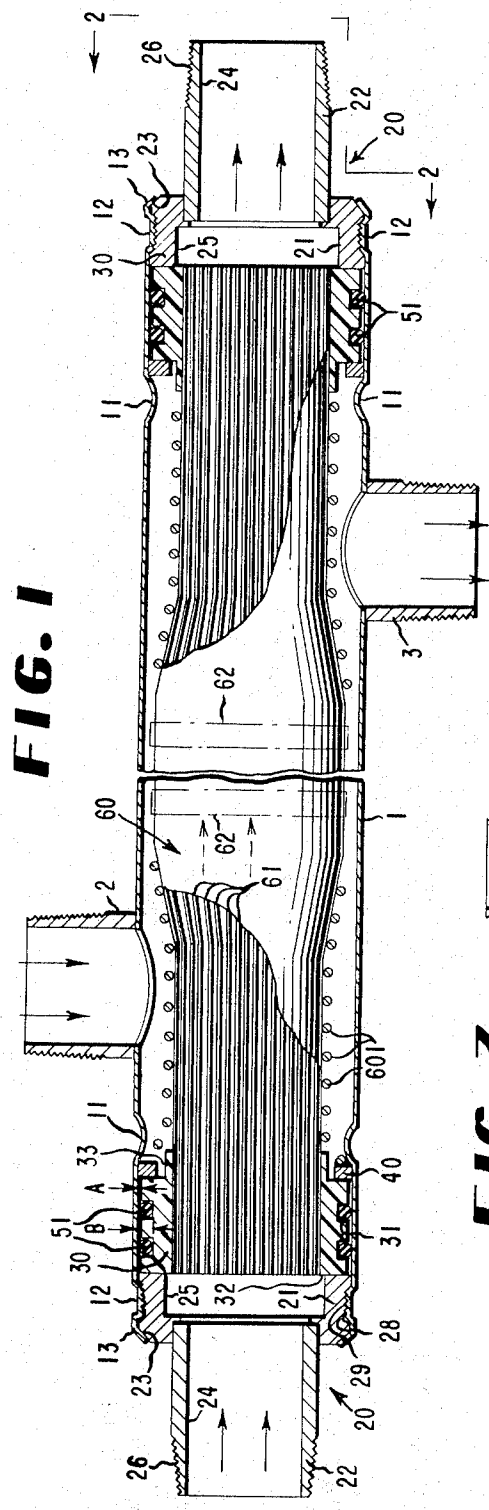

FIG. 1

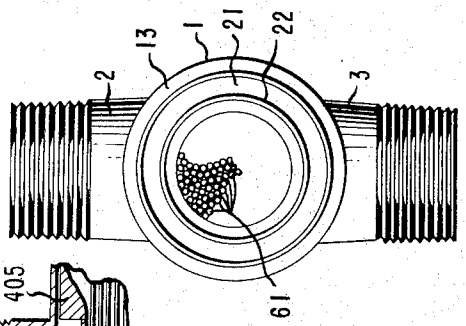

FIG. 2

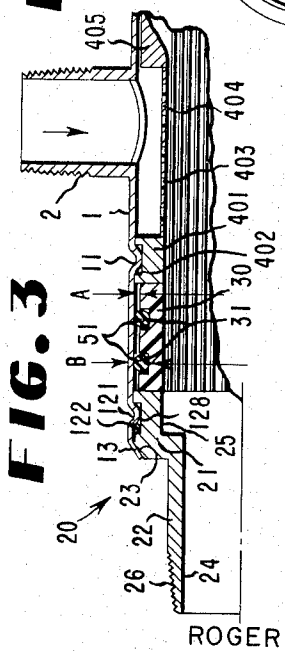

FIG. 3

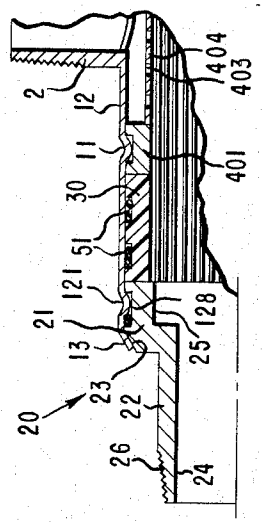

FIG. 4

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This invention relates to improved heat exchanger apparatus, and more specifically to a particular type heat exchanger apparatus utilizing plastic tubular elements in combination with metallic components.

As indicated generally in U.S. Patent No. 3,228,456 heat exchanger apparatus having plastic components have been found to be worthwhile in many applications and are now commercially available in increasing quantities. Because of the use of plastic components, especially the tubular elements, a number of special problems have been encountered in designing and manufacturing such apparatus. Some of these problems involve the relatively high coefficient of thermal expansion possessed by most plastic materials relative to the other materials of which the heat exchange apparatus may be formed. Other problems relate to the different properties such as compressive strength and melting points of these plastic materials relative to the other materials used, for example production or fabrication techniques and the apparatus designs must be such that the more conventional parts such as those still formed of the usual metallic compositions can be shaped, formed, and treated while in cooperative association with the plastic parts to produce economical, reliable and effective heat exchange units without destroying or damaging the associated plastic parts by application of excessive forces, impacts, or temperatures.

It is an object of the invention to provide a novel and improved heat exchanger apparatus having metallic and plastic components, which apparatus performs effectively and reliably and satisfactorily accommodates during its operation the different properties of the plastic and metallic components under the desired operating conditions, especially elevated temperatures.

It is a further object of the invention to provide such a novel and improved heat exchange apparatus combination which also is capable of being produced by economical commercially feasible fabrication techniques which accommodate or make adequate allowance for the rather marked difference in properties of the plastic and metallic components.

These objects have been achieved in applicant's improved heat exchanger apparatus which generally comprises in combination; a hollow cylindrical rigid metallic casing member having axial and transverse dimensions, said casing member comprising an end portion and having a given coefficient of thermal expansion, an elongated bundle of flexible tubular elements with continuously hollow interiors formed of an organic polymeric composition positioned in said casing member in a generally coextensive relationship, said tubular elements comprising open end portions, said end portions of said tubular elements lying in a substantially coplanar arrangement transversely of said casing member and adjacent said end portion of said casing member, said apparatus further comprising a composite header assembly cooperating with the open ends of said tubular elements, the end portion of said casing member, and constructed and arranged to cooperate with a fluid conduit element to maintain free fluid communication between such a fluid conduit element and the interiors of the hollow tubular elements, while preventing communication between the fluid in such a fluid conduit element and space defined between the exteriors of said hollow tubular elements and the interior of said

hollow casing member, said composite header assembly comprising a first annular header member of organic polymeric plastic composition having a coefficient of thermal expansion significantly greater than that of said casing member, said first annular member surrounding the open end portions of said tubular elements, said first annular member and the exterior of the open end portions of said tubular elements being joined to each other in fluid tight relationship, said first annular member positioned adjacent the open end portion of and inside the hollow casing member, said first annular member having dimensions which correspond to the transverse dimensions of the casing member such that a given clearance exists between the inside of the casing member and the nearest portion of the first annular member, at all temperatures up to and including the maximum operating temperature of the apparatus, said header assembly further comprising a second header member of rigid metallic composition having an annular portion closely fitted and extending into the open end portion of said casing member to a position of abutment against one side of said first annular member, said second member provided with another portion adapted to be coupled in fluid tight relation to a fluid conduit, said another portion having a fluid passageway therethrough constructed and arranged to provide free communication between a fluid conduit coupled with said another portion, through the said annular portion and the interiors of the hollow tubular elements of the bundle, said apparatus further comprising first securing means cooperating with said casing member and the annular portion of said second header member to maintain the second header member positively in position in said casing member and prevent axial movement of said abutting first header member out of the open end portion of said casing member, said composite header assembly further comprising a third header member of rigid metallic composition and annular configuration, said third header member closely fitted and positioned within said casing member in abutting relationship with an opposing side of said first header member, said apparatus further comprising second securing means cooperating with said casing member and said third header member to maintain said third header member positively in position in said casing member and prevent axial movement of said abutting first header member inwardly of the open end portion of the casing member, said second and third header members cooperating with said first header member to maintain it in fixed axial position relative to said open end of the casing member and permit transverse movement of said first header member relative to the casing member, and the second and third members to accommodate expansion and contraction of said first header member under varying temperature conditions to which the apparatus is subjected, said apparatus further comprising a first sealing means cooperating with said first header member and the casing member to prevent communication between a fluid in the interiors of said tubular elements and the exterior of said tubular elements in said casing member, said first securing means comprising a second sealing means cooperating with said casing member and said second header member to prevent communication between a fluid in the interiors of said tubular elements and the exterior of said casing member.

Other objects and advantages will appear from a consideration of the following specification and claims, taken in conjunction with the accompanying drawings in which:

FIGURE 1 is a longitudinal cross sectional view of a heat exchanger apparatus embodying features of the invention. Certain parts are broken away to better illustrate the construction.

FIGURE 2 is an end view of the apparatus shown in

FIGURE 1 as seen from the right hand end of the apparatus as viewed in FIGURE 1.

FIGURE 3 is a partial longitudinal cross sectional view of one end of a somewhat modified heat exchanger apparatus embodying features of the invention showing the relationship of parts existing in the desired operating temperature range of the apparatus.

FIGURE 4 is a similar view of the apparatus of FIGURE 3 showing the relationship of parts existing at the upper limit of the desired operating temperature range.

A preferred embodiment of the invention is shown in FIGURES 1 and 2. The heat exchange apparatus as shown in these figures comprises an elongated cylindrical casing member **1** formed of a rigid metallic material and provided with threaded fluid inlet and outlet connections **2** and **3** intermediate the ends thereof. A bundle **60** of hollow tubular elements **61** is positioned as shown inside the casing member **1**. The tubular elements **61** are formed of an organic polymeric plastic composition, preferably a polyfluorinated plastic such as a copolymer of tetrafluoroethylene and hexafluoropropylene. In order to achieve sufficient surface area and reduced wall thickness for good heat transfer the tubular elements are preferably in a size range between about 5 and about 275 mils outside diameter with a wall thickness between about 0.5 to 30.0 mils. The open end portions of tubular elements **61** lie in a substantially coplanar arrangement extending transversely across the cylindrical casing member **1** and are surrounded or enclosed within first annular header members **30** formed of the same or a similar material to that of which the tubular elements are formed and located adjacent each end of casing member **1**. The exteriors of the end portions of the tubular elements **61** are sealed in fluid tight relationship to each other and to the interior of the first annular header member **30** by suitable means such as a cementitious bonding material or by being melt bonded, fused or welded to each other by the controlled application of heat. The transverse cross section of the first header members **30** corresponds to the interior cross section of the casing member **1** such that an annular clearance such as shown at A in FIGURE 1 exists between the inside of the casing member and the nearest portion of the first header members **30**. Annular circumferentially extending grooves **31** are formed in the first header members as shown and in each is located a resilient sealing ring **51** made of suitable material such as rubber or neoprene to maintain an effective fluid-tight seal between the first header members **30** and the casing member **1**. At each end of the casing member is located a second header member **20** which has an annular portion **21** extending into and fitted inside the open end of the casing member **1** and into engagement or abutment with one side of the first annular header member **30**. The second header member **20** also is provided with another portion **22** which is adapted to be coupled to a suitable fluid conduit (not shown) by means of threaded section **26**. Internal passageways **24** and **25** maintain free communication between such a fluid conduit and the interior hollow portions of the tubular elements **61**. A third annular header member **40** is fitted within the casing member **1** and is maintained in abutment or engagement with the other opposed side of the first header member **30**. An annular clearance is provided between the interior opening in the third annular header member and an annular sleeve-like projection **39** formed on the first header member. The second and third header members are formed of the same or similar material as the casing member **1**.

The second header member **20** is positively secured against axial movement in the casing by means of radially inwardly directed flange element **13** on the casing member **1**, in interlocking engagement with a cooperating shoulder **23** and by means of an inwardly directed annular portion **12**, of the casing member **1**, in interlocking sealing engagement with an annular circumferentially extending groove **28** in the annular portion **21** of second header member **20**. The bottom portion of groove **28** may be threaded or finned as shown at **29** of FIGURE to improve the fluid seal, if desired. The third annular header member **40** is secured in position in the casing member **1** against axial movement by means of an inwardly directed annular groove **11** formed in the casing member **1** cooperating with a corresponding corner or shoulder on the third header member. The header construction is the same at each end of the apparatus. The first, second, and third header members at each end of casing member **1** are considered to constitute composite header assemblies. Helical spring-like elements **601**, preferably of metallic composition, surround the portions of the bundle **60** of the tubular elements in order to maintain the desired position of the tubular elements during operation of the apparatus. The elements **601** are secured by suitable means such as a welded or brazed joint to the third header elements **40**. The positional relationships of the tubular elements **61** are further maintained by a narrow elongated spacer strip **62** wound or interleaved between the tubular elements as shown in the drawings.

In operation a first fluid is supplied through the passageways **24** and **25** in one of the two second header members **20**, as shown by the solid line arrows in FIGURE 1, through the hollow tubular elements **61** as shown by the broken line arrows to the passageways in the other second header element **20** at the other end of the casing member **1**. A second fluid is maintained at least for some finite period of time in the space surrounding the tubular elements extending between the two composite header assemblies, and preferably is circulated from inlet **2** to outlet **3** of the casing member. During these flow conditions heat exchange can take place between the two fluids which at least in their initial exchange relationships are at different temperature levels. As the first header member **30** becomes heated up under the operating temperatures of the apparatus it expands at a significantly greater rate than the associated cooperating metal parts. This expansion is accommodated by the annular clearance A between the first header member and the interior of the casing member **1**.

For the preferred materials of construction an annular clearance A of about 1% of the outside diameter of the first annular member at about room temperature has been found adequate where the maximum operating temperature limit to be encountered is not above about 300° F. The depth of the annular grooves **31** in the first header member is, for the preferred materials and construction, sufficient to provide a 30% deformation of the sealing rings **51** at about ordinary room temperatures. The header assembly construction and cooperation between the first, second, and third header members is such that the second and third header members positively slidingly engage or abut the first header member on opposite sides thereof to positively maintain it in fixed axial position relative to the casing member, yet permit radial movement or expansion of the first header member under the varying elevated temperatures at which the apparatus may be operated; the necessary fluid seals being maintained by the resilient sealing rings **51** and the engagement of the second header member with the inside of the casing member **1**.

A modified construction of a heat exchange apparatus embodying features of this invention is shown in FIGURES 3 and 4. In this version of the apparatus the seal between the second header member portion **21** and the interior of casing member **1** comprises an annular groove **128** formed in portion **21** and containing a resilient sealing ring **122**, the groove and ring cooperating with an annular deformed portion **121** of the casing member. In addition, the spring-like helical member **601** of the apparatus of FIGURES 1 and 2 is replaced by a perforated sleeve **403** secured to the third header member **401**. The sleeve **403** if desired may support an annular baffle element **405** to control fluid flow in the casing member

and outside of the tubular elements **61**. In this version, the third header member **401** is secured in position axially by means of an annular groove **402** in the header member cooperating with an annular deformation **11** in the casing member **1**.

FIGURE 3 illustrates the general arrangement of parts and clearances when the apparatus is at ordinary room temperature, while FIGURE 4 illustrates the arrangement and clearance when the apparatus is at the upper limit of its operating temperature range.

The annular inwardly turned portions of the casing member may be accomplished by any suitable forming process such as forging, swaging, or the action of high energy electrical discharges through a winding surrounding a magnetic metallic tubular element. A commercially available example of the latter process is the "Magneforming" process and apparatus of the General Dynamics Corporation which has been found very effective in certain applications. In connection with the fabrication of the apparatus which requires fairly high energy and forces to suitably deform the metallic casing, it will be seen in the presently disclosed construction where the second and third header members are closely fitted in the casing member and the first plastic header member is spaced from the casing member, that the first header member is protected from direct shocks and high forces of the fabricating operation by the rigid stronger second and third header members.

It is believed to be clear that a novel and improved apparatus has been provided in accordance with the objects of the invention.

Although a single preferred embodiment of the invention has been described in detail in accordance with the patent laws, many variations and modifications within the spirit of the invention will be obvious to those skilled in the art, and all such are considered to fall within the scope of the following claims.

What is claimed is:

1. An improved heat exchanger apparatus comprising in combination: a hollow cylindrical rigid metallic casing member having axial and transverse dimensions, said casing member comprising an end portion and having a given coefficient of thermal expansion, an elongated bundle of flexible tubular elements with continuously hollow interiors formed of an organic polymeric composition positioned in said casing member in a generally coextensive relationship, said tubular elements comprising open end portions, said end portions of said tubular elements lying in a substantially coplanar arrangement transversely of said casing member and adjacent said end portion of said casing member, said apparatus further comprising a composite header assembly cooperating with the open ends of said tubular elements, the end portion of said casing member, and constructed and arranged to cooperate with a fluid conduit element to maintain free fluid communication between such a fluid conduit element and the interiors of the hollow tubular elements, while preventing communication between the fluid in such a fluid conduit element and space defined between the exteriors of said hollow tubular elements and the interior of said hollow casing member, said composite header assembly comprising a first annular header member of organic polymeric plastic composition having a coefficient of thermal expansion significantly greater than that of said casing member, said first annular member surrounding the open end portions of said tubular elements, said first annular member and the exteriors of the open end portions of said tubular elements being joined to each other in fluid tight relationship, said first annular member positioned adjacent the open end portion of and inside the hollow casing member, said first annular member having dimensions which correspond to the transverse dimensions of the casing member such that a given clearance exists between the inside of the casing member and the nearest portion of the first annular member, at all temperatures up to and including the maximum operating temperature of the apparatus, said header assembly further comprising a second header member of rigid metallic composition having an annular portion closely fitted and extending into the open end portion of said casing member to a position of abutment against one side of said first annular member, said second member provided with another portion adapted to be coupled in fluid tight relation to a fluid conduit, said another portion having a fluid passageway therethrough constructed and arranged to provide free communication between a fluid conduit coupled with said another portion, through the said annular portion and the interiors of the hollow tubular elements of the bundle, said apparatus further comprising first securing means cooperating with said casing member and the annular portion of said second header member to maintain the second header member positively in position in said casing member and prevent axial movement of said abutting first header member out of the open end portion of said casing member, said composite header assembly further comprising a third header member of rigid metallic composition and annular configuration, said third header member closely fitted and positioned within said casing member in abutting relationship with an opposing side of said first header member, said apparatus further comprising second securing means cooperating with said casing member and said third header member to maintain said third header member positively in position in said casing member and prevent axial movement of said abutting first header member inwardly of the open end portion of the casing member, said second and third header members cooperating with said first header member to maintain it in fixed axial position relative to said open end of the casing member and permit transverse movement of said first header member relative to the casing member, and the second and third members to accommodate expansion and contraction of said first header member under varying temperature conditions to which the apparatus is subjected, said apparatus further comprising a first sealing means cooperating with said first header member and the casing member to prevent communication between a fluid in the interiors of said tubular elements and the exterior of said tubular elements in said casing member, said first securing means comprising a second sealing means cooperating with said casing member and said second header member to prevent communication between a fluid in the interiors of said tubular elements and the exterior of said casing member.

2. The improved apparatus of claim **1** in which said first securing means comprises an annular transversely extending shoulder element formed on said annular portion of said second header member in cooperating interlocking engagement with a corresponding transversely deformed portion of said casing member.

3. The improved apparatus of claim **2** in which said second securing means comprises an annular transversely extending shoulder element formed on said third header member in cooperating locking engagement with a corresponding transversely deformed portion of said casing member.

4. The improved apparatus of claim **3** in which said corresponding transversely deformed portions of said casing member comprise annular permanently inwardly directed grooves extending circumferentially transversely around said casing member.

5. The improved apparatus of claim **1** in which said first sealing means comprises an annular depression formed in said first header member and a resilient sealing ring positioned in said annular depression and in cooperating fluid tight engagement between the first header member and the casing member.

6. The improved apparatus of claim **1** in which said second sealing means comprises a resilient sealing ring

compressed in fluid tight engagement between said second header member and said casing member.

7. The improved apparatus of claim 1 in which said given clearance between said first header member and said casing member varies between about 1% of the external transverse dimension of the first header member at about ordinary room temperature and about zero at 300° F., and said first header member is formed of a polyfluorinated plastic material.

8. An improved heat exchanger apparatus comprising in combination; a hollow rigid metallic unit having axial and transverse dimensions, said hollow unit comprising an end portion and having a given coefficient of thermal expansion, an elongated bundle of flexible tubular elements with continuously hollow interiors formed of an organic polymeric composition positioned in said hollow unit in a generally aligned relationship, said tubular elements comprising open end portions, said end portions of said tubular elements lying in a substantially coplanar arrangement transversely of said hollow unit and adjacent said end portion of said hollow unit, said apparatus further comprising a composite header assembly cooperating with the open ends of said tubular elements and the end portion of said hollow unit, said composite header assembly constructed and arranged to cooperate with a fluid conduit element to maintain free fluid communication between such a fluid conduit element and the interiors of the hollow tubular elements, while preventing communication between the fluid in such a fluid conduit element and space defined between the exteriors of said hollow tubular elements and the interior of said hollow unit, said composite header assembly comprising a first annular header member of organic polymeric plastic composition having a coefficient of thermal expansion significantly greater than that of said hollow unit, said first annular member surrounding the open end portions of said tubular elements, said first annular member and the exteriors of the open end portions of said tubular elements being joined to each other in fluid tight relationship, said first annular member positioned adjacent the open end portion of and inside the hollow unit, said first annular member having dimensions which correspond to the transverse dimensions of the hollow unit such that a given clearance exists between the inside of the hollow unit and the nearest portion of the first annular member, at all temperatures up to and including the maximum operating temperature of the apparatus, said header assembly

further comprising a second header member of rigid metallic composition having an annular portion extending to a position for abutment against one side of said first annular member, said second member provided with another portion adapted to be coupled in fluid tight relation to a fluid conduit, said another portion having a fluid passageway therethrough constructed and arranged to provide free communication between a fluid conduit coupled with said another portion, through the said annular portion and the interiors of the hollow tubular elements of the bundle, said apparatus further comprising first securing means cooperating with the annular portion of said second header member to maintain the second header member in position relative to said hollow unit and prevent axial movement of said first header member out of the open end portion of said hollow unit, said composite header assembly further comprising a third header member of rigid metallic composition and annular configuration, said third header member in engagement with said hollow unit and positioned for abutment with an opposing side of said first header member, said apparatus further comprising second securing means cooperating with said hollow unit and said third header member to maintain said third header member in position in said hollow unit and limit axial movement of said abutting first header member inwardly of the open end portion of the hollow unit, said second and third header members cooperating with said first header member to limit its axial position relative to said hollow unit and permit transverse movement of said first header member relative to the hollow unit, and the second and third members to accommodate expansion and contraction of said first header member under varying temperature conditions to which the apparatus is subjected, said apparatus further comprising a first seealing means cooperating with said first header member and the hollow unit to prevent passage of fluid between said first header member and said hollow unit.

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