Dec. 2, 1969 W. M. SEELEY 3,481,151

REFRIGERANT SYSTEM EMPLOYING LIQUID CHILLING EVAPORATORS

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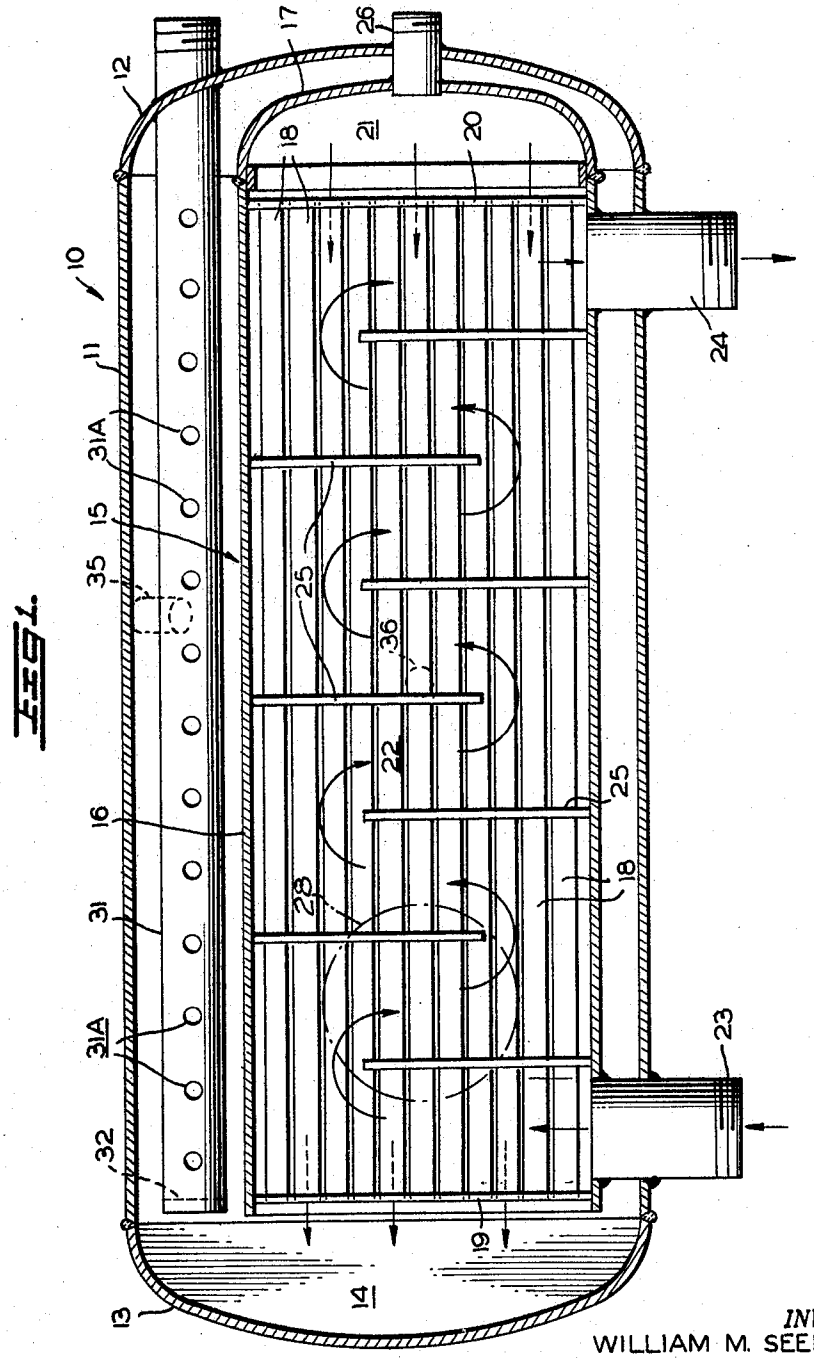


FIG. 1.

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REFRIGERANT SYSTEM EMPLOYING LIQUID CHILLING EVAPORATORS

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Fig 2.

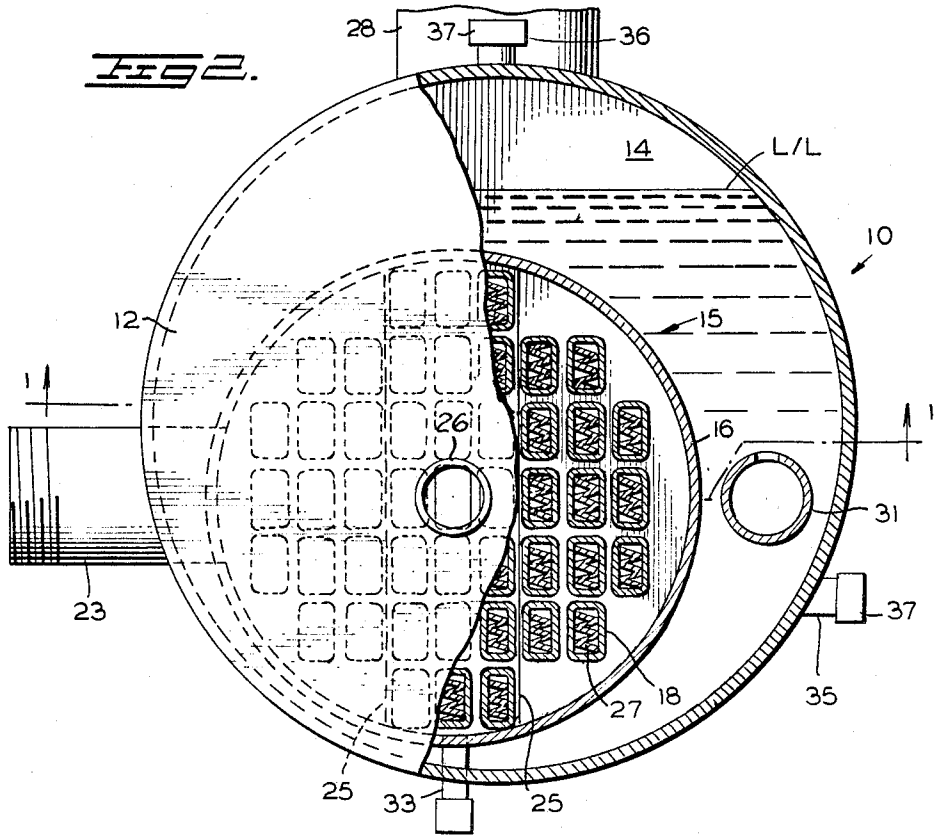
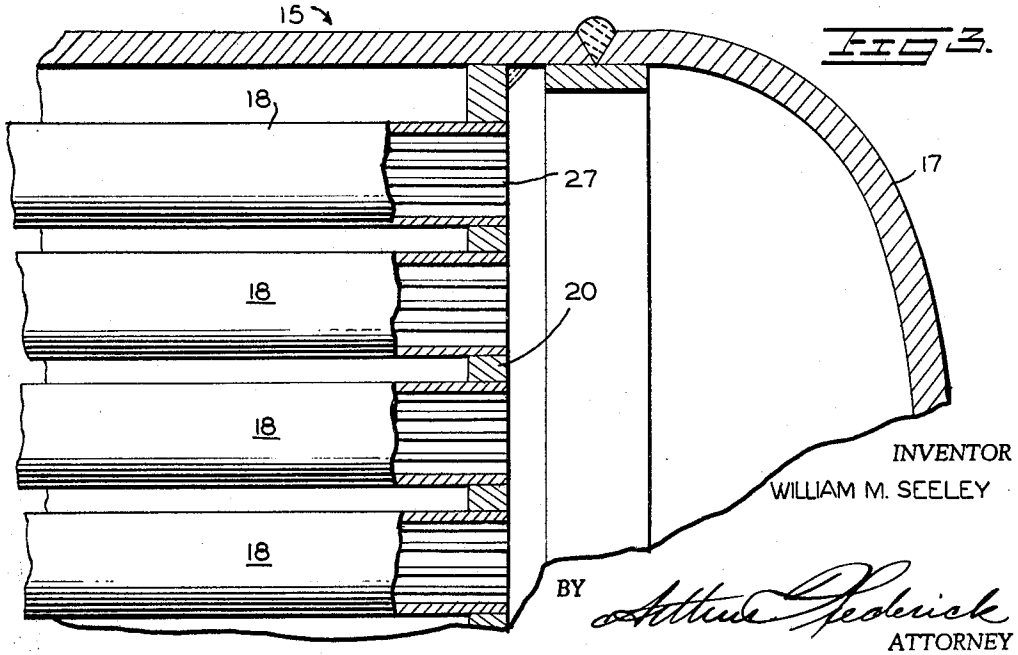


Fig 3.



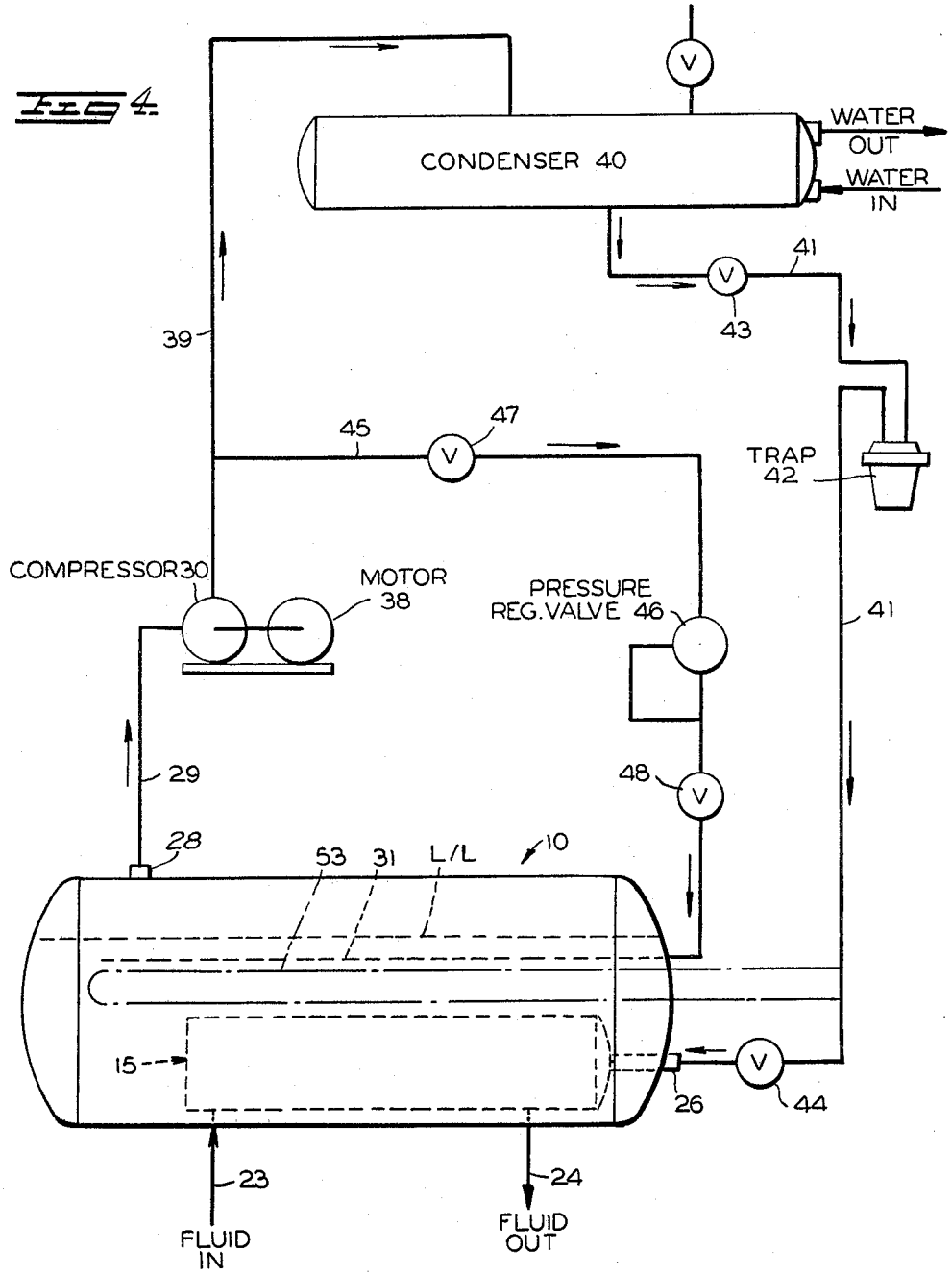
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REFRIGERANT SYSTEM EMPLOYING LIQUID CHILLING EVAPORATORS

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Fig 4.



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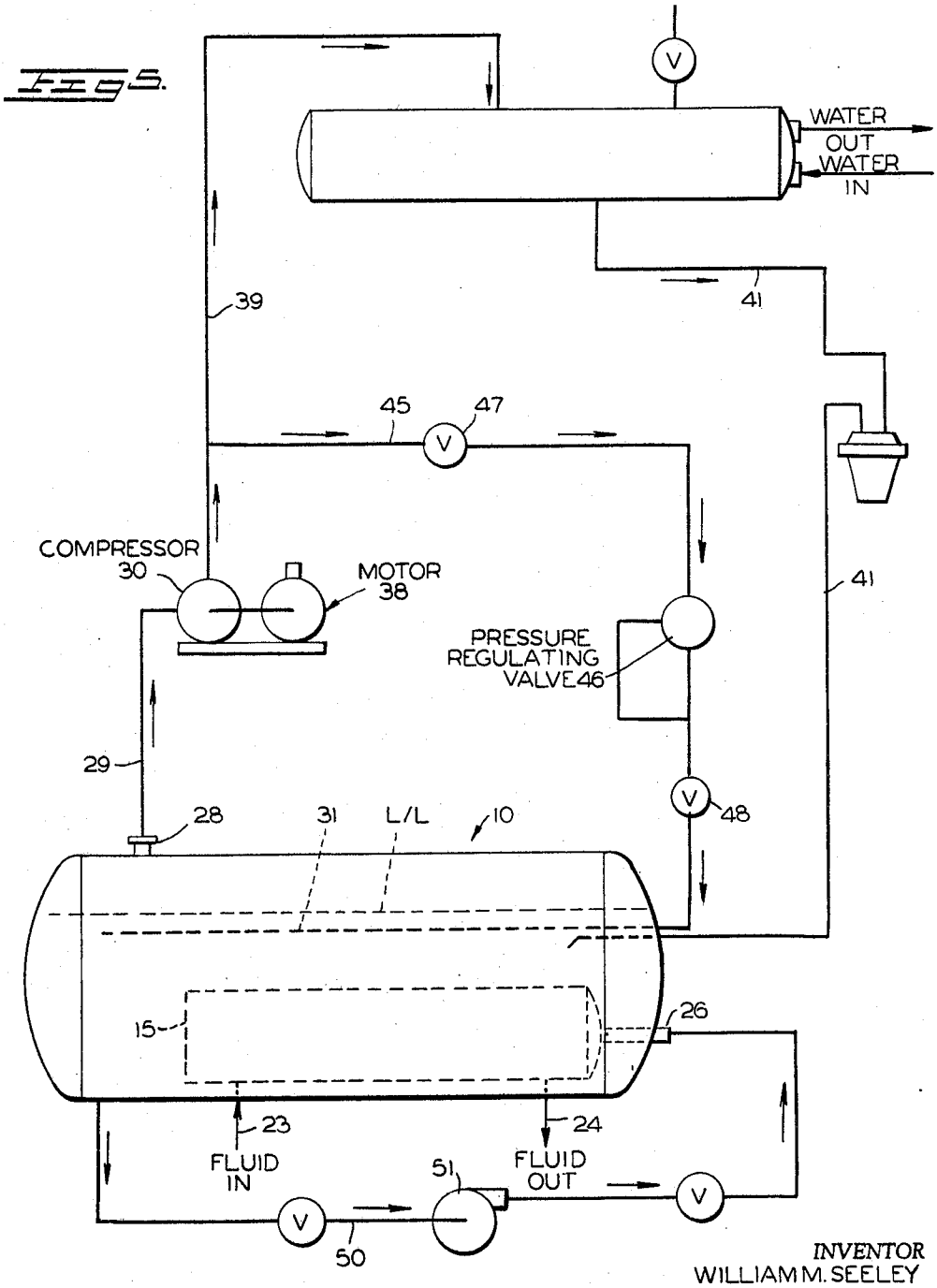
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Fig. 5.



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REFRIGERANT SYSTEM EMPLOYING LIQUID CHILLING EVAPORATORS

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Int. Cl. F25b 41/00, 39/02
U.S. Cl. 62—196 9 Claims

ABSTRACT OF THE DISCLOSURE

A refrigeration chilling system having a unitary accumulating and chilling apparatus in which refrigerant flow through the chiller is forced and wherein capacity control is achieved by bypassing controlled quantities of compressed, hot, gaseous refrigerant around the condenser and injecting it directly into the liquid refrigerant held in the accumulator and chilling apparatus to maintain the pressure in the accumulator and suction pressure on the compressing means.

This invention relates to refrigerant evaporating systems and, more particularly, to systems employing liquid chilling evaporators.

One important aspect of refrigeration systems employing liquid chillers is the necessity, at low load conditions, of preventing low suction pressure at the inlet of the compressor and attendant freeze-up of the chiller. One such capacity control system is disclosed in the U.S. Patent to Boling, No. 2,945,355. In many dry expansion evaporators of very large capacity, i.e., 350–400 tons, a plurality of refrigerant circuits are required for distribution of refrigerant to the liquid chiller circuits, each of which circuit includes a suction line, an expansion valve, a liquid line solenoid, and means for sensing load changes in one circuit independent of the other circuits. In this system capacity control is unsatisfactorily achieved by isolating one or more distribution circuits in accordance with the demand or load which necessitates complicated and expensive piping and components.

Another important aspect of refrigeration systems employing liquid chillers is the heat transfer efficiency of the liquid chillers. In present liquid chillers of the dry expansion type, a relatively large part of the capacity of the chiller is lost by reason of the need to utilize a portion of the evaporating surface for superheating the refrigerant to thereby provide the required modulation of the expansion valve in relation to load fluctuation.

Accordingly, it is one object of this invention to provide an improved liquid chilling refrigeration system in which capacity control is achieved in a relatively simple and inexpensive manner.

Another object of the present invention is to provide a liquid chilling refrigeration system in which efficient heat transfer between the refrigerant and liquid to be cooled is provided in the liquid chiller, thus permitting the use of smaller size liquid chillers for the same capacity than heretofore known systems.

A further object of this invention is to provide a liquid chilling refrigeration system in which capacity control, even in the very high capacity systems, is achieved simply and without raising suction superheat to an undesirable level or freezing of the liquid chiller at low loads.

A still further object of the present invention is to provide for a liquid chilling refrigeration system, a single unitary apparatus functioning as an accumulator and a liquid chiller.

Another object of this invention is to provide a high capacity liquid chilling refrigeration system in which refrigerant distribution is achieved without the need for a multiplicity of distribution circuits.

A feature of this invention is an accumulator and liquid chiller (evaporator) combined in a single vessel and having means for introducing hot, gaseous refrigerant into the subcooled liquid, which means forms part of the capacity control system.

Another feature of the present invention is a hot, gaseous refrigerant bypass conduit which is in communication at one end, to the compressor discharge and, at the opposite end, to the means for injecting hot, gaseous refrigerant into the subcooled liquid refrigerant in the accumulating and chilling apparatus according to this invention.

A still further feature of this invention is the forced circulation of liquid refrigerant through the liquid chiller.

Accordingly, it is contemplated by the present invention to provide a novel liquid chilling refrigeration system comprising a unitary accumulating and chilling apparatus interconnected with a compressor means and condensing means in a closed refrigerant circuit so as to provide forced circulation of liquid refrigerant through the unitary accumulating and chilling apparatus. The unitary accumulating and chilling apparatus comprises a closed vessel connected to receive liquid refrigerant and provide a reservoir of liquid therein. The apparatus also has a closed second vessel disposed in the first mentioned closed vessel so as to be submerged in the reservoir of liquid. An evaporator tube means is disposed in the second vessel to communicate, at one end, with an inlet header in the second vessel, to receive liquid refrigerant and, at the opposite end, with the reservoir of liquid refrigerant to discharge liquid refrigerant into the reservoir. Inlet means for passing liquid to be cooled into the second vessel and in indirect heat exchange relationship with the liquid refrigerant flowing through the tube means is provided. Outlet means is also provided for conducting cooled fluid to be cooled from the second vessel to a place of use or storage.

In one embodiment, the unitary accumulating and chilling apparatus is disposed below the condenser so as to provide a sufficient liquid head pressure to force the liquid through the evaporator tube means of the apparatus.

In another embodiment of the present invention, liquid refrigerant is delivered to the reservoir within the first mentioned vessel and a portion of the liquid refrigerant in the reservoir is pumped from the reservoir and forced into and through the evaporator tube means.

A bypass conduit means may be provided in communication with the discharge of the compressor means and the reservoir of liquid refrigerant to bypass a portion of the hot, gaseous refrigerant, around the condensing means, and introduce it into the liquid refrigerant under low load operating conditions of the refrigerating systems. The injection of hot, gaseous refrigerant into the liquid reservoir in quantities commensurate with refrigerating load below a predetermined design load prevents low fluid pressure in the accumulator and suction conduit to the compressor and the freezing of the liquid to be cooled in the second vessel of the accumulating and chilling apparatus.

The invention will be more fully understood from the following detailed description thereof when considered in conjunction with the accompanying drawings wherein various embodiments of the invention are illustrated by way of example, and in which:

FIG. 1 is a longitudinal view, in cross section, of the unitary accumulating and chilling apparatus according to this invention taken substantially along line 1—1 of FIG. 2;

FIG. 2 is an end view, in elevation, of the accumulator and chiller apparatus as view from the right in FIG. 1, and rotated 90° in clockwise direction, part of the end closure head being broken away for illustration purposes;

FIG. 3 is an enlarged, fragmentary view in cross section of the evaporative heat exchanger portion of the accumulating and chilling apparatus shown in FIGS. 1 and 2;

FIG. 4 is a refrigeration system according to the present invention, employing the accumulating and chilling apparatus illustrated in FIGS. 1 to 5; and

FIG. 5 is another embodiment of the refrigeration system according to this invention employing the accumulating and chilling apparatus shown in FIGS. 1 to 3.

Now referring to the drawing, and more specifically to FIGS. 1 to 3, the reference number **10** generally designates an accumulating and chilling apparatus which is particularly suitable for use in the refrigerant evaporating systems schematically illustrated in FIGS. 4 and 5.

The accumulator and chiller apparatus **10** comprises an open ended cylindrical, outer shell **11** which is closed at opposite ends by dish shaped end walls **12** and **13** sealingly secured, as by welding to shell **11**, to define an accumulation chamber or reservoir **14**. A chiller **15** is disposed within reservoir **14** so as to be wholly submerged in the liquid refrigerant held up in reservoir **14**, the normal level of which liquid is indicated at L/L in FIGS. 2, 4 and 5.

The chiller **15** comprises an open ended, inner cylindrical shell **16** which is closed at one end by a dish shaped header **17**. Within shell **16** is disposed a plurality of spaced parallel pipes or tubes **18** which are supported, at opposite ends, by tube sheets **19** and **20**. The tube sheet **19** is secured, as by welding, to shell **16**, adjacent the open end of shell **16**, while tube sheet **20** is secured, as by welding, to shell **16** in spaced relation to header **17** to define therebetween an inlet chamber **21**. The tube sheets **19** and **20**, with shell **16**, a define a fluid chamber **22**. An inlet connection **23** is secured in a fluid tight manner to shell **16**, adjacent tube sheet **19** so as to communicate with chamber **22** and through suitable conduit means, not shown, with a source of fluid to be cooled, such as water. An outlet connection **24** is secured in a fluid tight manner to shell **16**, adjacent tube sheet **20** so as to communicate with chamber **22** and, through suitable conduit means, not shown, with a place of use or storage of cooled fluid. Both the inlet and outlet connections **23** and **24** project through shell **11**, the interstices between the connections and the shell being sealed in a suitable way, such as by seal welding. To provide for a tortuous flow of fluid to be cooled between tubes **18** and thereby insure complete wetting of all the tubes and their surfaces, a plurality of spaced, chordal shaped plates or baffles **25** are disposed in chamber **22** between inlet and outlet connections **23** and **24**. The baffles **25** are provided with openings to receive tubes **18** therethrough and are alternately secured to the lower and upper circumference of shell **16** to direct fluid flow up and down across tubes **18**. An inlet connection **26** is secured to header **17** so as to communicate with inlet chamber **21** and project through end wall **12**. The inlet connection **26** is connected, through suitable piping, to a source of refrigeration fluid, such as a condenser, as hereinafter explained in connection with the system illustrated in FIG. 4. The tubes **18**, at their ends opposite from inlet chamber **21**, are in communication with chamber **14** to discharge refrigerant into the latter after it passes in indirect heat exchange relationship with the fluid to be cooled flowing through chamber **22** from inlet connection **23** to outlet connection **24**.

As best shown in FIG. 2, tubes **18** are preferably rectangular in cross section and have internal extended surface elements **27** which may be of the type disclosed in the U.S. patents to Hopkins, No. Re. 20,016 or Arnold No. 2,373,218. Although tubes are preferably constructed as illustrated, it is to be understood that tubes **18** may be circular in cross section and may be internally bare or have internal extended surface elements as disclosed in the Gaddis et al. U.S. Patent No. 2,726,681.

A suction outlet connection **28** is secured in a fluid tight manner to outer shell **11** and is connected to pass gaseous refrigerant fluid, from the reservoir **14**. As illustrated in FIGS. 4 and 5, outlet connection **28** is connected to a pipe **29** which communicates with the intake ports of a compressor **30**.

To provide for introduction of hot gaseous refrigerant into the liquid refrigerant in reservoir **14**, an injection pipe **31** is disposed to extend longitudinally in reservoir **14** and parallel to the longitudinal axis of shell **11**. The injection pipe **31** projects through an opening in end wall **12** and is secured in a fluid tight manner within the opening in end wall **12**. The distal end of injection pipe **31** is closed by a plate **32**, while the opposite end may be connected to a bypass conduit means as illustrated in FIGS. 4 and 5. The injection pipe is provided with a plurality of longitudinal spaced holes **31A** for effecting substantially uniform distribution of gaseous refrigerant into reservoir **14**.

A drain pipe **33** is disposed to project through outer shell **11** and inner shell **16** and communicate with the lower portion of chamber **22**. The drain pipe **33** serves to provide for drainage of chamber **22** when it is necessary to inspect or repair chiller **15**. A cap **34** is secured to the distal end of pipe **33** to close the pipe during normal use.

In the event accumulating and chilling apparatus **10** is employed in a refrigeration system using either a high or low side float control (not shown), equalizing nipples **35** and **36** are secured to shell **11** to, respectively, communicate with the liquid and vapor portions of chamber **16**. Conduit means (not shown) may be connected to each of the equalizing nipples **35** and **36** and to the high or low side float control (not shown), in the manner well known to those skilled in the art, to provide for proper operation of the float control. If equalizing connections **35** and **36** are not required, each connection can be closed by a cap **37** turned on their respective threaded end portions.

In FIG. 4 is schematically shown a forced circulation refrigeration system employing accumulating and chilling apparatus **10** according to one embodiment of this invention. In this embodiment, the components thereof are so arranged that the head pressure of the condensed liquid refrigerant provides for forced flow of refrigerant through accumulating and chilling apparatus **10**.

The forced circulation refrigeration system shown in FIG. 4 comprises the compressor **30** connected to receive gaseous refrigerant, from the gas space of chamber **14** of accumulating and chilling apparatus **10**, via suction pipe **29**. The compressor **30** is driven by a motor **38** in a suitable manner. A discharge pipe **39** is connected, at one end, to compressor **30** and, at the opposite end, to a condenser **40** to receive and conduct compressed, gaseous refrigerant from the compressor to condenser **40**. The condenser may be of any suitable type, such as a shell and tube type, herein illustrated, or an evaporative condenser, wherein gaseous refrigerant is flowed in indirect heat exchange relationship with a cooling fluid, such as water or air, to thereby be condensed. Condenser refrigerant is conducted from condenser **40** by a pipe **41** which is connected at one end to inlet connection **26** of chiller **15** and at the opposite end to the condenser. A trap **42** is disposed in pipe **41** to provide a liquid seal and to pass only liquid refrigerant. The trap **42** may be of the type manufactured by Armstrong Machine Works of Three Rivers, Michigan, U.S.A. If the system employes a receiver connected to receive refrigerant from a condenser and between which components a means for effecting a liquid seal is provided, a pressure regulating valve (not shown) may be connected in pipe **41** in place of trap **42**. To control flow of fluid through pipe **41**, valves **43** and **44** may be positioned on the upstream and downstream sides of trap **42**. As previously mentioned, chiller **15** is connected, through inlet connection **23**, to receiver a fluid to be cooled, such as water employed in an air conditioning system, and to discharge cooled fluid via outlet

connection 24. The heated and, at least, partially vaporized refrigerant discharges from tubes 18 (FIG. 1) into chamber 14, the gaseous refrigerant being withdrawn from the vapor space of chamber 14 (FIG. 2) through outlet connection 28 and suction pipe 29 to compressor 30.

The above described system is provided with the conventional low pressure safety control means (not shown) which is in communication with suction pipe 29. To prevent freeze-up of chiller 15 at very low load conditions a bypass pipe 45 and a pressure regulating valve 46 is provided in the system. Bypass pipe 45 is connected, at one end, to compressor discharge pipe 39 and, at the opposite end, to injection pipe 31 to conduct controlled amounts of hot, gaseous refrigerant into chamber 14. The pressure regulating valve 46 is set to pass hot, gaseous refrigerant at a predetermined minimum suction pressure which is slightly above the pressure at which the low pressure safety means is adjusted to terminate operation of the system. Under the low load condition where suction pressure reaches the minimum value for which pressure regulating valve 46 is set, hot, gaseous refrigerant flows through pipe 45 and is discharged into the liquid refrigerant in chamber 14 through injection pipe 31. The introduction of hot, gaseous refrigerant maintains a substantially constant predetermined pressure in chamber 14 corresponding to a temperature above freezing to thereby prevent freeze-up of chiller 15. On-off valves 47 and 48 are disposed in pipe 45 on opposite sides of pressure regulating valve 46.

In FIG. 5 is diagrammatically shown a forced circulation refrigerating system employing accumulating and chilling apparatus 10 according to another embodiment of this invention. This embodiment differs from the embodiment shown in FIG. 4 in that liquid refrigerant is forced to flow through tubes 18 of chiller 15 by a mechanical means rather than head pressure. In this embodiment parts corresponding to the like parts of the system shown in FIG. 4 will be designated by the same reference numbers.

As shown in FIG. 5, pipe 41 communicates with chamber 14 to directly discharge liquid refrigerant therein instead of being connected to chiller 15 as shown in the system illustrated in FIG. 4. To provide for forced flow circulation of liquid refrigerant through chiller 15, a recirculation pipe 50 and a pump 51 is provided. The recirculation pipe 50 is connected at one end to shell 11 so as to communicate with chamber 14 and, at the opposite end, to inlet connection 26 of chiller 15. The pump 51 is connected in pipe 50 to draw liquid refrigerant from chamber 14 and force the liquid chiller 15 via inlet connection 26. As previously described, the liquid refrigerant delivered by pump 51 to chiller 15 flows through tubes 18 in direct heat exchange relationship with fluid to be cooled flowing through chamber 22 from inlet connection 23 to outlet connection 24.

The embodiment shown in FIG. 5 also provides for the prevention of freeze-up of chiller 15 at low load conditions of operation by the same bypass pipe 45, pressure regulating valve 46 and injection pipe 31 arrangement described in connection with the system of FIG. 4.

As a further alternative embodiment, accumulating and chilling apparatus 10 may be provided with a coil 53 shown in dash-dot lines in FIG. 4 submerged in the liquid space of chamber 14 and connected to pipe 41 to receive liquid refrigerant and pass the same in indirect heat exchange relationship with the low pressure and temperature liquid refrigerant in reservoir 14 to be cooled thereby and, thence, back into pipe 41 for passage to chiller 15.

It is believed now readily apparent that an improved refrigeration chilling system has been provided wherein a relatively small chiller in relation to capacity is required because of the increased heat transfer efficiency of the chiller. This increased efficiency is achieved by reason of a chiller which is completely submerged in a reservoir of refrigerant and wherein refrigerant is forced through the tubes of the chiller, thereby increasing the refrigerant film coefficient and hence increased rate of heat transfer. It is a refrigeration chilling system in which capacity control is achieved by bypassing gaseous refrigerant and injecting the same directly into the liquid refrigerant in the accomulating reservoir to place a false load on the compressor, maintain the pressure in the accumulator reservoir and, thereby prevent freeze-up of the chiller at low load conditions. The novel accumulating and chilling apparatus of this invention is efficient since it provides complete wetting by the fluid to be cooled of all of the heat transfer tubes of the chiller.

Although several embodiments of the invention have been illustrated and described in detail, it is to be expressly understood that the invention is not limited thereto. Various changes can be made in the arrangement of parts without departing from the spirit and scope of the invention, as the same will now be understood by those skilled in the art.

What is claimed is:

1. A refrigeration system having interconnected compressing means with suction connecting means, condensing means, and a combined liquid chilling evaporating means and accumulating means, the combined means comprising an outer shell, an inner shell closed at one end and open at the opposite end and positioned in the lower portion of said outer shell, means for directing refrigerant from said condensing means into the closed end of said inner shell, means for passing liquid to be chilled within said inner shell and in heat exchange relation with said refrigerant, said inner shell being so positioned within said outer shell as to be normally substantially submerged in liquid refrigerant within said outer shell, and means for injecting hot gaseous refrigerant into the outer shell and externally of said inner shell in controlled amounts at low load operating conditions to maintain a predetermined pressure in the outer shell.

2. The combination of claim 1 wherein said injecting means comprises an elongated tube having means for discharging gaseous refrigerant and a control means responsive to a predetermined minimum fluid pressure in the suction connecting means.

3. The combination claim 1 wherein said injecting means comprises an elongated tubular member having a plurality of spaced openings therein to discharge gaseous refrigerant into the liquid space of the accumulating means and a control means responsive to a predetermined minimum fluid pressure in the suction connecting means to pass sufficient amounts of hot gaseous refrigerant to maintain the pressure in the suction connecting means and vapor space of the accumulating means at a predetermined value corresponding to temperature value above the freezing point of water.

4. The combination of claim 1 wherein a said injecting means includes a bypass conduit means connected to receive hot, compressed gaseous refrigerant from the compressing means and a pressure regulating valve responsive to a predetermined minimum pressure in the suction connecting means to pass sufficient amounts of hot gaseous refrigerant through the bypass conduit means to maintain the pressure in the suction connecting means, and the vapor space of the accumulating means, a predetermined value corresponding to a temperature value above the freezing point of water.

5. The combination of claim 1 wherein said evaporating means comprises an elongated vessel closed at one end and open at the opposite end, a first tube sheet disposed adjacent the open end of the vessel, a second tube sheet disposed in close spaced relationship with the closed end of the vessel to define an inlet chamber, said first and second tube sheets and the vessel forming therebetween a heat exchange chamber and a plurality of spaced heat exchange conduits disposed to extend through

said heat exchange chamber and said first and second tube sheets to communicate at one end with the inlet chamber and at the opposite end with the liquid space of the accumulating means.

6. The combination of claim 5 wherein said heat exchange conduits are each rectangular in cross section and contain extended surface elements therein.

7. The combination of claim 1 wherein said evaporating means is disposed below the condensing means and is in communication with the condensing means to receive liquid refrigerant.

8. The combination of claim 1 wherein a recirculation conduit means is connected at one end to receive liquid refrigerant from the liquid space of the accumulating means and at the opposite end to the evaporating means to deliver liquid refrigerant to the latter and a pump means in said conduit means to force flow of liquid refrigerant through the evaporating means.

9. In a refrigeration system having a condensing means and compressing means, an accumulating and chilling apparatus comprising

(a) an outer shell defining therein an accumulating chamber having a liquid space and a vapor space,

(b) an inner shell closed at one end and open at the opposite end to communicate with the liquid space of the accumulating chamber,

(c) first tube sheet means adjacent the open end of the inner shell and second tube sheet means adjacent the opposite end to define with the closed end of the inner shell an inlet chamber,

(d) the first and second tube sheet means and the inner shell defining therebetween a heat transfer chamber,

(e) a plurality of tube means in said heat transfer chamber supported by the first and second tube sheet means so that said tube means communicates with the liquid space of the accumulating chamber and the inlet chamber,

(f) means for delivering and forcing flow of liquid refrigerant through said inlet chamber and said plurality of tube means,

(g) inlet connecting means for delivering fluid to be cooled to said heat transfer chamber and into indirect heat exchange relationship with the liquid refrigerant flowing through said plurality of tube means to thereby be cooled,

(h) an outlet connecting means for conducting cooled fluid from the heat transfer chamber to a place of use or storage,

(i) a suction connecting means secured to said outer shell to communicate with the vapor space of the accumulating chamber to receive gaseous refrigerant fluid and deliver the same to the compressing means, and

(j) an injecting means in said outer shell for introducing hot, compressed, gaseous refrigerant into the liquid space of the accumulating chamber,

(k) means including control means for communicating the injecting means with the compressing means to conduct hot, compressed gaseous refrigerant to the injecting means at a predetermined minimum pressure in said suction connecting means.

References Cited

UNITED STATES PATENTS

2,344,215	3/1944	Saling	62—196
2,718,766	9/1955	Imperatore.	
3,270,517	9/1966	Clark	62—196 XR

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U.S. Cl. X.R.

62—278, 512