

Oct. 21, 1969

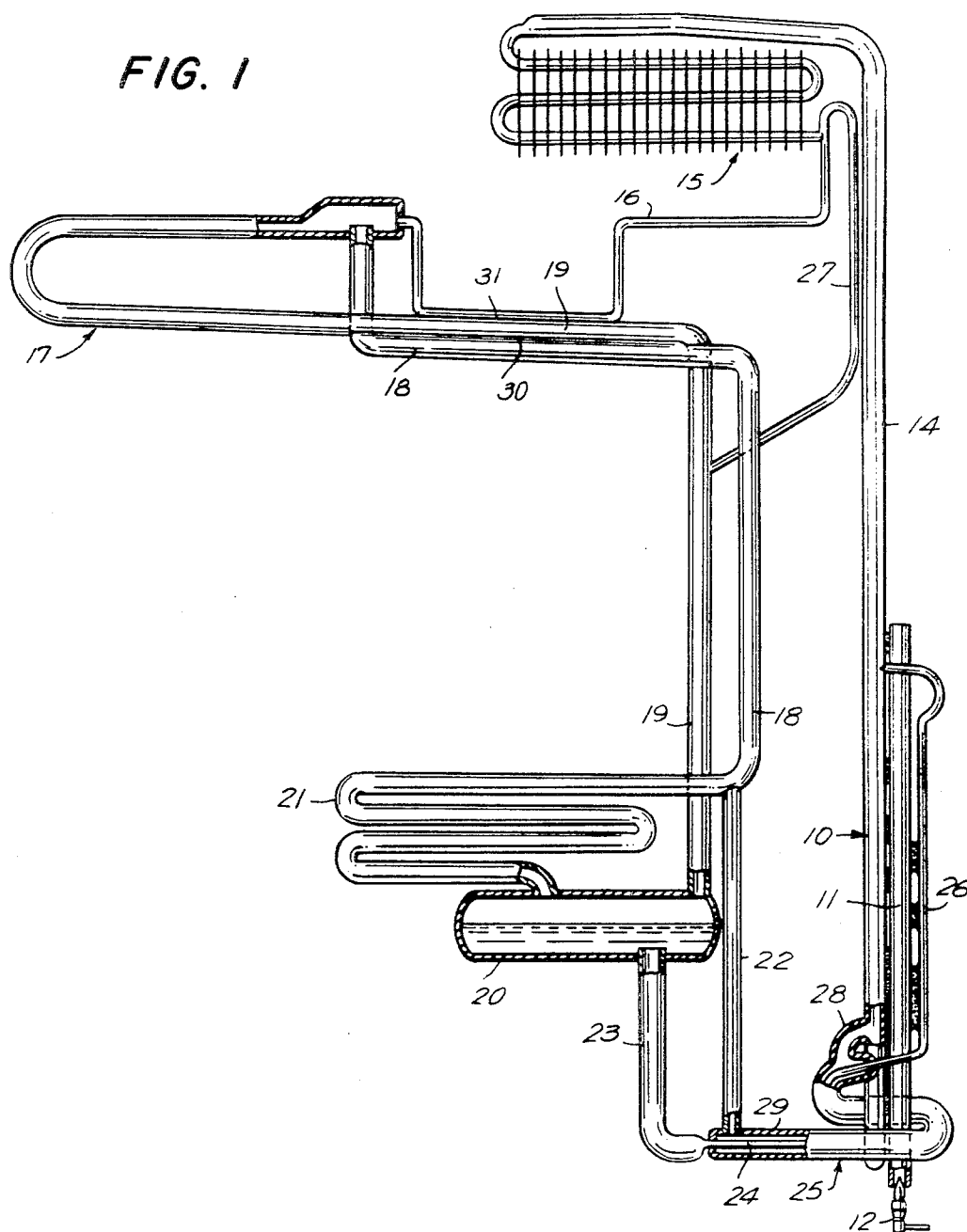
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3,473,346

COIL FOR ABSORPTION REFRIGERATION APPARATUS

Original Filed March 27, 1964

3 Sheets-Sheet 1



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FIG. 3

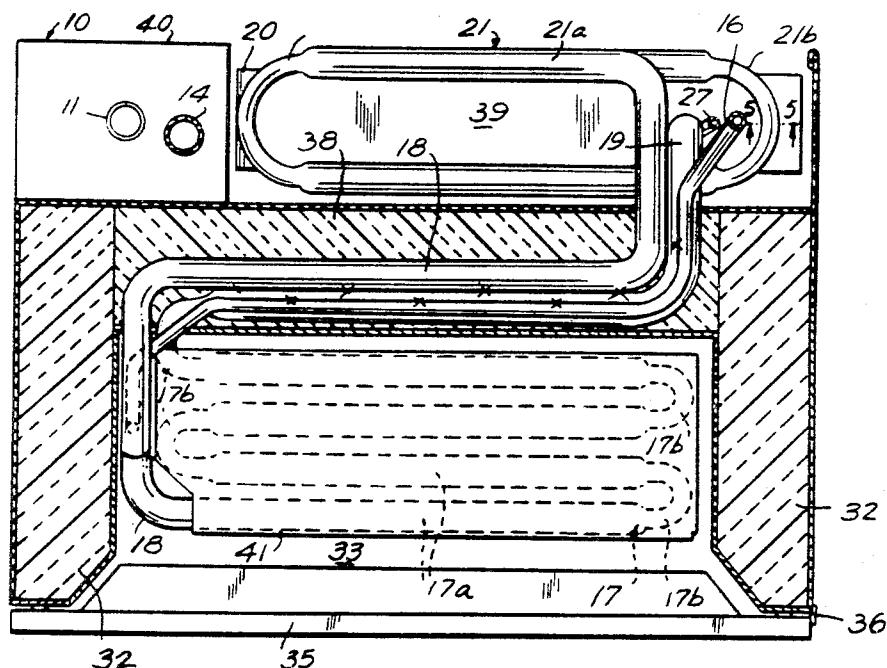


FIG. 2

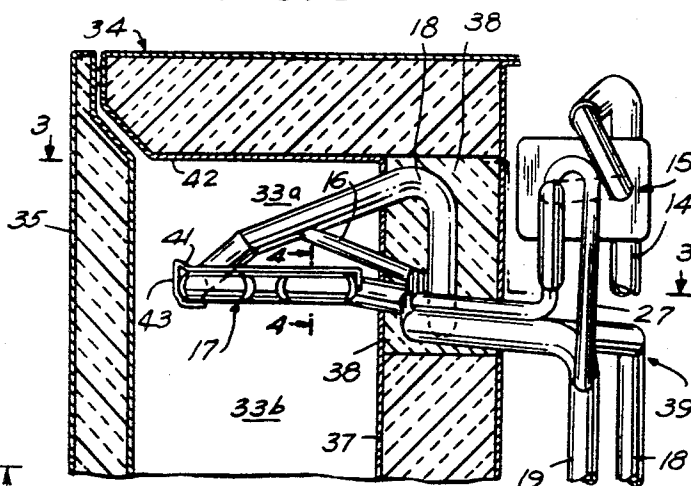
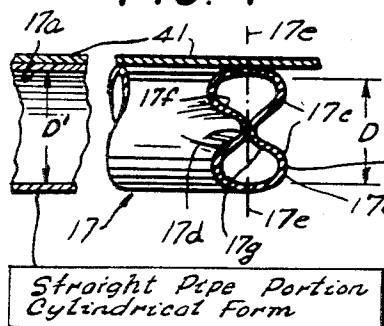


FIG. 4



Connecting Bend
Shape of the
Numeral Eight

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FIG. 5

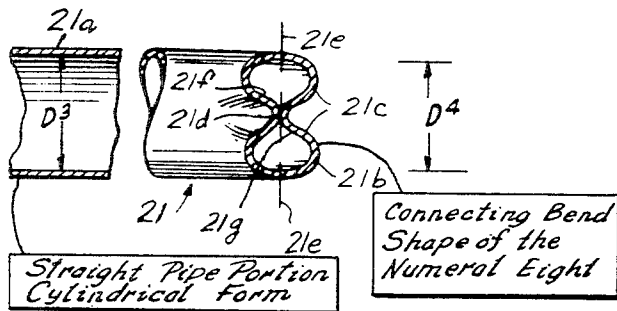


FIG. 6

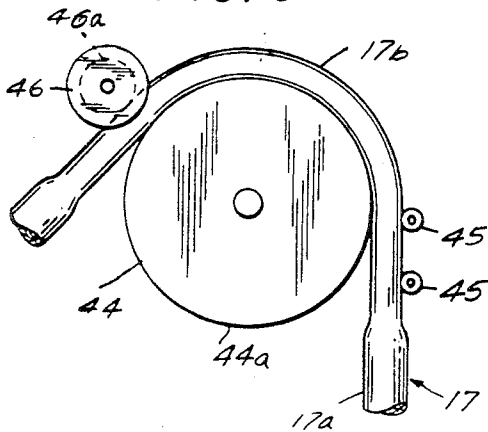


FIG. 8

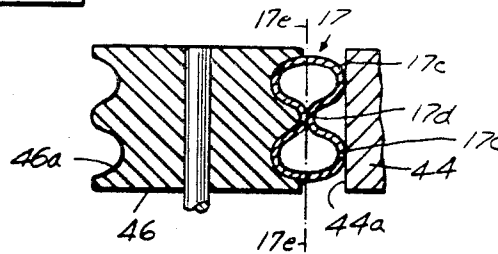


FIG. 7

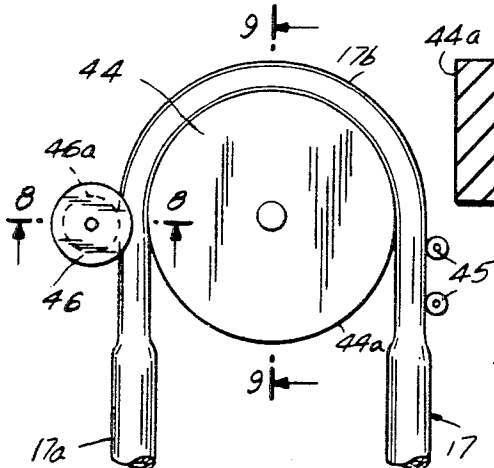
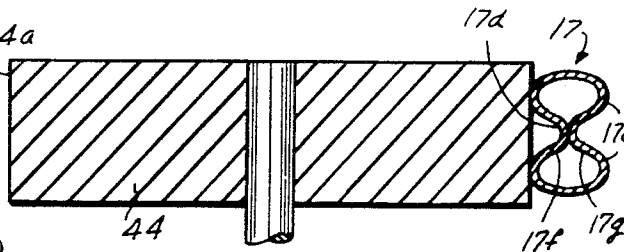


FIG. 9



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3,473,346

COIL FOR ABSORPTION REFRIGERATION APPARATUS

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Original application Mar. 27, 1964, Ser. No. 355,337, now Patent No. 3,348,402, dated Oct. 24, 1967. Divided and this application Sept. 1, 1967, Ser. No. 665,166

Claims priority, application Sweden, Mar. 29, 1963, 3,507/63

Int. Cl. F25b 15/10, 39/02

U.S. Cl. 62—476

5 Claims

ABSTRACT OF THE DISCLOSURE

Absorption refrigeration apparatus having a circuit for inert gas including a coil formed of ferrous metal having horizontally extending straight pipe sections of cylindrical form and connecting bends and an inlet at one elevation and an outlet at a lower elevation, at least one bend being formed of piping having a minor axis and a longer major axis, the longer major axis extending vertically in the same general direction as the axis of the radius of curvature of the bend, the inner side of the bend at one side of its longer major axis having a longitudinal reentrant portion which extends toward the opposite outer side of the bend, the inner extremity of the reentrant portion contacting and abutting the opposite outer side of the bend, and the straight piping sections connected to the bend each having an inner diameter equal to the vertical distance between the top and bottom of the opposing walls of the piping at the bend at the vicinity of its longer major axis.

This application is a division of my application Ser. No. 355,337, filed Mar. 27, 1964, for "Method of Making Coil for Absorption Refrigeration Apparatus," now Patent No. 3,348,402 granted Oct. 24, 1967.

BRIEF SUMMARY OF THE INVENTION

My invention relates to a coil for absorption refrigeration apparatus, and more particularly to evaporator and absorber coils for absorption refrigeration apparatus of the inert gas type.

It is an object of my invention to provide an improved coil of this type which includes straight portions and connecting bends having small radii of curvature, whereby a maximum number of straight coil portions may be provided in a space of a given size.

Another object of the invention is to provide an improved coil of this type which includes two banks of straight portions spaced from one another and connecting bends having small radii of curvature, whereby the space between the two banks of straight portions will be at a minimum.

A further object of my invention is to provide an improved coil of this type which is formed of piping or tubing of cylindrical form and includes at least one bend which is non-circular in cross-section and has a reentrant part at a first side wall at the inner side of the bend which functions as a support for the opposite second side wall at the outer side of the bend, the straight pipe sections connected to the bend each having an inner diameter substantially equal to the distance between the inner surfaces of the opposing walls of the piping at the bend at the immediate vicinity of its major axis.

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The above and other objects and advantages of my invention will be better understood from the following description taken in connection with the accompanying drawing forming a part of the specification.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWING

FIG. 1 is a view more or less diagrammatically illustrating an absorption refrigeration apparatus of the inert gas type to which the invention has been applied;

FIG. 2 is a fragmentary vertical sectional view of a refrigerator and an evaporator therefor which embodies the invention and is associated with refrigeration apparatus like that shown in FIG. 1;

FIG. 3 is a horizontal sectional view taken at line 3—3 of FIG. 2 to illustrate the evaporator more clearly and also an absorber which embodies the invention;

FIG. 4 is a fragmentary vertical sectional view taken at line 4—4 of FIG. 2;

FIG. 5 is a fragmentary vertical sectional view taken at line 5—5 of FIG. 3;

FIGS. 6 and 7 are diagrammatic views illustrating the manner in which the bends are formed in a bending machine; and

FIGS. 8 and 9 are vertical sectional views taken at lines 8—8 and 9—9, respectively, of FIG. 7.

DETAILED DESCRIPTION

In FIG. 1 I have shown absorption refrigeration apparatus of a uniform pressure type which is well known in the art and in which an inert pressure equalizing gas is employed. Such a refrigeration apparatus comprises a generator or boiler 10 containing a refrigerant, such as ammonia, in solution in a body of absorption liquid, such as water. Heat may be supplied to the boiler 10 from a heating tube or flue 11 thermally connected therewith, as by welding. The heating tube 11 may be heated in any suitable manner, as by a liquid or gaseous fuel burner 12, for example, which is adapted to project its flame into the lower end of the tube.

The heat supplied to the boiler 10 and its contents expels refrigerant vapor out of solution, and the vapor thus generated flows through a conduit 14 to an air-cooled condenser 15 in which it is condensed and liquefied. Liquid refrigerant flows from condenser 15 through a conduit 16 into an evaporator 17 in which it evaporates and diffuses into an inert pressure equalizing gas, such as hydrogen, which enters the upper part thereof through a conduit 18. Due to evaporation of refrigerant fluid into inert gas, a refrigerating effect is produced and heat is abstracted from the surroundings.

The rich gas mixture of refrigerant vapor and inert gas formed in evaporator 17 flows from the lower part thereof through a conduit 19 and absorber vessel 20 into the lower part of an absorber coil 21. In absorber coil 21 the rich gas mixture flows countercurrent to downwardly flowing absorption liquid which enters through a conduit 22. The absorption liquid absorbs refrigerant vapor from inert gas, and inert gas weak in refrigerant flows from the upper part of absorber coil 21 through conduit 18 into the upper part of cooling element 16.

The circulation of gas in the gas circuit just described is due to the difference in specific weight of the columns of gas rich and weak, respectively, in refrigerant vapor. Since the column of gas rich in refrigerant vapor and flowing from the evaporator 17 to the absorber coil 21 is heavier than the column of gas weak in re-

frigerant vapor and flowing from absorber coil 21 to the evaporator 17, a force is produced or developed within the apparatus for causing circulation of gas in the manner described.

Absorption solution flows downward through coil 21 into the absorber vessel 20, and such solution, which is enriched in refrigerant, passes from the vessel through a conduit 23 and an inner passage or pipe 24 of liquid heat exchanger 25 into the lower end of a vapor lift pipe or tube 26 which is in thermal exchange relation with the heating tube 11, as by welding. Liquid is raised by vapor-liquid lift action through pipe 26 into the upper part of boiler 10. Refrigerant vapor expelled out of solution in boiler 10, together with refrigerant vapor entering through pipe 26, flows upward from the boiler through the conduit 14 to the condenser 15, as previously explained.

The outlet end of condenser 15 is connected by an upper extension of conduit 16 and a conduit 27 to a part of the gas circuit, as to the upper part of conduit 19, for example, so that any inert gas which may pass through the condenser 14 can flow into the gas circuit. The absorption liquid from which refrigerant vapor has been expelled flows from the boiler 10 through a connection 28, an outer pipe or passage 29 of the liquid heat exchanger 25 and conduit 22 into the upper part of the absorber coil 21. The circulation of absorption solution in the liquid circuit just described is effected by raising of liquid through pipe 26.

In order to effect heat exchange between inert gas which is weak in refrigerant and flowing to the evaporator 17 through the conduit 18 and inert gas which is rich in refrigerant and flowing from the evaporator 17 through the conduit 19, the conduits 18 and 19 may be heat conductively connected to one another at 30 in any suitable manner. Also, the conduit 16 through which liquid refrigerant flows from the condenser 15 to the evaporator 17 may be heat conductively connected at 31 to the conduit 19 through which inert gas rich in refrigerant flows to the absorber vessel 20, thereby cooling the liquid refrigerant before it is introduced into the evaporator 17.

While the evaporator 17 in FIG. 1 is diagrammatically shown in the form of a vertical looped coil, a practical form of such a cooling element may be an arrangement in which the looped coil is disposed substantially in a single horizontal plane across the space to be cooled. Such a practical embodiment is shown in FIGS. 2 and 3 in which parts similar to those shown in FIG. 1 are designated by the same reference numerals.

The evaporator 17 in FIGS. 2 and 3 comprises a looped coil which is disposed substantially in a single horizontal plane and adapted to extend from one lateral side wall 32 to the opposite lateral side wall 32 of a thermally insulated storage compartment 33 of a refrigerator cabinet 34 provided with a door 35 hinged at 36 to the front of the cabinet. The thermally insulated walls defining the storage compartment 33 include a rear insulated wall 37 having an opening and a removable enclosure member 38 therefor and through which the evaporator 17 is adapted to be inserted into the insulated interior of the cabinet 34. The parts of the conduits 18 and 19 heat conductively connected to one another at 30 and the part of the liquid refrigerant conduit 16 heat conductively connected to the conduit 19 at 31 may be disposed within the closure member 38 and retained therein within a body of insulation.

In FIGS. 2 and 3 the boiler 10, absorber vessel 20, absorber 21 and condenser 15 are disposed in a vertically extending apparatus space 39 at the rear of the refrigerator cabinet 34. The parts of the boiler 10 are embedded in insulation retained within a shell 40, the heating tube 11 projecting through openings in the top and bottom, respectively, of the shell. Upward circulation of air is induced by natural draft in the compartment 39 which defines a vertically extending flue, and

such upward movement of air effects cooling of the absorber coil 21 at one level and the condenser 15 located at a higher level.

As shown in FIGS. 2 and 3, the evaporator 17 is heat conductively connected in any suitable manner to the underside of a horizontally disposed plate 41. The plate 41 which is positioned closely adjacent to and at the vicinity of the ceiling 42 of the storage compartment 33, extends substantially over the entire width of the storage compartment 33 and from the rear insulated wall 37 to a region 43 at the open front which is relatively close to the rear face of the door to divide the compartment 33 into upper and lower spaces 33a and 33b, respectively.

The evaporator 17, which is adapted to be operated below the freezing temperature of water, is employed to abstract heat from the plate 41 which constitutes the bottom of the upper space 33a which functions as the freezing section of the refrigerator. The plate 41 and evaporator 17 in thermal exchange therewith also are employed to effect cooling of air in the lower space 33b of the storage compartment 33 which flows in thermal exchange relation therewith. Hence, the plate 41 has a limited heat transfer surface which is employed to effect cooling of air in the bottom space 33b of the storage compartment 33.

The parts of the absorption refrigeration apparatus shown in FIGS. 2 and 3 and just described, whose relative positions are substantially fixed, usually are formed of iron or steel when ammonia and water are employed as the refrigerant and liquid absorbent, respectively. Therefore, the piping for the evaporator 17 and absorber 21, which are connected by conduits to other parts of the refrigeration apparatus and form a unitary part thereof, are formed of such ferrous metal having relatively thick walls. As best shown in FIG. 3, the looped coil forming the evaporator 17 includes straight sections 17a and connecting bends 17b; and the looped coil forming the absorber 21 includes straight sections 21a and connecting bends 21b.

In accordance with my invention, in order to provide evaporator and absorber coils having straight portions connected by bends having small radii of curvature, the piping forming the bends of the coils is non-circular in cross-section with a minor axis and longer major axis which is substantially parallel to the axes of the bends, whereby a maximum number of straight coil sections or portions may be disposed in a space of a given size. As shown in FIG. 4, the bends 17b of the evaporator coil 17 are formed of piping which is non-circular in cross-section and has the shape of the numeral eight with the top and bottom parts 17c of annular form and a narrow neck part 17d therebetween.

As seen in FIG. 4, the bends 17b of the evaporator coil 17 have horizontal minor axes and longer vertical major axes 17e—17e which are parallel to the axes of the radii of curvature of the bends. The narrow neck parts 17d of the bends 17b are formed by reentrant portions 17f and 17g at the longer vertical side walls of the piping, the inner extremities of which contact and abut one another. Hence, the major axis 17e—17e of each bend 17b extends substantially in the same direction as the axis of the radius of curvature of the bend.

As seen in FIG. 5, the bends 21b of the absorber coil 21 also are non-circular in cross-section and have the shape of the numeral eight with top and bottom parts 21c and narrow connecting neck parts 21d therebetween. The longer vertical major axes 21e—21e of the bends 21b are parallel to the axes of the radii of curvature of the bends. Hence, the major axis 21e—21e of each bend 21b extends substantially in the same direction as the axis of the radius of curvature of the bend. Also, the neck parts 21d are formed by reentrant portions 21f and 21g at the longer vertical sides of the piping, the inner extremities of which contact and abut one another. The straight portions 17a of the evaporator coil 17 are of cylindrical

form and have inner diameters D^1 substantially equal to the distance D^2 between the inner surfaces of the top and bottom opposing walls of the coil 17 at the connecting bends 17b at the immediate vicinities of the major axes 17e—17e thereof, as shown in FIG. 4. Likewise, the straight portions 21a of the absorber coil 21 are of cylindrical form and have inner diameters D^3 substantially equal to the distance D^4 between the inner surfaces of the top and bottom opposing walls of the coil 21 at the connecting bends 21a at the immediate vicinities of the major axes 21e—21e thereof, as shown in FIG. 5.

By providing evaporator and absorber coils 17 and 21 formed with bends 17b and 21b of the kind just described and shown in FIGS. 4 and 5, a greater number of coil straight sections can be employed in a given space than otherwise would be possible. This is so because the bends 17b and 21b can be formed with smaller radii of curvature than the bends that could be formed from the piping which is cylindrical in cross-section and provide the straight sections of the coils. By providing the bends 17b for the evaporator coil 17 in FIG. 3, for example, a maximum number of straight pipe sections 17a can be employed alongside one another in heat conductive relation with the underside of the plate 41. In this way a longer path of flow for the liquid refrigerant can be provided at the underside of the plate 41 whereby the refrigerating effect produced due to evaporation of refrigerant fluid into inert gas is increased.

I make the evaporator and absorber coils 17 and 21 by deforming into the shape of the numeral eight longitudinally spaced regions of ferrous piping which is cylindrical in cross-section. After straight lengths of piping are deformed at regions at which the bends of the piping are to be formed, the piping is positioned in a suitable pipe bending machine having a pivot 44, a pair of back-up rollers 45, and a roller 46 which is mounted for movement on an arm in any suitable manner (not shown) to bend the piping. The roller 46 is shown in one position in FIG. 6 after a bend is partly made and in another position in FIG. 7 after the bend is completed.

As shown in FIG. 8, the roller 46 is formed with an outer peripheral wall 46a having the shape of the outer vertical side of the piping against which it bears. However, the outer peripheral wall 44a of the pivot 44, which bears against the inner vertical side of the piping, is essentially straight, as shown in FIG. 9. Accordingly, after the bend is formed the roller 46 can be retracted from the position shown in FIG. 7 and the bend just formed can be removed from the pivot 44 by a simple lifting movement.

As shown in FIGS. 7 and 8, the axis of the radius of curvature of the bend is parallel to the major axis 17e—17e of the region of the piping deformed into the shape of the numeral eight. While the bend is being formed, the reentrant portion 17f at the inner side wall of the piping functions as a support against which the reentrant portion 17g at the outer side wall of the piping bears. This enables the bends in the evaporator and absorber coils 17 and 21 to be formed by cold bending without the necessity of heating the piping before or during the bending operation. By first deforming longitudinally spaced regions in suitable apparatus to provide piping sections having opposed reentrant portions in the longer side walls thereof, the deformed regions offer less resistance to bending than the piping of circular cross-section before it was deformed.

When the deformed region of the piping is being bent, the outer side wall thereof is subjected to tensile forces and the inner side wall thereof is subjected to compressive forces. The magnitude of the tensile and compressive forces developed in piping when it is being bent and the ability of the piping to withstand these forces without localized buckling is dependent upon the ratio of the diameter of the piping to the radius of curvature of the bend.

By deforming the piping in the manner shown in FIGS. 4 and 5 at the regions at which the bends are to be formed, the effective diameter of the piping is reduced for the bending operation without unduly decreasing the overall cross-sectional area of the piping at the bends.

In absorption refrigeration apparatus of the inert gas type a force is produced within the apparatus for causing circulation of gas through and between the evaporator 17 and absorber 21, as explained above. In the event the deforming of the piping by providing opposed reentrant portions at the longer side walls thereof reduces the overall cross-section of the piping to such an extent that the circulation of gas in the gas circuit will be impaired, it may be desirable to select piping for the evaporator and absorber coils of such size that, after forming bends in the coils in the manner shown and described above, the overall cross-sectional areas at the bends of the coils will be sufficiently large not to impair operation of the refrigeration apparatus.

It will thus be seen that I have provided an improved evaporator and absorber formed by coils having straight portions and connecting bends and an inlet and outlet for inert gas at different elevations. By providing the reentrant portions at the opposing longer side walls of the piping with their inner extremities contacting and abutting one another, the inner side wall of the piping effectively functions to support the outer side wall during the bending operation. Although the piping of the evaporator coil 17 is deformed to provide the bends 17b, the height of the piping at the bends is not changed to such an extent that it will adversely affect the downward flow of liquid refrigerant through the coil by gravity.

By providing bends 21b for the absorber coil 21 having small radii of curvature in accordance with my invention the two banks of the straight sections 21a of the coil will be closer to one another so that the depth of the apparatus space 39 can be reduced. Moreover, by providing bends 21b which not only have small radii of curvature but also are inclined downward, the absorber coil 21 can be formed with straight sections 21a which are essentially horizontal, whereby a greater number of straight pipe sections can be employed in an absorber coil of a given height than in an absorber coil where the straight pipe sections and bends are both inclined to the horizontal.

I claim:

1. Absorption refrigeration apparatus of the class described having, in combination, a circuit for gas including a coil formed of ferrous metal having straight portions and connecting bends, and an inlet and outlet at different elevations, the straight portions of said coil being circular in cross-section, at least one bend of said coil being non-circular in cross-section and having a minor axis and a longer major axis which extends substantially in the same direction as the axis of the radius of curvature of said one bend, and the straight portions of said coil connected to said one bend each having an inner diameter substantially equal to the distance between the inner surfaces of the opposing walls of said coil at said one bend at the immediate vicinity of said major axis thereof.

2. Apparatus as set forth in claim 1 in which said non-circular bend of said coil comprises piping having a longitudinal reentrant portion at one side of the major axis thereof which extends toward the opposite side of said piping, the inner extremity of said reentrant portion contacting and abutting the opposite side of said piping.

3. Apparatus as set forth in claim 1 in which said longitudinal reentrant portion at one side of the major axis of said piping is at the inner side of said one bend and extends toward the opposite outer side of said one bend, the inner extremity of said reentrant portion contacting and abutting the opposite outer side of said one bend.

4. Apparatus as set forth in claim 3 in which said longitudinal reentrant portion at the inner side of said

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one bend functions as a first longitudinal reentrant portion and said piping at the opposite side of the major axis thereof and at the outer side of said one bend has a second longitudinal reentrant portion which extends toward the inner side of said one bend, the inner extremities of said first and second reentrant portions contacting and abutting one another.

5. Apparatus as set forth in claim 1 in which said one bend of said coil comprises piping having the shape of the numeral eight in cross-section with adjacent parts of annular form and a contracted neck therebetween, the longer major axis passing through the contracted neck portion and bisecting the parts of annular form.

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U.S. Cl. X.R.

62—490, 515