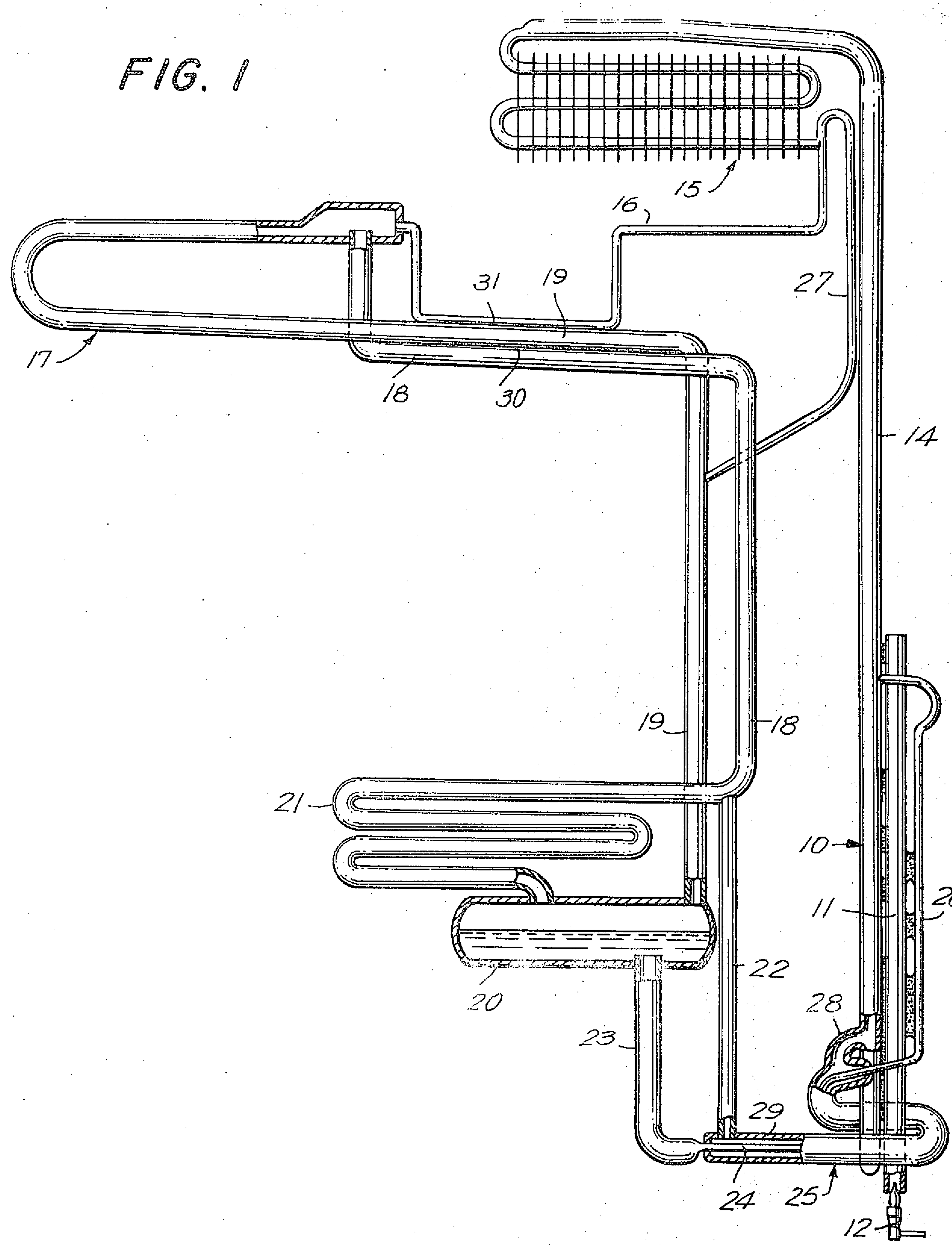
Oct. 24, 1967 B. R. REISTAD 3,348,402

METHOD OF MAKING COIL FOR ABSORPTION REFRIGERATION APPARATUS

Filed March 27, 1964 3 Sheets-Sheet 1

FIG. 1



INVENTOR.
Bengt Reistad Reistad
BY
Attorney
ATTORNEY

Oct. 24, 1967 B. R. REISTAD 3,348,402

METHOD OF MAKING COIL FOR ABSORPTION REFRIGERATION APPARATUS

Filed March 27, 1964

FIG. 3

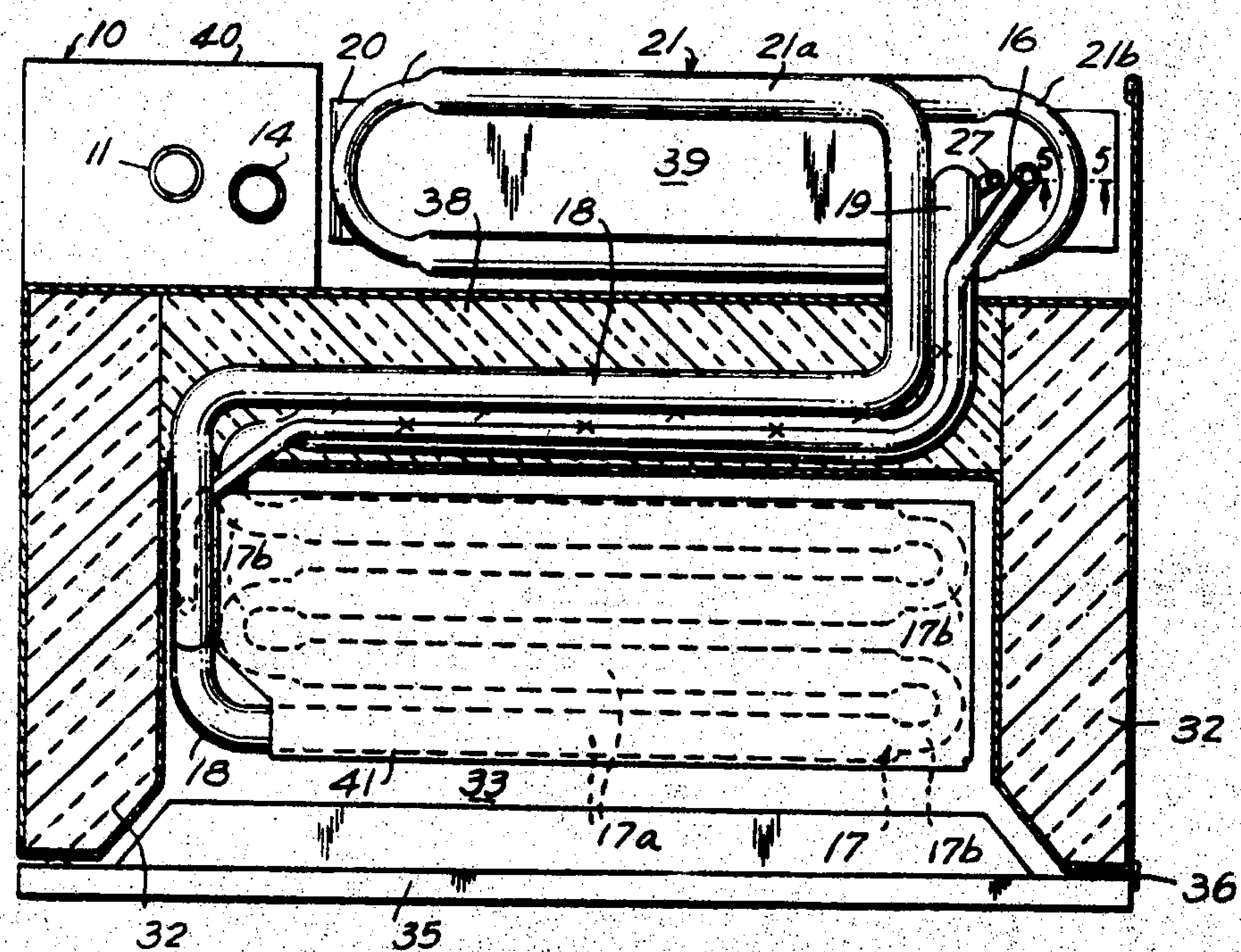


FIG. 2

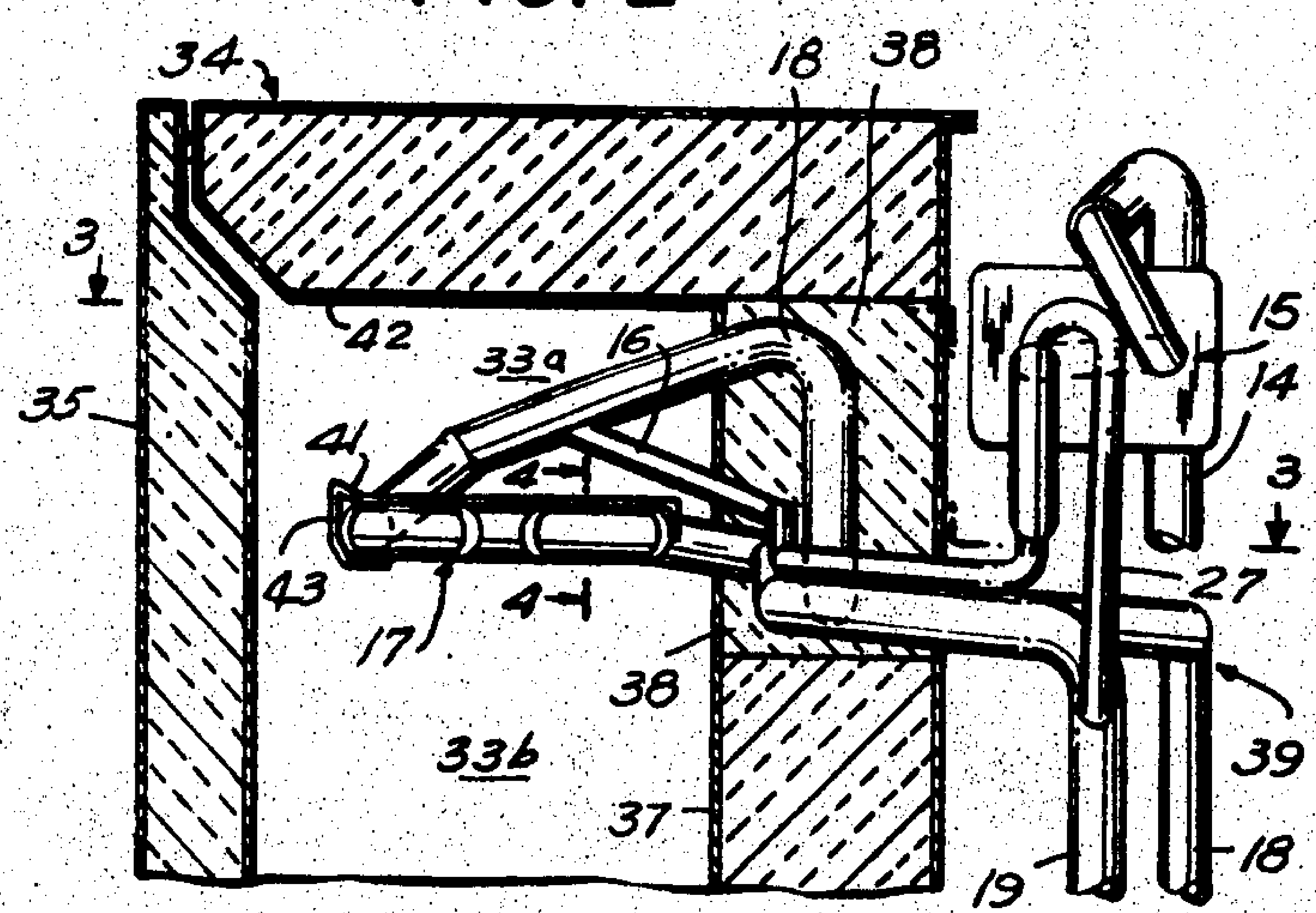
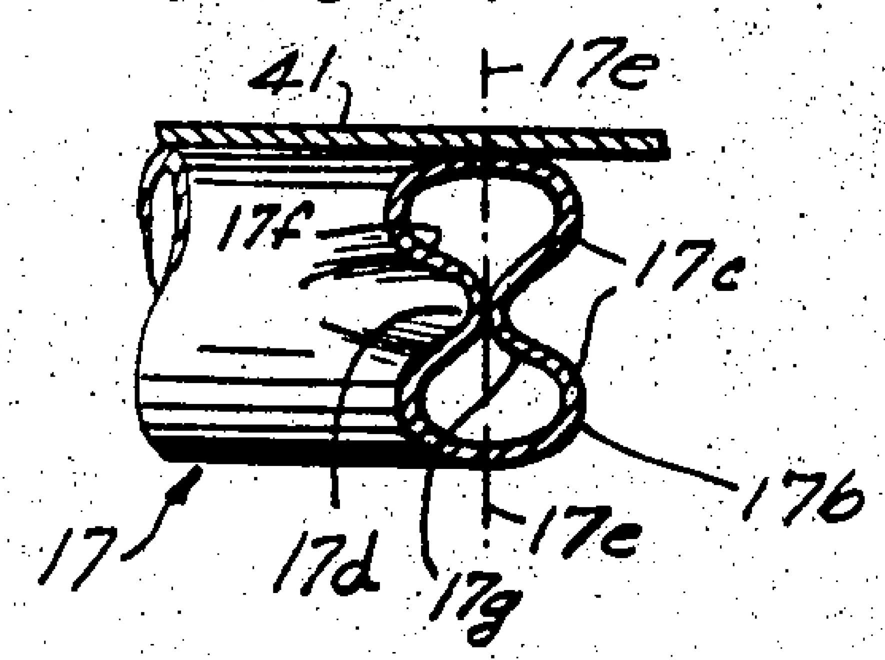


FIG. 4



INVENTOR.
Bengt Reistad Reistad
BY
[signature]
his ATTORNEY

Oct. 24, 1967 B. R. REISTAD 3,348,402

METHOD OF MAKING COIL FOR ABSORPTION REFRIGERATION APPARATUS

Filed March 27, 1964 3 Sheets-Sheet 3

FIG. 5

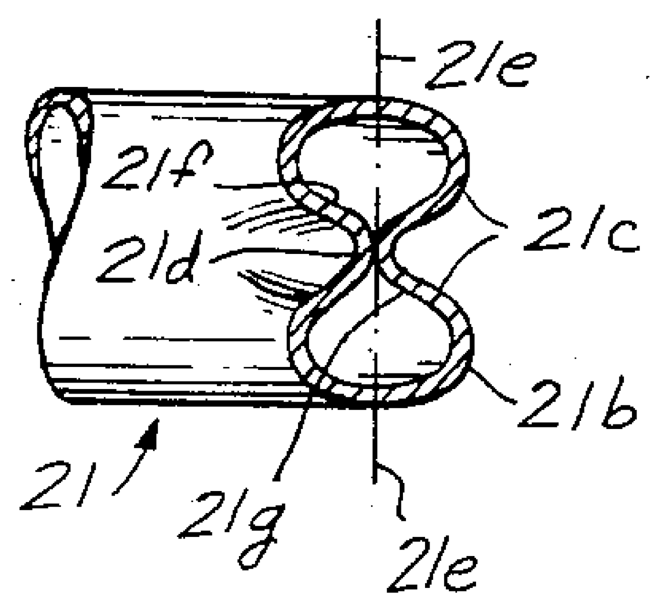


FIG. 8

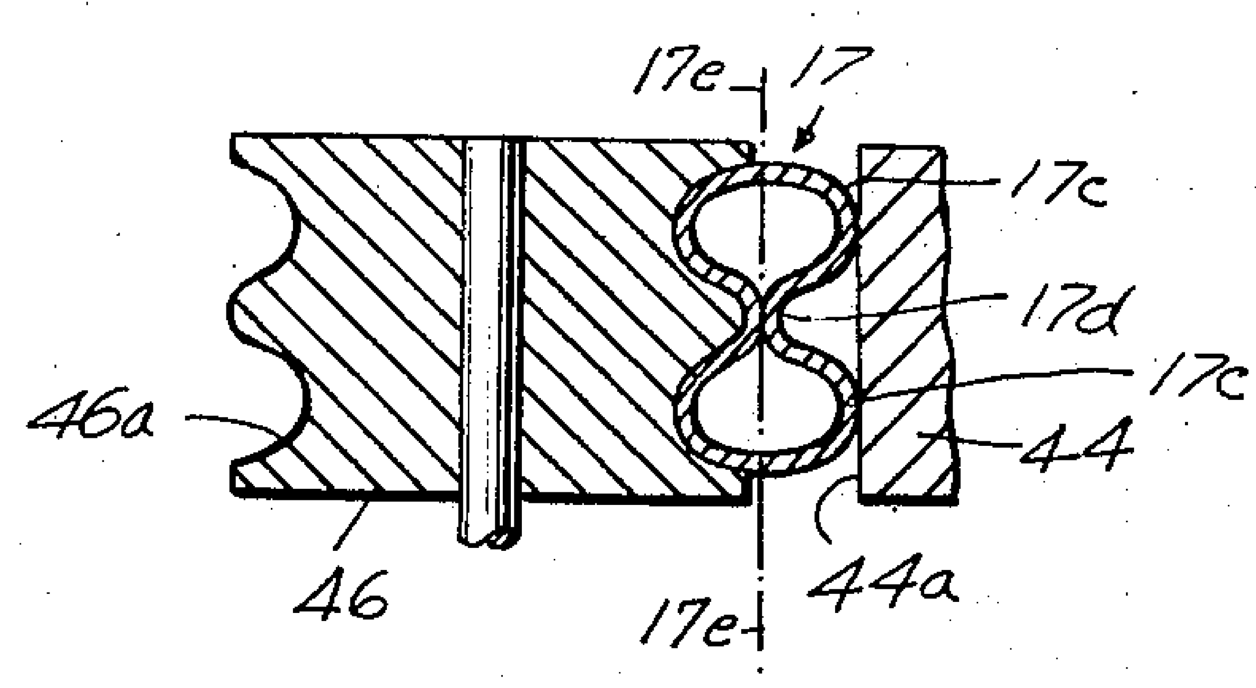


FIG. 6

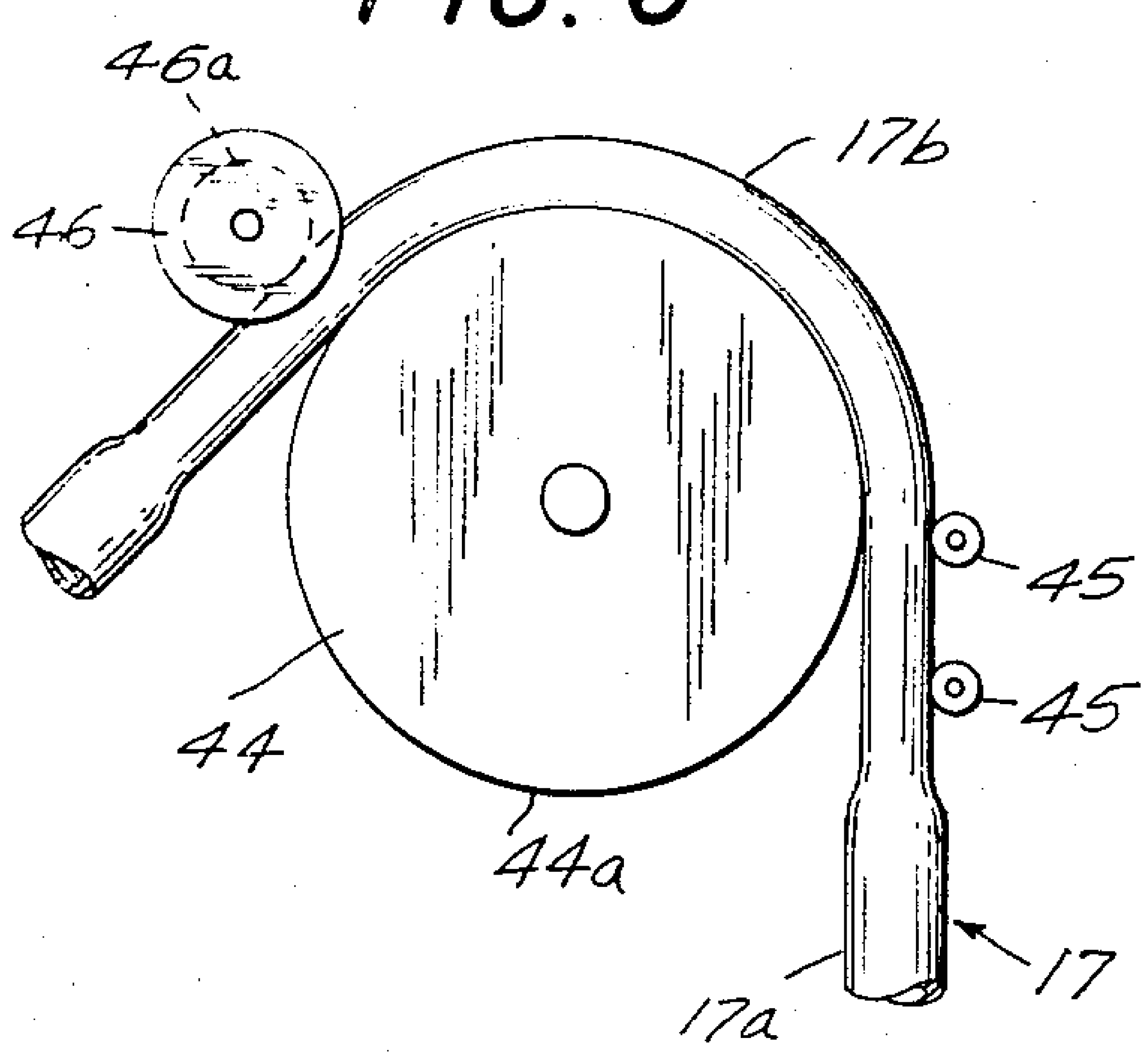


FIG. 7

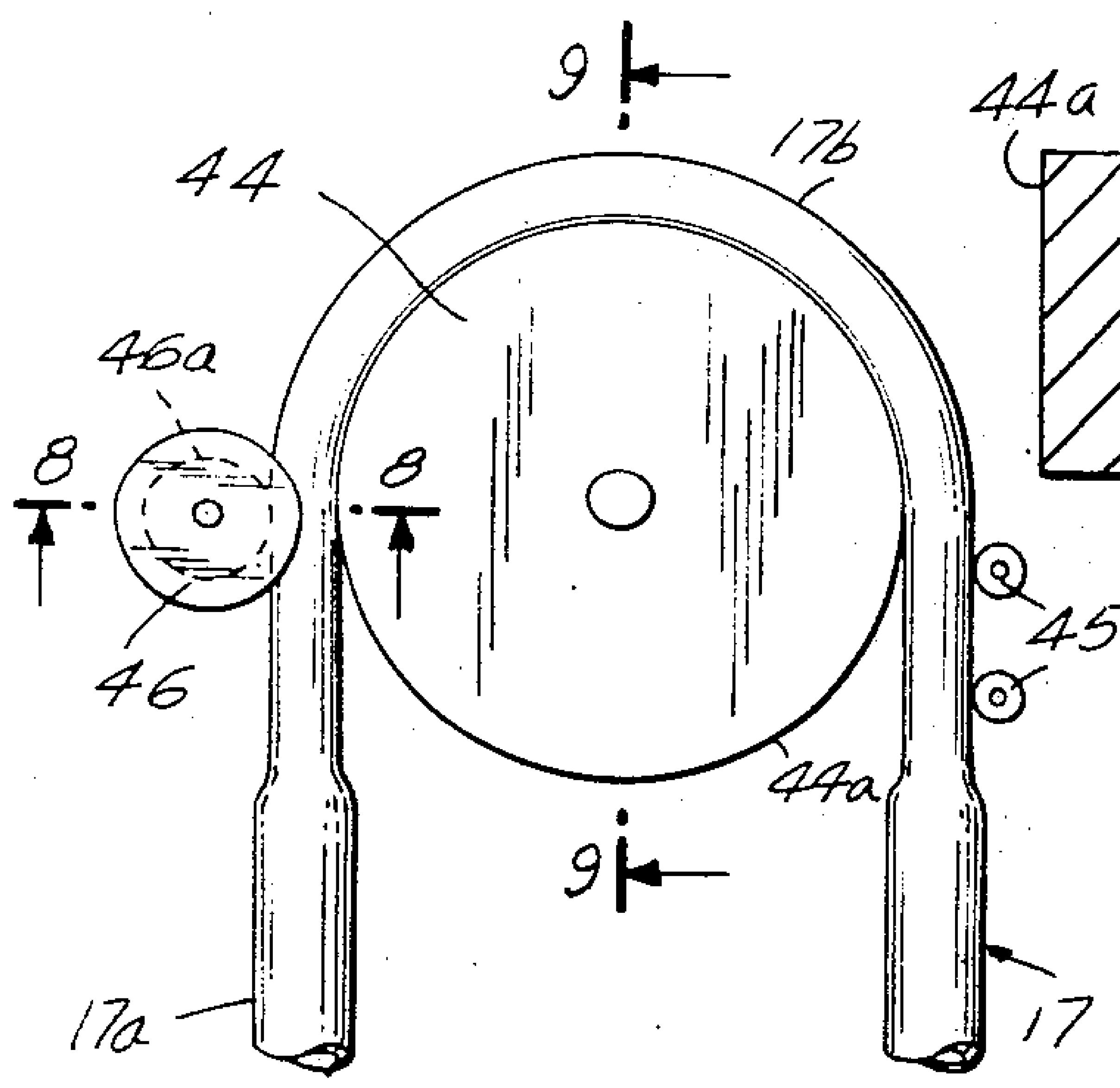
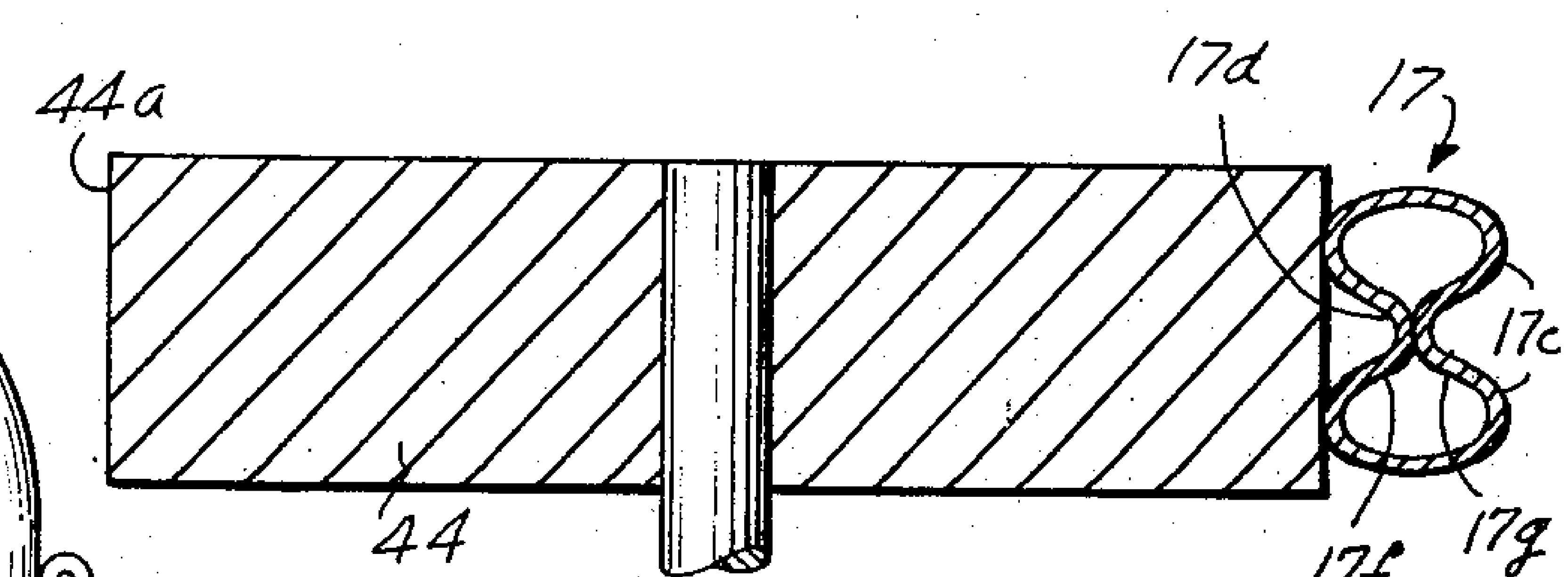


FIG. 9



INVENTOR
Bengt Reistad

BY

his ATTORNEY

United States Patent Office

3,348,402

Patented Oct. 24, 1967

1

3,348,402
METHOD OF MAKING COIL FOR ABSORPTION REFRIGERATION APPARATUS

Bengt Reistad Reistad, Bromma, Sweden, assignor to Aktiebolaget Electrolux, Stockholm, Sweden, a corporation of Sweden

Filed Mar. 27, 1964, Ser. No. 355,337
Claims priority, application Sweden, Mar. 29, 1963, 3,507/63
4 Claims. (Cl. 72—217)

My invention relates to a method of making a coil for absorption refrigeration apparatus. More particularly, the invention relates 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 method of making a coil of this type in which spaced longitudinal regions of straight piping or tubing of cylindrical form are deformed to produce portions which are non-circular in cross-section and include a reentrant part at a first side wall which functions as a support for the opposite second side wall when the non-circular portion is bent about the first side wall to produce a bend in the coil.

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 this specification, and in which:

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.

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

2

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 refrigerant 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 **33***a* and **33***b*, 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 **33***a* 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 **33***b* 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 **33***b* 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 **17***a* and connecting bends **17***b*; and the looped coil forming the absorber **21** includes straight sections **21***a* and connecting bends **21***b*.

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 **17***b* 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 top and bottom parts **17***c* of annular form and a narrow neck part **17***d* therebetween.

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

As seen in FIG. 5, the bends **21***b* 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 **21***c* and narrow connecting neck parts **21***d* therebetween. The longer vertical major axes **21***e*—**21***e* of the bends **21***b* are parallel to the axes of the radii of curvature of the bends. Hence, the major axis **21***e*—**21***e* of each bend **21***b* extends substantially in the same direction as the axis of the radius of curvature of the bend. Also, the neck parts **21***d* are formed by reentrant portions **21***f* and **21***g* at the longer vertical sides of the piping, the inner extremities of which contact and abut one another. The straight portions **17***a* of the evaporator coil **17** are of cylindrical form and have inner diameters substantially equal to the distance between the inner surfaces of the opposing walls of the coil **17** at the connecting bends **17***b* at the immediate vicinities of the major axes **17***e*—**17***e* thereof. Likewise, the straight portions **21***a* of the absorber coil **21** are of cylindrical form and have inner diameters substantially equal to the distance between the inner surfaces of the opposing walls of the coil **21** at the connecting bends **21***a* at the immediate vicinities of the major axes **21***e*—**21***e* thereof.

By providing evaporator and absorber coils **17** and **21** formed with bends **17***b* and **21***b* 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 **17***b* and **21***b* 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 **17***b* for the evaporator coil **17** in FIG. 3, for example, a maximum number of straight pipe sections **17***a* 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 backup 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 **46***a* having the shape of the outer vertical side of the piping against which it bears. However, the outer peripheral wall **44***a* 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.

Although I have illustrated and described a particular embodiment of my invention, I do not desire to be limited to the particular arrangement set forth, and I intend in the following claims to cover all modifications which do not depart from the spirit and scope of my invention.

I claim:

1. A method of making a coil for a gas circuit of absorption refrigeration apparatus which comprises first deforming a region of a straight piece of pipe which is cylindrical in cross-section and formed of ferrous metal to provide a pipe section at said region having a minor axis and a longer major axis and a longitudinal reentrant portion in the wall thereof, and thereafter bending the pipe back upon itself to form a bend at said region and straight pipe sections connected thereto with the major axis of said region extending substantially in the same direction as the axis of the radius of curvature of the bend and the reentrant portion at the inside wall of the bend and the inner diameter of each straight pipe section being substantially equal to the distance between the inner surfaces of the opposing walls of said pipe section at the bend at the immediate vicinity of the major axis thereof, the longitudinal reentrant portion functioning to support the opposite outer side wall of the pipe at the bend while it is being formed.

2. A method of making a coil for a gas circuit of absorption refrigeration apparatus which comprises first deforming a region of a straight piece of pipe which is circular in cross-section and formed of ferrous metal to provide a pipe section which is non-circular in cross-section with a longitudinal reentrant portion in the wall thereof and has a minor axis passing through the reentrant portion and a longer major axis transverse thereto, and thereafter bending the pipe back upon itself to form a bend at said region and straight pipe sections connected thereto with the major axis of said region extending substantially in the same direction as the axis of the radius of curvature of the bend and the reentrant portion at the inside wall of the bend and the inner diameter of each straight pipe section being substantially equal to the distance between the inner surfaces of the opposing walls of said pipe section at the bend at the immediate vicinity of the major axis thereof, the longitudinal reentrant portion functioning to support the opposite outer side wall of the pipe at the bend while it is being deformed.

3. A method of making a coil for a gas circuit of absorption refrigeration apparatus which comprises first deforming a region of a straight piece of pipe which is circular in cross-section and formed of ferrous metal to provide a pipe section which is non-circular in cross-section with longitudinal reentrant portions in the wall at opposite sides thereof and has a minor axis passing through the reentrant portions and a longer major axis transverse thereto, and thereafter bending the pipe back upon itself to form a bend at said region and straight pipe sections connected thereto with the major axis of said region extending substantially in the same direction as the axis of the radius of curvature of the bend and one of the reentrant portions at the inside wall of the bend and the inner diameter of each straight pipe section being substantially equal to the distance between the inner surfaces of the opposing walls of said pipe section at the bend at the immediate vicinity of the major axis thereof, said one longitudinal reentrant portion contacting and bearing against the other of the longitudinal reentrant portions at the outer side wall of the pipe at the bend and functioning to support the outer side wall of the pipe at the bend while it is being formed.

4. A method of making a coil for a gas circuit of absorption refrigeration apparatus which comprises first deforming a region of a straight piece of pipe which is circular in cross-section and formed of ferrous metal to provide a pipe section which in cross-section has the shape of the numeral eight having adjacent parts of annular form and a contracted neck part therebetween and has a minor axis and a longer major axis transverse thereto passing through the contracted neck part and bisecting the parts of annular form, and thereafter bending the pipe back upon itself to form a bend at said region and straight pipe sections connected thereto with the major axis of said region exetnding substantially in the same direction as the axis of the radius of curvature of the bend and one of the reentrant portions at the inside wall of the bend and the inner diameter of each straight pipe section being substantially equal to the distance between the inner surfaces of the opposing walls of said pipe section at the bend at the immediate vicinity of the major axis thereof, said one longitudinal reentrant portion contacting and bearing against the other of the longitudinal reentrant portions at the outer side wall of the pipe at the bend and functioning to support the outer side wall of the pipe at the bend while it is being formed.

References Cited

UNITED STATES PATENTS

2,008,343	7/1935	Thomas	62—515
2,746,727	5/1956	Earl	165—168
2,748,455	6/1956	Draper et al.	29—157.6
2,819,731	1/1958	Louthan	138—38
3,020,725	2/1962	Kogel	62—490
3,042,099	7/1962	Neeley	153—2

CHARLES W. LANHAM, *Primary Examiner.*

ROBERT A. O'LEARY, *Examiner.*

R. D. GREFE, *Assistant Examiner.*