Sept. 1, 1970 R. J. GARDNER 3,526,274

CROSS FLOW BOX COOLER UNIT

Filed June 4, 1968 2 Sheets-Sheet 1

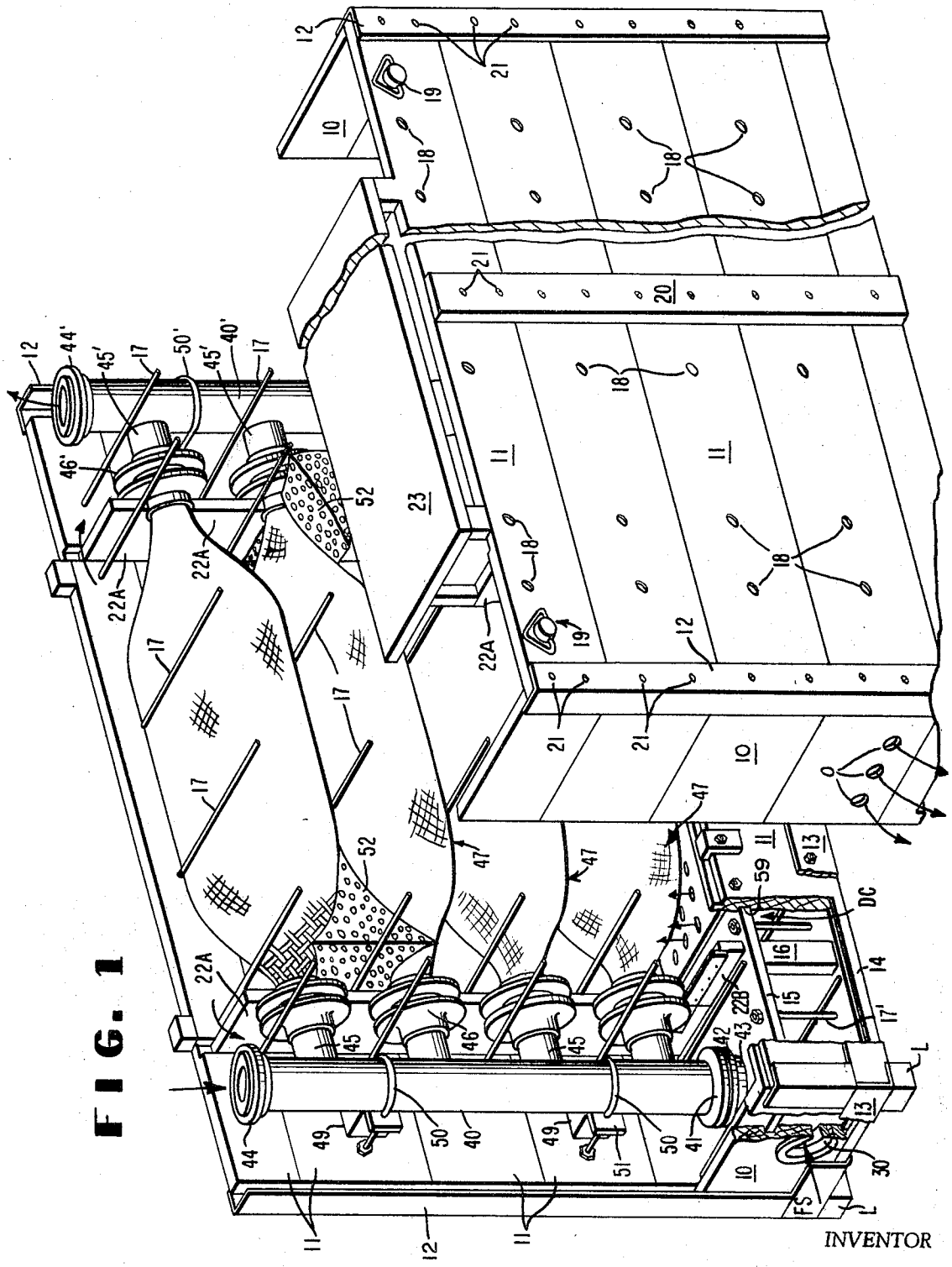

FIG. 1

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Sept. 1, 1970 R. J. GARDNER 3,526,274

CROSS FLOW BOX COOLER UNIT

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FIG. 2

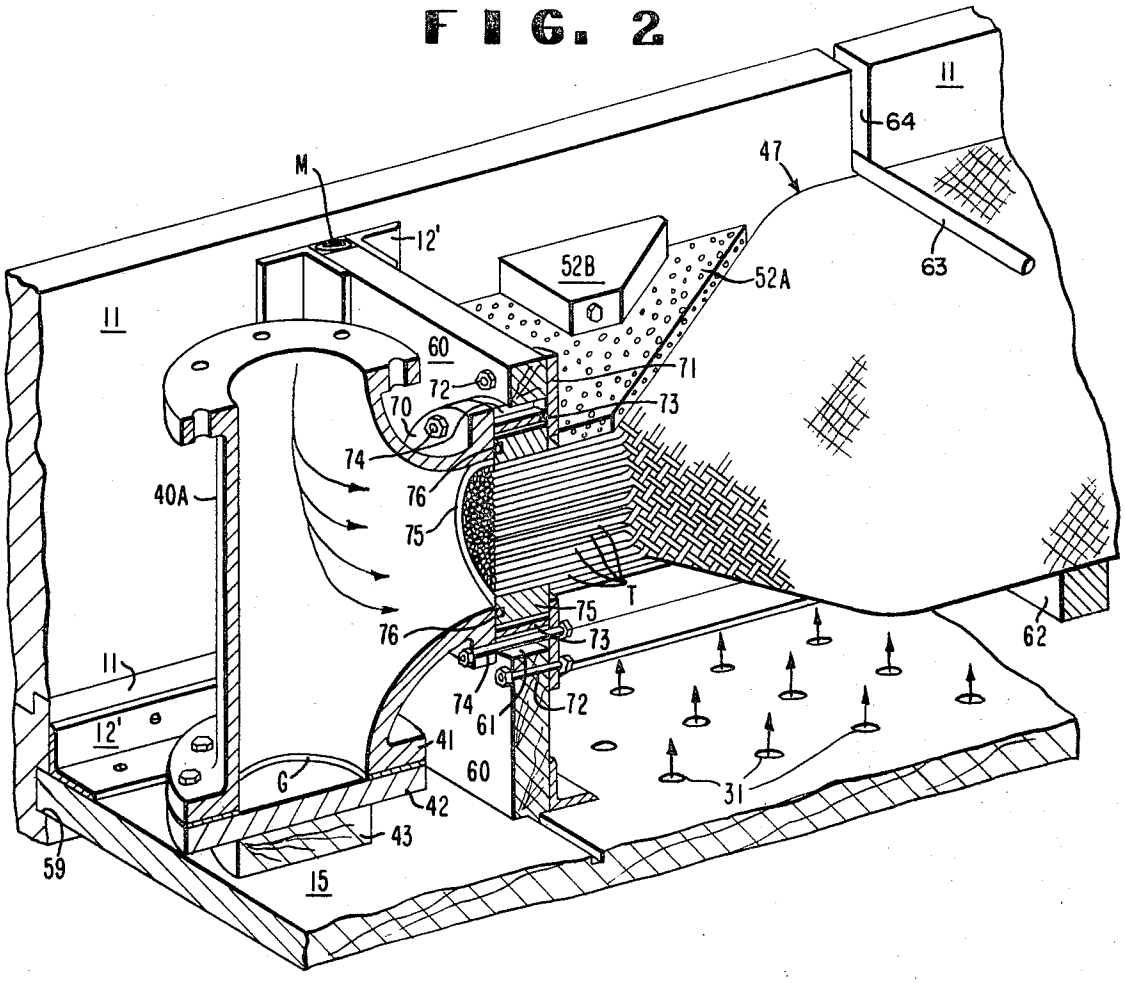
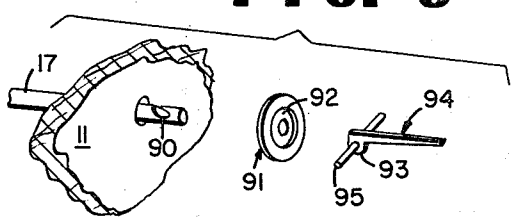



FIG. 3

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United States Patent Office 3,526,274 Patented Sept. 1, 1970



3,526,274

# CROSS FLOW BOX COOLER UNIT

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Int. Cl. F28f 9/00, 9/22
U.S. Cl. 165—145 11 Claims

## ABSTRACT OF THE DISCLOSURE

An easily transportable and demountable heat transfer apparatus combination in which a low pressure fluid stream is directed across a braided array of flexible plastic tubes mounted transversely of a substantially unpressurized fluid conduit the transverse cross section of which corresponds to the dimensions of the braided array so that the action of the fluid stream causes uniform distribution of the flexible tubes across the conduit and causes cooperation of the tubes with the conduit walls to substantially eliminate bypassing and localized compaction of tubes.

## CROSS REFERENCES TO RELATED APPLICATIONS AND PATENTS

U.S. Pat. No. 3,228,456 to Brown et al., filed Mar. 1, 1965, issued Jan. 11, 1966; U.S. Pat. No. 3,315,740 to M. S. Withers, filed Jan. 14, 1965, issued Apr. 25, 1967; U.S. Pat. No. 3,277,959 to M. S. Withers, filed Aug. 12, 1964; issued Oct. 11, 1966; application for U.S. patent Ser. No. 634,631 to T. B. Baker et al., filed Apr. 28, 1967, now Pat. No. 3,419,069, issued Dec. 31, 1968.

## FIELD OF THE INVENTION

This invention relates to the field of heat transfer or heat exchange, and more specifically to heat transfer apparatus combinations of the cross flow type utilizing flexible plastic tube elements mounted in substantially unpressurized casing members.

It is a general object of the invention to provide novel and improved heat transfer apparatus combinations of this type which are simple and economical to construct, assemble, operate and maintain, yet rugged, reliable, and effective in operation; and which preferably have low pressure casing or shell members which are easily transportable and demountable.

Other objects and advantages will be apparent from the following specification, claims, and accompanying drawings.

## PRIOR ART BACKGROUND OF THE INVENTION

As indicated generally in U.S. Pat. Nos. 3,288,456, 3,363,680; 3,277,959, and 3,380,513, heat transfer arrangements utilizing plastic tubular elements are known and have been found to be advantageous in many commercial applications. Because of the use of small flexible plastic tubular elements and other associated plastic parts, a number of problems have been encountered, not only in designing such arrangements but also in their operation. Some of these problems involve the relatively low heat transfer coefficients and the relatively high coefficients of thermal expansion possessed by most plastic materials as compared with parts made of more conventional materials such as metals. Other problems relate to the different properties such as compression strength, tensile strength, toughness, flexibility, and melting points of these plastic materials relative to the other materials used. Production and operating techniques as well as apparatus designs have to be established such that the more conventional parts such as those still formed of the usual metallic compositions can be formed, treated, assembled, and



used while in cooperative association with the plastic parts to produce and operate economical, reliable, and effective heat transfer arrangements without destroying or damaging the associated plastic parts by application of excessive forces, impacts, temperatures or other conditions.

In the industrial field there has been a need for an improved efficiency low cost heat transfer apparatus of the type, for example, in which a hot corrosive fluid such as sulfuric acid must be cooled utilizing large volumes of low pressure cooling water which may be fairly dirty. Such an improved apparatus requires a simple, low cost, easily assemblable and disassemblable unit (to permit rapid easy inspection, testing, and repairs) which unit, in addition, is rugged and relatively free of trouble such as clogging by dirty cooling streams. The requirement for a simple, low cost, low pressure design indicates something quite different from the usual "shell and tube" arrangement with the usual "pressure vessel" type shell and fittings. It has been found that with the proper design and arrangement of parts, small flexible plastic tubular elements can be beneficially and successfully fabricated to form heat transfer apparatus combinations which fill the need discussed in the earlier portion of this paragraph yet which avoid the problems mentioned above. Such combinations, as embodiments of this invention, will be more fully described hereinafter.

## SUMMARY OF THE INVENTION

Generally stated, the problems inherent in the use of small flexible plastic tubes are overcome and the need is filled for a simple, low cost, low pressure, cross flow heat exchanger of the type discussed in the preceding section by a heat transfer apparatus combination which comprises a plurality of flexible plastic tubular elements arranged in a special array of configuration across a fluid passageway to be acted upon by a substantially uniformly distributed fluid stream in cross flow to transfer heat between the fluid stream and a fluid circulated through the tubular elements, the special array being such that under action of the fluid stream the flexible tubular elements distribute themselves uniformly in a low flow resistance pattern which substantially prevents fluid bypassing, minimizes localized compaction of the tubular elements and clogging due to foreign matter in the fluid stream. Among other special features utilized is a special arrangement for cooling certain component assemblies having combined metal and plastic parts in order to minimize relative movement between such parts due to their different coefficients of thermal expansion. Other features are described in the following portions of the specification.

## DESCRIPTION OF THE DRAWINGS

FIG. 1 is a partial general perspective view of one version of a heat transfer apparatus embodying features of the present invention, parts of the structure have been broken away and other parts shown displaced somewhat from their normal positions for a clearer showing.

FIG. 2 is an enlarged view of a portion of an apparatus similar to that shown in FIG. 1 illustrating a preferred arrangement for connecting the fluid supply means to the tubular elements of the bundle and illustrating the baffle means cooperating with the end portions of the bundle to limit fluid bypassing of the bundle at the end portions. Also illustrated is a preferred construction of the casing member which defines the main fluid passageway in which the bundles are positioned.

FIG. 3 is a partial enlarged exploded view showing a quick-disconnect fastener and a resiliently flexible self-sealing washer which cooperate with one end of a tie-rod member of the type which are used to secure the parts of the housing in operative position.

An improved heat transfer apparatus embodying features of the invention is shown in FIG. 1 and comprises a box-like housing assembly formed by assembling opposed rectangular side elements **11**, opposed end elements **10**, corner elements **12** and side braces **20**, all of suitable material such as for example, redwood for the side and end elements and metal for the corner or angle elements **12**. Corner elements **12** and side braces **20** are fastened to side elements **10** and end elements **12** by suittable fastening means **21**, such as for example screws. The assembled elements are held together with a plurality of tie-rods or tie-bolts **17** having enlarged heads (not shown) at one end, and quickly disconnectable devices at the other end as generally shown in FIG. 3. The box-like housing assembly is provided with bottom corner elements **13** and legs or support elements L to maintain it in the preferred upright position, and a planar bottom element **14** formed of a suitable material such as for example redwood. The housing assembly is further provided with a similar planar element **15** spaced from and parallel to bottom element **14** and secured by vertical tie-rod elements **17'** and compressional support elements **16** in position as shown to form a chamber DC at the bottom of the housing assembly. Preferably planar element **15** is also supported at its edge portions in close-fitting grooves or recesses **59** formed in the side and end elements **10** and **11**. An inlet **30** is provided in one of the lower end elements **10** to provide for supplying a fluid stream FS into the chamber DC as shown by the arrow in the lower left-hand corner of FIG. 1. Vertical manifold members **40** and **40'** are positioned inside each end of the housing assembly, maintained substantially parallel to each other as shown; and are provided at their upper ends with flange elements **44**, **44'** and at the lower ends with flanges **41**, **41'**, which lower flanges are blanked off or closed by solid plate elements **42** which in turn receive vertical support from solid spacer members **43**, **43'** (not shown) which are carried by planar element **15**. Lateral support is provided for the manifold members **40**, **40'** by U-bolts **50** and spacer elements **49** and **51**, the U-bolts **50** projecting through the side wall elements **11** and secured by threaded engagement with nut elements not shown.

Each vertical manifold member is provided with a corresponding set of fittings **45**, **46**, **45'**, **46'** between which are operatively connected bundles **47** of small diameter, thin-walled flexible tubular elements T as shown generally in FIG. 1. FIG. 2 shows in more detail a somewhat different preferred arrangement for connecting the bundles **47** to the appropriate fittings on the manifold members. Referring to FIG. 2, the bundle **47** is preferably in the form of a flat braided array which is closely fitted between opposing side elements **11**. The flexible tubular elements T of the bundle **47** are brought together at the ends of the bundles and bonded to each other and to an annular unit **75**, the tubular elements T and unit **75** are preferably formed of a solid polymeric material, while the manifold members **40**, **40'**, **40A** (FIG. 2) are preferably formed of a suitable metallic composition such as stainless steel or cast iron. In the construction of FIG. 2 the plastic units **75** are received in an annular sleeve element **73** of suitable material such as a metal. Annular sleeve element **73** is radially spaced from the outer periphery of annular unit **75** to allow for thermal expansion of unit **75** at all desired operating conditions.

Element **73** is axially coextensive with unit **75** and both are clamped or secured between flange **70** of manifold member **40A** and a flat annular ring element **71** by means of bolts **74**. Ring element **71** is secured by bolts **72** to an interior cross wall element **60** which will be described at a later point in this specification. An end face of the annular unit **75** is provided with a resilient sealing ring **76** positioned in an annular end groove as shown, in order to prevent leakage of a fluid passing from the manifold member **40A** into and through the



tubular elements T of the bundle **47**. Sufficient clearance is provided between the end face of unit **75** and the opposed flange **70** of the manifold member **40A** to permit axial thermal expansion of unit **75** without detrimental contact between these parts or overstressing of the sealing ring **76**.

Preferred examples of the arrangements for bonding the terminal portions of tubular elements T to each other and to the annular unit **75** are disclosed in U.S. Pat. No. 3,315,740 mentioned above. Suitable materials of which the tubular elements may be formed are disclosed in U.S. Pats. 3,228,456; 3,277,959, and 3,315,740, a preferred composition at the present time being a polyfluorinated plastic such as a copolymer of tetrafluoroethylene and hexafluoroproplylene. The flexible tubular elements of the bundle preferably are in a size range between about 5 and 275 mils outside diameter with a wall thickness between about 0.5 and about 30.0 mils. However, it is believed to be clear to those of ordinary skill in the art involved that other materials and dimensions could be utilized without departing from the spirit of the invention. Many other materials, such as for example, completely organic or partly organic polymeric compositions could be used so long as they were readily fabricatable, possessed suitable compatability with the fluids to be handled, possessed adequate properties such as strength at the desired operating conditions and further possessed adequated thermal conductivity for the intended use.

The bundles **47** of flexible tubular elements are, as mentioned above, arranged in a braided configuration, preferably in a flat braided array. It is believed that any form of interlacing, braiding, or interweaving will be satisfactory so long as substantial overall uniformity is achieved with respect to its effects on fluid flow and tubular element packing. Bundles formed on braided sleeve-like arrays, one inside the other, for example, have been found to perform satisfactorily.

Formation of the braided or interwoven bundles can be suitably accomplished on conventional well-known braiding machinery with a few minor modifications obviously necessary to convert them from operation with small solid wires or yarns to operation with the small flexible tubular elements utilized in the apparatus of this invention. One example of a satisfactory arrangement for forming the interlaced bundles utilized in the apparatus of this invention is disclosed in Catalog 56 (ELF–20004–1M–11–64) on "Braiders" of the New England Butt Co., 304 Pearl St., Providence, R.I.

Generally speaking, each bundle comprises a portion having a first plurality of tubular elements positioned in a first pattern and an interengaged, interlaced second plurality of tubular elements positioned in a second somewhat opposed pattern. It has been found that if the tubular elements are interwoven or braided together too tightly, a substantially closed pattern with prohibitive resistance to fluid flow, unacceptable susceptability to plugging, and undesirable kinking or distortion of individual tubular elements is formed. On the other hand, if the tubular elements are interwoven or braided too loosely, the bundle loses its desired coherence and compactness; also, the position of the elements relative to each other to maintain a desired uniform packing and resistance to fluid flow through the bundle cannot be established or maintained. An important factor in controlling the packing and resistance to fluid flow has been found to be the angle of intersection formed where tubular elements of one plurality cross over the elements of the other plurality. For tubular elements in the size ranges discussed above, and for the cross flow conditions of the apparatus of this invention, this angle is preferably maintained between about 20° and about 160°.

In FIGS. 1 and 2 it will be seen that an inner transverse vertical wall is formed a short distance from each of the end walls and substantially parallel thereto to form end chambers which enclose the manifold members

40, 40'. In FIG. 1 these inner transverse walls extend between the opposed side elements 11 and are formed by corresponding abutting wall elements 22A and 22B which extend inwardly from the side wall elements 11. Wall elements 22A and 22B are provided with cut out portions which engage and fit around the end portions of bundles 47. The lower end elements 10 are provided with openings or passageways O which provide free communication between the end chambers and space outside the overall casing assembly. Wall elements 22A and 22B when in asembled cooperating position define a fluid passageway of substantially constant substantially rectangular cross section extending across the vertical array of bundles 47. The transverse dimensions of this passageway (between opposed side elements 11) correspond closely with the transverse dimensions of the central major portions of the bundles 47. It will be seen in FIG. 1 that the uppermost wall elements 22A, 22B terminate at a point lower than the cooperating side elements 11. The central portion of the element 15, between the inner walls formed by elements 22A and 22B, is provided with an evenly distributed plurality of openings or small passageways 31 to provide free communication between chamber DC and the fluid passageway defined between opposed side elements 11 and opposed walls formed by elements 22A and 22B, in which fluid passageway the bundles 47 are positioned as shown.

In the FIG. 1 version of the apparatus the tie-rods 17 are positioned to engage and limit the movement of bundles 47 when in both operating and non-operating positions related to fluid flow through the passageway through which the bundles extend. Also shown in this figure are baffle elements 52 which may be formed of any suitable material such as a cellular or foamed plastic composition. Preferably, baffle elements 52 are resilient and shaped as indicated in FIG. 1 to yieldingly engage the end portions of bundles 47, the wall elements 22A, 22B, and opposed side wall elements 11 to prevent fluid moving through the passageway in which the bundles are positioned from by-passing and channeling past the major portions of the bundles.

A top cover element 23 is provided to provide general protection for the plastic tubular elements of the bundles against debris and falling objects.

As further indicated in FIG. 1, the housing assembly is constructed so that the end elements and side elements of one side of the apparatus can be removed as one subassembly by suitable means such as a chain hoist or a light duty crane. Lifting rings 19 are provided to assist in this removal or disassembly which, as shown, makes the entire interior and internal components of the apparatus readily accessible for inspection, testing, repair or removal of other components such as bundles 47.

The version of the apparatus shown in FIG. 1 is adapted to be used in an upright position as shown, being supported on legs or support elements L over an open drainage ditch or grating for conducting away one of the fluids used in the heat exchange operation. One fluid supply conduit (not shown) is adapted to be operatively connected with inlet 30 at the end of the housing assembly and chamber DC. Another fluid is supplied to the upper end 44 of manifold member 40 through a suitable connection, and removed from the upper end 44' of the other manifold member 40' after passing through the interiors of the tubular elements T of bundles 47. The operation of the apparatus is believed to be clear. The fluid supplied through inlet 30 into chamber DC under some low degree of pressure passes upwardly through openings 31 in element 15 to form a uniformly distributed stream moving upwardly across the bundles 47 in the passageway defined by side elements 11 and by wall elements 22A and 22B. As this stream reaches the upper portion of the passageway it spills over the uppermost elements 22A and 22B at each end of the casing assembly into the end chambers surrounding the header members 40 and 40' where it moves downwardly under the action of gravity and leaves the end chambers and the housing assembly through openings O in the end elements 10 as shown by the arrows in the lower portion of FIG. 1.

Usually the hot fluid to be cooled, such as for example hot sulfuric acid is passed through the interior of the tubular elements T of the bundles 47 while the low pressure cooling fluid such as water is passed through the housing assembly as described above, entering distribution chamber DC through inlet 30, passing through openings 31 in element 15 and upwardly in full cross flow across the bundles 47, where most of the heat transfer occurs, and downwardly at each end through the end chambers surrounding the header members 40, 40', exiting through openings O to a suitable drain or disposal means. Some heat is transferred between the fluid inside the header members and the fluid moving in the end chambers outside of the header members.

The general arrangement and functioning of parts shown in FIG. 2 are essentially the same as the FIG. 1 embodiment, there being a different fluid connection unit acting between the header 40A and the bundle 47, a somewhat different form of header members, a different form of baffle element 52A which is held in position against the sides of the bundle end portions between opposed brackets 52B which are secured in position to the side wall elements 11, a somewhat different but equivalent means of assembling the various side, end and bottom elements, and a different inner wall structure which forms the end chamber enclosing the header member. In this version of the apparatus the inner wall which forms the end chamber comprises wall elements 60 each having the opening 61 formed therein to receive an end portion of the bundle 47. Elements 60 as well as elements 15 are maintained in position by angle elements 12' which are secured to the side elements 11 by any suitable means. A resilient tubular sealing element M is positioned as shown in cooperation with the side wall element 11, the angle elements 12', and the edge of wall element 60 to maintain a suitable sealing arrangement. Reference numeral 62 indicates a limit stop element which is one of a number adapted to limit the downward movement of bundle 47 and support the bundle when the fluid stream is not moving through the housing assembly outside of the tubular elements of the bundle. The rod 63 is shown mounted in a vertically extending slot 64 to permit selective positioning of the rod as it acts to limit the upward movement of the bundle 47 during upward flow of fluid across the bundle and maintain the other parts of the housing casing assembly in operative position.

FIG. 3 illustrates generally one preferred version of a conventional quickly disconnectable device for securing the tie-rods or tie-bolts 63 and 17 in position. As seen in this figure the end of the tie-rod is provided with a recess or groove 90, a flexible bowed disc element 91 having a central depression 92 in which is formed an opening to receive the end of rod 17, is held against the side element 11 by engagement of a cam portion 93 of an actuating element 94 with the depression 92, the pivot pin 95 of element 94 being rotatably received in the recess 90 in the end of the rod. In assembly of the apparatus, the end of a tie-rod with the recess 90 is positioned to extend through one of the openings 18 in the elements forming the casing assembly as shown in FIG. 3, the disc element 91 is placed against the side element 11 with the rod extending through its central orifice, then the pivot pin 95 is positioned in the recess 90 with the actuating element 94 aligned generally as shown in this figure, and the actuating element is rotated about the pivot pin 95 to bring cam portion 93 into engagement with the recess in the disc and tension the tie-rod to to secure side element 11 in position.

In operation, the fluid stream moving across the bundles is evenly distributed over its transverse cross-

section by the openings 31 which communicate with distribution chamber DC. The flexible interwoven array of tubular elements of each bundle 47, under action of this fluid stream, distributes itself uniformly across this passageway in a open low resistance pattern which cooperates with the side elements defining the passageway to substantially eliminate by-passing over the major portion of the bundles and localized compaction of the tube elements, thereby avoiding "dead" or stagnant flow conditions and minimizing the risk of plugging due to foreign matter in this stream. Elements 52A and 52 prevent the fluid stream from by-passing the bundle at the ends of the bundles 47. Causing the fluid stream to move through the end chambers surrounding the manifold members makes possible additional heat transfer and controls the temperature of the manifold members and connections to the bundles which possess cooperating parts of plastic and metal as described above. Controlling the temperature of these connections is done in a way to minimize relative movement and generation of undesirable forces due to the different coefficients of thermal expansion of these parts.

It is believed to be clear from the preceding description that a novel improved heat exchanger apparatus has been provided to meet the special needs of the field while avoiding the problems of the prior art as discussed above, in accordance with the objects of the invention.

What is claimed is:

1. An improved heat transfer apparatus comprising in combination; a housing assembly comprising structure defining a fluid passageway constructed and arranged to conduct a fluid in a given generally upward path from a first lower position to a second upper position, said fluid passageway having a given substantially constant substantially rectangular cross-sectional configuration transversely of the general direction of fluid movement and being generally open to the atmosphere at its upper position, a foraminous fluid distribution means cooperating with said housing assembly and positioned below said first position for receiving a continuous supply of a pressurized fluid and supplying said fluid to said passageway by distributing said fluid substantially uniformly over the transverse cross-sectional configuration of said passageway at said first position, a plurality of elongated flexible bundles of small diameter thin-walled flexible hollow tubular elements formed of a polymeric composition, said bundles positioned and arranged in sequential order in said passageway along the given general path between said first and said second positions in a manner such that limited movement of at least the center portion of said bundle is possible, at least a major portion of each bundle extending transversely across said passageway and having dimensions substantially conforming with the transverse cross-sectional configuration of said passageway, said major portion of each bundle comprising a first plurality of tubular elements arranged in a given pattern, and a second plurality of tubular elements arranged in a similar opposed pattern, said elements of each plurality being loosely interlaced in a substantially uniform manner to provide a flexible coherent bundle of a substantially stable configuration in which each tubular element is readily accessible, the extent of interlacing and number of tubular elements in each bundle selected such that, relative to the cross-sectional configuration and dimensions of said passageway, a predetermined degree of packing and a predetermined resistance to fluid flow through said passageway is provided to maintain heat transfer at desired levels between a first fluid passing through the hollow tubular elements and a second fluid passing through said passageway, means disposed within said fluid passageway cooperating with said bundles to prevent fluid channeling in the region of said passageway in which said bundles do not substantially conform to the cross-section of said passageway, said apparatus further comprising fluid supply means cooperating with said housing assembly and operatively connected with the tubular elements of said bundles to receive a fluid from an external source and pass such fluid through the tubular elements of said bundles, and support means cooperating with said bundles to maintain said bundles in the desired general positions while still allowing limited movement of said bundles to free said bundles from accumulated trapped solids.

2. The improved apparatus of claim 1 in which said structure of said housing assembly defining said passageway is provided with resilient foraminous baffle members disposed between said bundles at the points where they are most widely spaced in a manner such as to cooperate with other minor portions of said bundles to assist further in eliminating fluid by-passing of said bundles.

3. The improved heat transfer apparatus of claim 1 in which said housing assembly further comprises additional structure containing said fluid supply means and being disposed relative to that portion of said housing assembly containing said bundles in a manner such that at least a portion of the fluid passing through said passageway passes from the second position in said fluid passageway into the additional structure of said housing assembly and into operative heat transfer engagement with said fluid supply means to control the temperature thereof.

4. The improved apparatus of claim 3 in which said fluid supply means comprises in cooperative association certain parts of polymeric composition having a relatively high coefficient of thermal expansion, and certain other parts of metallic composition having a lower coefficient of thermal expansion, and in which said housing assembly further comprising additional structure containing said fluid supply means and disposed relative to that portion of said housing assembly containing said bundles in a manner such that at least a portion of the fluid passing through said passageway passes from the second position in said fluid passageway into the additional structure of said housing assembly and into operative heat transfer engagement with said fluid supply means and its fluid connection means to control their temperatures and minimize relative movement between said parts having different coefficients of thermal expansion.

5. The improved apparatus of claim 1 in which said passageway is substantially straight and generally aligned in a vertical direction with said first position located at the bottom thereof such that a pressurized fluid supplied thereto moves upwardly from said first to said second position under action of its pressure, and in which said housing assembly further comprises additional structure containing said fluid supply and being disposed relative to said passageway in a manner such that, beyond said second position, the pressurized fluid is conducted in heat transfer engagement with said fluid supply means under action of gravity.

6. The improved apparatus of claim 1 in which said first and second pluralities of tubular elements are arranged in symmetrically opposed patterns and are interwoven in a regular pattern to provide a braided arrangement in which the elements of one plurality cross over the engaged tubular elements of the other plurality to form included angles of intersection of between about 20° and 160°, the tubular elements of a bundle constructed and arranged to cooperate with the structure defining the passageway and a fluid moving therethrough to maintain the elements of a bundle in an expanded evenly distributed low flow resistance pattern transversely of said passageway and maintain the said portion of each bundle in substantial conformity with the transverse cross sectional configuration of said passageway without substantial fluid by-passing or localized compaction of said bundle.

7. The improved apparatus of claim 6 in which said support means comprise a plurality of rods, passing through said passageway and through the sides of said housing assembly, and a plurality of quick conneet clips for securing said rods on the outside of said housing assembly and in which said housing assembly comprises an easily transportable integrated assembly of removable dis-

assemblable component parts held together by said rods and said clips, said parts capable of easy selective removal and replacement to facilitate selective independent removal, repair, and removal of tubular elements or individual bundles of said apparatus.

**8.** The improved apparatus of claim **7** in which said housing assembly comprises a releasably interconnected multitier vertically stacked series of box-like sections.

**9.** The improved apparatus of claim **2** in which said fluid supply means comprises two substantially parallel manifold members supported by and cooperating with said housing assembly and having corresponding opposed openings, said fluid supply means further comprising fluid connection means cooperating with said manifold members and said bundles for receiving and sealing opposed end portions of said bundles to said manifold members between opposed openings thereof in a substantially parallel array extending transversely across said passageway.

**10.** The improved apparatus of claim **9** in which said support means comprises for each bundle a first plurality of limit stop elements mounted in said passageway above each bundle to limit the movement of each flexible bundle during operation of said apparatus and movement of a fluid stream through said passageway, said support means further comprising a second plurality of limit stop elements mounted below each bundle in said passageway to limit the position of each flexible bundle when said apparatus is not in operation and a fluid stream is not moving through said passageway.

**11.** An improved heat transfer apparatus comprising in combination; a housing assembly comprising structure defining a fluid passageway constructed and arranged to conduct a fluid in a given generally upward path from a first lower position to a second upper position, said fluid passageway having a given cross-sectional configuration transverse to the general direction of fluid movement and being generally open to the atmosphere at its upper position, a foraminous fluid distribution means cooperating with said housing assembly and positioned below said first position for receiving a continuous supply of pressurized fluid and supplying said fluid to said passageway by distributing said fluid substantially uniformly over the transverse cross-sectional configuration of said passageway at said first position, a plurality of elongated, flexible, small-diameter, thin-walled hollow tubular elements formed of a polymeric composition, said tubular elements arranged in said passageway along the given general path between said first and said second positions in a manner such that limited movement of at least the center portions of said tubular elements is possible, at least a major portion of said plurality extending transversely across said passageway and substantially conforming with the transverse cross-sectional configuration of said passageway, said major portion of said plurality comprising a first plurality of tubular elements arranged in a given pattern, and a second plurality of tubular elements arranged in a similar opposed pattern and interwoven in a regular pattern to provide a loosely braided arrangement of a substantially stable coherent configuration in which each tubular element is readily accessible, the extent of interlacing and the number of tube elements in each plurality selected such that, relative to the cross-sectional configuration and dimensions of said passageway, a predetermined degree of packing and a predetermined resistance to fluid flow through said passageway is provided to maintain heat transfer at desired levels between a first fluid passing through the hollow tubular elements and a second fluid moving through said passageway, said tubular elements of said arrangement constructed and arranged to cooperate with said structure defining the passageway and a fluid moving therethrough to maintain the tubular elements in an expanded evenly distributed pattern across said passageway and maintain the tubular elements of said arrangement in substantial conformity with the transverse cross-sectional configuration of said passageway to prevent substantial fluid by-passing or localized compaction of said tubular elements, means disposed within said fluid passageway cooperating with said bundles to prevent fluid channeling in the region of said passageway in which said bundles do not substantially conform to the cross-section of said passageway, said apparatus further comprising fluid supply means cooperating with said housing assembly and operatively connected with the tubular elements to receive a fluid from an external source and pass such fluid through said tubular elements.

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U.S. Cl. X.R.

165—76, 81, 158, 159, 162, 163

PO-1050
(5/69)

# UNITED STATES PATENT OFFICE
# CERTIFICATE OF CORRECTION

Patent No. 3,526,274 Dated September 1, 1970

Inventor(s) Robert John Gardner

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 8, line 10, delete "foraminous".

SIGNED AND
SEALED
FEB 2[illegible]

(SEAL)
Attest:

Edward M. Fletcher, Jr.
Attesting Officer

WILLIAM E. SCHUYLER, JR.
Commissioner of Patents