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(54) In-line heat-exchangers and methods of forming the same

(57) An in-line heat exchanger (10) comprising first (20) and second lengths (30) of seamless, walled tubing, the first length of tubing characterized by a larger diameter than the diameter of the second length of tubing, and the second length of walled tubing disposed within the first length of walled tubing. A plurality of longitudinally-extending channels (21) are defined in the wall of at least one of the first and second lengths of tubing, the channels (21) defining therebetween a plurality of longitudinally-extending passageways (40) in the area between the walls of the first and second lengths of tubing. Terminal portions (22a,22b) provided at opposite ends of the first length of tubing are each sealed with respect to the second length of tubing, each terminal portion defining one of an inlet or an outlet, and each terminal portion defining at least one interior passageway between the terminal portion and the wall of the second length of tubing, the at least one interior passageway (24a;24b) communicating the plurality of longitudinally-extending passageways (40) with one of the inlet or outlet.

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Description

[0001] The present invention relates to tube-in-tube style, in-line heat exchangers and their manufacture.

[0002] Conventional refrigeration systems continuously circulate refrigerant in an evaporator and a condenser in a closed system such as shown in the simplified diagram of **FIG.** 1. These systems have a high-pressure side (indicated by the thin lines **2**) and a low-pressure side (indicated by the thick lines **3**). Beginning at the inlet to evaporator **1** and moving counter-clockwise in the direction of the arrows, a supply of low-pressure refrigerant liquid expands, absorbs heat, and evaporates, changing to a low-pressure, saturated, dry gas. A compressor **4** draws this gas from the evaporator **1** through a suction line **(3).** Compressor **4** increases the pressure of the gas, and discharges the high-pressure and high temperature refrigerant gas to a condenser **5** through a discharge line. Heat is removed from the gas at the condenser **5,** which gas then condenses and becomes a high-pressure liquid. The high-pressure refrigerant liquid flows from the condenser **5** into a receiver tank **6.** From the receiver **6** the high-pressure refrigerant liquid flows toward the evaporator **1** in a pipe called the liquid line. In order for the refrigerant liquid to evaporate and cool the fluid needing refrigeration, its pressure must be reduced. This pressure reduction is achieved by passing the high-pressure refrigerant liquid through a flow restrictor (also called an expansion device). One frequently employed flow restrictor is a thermal expansion valve **7**, or "TXV," positioned proximate the evaporator and operative to sense both the pressure in the evaporator and, via sensor **9** operatively connected (shown in dotted line) thereto, the temperature at the refrigerant vapor outlet of the evaporator. The flow of refrigerant into the evaporator **1** is controlled by the degree of superheat of the suction gas.

[0003] A heat exchanger **8** (depicted in dashed lines) between the liquid line and the suction line is also conventionally provided to facilitate cooling of the high-pressure and high-temperature liquid by moving it in close proximity to, and flowing oppositely of, he low-pressure and low-temperature gas drawn from the evaporator **1.** Conventionally, heat exchangers comprise tubing made up of concentric inner and outer tubes. According to this construction, also referred to as a tube-in-tube style heat exchanger, the high-pressure, high-temperature liquid is caused to flow through the annular space between the inner and outer tubes, while evaporated low-pressure, low-temperature refrigerant gas is caused to flow through the inside of the inner tube of the heat exchanger. The high-pressure, high-temperature liquid and the low-pressure, low-temperature gas exchange heat through the inner tube, whereby the high-pressure, high-temperature liquid is cooled. This heat transfer process of the high-pressure and high-temperature liquid increases the subcooling thereof.

[0004] Conventional tube-in-tube style heat exchangers are, unfortunately, complex in construction and therefore costly to manufacture. Exemplary in these regards are the heat exchanger tubes disclosed in Usui, USPN 7044210, and McLain, USPN 3831675. It would therefore be desirable to have a tube-in-tube style heat exchanger that is easy and inexpensive to manufacture, and which allows efficient heat transfer between the inner and outer tubes thereof.

[0005] According to a first aspect of the invention, there is disclosed an in-line heat exchanger, comprising first and second lengths of seamless, walled tubing, the first length of tubing characterized by a larger diameter than the diameter of the second length of tubing, and the second length of walled tubing disposed within the first length of walled tubing. A plurality of longitudinally-extending channels defined in the wall of at least one of the first and second lengths of tubing, the channels defining therebetween a plurality of longitudinally-extending passageways in the area between the walls of the first and second lengths of tubing. Terminal portions provided at opposite ends of the first length of tubing are each sealed with respect to the second length of tubing, and each defines one of an inlet or an outlet. Each terminal portion further defines at least one interior passageway between the terminal portion and the wall of the second length of tubing, the at least one interior passageway communicating the plurality of longitudinally-extending passageways with one of the inlet or outlet.

[0006] The terminal portions may each be defined by opposite ends of the first length of tubing that are sealed against the wall of the second length of tubing. In another embodiment, the terminal portions comprise separate lengths of tubing that are connected to each of the first and second lengths of tubing.

[0007] The terminal portions may have different longitudinal dimensions with respect to each other so as to define interior passageways of different volumes. Furthermore, one of the terminal portions may define an interior passageway capable of accommodating an amount of a high-pressure, sub-cooled fluid at least equivalent to the weight of the quantity of a high-pressure fluid that can be accommodated in the receiver dryer in a fully charged air-conditioning system.

[0008] The plurality of longitudinally-extending channels may be defined in only the wall of the first length of tubing. However, the plurality of longitudinally-extending channels may, alternatively, be defined in the wall of only the second length of tubing, or in the walls of both of the first and second lengths of tubing.

[0009] The plurality of longitudinally extending channels may comprise at least two discrete sets of longitudinally extending channels. Each discrete set of channels may, moreover, be separated from the other by an intermediate space defined in the area between the walls of the first and second lengths of tubing. At least one such discrete set of channels may be offset relative to the one or more other sets of channels.

[0010] The plurality of longitudinally-extending channels may each define a helical path.

[0011] According to a second aspect of the invention, there is provided a method for forming in-line heat exchangers, comprising the steps of: providing at least first and second lengths of seamless, walled tubing, the first length of tubing characterized by a larger diameter than the diameter of the second length of tubing, and each of the at least first and second lengths of walled tubing characterized by generally circular cross-sectional shapes; inwardly deforming circumferentially spaced-apart portions of the wall of at least one of the first and second lengths of tubing to form along a longitudinal length thereof a plurality of longitudinally-extending channels; and positioning the second length of walled tubing within the first length of walled tubing so that the walls of the first and second lengths of tubing are in contact proximate the plurality of longitudinally-extending channels, and so that, intermediate the areas of contact between the first and second lengths of walled tubing proximate the plurality of longitudinally-extending channels there are defined between the walls of the first and second lengths of tubing a plurality of longitudinally-extending passageways.

[0012] The method may include the step of positioning the second length of walled tubing within the first length of walled tubing is carried out before the step of inwardly deforming circumferentially spaced-apart portions of the wall of at least one of the first and second lengths of tubing.

[0013] The method may include the step of positioning the second length of walled tubing within the first length of walled tubing is carried out after the step of inwardly deforming circumferentially spaced-apart portions of the wall of at least one of the first and second lengths of tubing.

[0014] The method may include the step of inwardly deforming circumferentially spaced-apart portions of the wall of at least one of the first and second lengths of tubing comprises inwardly deforming circumferentially spaced apart portions of the wall of the second length of tubing.

[0015] The method may include the step of inwardly deforming circumferentially spaced-apart portions of the wall of at least one of the first and second lengths of tubing comprises inwardly deforming circumferentially spaced apart portions of the walls of the first and second lengths of tubing.

[0016] The method may include the step of inwardly deforming circumferentially spaced-apart portions of the wall of at least one of the first and second lengths of tubing to form along a longitudinal length thereof a plurality of longitudinally-extending channels further comprises forming those channels intermediate of terminal sections of the first length of tubing, and wherein the method further comprises the step of sealing the ends of the terminal sections against the wall of the second length of tubing to define terminal portions each defining at least one interior passageway between the terminal portion and the wall of the second length of tubing, the at least one interior passageway communicating the plurality of longitudinally-extending passageways, and the step of forming one of an inlet or outlet passageway in each terminal section, the inlet and outlet each communicating one or the other of the at least one interior passageways defined in each terminal portion.

[0017] The terminal portions may have different longitudinal dimensions with respect to each other so as to define interior passageways of different volumes.

[0018] One of the terminal portions may define an interior passageway capable of accommodating an amount of a high-pressure, sub-cooled fluid at least equivalent to the weight of the quantity of a high-pressure fluid that can be accommodated in the receiver dryer in a fully-charged air-conditioning system.

[0019] The plurality of longitudinally-extending channels may comprise at least two discrete sets of channels, each discrete set of channels comprising a plurality of longitudinally-extending channels.

[0020] At least one discrete set of channels may be offset relative to the one or more other discrete sets of channels.

[0021] Each such discrete set of channels may be separated from the other by an intermediate space defined in the area between the walls of the first and second lengths of tubing.

[0022] The plurality of longitudinally extending channels may each define a helical path.

[0023] For a better understanding of the present invention and to show more clearly how it may be carried into effect, reference will now be made, by way of example, to the accompanying drawings, which show exemplary embodiments of the present invention, and in which:

FIG. 1 is a simplified diagram of a conventional air-conditioning system;

FIG. 2A is a lateral elevational view of a heat exchanger in accordance with an exemplary embodiment of the invention;

FIG. 2B is a cross-sectional view of the heat exchanger of **FIG. 2A;**

FIG. 3 is a lateral elevational view of a heat exchanger in accordance with a second exemplary embodiment of the invention;

FIG. 4 is a simplified schematic depicting the heat exchanger of **FIG. 3** in an exemplary operational environment;

FIG. 5 is a lateral elevational view of a heat exchanger in accordance with a third exemplary embodiment of the invention;

FIG. 6 is a lateral elevational view of a heat exchanger in accordance with a fourth exemplary embodiment of the invention;

FIG. 7 is a lateral elevational view of a heat exchanger in accordance with a fifth exemplary embodiment of the invention;

FIG. 8 is a cross-sectional view of a heat exchanger in accordance with an alternative construction;

FIG. 9 is a cross-sectional view of a heat exchanger in accordance with an alternative construction;

FIG. 10 is a perspective view of an exemplary forming apparatus for making heat exchangers in accordance with the present invention; and

FIGS. 11 A and **11 B** are cross-sectional view of the press portion of the apparatus of **FIG. 10**, depicting the step of forming channels in the walled tubing comprising the heat exchanger.

[0024] As required, a detailed embodiment of the present invention is disclosed herein. However, it is to be understood that the disclosed embodiments are merely exemplary of the invention that may be embodied in various and alternative forms. The accompanying drawings are not necessarily to scale, and some features may be exaggerated or minimized to show details of particular components. Therefore, specific structural and functional details disclosed herein are not to be interpreted as limiting, but merely as a representative basis for teaching one skilled in the art to variously employ the present invention.

[0025] Referring now to the drawings, wherein like numerals refer to like or corresponding parts throughout the several views, the present invention is characterized, according to a first embodiment thereof, as a tube-in-tube style, inline heat exchanger (identified generally at **10**) comprising first **20** and second **30** lengths of walled tubing arranged with the second length **30** of tubing disposed within the inner diameter of the first length **20** of tubing. **FIGS. 2A** and **2B.** While generally described herein in connection with air conditioning systems, it will be understood by those skilled in the art that the heat exchanger of the present invention may be incorporated in any system employing a two-phase refrigerant fluid.

[0026] As shown best in **FIG. 2B,** the second length **30** of tubing is characterized by a generally circular cross-section, with the area **31** defined by the inner diameter defining a passageway for the flow of a low-pressure, low-temperature fluid, such as a refrigerant gas, therethrough. The first length **20** of tubing is characterized by a corrugated or wavy cross-section defined by a plurality of circumferentially spaced-apart, longitudinally-extending channels **21.** Proximate the nadir of each such channel **21,** the inner surface of the wall of the outer, first length **20** of tubing is in contact with the exterior surface of the wall of the inner, second length **30** of tubing. Intermediate the channels **21** is defined in the annular space between the first **20** and second **30** lengths of tubing a plurality of longitudinally-extending passageways **40,** each such passageway closed off from the other by reason of the contact between the interior of the wall of first length of tubing **20** and the exterior of the wall of the second length of tubing **30.** Each passageway **40** defines an internal channel for the flow of a high-pressure fluid, such as a high-pressure liquid, therethrough in a direction opposite the direction of the low-pressure fluid flow through the inner diameter **31** of the second length of tubing **30.**

[0027] Referring particularly to **FIG. 2A,** the heat exchanger according to the illustrated embodiment will, in order to be integrated in-line into a refrigeration system (such as depicted in schematically in **FIG. 3**) or other operational environment, include terminal portions **22a, 22b** disposed exteriorly of, and sealed with respect to, the second length of tubing **30,** as shown in **FIG. 2A** (where the second length of tubing **30** is shown in dashed lines). Each terminal portion **22a, 22b** communicates a passageway **23a, 23b,** respectively, defining one of an inlet or an outlet for a high-pressure fluid (such as for a high-pressure liquid in a vehicle air-conditioning system) with, respectively, at least one interior passageway **24a** or **24b** (such as, for instance, a circumferential space) defined in the area between the terminal portion and the wall of the second length of tubing **30.** Where passageway **23a** defines the inlet, interior passageway **24a** communicates the high-pressure fluid from the inlet to the passageways **40,** while the passageway **23b** communicates the high-pressure fluid exiting passageways **40** to the outlet defined (in this example) by the passageway **23b.**

[0028] As those skilled in the art will appreciate, the number of passageways **40** and their individual cross-sectional dimensions, as well as the dimensions of the inner diameter **31** of the second length of tubing **30,** and the thickness of the walls of each of the first **20** and second **30** lengths of tubing will vary in accordance with the type of two-phase fluids employed in, and other known operating parameters of, the system. Generally speaking, however, it is contemplated that the number of passageways **40** and their individual cross-sectional dimensions will correspond to the cross-sectional dimensions of the interior passageways **24a** or **24b** defined in the area between the terminal portions **22a, 22b,** respectively, and the exterior of the wall of the second length of tubing **30.**

[0029] It will also be understood by those skilled in the art that the length of the active heat-transfer area - that is, the length of the portion of heat-exchanger **10** comprising channels **21** and corresponding passageways **40 -** will vary according to the particular parameters (e.g., air conditioner size and cooling load) of the system in which it is incorporated. Furthermore, while the heat exchanger **10** depicted in the several embodiments disclosed herein is straight, it will be understood that the tubing may be bent -- typically along the length of the active heat transfer surface -- as required to accommodate the physical limitations of the space in which the heat exchanger **10** is disposed, to make necessary connections between the opposite ends of the second length of tubing **30,** etc. And, in practice, the heat exchanger as disclosed herein has demonstrated the ability to be bent in multiple locations without collapsing the passageways **40.**

[0030] As depicted, the second length of tubing **30** extends beyond the terminal portions **22a, 22b**. The length of these extensions will vary according to the particular application and, in any known manner, the opposite free ends of the second length **30** of tubing may be secured to. upstream and downstream components in the system in which the heat-exchanger is employed.

[0031] With continuing reference to **FIG. 2A,** it is contemplated that the terminal portions **22a, 22b** may, as shown, be formed from terminal sections of the first length of tubing **20** that are not formed with channels **21** (so that the high-pressure fluid can move freely from the inlet into each of the passageways **40** and, at the opposite end of each of these passageways **40,** may likewise move freely to the outlet). This may be accomplished, for example, by crimping the ends **25a, 25b** against the second length of tubing **30.** The crimped ends **25a, 25b** may be brazed or otherwise sealed by conventional means against the tubing **30** so that high-pressure fluid is able to move only between the inlet and outlets of terminal portions **22a, 22b.**

[0032] Alternatively, it is contemplated that the terminal portions may comprise separate lengths of tubing that are connected to each of the first and second lengths of tubing.

[0033] While a variety of materials may be employed for the heat exchanger of the present invention, including for the first **20** and second **30** lengths of tubing, suitable exemplary materials include metals such as steel, stainless steel, aluminum, aluminum base, copper, copper base alloys and nickel and nickel base alloys.

[0034] Referring next to **FIGS. 3** and **4,** there is shown an alternative embodiment wherein the heat exchanger **10'** is characterized by terminal portions **22a', 22b'** of dissimilar longitudinal dimensions. More particularly, the terminal portion at which the outlet is defined (**22b'** in the illustrated example) has relatively greater longitudinal dimensions than the terminal portion at which the inlet is defined (**22a'** in the example). The longitudinal dimension of terminal portion **22b'** is such that the volume of the interior passageway **24b'** defined in the area between the terminal portion **22b'** and the exterior of the wall of the second length of tubing **30'** is capable of accommodating, by weight (e.g., in grams), an amount of high-pressure, high-temperature fluid at least equivalent to the weight (e.g., in grams) of the quantity of high-pressure, high-temperature fluid that can be accommodated in the receiver dryer (whether integrated with the condenser or of the stand-alone type) in a fully-charged vehicle air conditioning system. Referring specifically to **FIG. 4,** it will further be noted that the outlet to the thermal expansion valve 7 is oriented to provide gravity feed of sub-cooled, high-pressure fluid thereto. Such orientation in particular serves to reduce noise at the thermal expansion valve.

[0035] By the foregoing, the inventive heat exchanger provides a fluid storage capability and, moreover, the sub-cooled fluid metered to the thermal expansion valve 7 is characterized by a lower pressure drop than in conventional systems. This improves vehicle fuel economy (when employed in a vehicle air-conditioning system), increases the cooling capacity of the evaporator, and permits relocation or even removal of the receiver dryer or integrated receiver found in conventional vehicle air-conditioning systems.

[0036] While, according to the aforedescribed embodiments, the channels **21, 21'** (and corresponding passageways **40, 40')** are depicted as being continuous for the length of the active heat-transfer area, it will be understood that they may be alternatively configured. Thus, for instance, it is contemplated that, according to the embodiment of **FIG.** 5, heat exchanger **10"** may have formed therein a plurality of longitudinally discontinuous channels **21 a", 21 b"** that are interrupted one or more times along the length of the tubing **20"** to define therebetween, and in the area between the first **20"** and second **30"** lengths of tubing, one or more intermediate spaces **41"** in which high-pressure, high-temperature fluid exiting the passageways **40a"** would flow before entering further, downstream passageways **40b".** It will be understood that such intermediate spaces **41"** beneficially facilitate mixing of the fluid flowing therein.

[0037] Alternatively, in another embodiment of the heat exchanger **10"' (FIG. 6),** the channels **21a"', 21b"', 21c"'** are longitudinally discontinuous, being interrupted by one or more intermediate spaces **41a"', 41b"'**, with the successive set of channels **21b"'**, **21c"'** (and, therefore, downstream passageways, e.g., **40b"', 40c"'**) being offset relative to each preceding set of channels **21a"', 21b"'** (and, therefore, upstream passageways, e.g., **40a"', 40b"'**). As shown the intermediate spaces **41a"'**, **41 b"'** of this embodiment are of shorter longitudinal dimensions than those of the embodiment of **FIG. 5.** It will be appreciated that the length of such intermediate spaces may be varied as desired, subject only to the provision that fluid flowing through one set of upstream passageways be able to continue flowing into successive downstream passageways.

[0038] It will also be appreciated that any number of sets of such discontinuous channels, whether aligned or offset, may be provided, depending upon the length of the channels in such sets and the overall length of the heat exchanger.

[0039] According to a still further embodiment of the heat exchanger **10""** of the present invention, shown in **FIG. 7,** the channels **21""** may be formed so as to each define a helical path along the length of the first length of tubing **20""** between the terminal portions **22a""**, **22b"".** Optionally, the heat exchanger **10""** of this embodiment may be further characterized by longitudinally discontinuous channels, such as exemplified in foregoing embodiments, and one or more intermediate spaces (not shown) disposed therebetween.

[0040] While, in each of the aforedescribed embodiments, the plurality of longitudinally-extending channels **21, 21', 21",** etc. are shown as being defined in the wall of the first length of tubing **20, 20', 20",** etc., it is contemplated that these channels may, alternatively, be defined in the second length of tubing **30, 30', 30"**, etc., such as depicted in **FIG. 8**, or even on both lengths of tubing, such as shown in **FIG. 9.**

[0041] Referring next to **FIGS. 10** through **11 B**, the exemplary method by which the heat exchangers as heretofore described may be manufactured will be better understood.

[0042] According to the illustrated embodiment, there is provided a forming apparatus (indicated generally at **100**) essentially comprising an hydraulically actuated press **101** and an hydraulically-actuated carriage assembly **120.** Press **101** more particularly comprises a stationary, split-ring element **102** supporting a plurality of rollers **103** arranged circumferentially, and equidistant from each other, about a central opening **104** which, in operation of the apparatus, is occupied by one or both of the first **20** and second **30** lengths of tubing. The relative distance between each roller **103** corresponds to the dimensions of the plurality of passageways **40** to be formed in the tubing. While, in the illustrated embodiment, eight such rollers **103** are depicted, it will be understood that the number may be varied according to the desired number, and dimensions, of the channels **21** and corresponding passageways **40.**

[0043] Rollers **103** are each disposed on support members **105** riding in, and reciprocally moveable with respect to, radial openings **106** defined in the ring element **102.** As shown best in **FIG. 9,** each support member **105** has an angled cam-following surface **107** corresponding approximately in shape to the angled surface **108** of cam member **109.** Cam member **109** defines a ring-like shape of greater diameter than the split-ring element **102.** Cam member **109** is hydraulically reciprocally-moveable along an axis coaxial with the central axis of split-ring element **102** so as to selectively move the angled surface **108** thereof into and out of engagement with the co-acting, cam-following surfaces **107.**

[0044] With reference particularly to **FIG. 9,** carriage assembly **120** comprises a mechanical grip **121,** such as, for example, a chuck, in the opening **122** of which are fixedly retained first **20** and/or second **30** lengths of tubing. Mechanical grip **121** is secured to a sled **123** that rides, under power of an hydraulic piston **125,** freely along rails **124.**

[0045] Referring also to **FIGS. 9A** and **9B** there are provided in operation of the aforedescribed apparatus first **20** and second **30** lengths of cylindrical, walled tubing arranged with the second length of tubing 30 disposed within the first **20.** The tubes **20, 30** so arranged are fixed in position within opening **122** of the mechanical grip **121** so that a length of the tubes **20, 30** extends from the grip **121** in the direction of the press **101.** As noted, at this stage both the first **20** and second **30** lengths of tubing are characterized by generally circular cross-sections, as shown in **FIG. 9A,** the first length **20** having an inside diameter larger than the outer diameter of the second length **30** of tubing so that, when the lengths of tubing are arranged one within the other, an annular space is defined between the exterior and interior surfaces of the walls thereof.

[0046] Subsequently, the sled **123** is moved by operation of the piston **125** in the direction of the press **101** so as to position the tubing **20, 30** in the central opening **104. FIG. 9A.** At the desired position along the length of the tubing **20, 30,** and as the tubing is continually urged through the central opening **104** by corresponding movement of the sled **123,** the cam member **109** is moved over the split-ring element **102** so as to bring the angled surface **108** into engagement with cam-following surfaces **107** of the support members **105.** By the co-action of these surfaces **107, 108,** each support member **105** is driven radially inward into its respective radial opening **106** until the rollers **103** are brought into contact with the exterior surface of the first length **20** of tubing to form the longitudinally extending channels **21** heretofore described. More particularly, as the pressure applied by rollers **103** increases, the wall of the first length **20** of tubing is locally deformed in the area of each deforming member **60. FIG. 9B.** The pressure applied by each roller **103** is sufficient to inwardly deform the wall of the first length **20** of tubing proximate thereto until the wall has been urged inwardly to the point where the interior surface thereof is in contact with the exterior surface of the wall of the second length **30** of tubing. As the tubing continues to be urged through the central opening **104** by corresponding movement of the sled **123,** this deforming pressure continues, thus forming channels **21** (and the corresponding passageways **40**) of lengths determined by the duration of operation of the forming apparatus.

[0047] The amount of deforming pressure applied will, naturally, vary with the material of the first **20** and second **30** lengths of tubing; however, the amount of deforming pressure will at least be sufficient to bring the interior surface of the wall of the first length **20** of tubing into contact with the exterior surface of the second length **30** of tubing so as to form the plurality of channels **21** and, correspondingly, the plurality of passageways **41** between the first and second lengths of tubing.

[0048] It will be appreciated that, by the foregoing method of construction, the inventive heat exchangers may be fashioned from seamless tubing, rather than being formed from sheets of material that are first formed to include the plurality of channels and then joined end-to-end to define tubular shapes.

[0049] According to the aforedescribed methodology, it will be appreciated that the several embodiments of heat exchangers as described herein may be formed by modifying the manner of operation of the forming apparatus. For instance, the formation of discontinuous channels **21** may be accomplished by selectively moving the cam member **109** away from the split-ring element **102** while the tubing is being moved through the central opening **104** so as to temporarily disengage the angled surfaces **108** from cam-following surfaces **107,** thereby eliminating the deforming pressure applied by the rollers **103.** Related to this, the formation along the length of the heat exchanger of offset channels may be accomplished by rotating by a predetermined amount the lengths of tubing **20, 30** within the grip **121** before bringing the angled surfaces **108** of the cam member **109** back into engagement with the cam-following surfaces **107.** And relative to the embodiment herein described wherein the channels extend along a helical path, it will be appreciated that such a configuration may be accomplished by rotating the lengths of tubing **20, 30** within the grip **121** simultaneously with both the continued movement of the tubing through the central opening **104** by corresponding movement of the sled **123** and the application of deforming pressure by the press **101** as heretofore described.

[0050] It will be understood that, according to the afore-described methodology, the formation of a heat exchanger wherein the inner, second length of tubing **30** is formed to include channels **21** will necessitate first forming such channels on the second length of tubing in the forming apparatus **100** and then disposing that length of tubing within the first length of tubing **20;** the exemplary forming apparatus **100** as described does not permit disposing the second length of tubing **30** within the first **20,** and then forming channels **21** on the second length of tubing **30.**

[0051] It will be appreciated that the cross-sectional shape of channels **21** may be varied by varying the cross-sectional shape of the rollers **103** employed.

[0052] The foregoing description of the exemplary embodiments of the invention have been presented for purposes of illustration and description. They are not intended to be exhaustive or to limit the invention to the precise forms disclosed, and modifications and variations are possible in light of the above teachings or may be acquired from practice of the innovation. The embodiments shown and described in order to explain the principals of the innovation and its practical application to enable one skilled in the art to utilize the innovation in various embodiments and with various modifications as are suited to the particular use contemplated. Although only a limited number of embodiments of the present innovations have been described in detail in this disclosure, those skilled in the art who review this disclosure will readily appreciate that many modifications are possible without materially departing from the novel teachings and advantages of the subject matter recited. Accordingly, all such modifications are intended to be included within the scope of the present innovations. Other substitutions, modifications, changes and omissions may be made in the design, operating conditions and arrangement of the exemplary embodiments without departing from the scope of the present innovations.

Claims

1. An in-line heat exchanger, comprising:

first and second lengths of seamless, walled tubing, the first length of tubing **characterized by** a larger diameter than the diameter of the second length of tubing, and the second length of walled tubing disposed within the first length of walled tubing;

a plurality of longitudinally-extending channels defined in the wall of at least one of the first and second lengths of tubing, the channels defining therebetween a plurality of longitudinally-extending passageways in the area between the walls of the first and second lengths of tubing; and

terminal portions provided at opposite ends of the first length of tubing, the terminal portions each sealed with respect to the second length of tubing and each defining one of an inlet or an outlet, and each terminal portion defining at least one interior passageway between the terminal portion and the wall of the second length of tubing, the at least one interior passageway communicating the plurality of longitudinally-extending passageways with one of the inlet or outlet.

2. The heat exchanger of claim 1, wherein the terminal portions are each defined by opposite ends of the first length of tubing that are sealed against the wall of the second length of tubing.

3. The heat exchanger of claim 1, wherein the terminal portions comprise separate lengths of tubing that are connected to each of the first and second lengths of tubing.

4. The heat exchanger of any preceding claim, wherein the terminal portions have different longitudinal dimensions with respect to each other so as to define interior passageways of different volumes.

5. The heat exchanger of any preceding claim, wherein one of the terminal portions defines an interior passageway capable of accommodating an amount of a high-pressure, sub-cooled fluid at least equivalent to the weight of the quantity of a high-pressure fluid that can be accommodated in the receiver dryer in a fully charged air-conditioning system.

6. The heat exchanger of any preceding claim, wherein the plurality of longitudinally extending channels are defined in the wall of the first length of tubing.

7. The heat exchanger of any preceding claim, wherein the plurality of longitudinally extending channels are defined in the wall of the second length of tubing.

8. The heat exchanger of any preceding claim, wherein the plurality of longitudinally extending channels comprises at least two discrete sets of longitudinally extending channels.

9. The heat exchanger of claim 8, wherein each discrete set of channels is separated from the other by an intermediate space defined in the area between the walls of the first and second lengths of tubing.

10. The heat exchanger of claim 8 or 9, wherein at least one discrete set of channels is offset relative to the one or more other sets of channels.

11. The heat exchanger of any preceding claim, wherein the plurality of longitudinally extending channels each define a helical path.

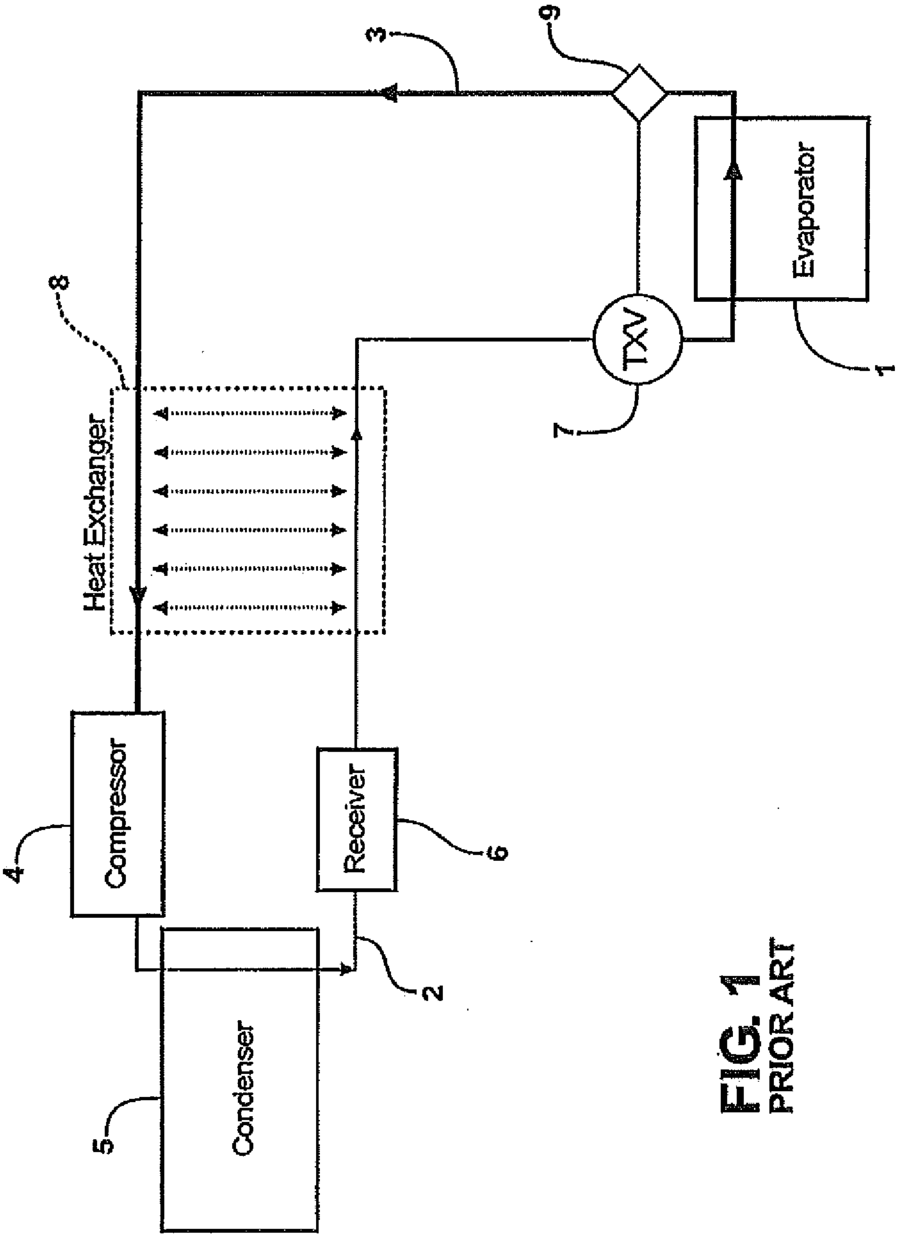

FIG. 1
PRIOR ART

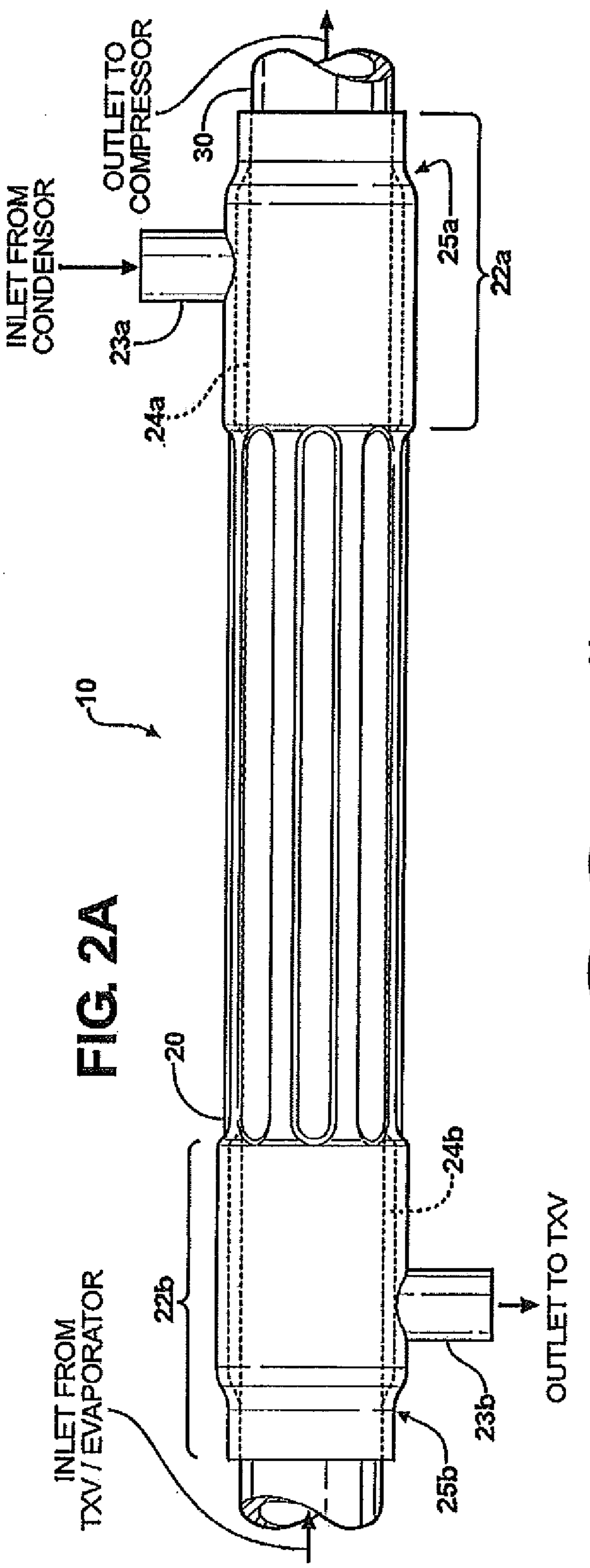
OUTLET TO COMPRESSOR
INLET FROM CONDENSOR
30
25a
22a
23a
24a
10
20
24b
22b
INLET FROM TXV / EVAPORATOR
OUTLET TO TXV
23b
25b

FIG. 2A

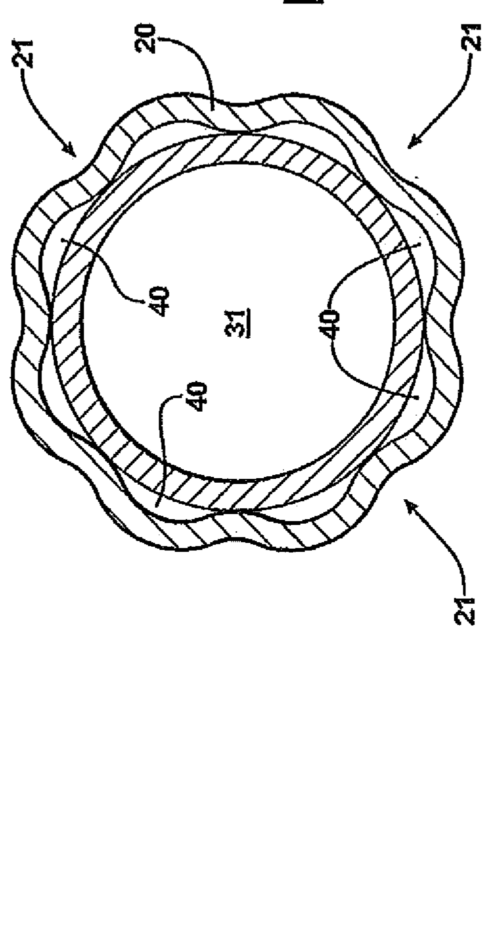
21
20
21
40
31
40
40
21

FIG. 2B

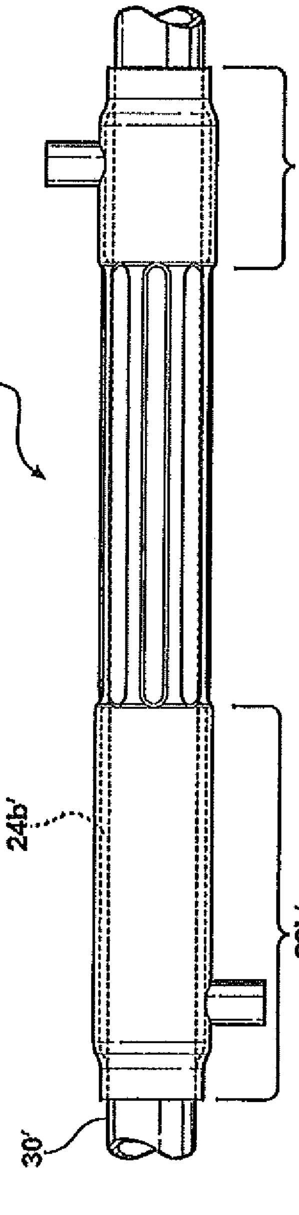

FIG. 3

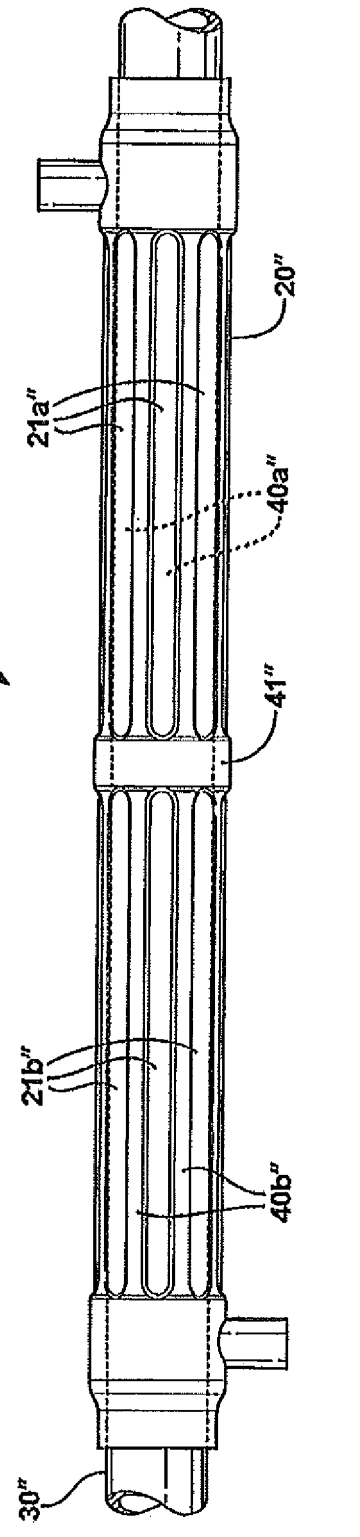

FIG. 5

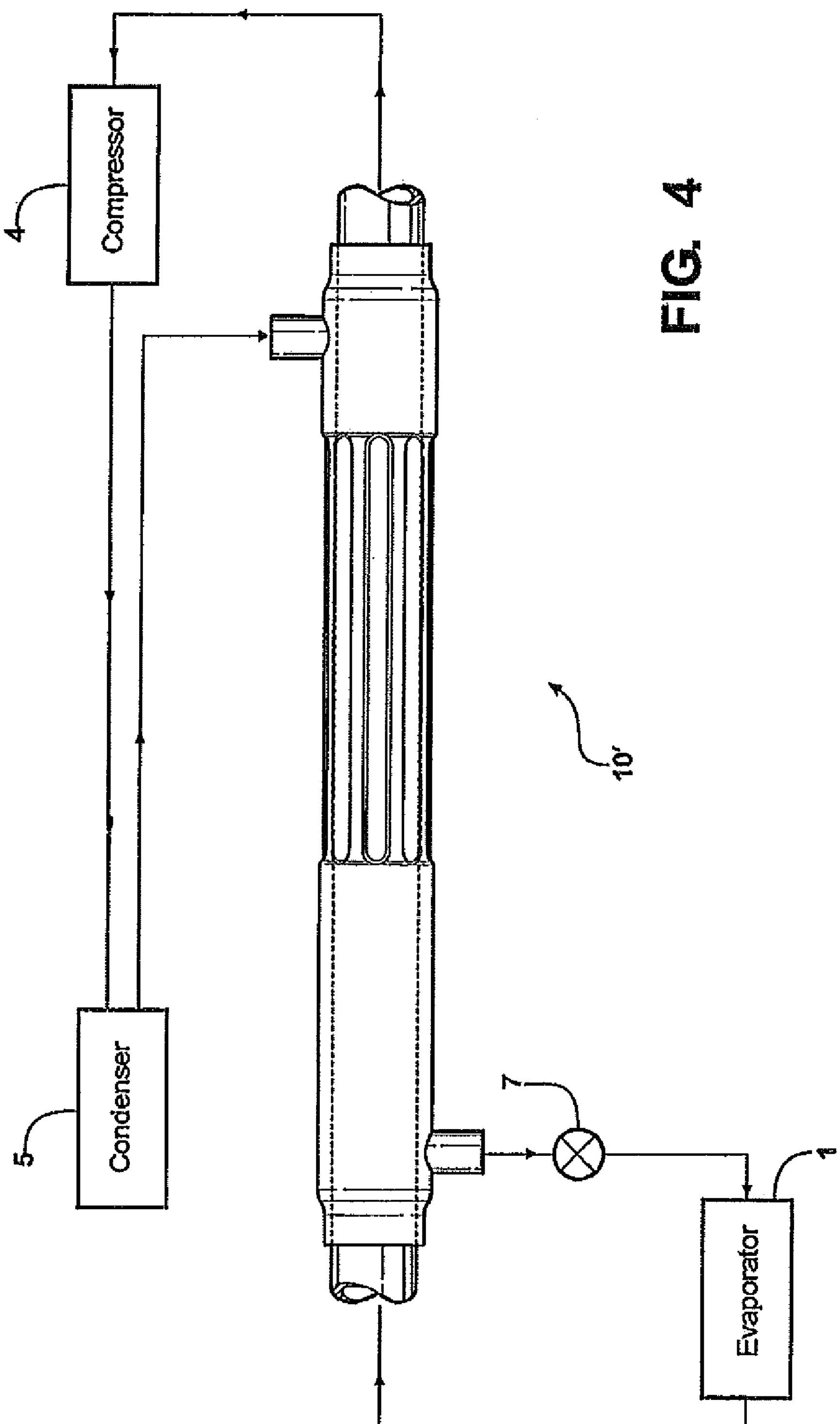

FIG. 4

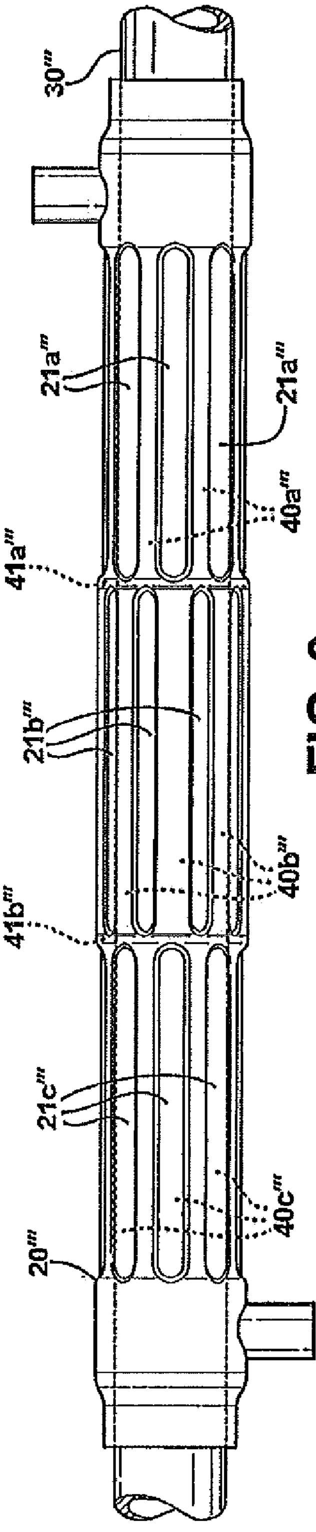

FIG. 6

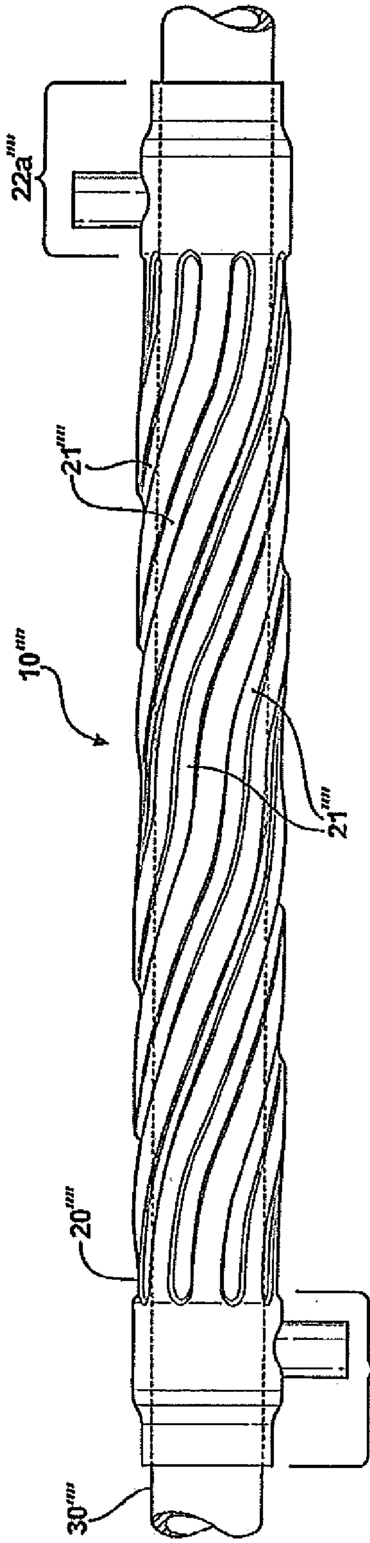

FIG. 7

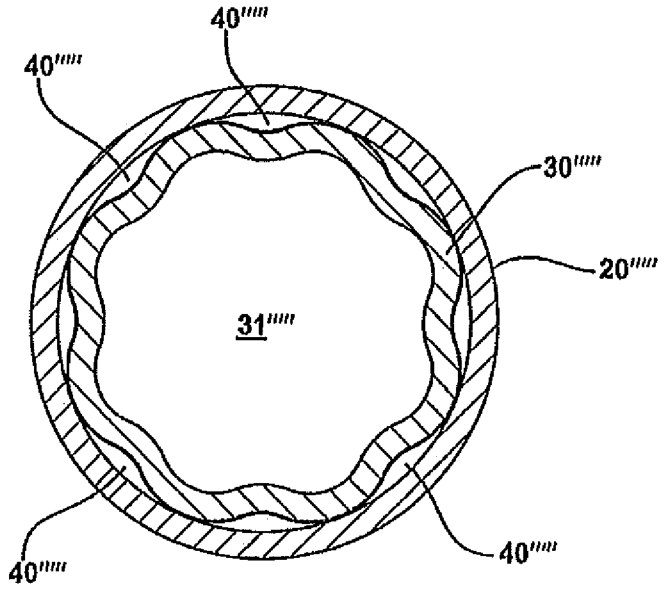

FIG. 8

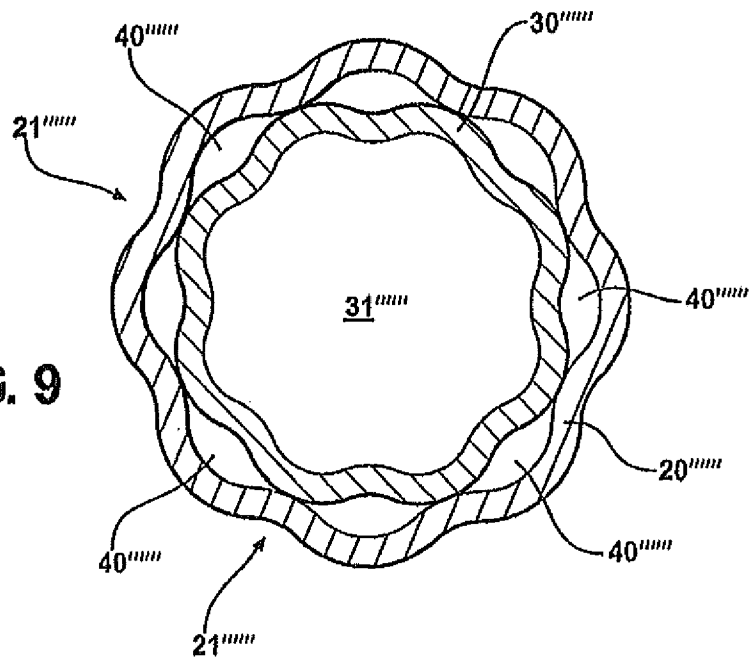

FIG. 9

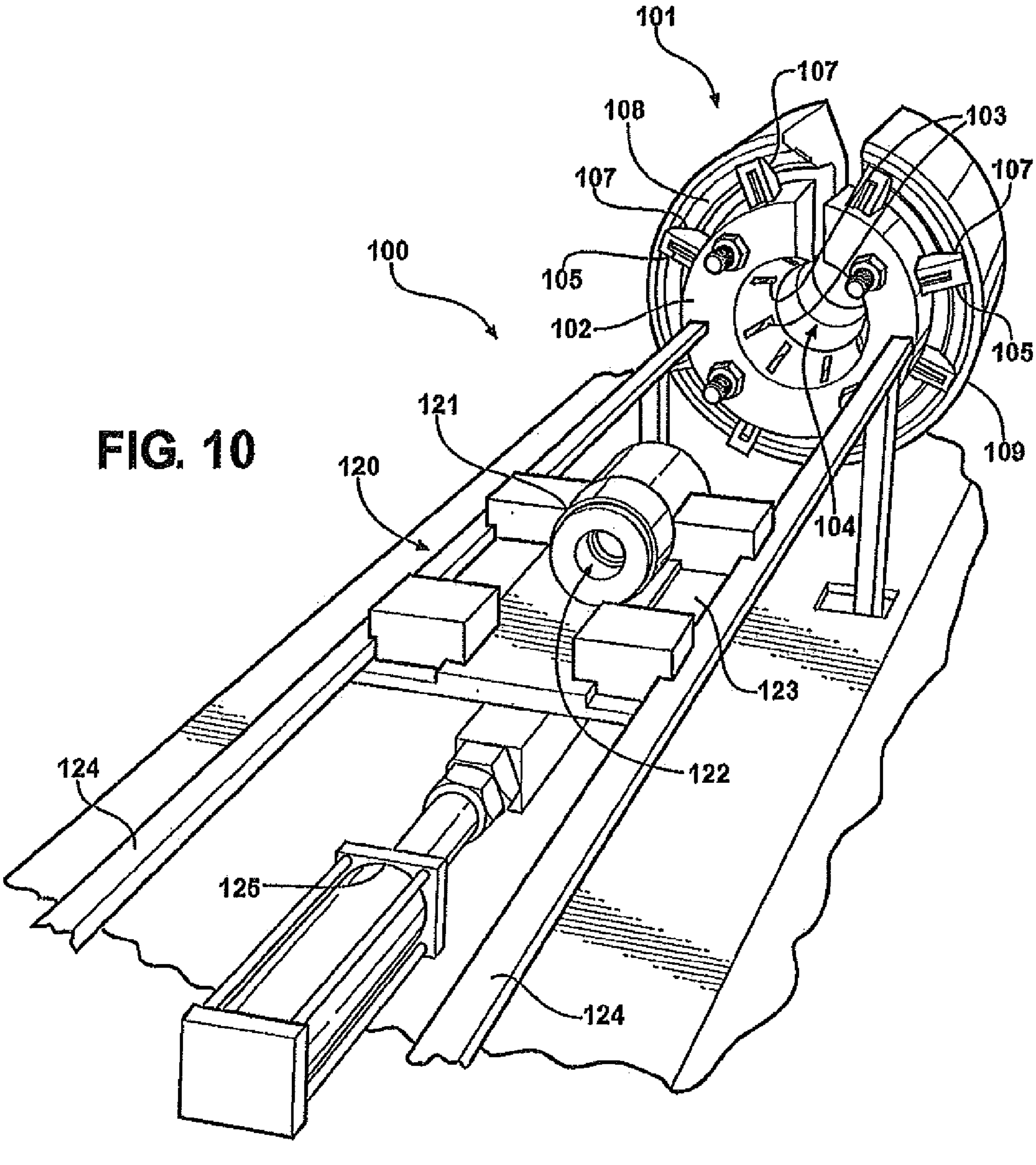
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FIG. 10

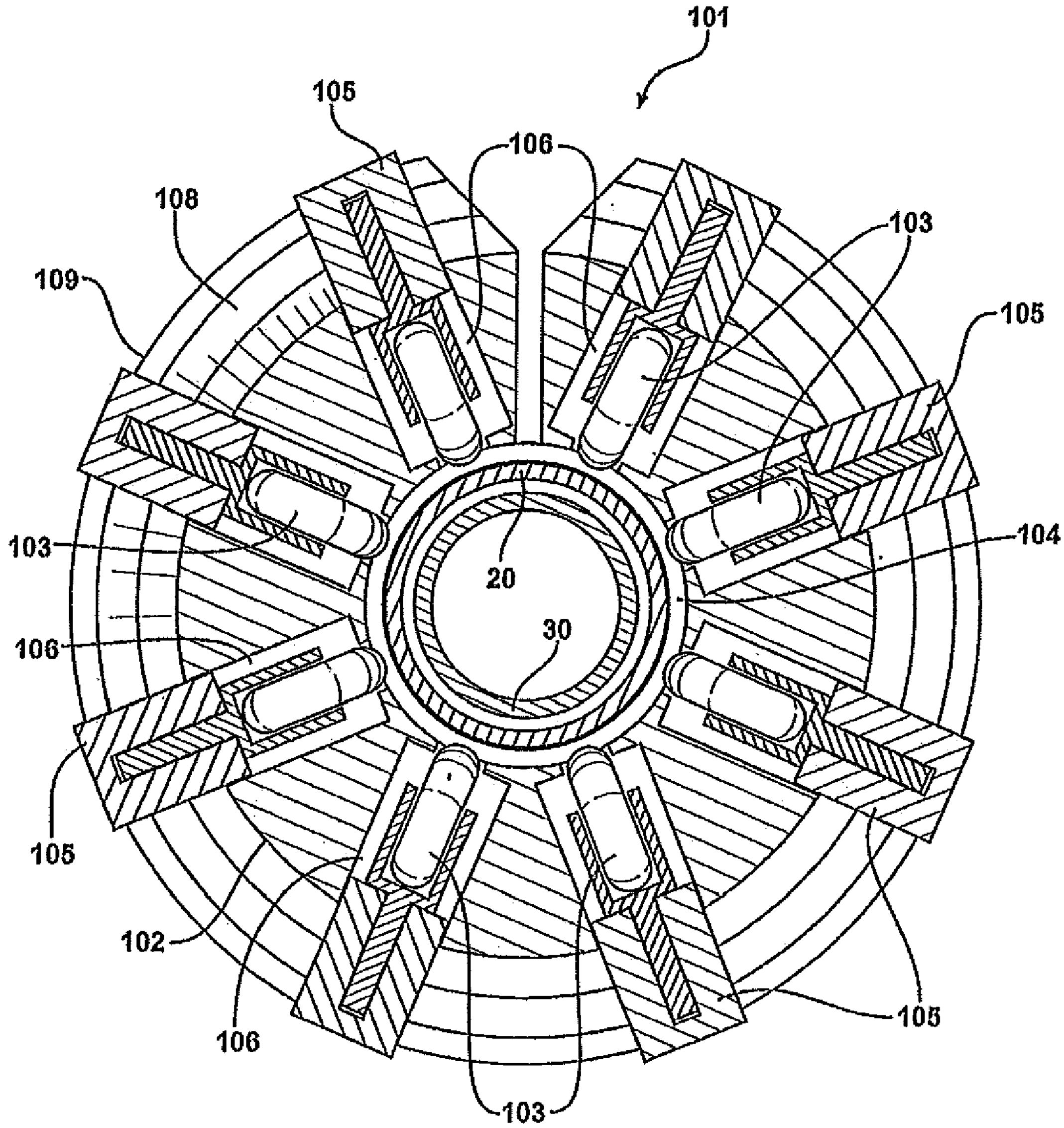

FIG. 11A

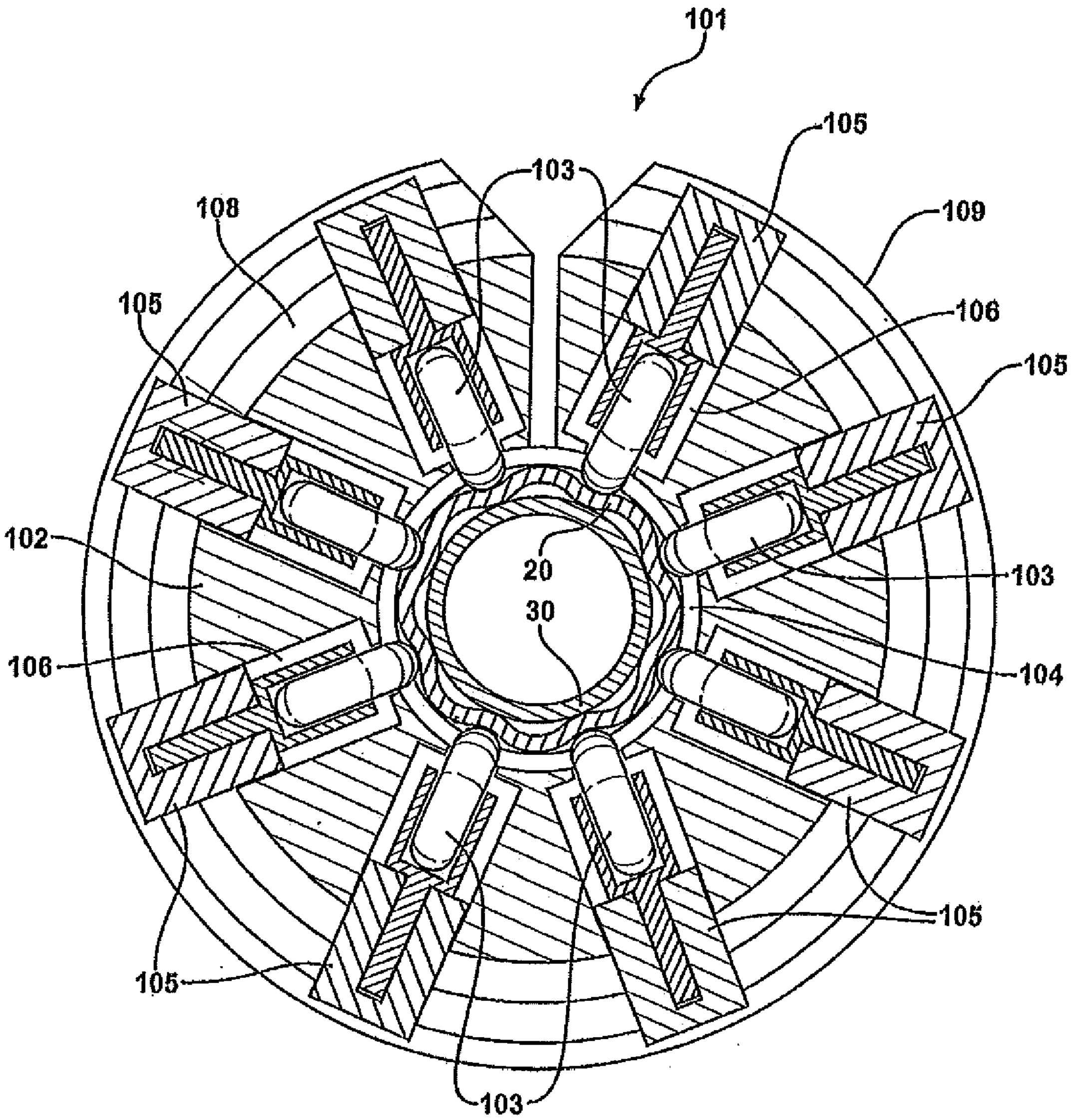

FIG. 11B