

[54] **REFRIGERATED AIR DRYER**
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[52] U.S. Cl.....**165/156, 165/176**
[51] Int. Cl.....**F28d 7/12**
[58] Field of Search.....**165/154, 156, 140, 141, 163, 165/176; 138/110, 111, 114**

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[57] **ABSTRACT**
A refrigerated air dryer for compressed air systems wherein water vapor and other contaminants are removed from said air by means of controlled condensation. The disclosed system utilizes a novel pump-down arrangement wherein a major portion of the refrigerant may be removed from the cooler coils when the system is not in use, thereby preventing damage due to refrigerant expansion. Further, the coil assembly for the disclosed system utilizes a novel, dual-passage coil construction and method of assembly. More specifically, regarding this latter point, inner and outer tubular members are employed, with a selected section of the inner tubular member collapsed partially during forming to effect engagement of said inner tubular member with said outer tubular member and thereby properly supporting said inner tubular member within said outer tubular member.

9 Claims, 8 Drawing Figures

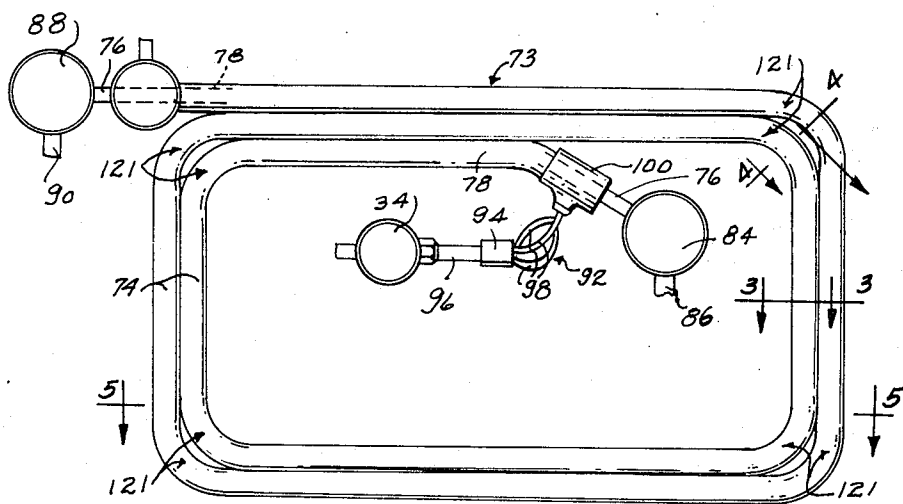


FIG. 1

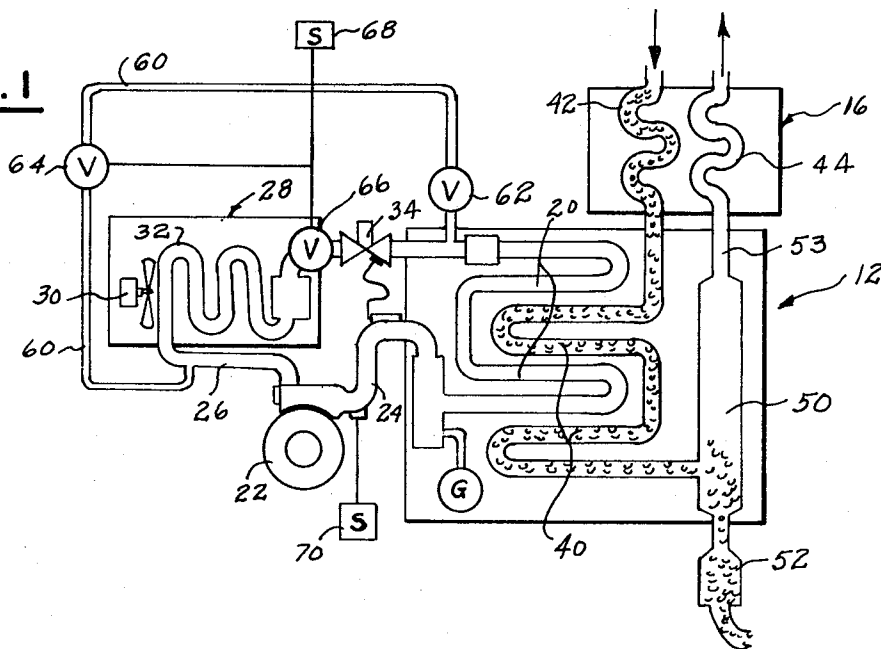


FIG. 2

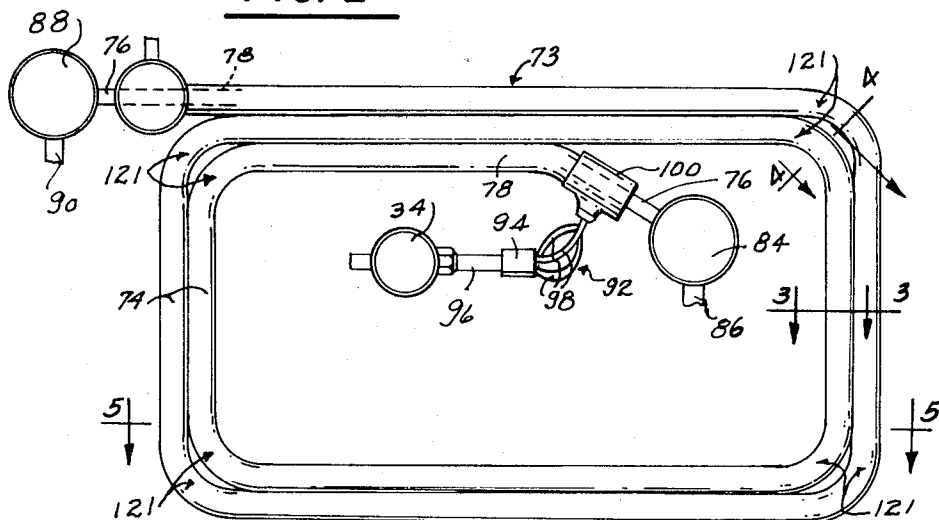
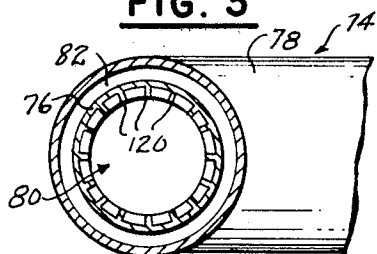


FIG. 3



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FIG. 4

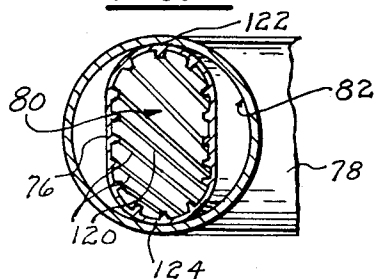


FIG. 8

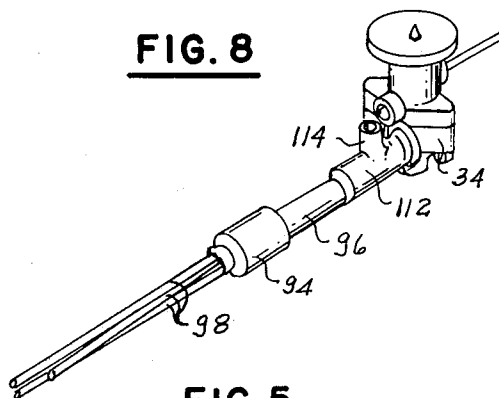


FIG. 5

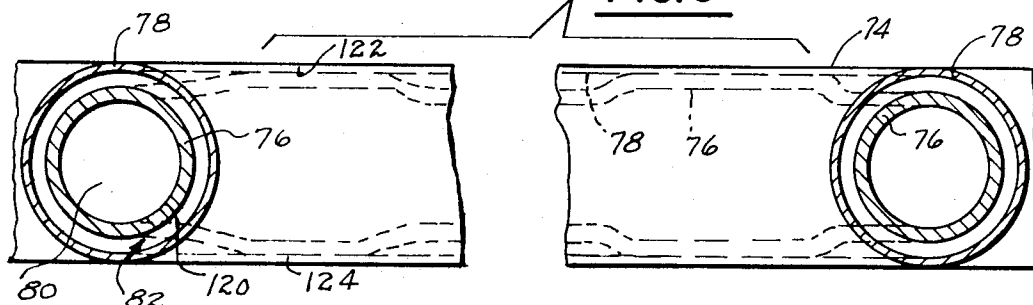


FIG. 6

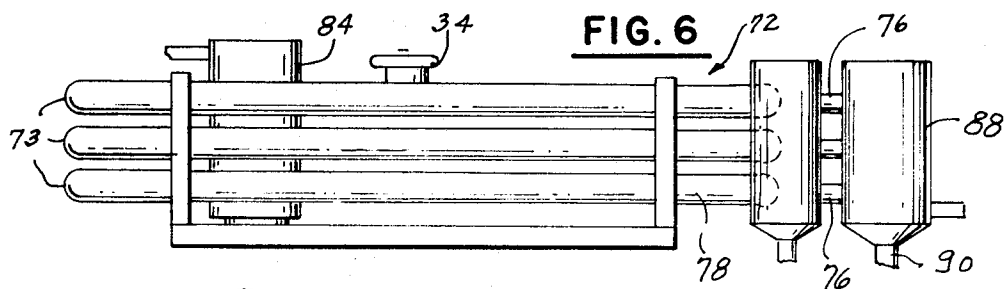
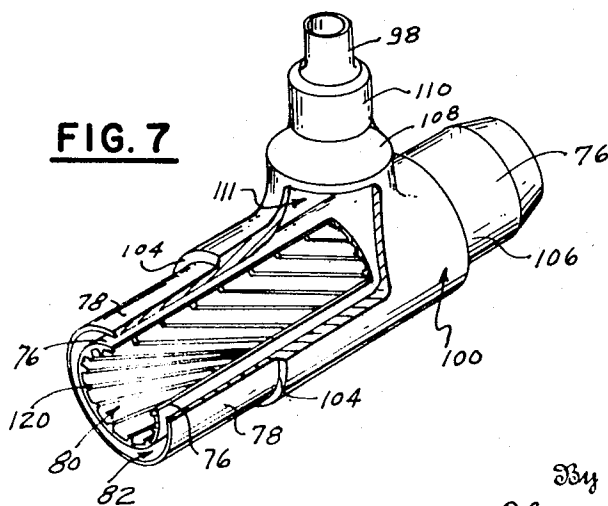


FIG. 7



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REFRIGERATED AIR DRYER

BACKGROUND OF THE INVENTION

The present invention is concerned with compressed air systems, and more specifically with apparatus for removing moisture from compressed air, prior to use.

In today's modern manufacturing and assembling plants, pneumatically operated tools and pneumatically controlled machines are used extensively. These machines and tools are, for the most part, expensive and subject to corrosive damage occasioned by the presence of moisture in the compressed air operating systems. This corrosion and rusting of parts results in excessive maintenance and ultimate replacement. Further, the operation of sensitive pneumatic instruments and controls, coupled to these systems, is materially effected by excessive moisture in the air. In addition to the corrosive action, the water vapor often will contain numerous impurities and contaminants such as oil, dust and pipe scale that can and do produce harmful results upon condensing of the water vapor.

So long as the water vapor remains in suspension, there is little danger of damage in most compressed air systems. It is only when the water vapor condenses to produce free water, that damage occurs.

Numerous forms of air dryers have been proposed and are presently in use. One example is the absorbent type of air dryer which employs a large chamber or tank within which a dessicant is stored. The compressed air is passed through the tank, prior to being supplied to the air line, with the dessicant absorbing a considerable amount of vapor. However, the operating and recharging costs of this type of air dryer are high.

The present invention is concerned with still another type of air dryer, and that is a refrigerated air dryer. In this type of dryer, the relatively hot compressed air is brought into contact with a refrigerant carrying coil to lower the air temperature and produce condensation of the water vapor, which is then collected in a moisture separator. Most importantly, this type of air dryer is capable of lowering the dew point of the air, such that there is little or no chance of subsequent condensation occurring.

More specifically, the present invention provides a novel coil construction and method of fabrication which increases the efficacy of and facilitates the manufacture of a refrigerated air drying system. Also, the present invention is concerned with an improved refrigerated air drying system employing automatic pump-down means. With this novel arrangement, the refrigeration portion of the system can be charged with refrigerant at all times without any danger of damage to the various coil constructions, due to expansion of the refrigerant during transit or shutdown.

DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic representation of a refrigerated air drying system constructed in accordance with the present invention;

FIG. 2 is a top plan view of one coil construction that is to be employed in the coil assembly of a preferred form of the invention;

FIG. 3 is a partial sectional view through the coil construction of FIG. 2, taken along the line 3—3 in the direction indicated;

FIG. 4 is a partial sectional view taken through the coil construction of FIG. 2 at a bend and taken along the line 4—4, in the direction indicated;

FIG. 5 is a fragmentary, sectional view taken through the coil construction of FIG. 2 along the line 5-5, in the direction indicated;

FIG. 6 is a front, elevational view of the heat exchange segment of the system of FIG. 1, showing a plurality of coil constructions disposed in stacked relation;

FIG. 7 is a perspective view, partially in section, illustrating a preferred form of fitting used at the inlet portion of the coil construction of FIG. 2; and

FIG. 8 is a perspective view of the distributor arrangement employed for the refrigerant to be introduced into the coil assembly of FIG. 6.

DETAILED DESCRIPTION OF THE ILLUSTRATED EMBODIMENT

Referring now to FIG. 1, there is illustrated schematically a system for the refrigerated drying of compressed air, which system is constructed in accordance with the present invention. The system of FIG. 1 is designated generally 10 and is comprised of a heat exchanger section 12 and a refrigerant regenerating section 14. While the basic construction and operation of each of these sections will be detailed more completely hereinafter, it will facilitate understanding of the overall invention to review briefly the basic operation of the system.

Initially the air, upon leaving the compressor (not shown), will be at a temperature of approximately 300° F., depending, of course, on the compression ratio or other factors. Immediate cooling of this air will take place preferably in an after-cooler (not shown), such that the air entering the section 12 of the system 10 will be at approximately 100° F. The heat exchanger section 12 preferably includes a pre-cooler unit 16 into which the compressed air will initially pass. In the pre-cooler unit 16, the relatively hot incoming air is placed in heat exchanging relationship with tubing or coils carrying previously cooled dry air to attain a primary cooling effect. As can be realized, this primary cooling will greatly enhance the overall efficiency of the system. After passing through the pre-cooler 16, the incoming air will enter the main heat exchanger portion 18 where it is subjected to the cooling effect of a refrigerant supplied by the refrigerant regenerating section 14.

As was mentioned previously, the temperature of the air entering the system is approximately 100° F. The action of the pre-cooler will reduce the air temperature somewhat, producing a small degree of condensation. However, as the air is brought into heat exchange relationship with the refrigerant carrying portion of the system, its temperature is reduced to approximately 35° F., which produces further condensation and lowers the dew point of the air to approximately 35° F. Accordingly, after the air leaves the system, there is little danger of further condensation in the supply lines or in the pneumatically operated devices.

Attention is now invited to the general construction of the refrigerant regenerating section 14. In this regard, the refrigerant regenerating section 14 is connected across the inlet and outlet of a refrigerant coil assembly, designated generally 20 in FIG. 1. It should

be kept in mind, that FIG. 1 is a schematic representation and that in actual practice, an assembly of a plurality of coil constructions, such as shown in FIGS. 2 and 6, will be employed to define assembly 20.

The refrigerant regenerating section 14 is comprised primarily of a compressor 22 which receives the refrigerant from the outlet of the coils 20. Refrigerant in the form of a low pressure gas is drawn into the compressor 22 by the suction created in the inlet line 24, due to the operation of the compressor pistons. Once in the compressor, the refrigerant, initially in the form of a gas, is compressed by the action of the compressor pistons and is delivered through the discharge conduit 26 to the condenser 28. The condenser 28 includes a fan 30, as well as numerous coils of finned tubing 32 surrounded by air or some other medium such as water providing a heat sink. In the condenser 28, the combined action of the fan 30 and the finned tubing 32 releases heat from the refrigerant gas to the heat sink. This loss of heat causes the high pressure, refrigerant gas to revert to its liquid state. Accordingly, upon leaving the condenser 28, the refrigerant is in the form of a high pressure liquid, and it is necessary to employ some type of metering device 34 to control entry of the refrigerant into the coils 20, which are at a much lower pressure.

In the illustrated embodiment, the metering device 34 is in the form of an expansion valve; however, it should be realized that a capillary tube, or some other type of arrangement, could also be used. In either case, the metering device 34 controls the flow of liquid into the tubing 20 which, it will be recalled, is a relatively low pressure area. Upon entering the tubing 20, the refrigerant will boil and evaporate, tending to withdraw heat from the surrounding area, thus producing the desired cooling effect. It is during this operation that the refrigerant reverts back to a low pressure gas which is then recycled through the compressor 22 and condenser 28 in the manner described above.

The heat exchanger section 12 includes, not only the refrigerant coil assembly 20, but also a second coil assembly 40 in heat exchanging relation with the coils 20. The coil assembly 40 is connected to the outlet of the compressor and provides the air passageway of system 10. It will be noted that the inlet for the coil assembly 40 is at the discharge portion of the pre-cooler unit 16. The pre-cooler unit 16 has two sets of coils 42 and 44 in heat exchanging relationship. The coils 42 receive the hot, moist air initially, which is subjected to the cooling effect of the coils 44 that now contain the dry, cooled air. This action produces a slight, but significant lowering of the air temperature.

The pre-cooled air will then proceed into the main heat exchanger portion of the system 10, where it is subjected to the cooling effect of the refrigerant in the coils 20 and its temperature is lowered to approximately 35° F., which produces relatively rapid condensation of the water vapor. The moisture laden air is then transmitted to a moisture separator 50 disposed intermediate the coils 44 and the outlet of the coil assembly 40. In the moisture separator 50, all water, dirt and other contaminants are removed from the air stream and these will flow into a drain trap 52 for subsequent removal. The cooled, dry compressed air is now conveyed out of the water separator 50 into a conduit sec-

tion 53 and from there to the coil arrangement 44, and ultimately to the point at which the air is to be used to operate a pneumatic device.

One problem which is encountered in refrigerated systems such as that of FIG. 1, is over-cooling or freezing-up of the coils during periods when the demand for compressed air is low, such as at the lunch hour or during coffee breaks in a factory. However, it is not practical to shut-down the compressor during these relatively short periods of inactivity, and to alleviate this problem, the preferred form of the present invention employs a hot gas bypass arrangement.

The hot gas bypass arrangement of the preferred embodiment includes a bypass conduit 60 which is in communication with the discharge tube 26 of the compressor 22 and the coils 20 at a point immediately downstream of the expansion valve 34. Interposed in the bypass conduit 60, is a normally closed control valve 62. Valve 62 is operated in response to a temperature sensing device (not shown) in the coils 20. Accordingly, once the temperature in coils 20 reaches a predetermined level, valve 62 will open to permit the hot gas being expelled from the compressor 22 to enter coils 20 directly without passing through the condenser 28. This introduction of hot gases into the coils 20 will lower the temperature thereof to a point wherein the valve 62 is again closed. As such, over-cooling of the system is effectively controlled to prevent freezing of the coils.

Still another problem encountered with a refrigerated drying system, as that under discussion, is the fact that preferably the system 10 is charged with refrigerant prior to delivery to the customer. This feature is desirable in that the customer need only connect his air lines to the inlet and outlet portions of the unit and need not worry about the rather difficult and sometimes dangerous job of handling refrigerant.

Unfortunately, however, in practice the refrigerants generally used are extremely sensitive to temperature changes, and problems have been encountered, in that if the unit is subjected to high temperatures during periods of nonuse, the refrigerant will expand in the coils 20, producing damage to these coils, as well as the coils 40 which are in immediate contact therewith. As will be appreciated hereinafter, a preferred form of the present invention envisions the employment of double-walled, dual-passage tubing wherein the refrigerant is carried in the outermost passage and the air in the innermost passage, note FIG. 3. Thus, if the refrigerant in the outermost passage expands, there is the danger that the soft copper inner tube will collapse, thus pinching-off the air passage.

To overcome this problem of refrigerant expansion, the present invention envisions a novel pump-down arrangement employed as an integral part of the system 10. The basic function of this arrangement is to remove a major portion of the refrigerant from the coils 20 so as to obviate any problem occasioned due to expansion. In this regard, said pump-down includes a pair of normally open solenoid operated valves 64 and 66, capable of being operated to the closed condition by a remote control switch 68. The valve 64 is disposed in the bypass 60, while the valve 66 is positioned intermediate the condenser 28 and the expansion valve 34. In addition, there is provided a pressure sensitive

switch 70 which is attached to the inlet portion 24 of the compressor 22. During periods of inactivity or prior to transit, the switch 68 is depressed to close the valves 64 and 66, while the compressor 22 is running. When this happens, the supply of liquid refrigerant to the expansion valve 34 and the coils 20 is cut off; however, compressor 22 will continue to run with the suction effect thus produced lowering the pressure in the coils 20 and withdrawing a major portion of the refrigerant therefrom. When the pressure in the coils 20, which is approximately the same as that in the inlet conduit 24, reaches a pre-set level, the switch 70 will be operated to de-energize the compressor 22. As a net result, only a small amount of refrigerant remains in the coils 20 so that, should they be subjected to high ambient temperature, the expansion that occurs will not be sufficient to cause any damage.

Turning now to FIGS. 2 and 6-8, there is illustrated a preferred form of coil assembly for the system 10, which assembly is designated generally 72. The coil assembly 72 is comprised of a plurality of coil constructions or units 73, each of which is formed of a convoluted section of double-walled, dual-passageway tubing 74. The particular construction and method of fabricating the tubing 74, which is also novel, will be detailed more completely hereinafter.

At this point, it must be kept in mind that FIG. 1 is a schematic representation of the entire system 10, and that the previously designated coil assemblies 20 and 40, illustrated in separated fashion in FIG. 1, are in reality representations of the passageways provided by tubing 74. With reference to FIG. 3, which is a sectional view of the double-walled tubing 74, it can be seen that said tubing is formed from an inner tubular member 76 and an outer tubular member 78. The inner tubular member 76 provides the passageway 80 which corresponds to the coil assembly 40 of FIG. 1. The inner tubular member 76 also cooperates with the outer tubular member 78 to provide an annular passage 82 which is adapted to carry a refrigerant and corresponds to the aforesaid coils 20.

In the coil construction 73 of FIG. 2, the various convolutions of double-walled tubing 74 are substantially co-planar. Accordingly, in fabricating the entire coil assembly 72 for the heat exchanger section 12, a plurality of these constructions 73 are placed in stacked relation as shown in FIG. 6. This disposition of the coil constructions 73 in stacked relation require the employment of various manifold or distributing means for control of the flow of fluid medium in the respective passages 80 and 82.

Consideration is first directed to the arrangement employed for passage 80 provided by the inner tubular members 76 which is to carry the compressed air. Looking to FIG. 2, and keeping in mind that the representation thereof of the coil construction 73 is identical for each said coil construction, it can be seen that an end of the inner tubular member 76 extends beyond the corresponding end of tubular member 78. A manifold 84 is provided to which the ends of the inner tubular members 76 are connected. The manifold 84 has an air inlet port 86 which is in communication with a source of compressed air. Accordingly, the moist hot air will enter the manifold 84 and is then supplied from said manifold to the various inner tubular members 76.

At the discharge end of the coil construction 73, a second manifold 88 is employed. This manifold 88 is connected to the outlet end of each inner tubular member 76. Accordingly, the now cool combination of air and condensed moisture vapor is collected in the manifold 88 and flows therefrom through a port 90 to the aforementioned water separator 50 and then eventually, to a supply line.

Even, controlled distribution of refrigerant to the passages 82 is somewhat more critical than the supply of air to passages 80, and is preferably effected in a different manner. Such is the case, in that the degree of cooling attained by each coil construction 73 is dependent upon the amount of refrigerant supplied thereto. With this in mind, it is preferred to employ a distributor arrangement 92, which assures a high degree of uniformity in the supply of refrigerant to the passages 82.

A preferred form of the distributor arrangement 92 is illustrated in FIG. 8. This arrangement 92, as shown in FIG. 2, is connected intermediate the refrigerant expansion valve 34 and the inlet to the refrigerant carrying passage 82. Primarily, said arrangement 92 includes a distributor housing 94 having an inlet 96 and a plurality of outlet ports, each said port being connected to a section of tubing 98. The individual sections of tubing 98 are, in turn, operatively connected to supply fittings 100.

The construction of fitting 100, and its manner of connection to the double-walled tubing section 74, is best understood with reference to FIG. 7. In this regard, the fitting 100 is of a generally T-shaped configuration, having a cylindrical portion 102 defining opposite open ends 104 and 106. In the wall of the cylindrical portion 102, there is provided an entry port or portion 108, with an end section of a length of tubing 98 being connected to said portion 108 by a nut 110 or some other form of well-known coupling device.

As can be seen from FIG. 7, the fitting 100 surrounds the inner tubular member 76 with the end portion 104 being joined to the end of the outer tubular member 78. The opposite end portion 106 is of a smaller diameter than said end portion 104 and is sealed to the outer wall of the inner tubular member 76 by soldering or some other well-known method. As such, fitting 100 provides an inlet chamber 111 which is in direct communication with the refrigerant carrying passage 82.

FIG. 8 illustrates the basic arrangement of the distributor housing 94 and the expansion valve 34. Recalling the previously discussion of the hot gas bypass system provided by the valve 62 in the section of tubing 60, a fitting 112 is connected to the outlet end of the valve 34, this fitting having a side port 114 to which the outlet of valve 62 may be connected.

One of the most important features of the present invention is the construction and method of fabrication of the double-walled tubing 74 which permits a fabricator to achieve a dependable coil construction in a relatively inexpensive manner. In this regard, the overall configuration and method of construction of the double-walled tubing 74 will be discussed hereinafter with primary reference to FIGS. 3-5.

Concerning the double-walled tubing 74, it will be recalled that same is constructed from generally coaxial inner and outer tubular members 76 and 78, respectively, which provide the concentric passages 80

and 82. The material employed for the multi-wall tubing section 74 is preferably soft, annealed copper, such that said tubing can be easily fabricated by use of well-known forming methods. In practice, it has been found advantageous to employ hand-forming tools of a known type which permit the formation of right angle bends without collapsing the outer tubing wall.

Directing attention now to FIG. 3, which is a sectional view taken through a relatively straight section of the coil construction 73, it can be seen that the inner tubular member 76 is of a substantially circular cross-section, and that the inner wall of said member is provided with a plurality of radially inwardly extending fins 120. These fins 120, which are preferred, are helically disposed along the length of the inner tubular member 76, as can be seen from FIG. 7. As such, fins 120 serve a number of rather important functions; namely, they provide a vastly increased surface area for the conduction of heat; they produce a turbulence in the air as it passes through the tubing which assures rapid heat transfer; and further, these fins 120 also provide added strength to the inner tubular member 76.

One of the problems encountered in the fabrication of double-walled tubing is the assurance of centering of the inner tubular member 76 with respect to the outer tubular member 78. That is, the inner member 76 should be spaced from the inner wall of the outer member 78 so that refrigerant can circulate about the entire periphery of the inner member 76.

In order to attain proper centering, the present invention envisions a novel, overall construction and method of fabrication. More specifically, with reference to FIGS. 4 and 5, it can be seen that in the area of the bends, each designated generally 120 for reference purposes, the inner tubular member 76 is partially collapsed or constricted. That is to say, the inner tubular member 76 is no longer circular in cross-section, but has assumed a generally elliptical configuration.

In this partially collapsed or constricted state, the inner tubular member 76 will firmly engage the inner wall of the outer tubular member 78 at opposed locations, designated generally 122 and 124 in FIG. 4. Considering now the section of tubular member 76 extending between adjacent bends 121, it can be seen that the aforementioned engagement provides a fixed support for the ends of this section and centers said section with respect to the outer tubular member 78. Although theoretically, a co-axial relationship throughout the entire length of the coil would be desired, it is not absolutely essential to the attainment of satisfactory results. In practice, it is sufficient that spacing between the inner and outer tubular members 76 and 78 be maintained along a major portion of the coil length. As is illustrated in FIG. 4, in the area of the bends 121, refrigerant flow is somewhat restricted by the engagement of the tubular members; however, this factor is of only minor significance when compared with the overall length of the coil, and most certainly, does not overcome the other advantages attained with this construction.

The collapsing of the inner tubular member 76, in the area of the bends 121, is achieved during the fabricating operation. Initially, the inner tubular member 76 is circular in section throughout its entire length and is of a diameter, such as to be easily received

within the outer tubular member 78. Once this is accomplished, the first bend in the double-walled tubing 74 is fabricated by forming the tubing over a mandrel or tool which includes means for preventing collapse of the outer tubular member 78. During this bending operation, the inner tubular member 76 is unsupported and is allowed to collapse partially until such time as the outer wall of said inner tubular member 76 engages the inner wall of the outer tubular member 78. At this point in the forming operation, the outer tubular member 78 lends support to the inner tubular member 76 and will preclude further collapsing. This procedure is repeated at each location at which a bend 121 is desired, until fabrication of the double-walled tubing section 74 is completed.

In designing the tube constructions 73, the requirements of the system, regarding the cross-sectional area of the passages 80 and 82, are considered, and the diameter of the tubular members 76 and 78 are adjusted accordingly.

It will be recalled that the inner tubular member 76 is provided with a plurality of helically disposed, elongate fins 120. The preferred arrangement of fins 120 facilitates the fabricating operation, in that while said fins provide support, the helical disposition thereof permits the simultaneous, partial collapsing and bending of the inner tubular member 76 without direct buckling of any individual fin 120.

It is believed clear that the present invention, as described above and as illustrated in the drawings, provides an improved system for refrigerated air drying and a novel tubing construction for use therein. It is to be understood that this system, shown schematically in the drawings, is illustrative of but a preferred form of the invention. Various changes or modifications will no doubt occur to those skilled in the art; as such, said changes or modifications are to be understood as forming part of the present invention insofar as they fall within the spirit and scope of the appended claims.

What is claimed is:

1. A coil construction for use with a refrigerated heat exchanger, or the like, said construction including an outer tubular member and an inner tubular member disposed within said outer tubular member and having an outer diameter smaller than the inner diameter of said outer tubular member whereby the space between said inner and outer members define a first passage capable of carrying a refrigerant, and a second passage being defined by the inner wall of said inner tubular member for a fluid medium to be cooled, said coil construction including at least one bend; and means for maintaining said inner and outer tubular members in generally coaxial relation, said means including a partially collapsed portion of said inner tubular member in the area of said bend, said partially collapsed portion providing a generally elliptical shaped wall section, different in configuration than the outer tubular member, with said elliptical shaped wall section engaging the inner wall of said outer tubular member at circumferentially spaced areas, said engagement preventing total collapse of said inner tubular member and supporting said inner tubular member with respect to said outer tubular member.

2. A coil construction as defined in claim 1 wherein said inner tubular member includes a plurality of fins

formed on the inner wall thereof to strengthen said member and facilitate heat exchange.

3. A coil construction as defined in claim 2 wherein said fins are disposed in a helical pattern.

4. A coil assembly for a heat exchanger, or the like, including; a plurality of stacked coil constructions, each said coil construction including an outer tubular member and an inner tubular member disposed for said outer tubular member, the space between said inner and outer tubular members providing a first passage for a first fluid medium and said inner tubular member providing a second passage for a second fluid medium whereby heat transfer can take place between said fluid mediums through the wall of said inner tubular member; distribution means in communication with said first passage of each coil construction and including means for connection to a source of supply of said first fluid medium; and manifold means in connection with said second passageway of each coil construction and including means for connection to a source of supply of said second fluid medium, each said coil construction having at least one bend; and means for maintaining said inner and outer tubular members in generally coaxial relation, said means including a partially collapsed portion of said inner tubular member in the area of said bend, which provides a generally elliptical shaped wall section, different in configuration than that of the outer tubular member, said elliptical shaped wall section engaging the inner wall of said outer tubular member at circumferentially spaced areas, said engage-

ment preventing total collapse of said inner tubular member and supporting said inner tubular member with respect to said outer tubular member.

5. A coil assembly as defined in claim 4 wherein said distributing means includes a distributor housing having an inlet port for attachment to said source of supply of the first fluid medium, and a plurality of outlet ports; a like number of tubing elements connecting said outlet ports of the distributor housing with said first fluid passage.

6. A coil assembly as defined in claim 5 and further including a tubular fitting disposed about and having one end sealed with respect to each said inner tubular member and having the opposite end thereof operably connected to the corresponding outer tubular member, and an inlet port in the wall of said tubular fitting, with said like number of tubing elements being connected to said inlet ports of said tubular fittings.

7. A coil assembly as defined in claim 4 further including an accumulator connected to the outlet ends of said first fluid passages and outlet manifold means operably connected to said second fluid passages.

8. A coil assembly as defined in claim 4 wherein each said inner tubular member includes a plurality of fins formed on the inner wall thereof to strengthen said member and facilitate heat exchange.

9. A coil assembly as defined in claim 8 wherein said fins are disposed in a helical pattern.

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