May 13, 1969 J. S. KNONICK 3,443,394

WATER CHILLER WITH IMPROVED FREEZE-UP PROTECTION

Filed Aug. 23, 1967

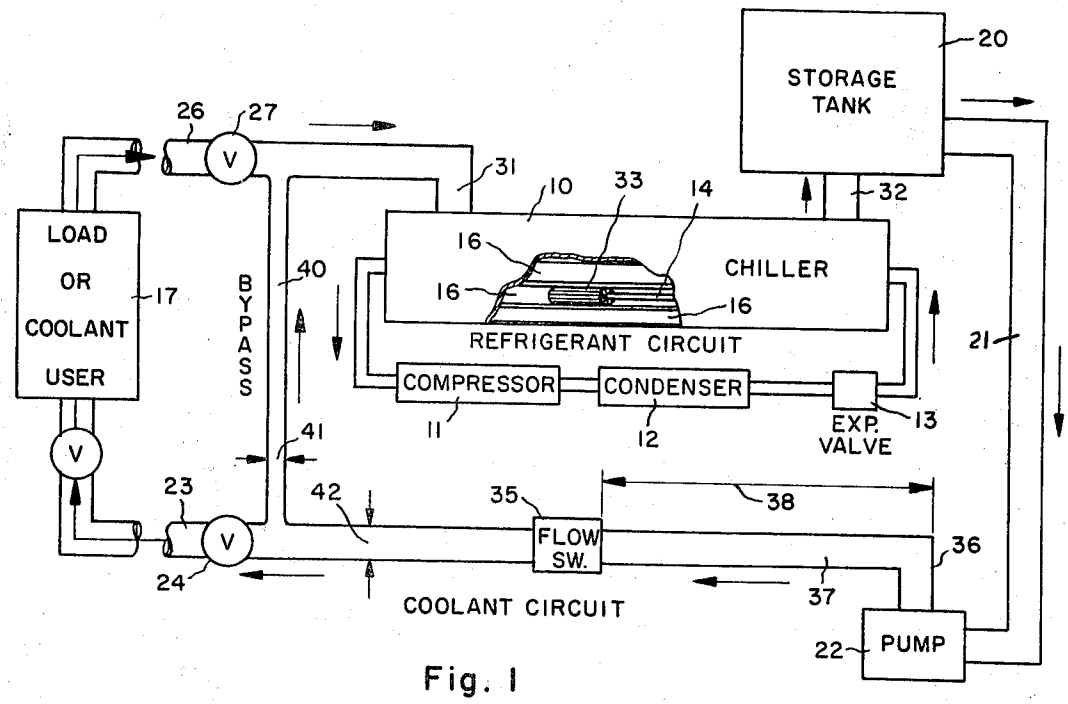


Fig. 1

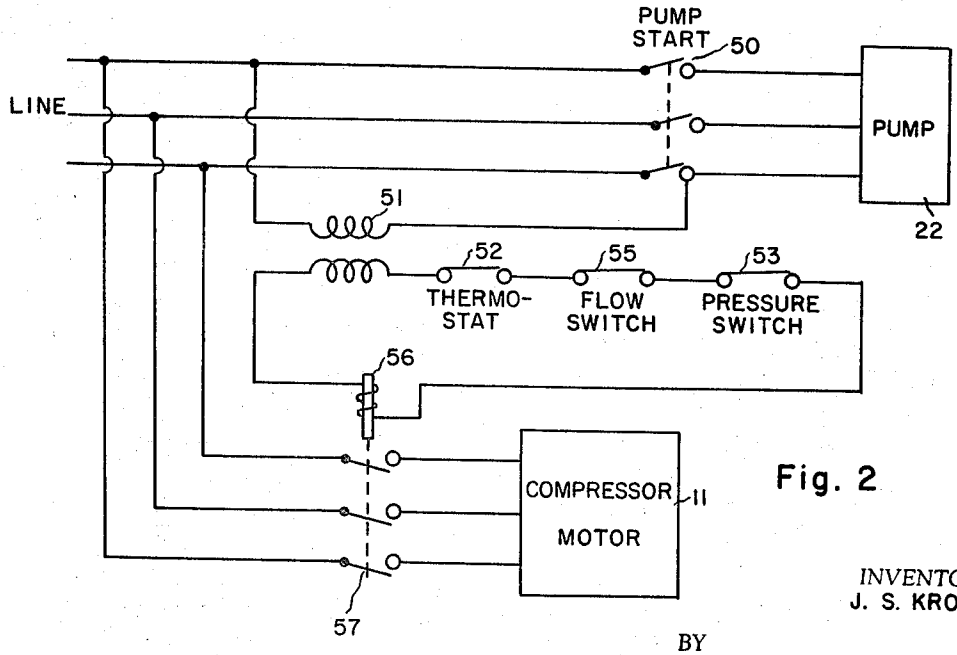


Fig. 2

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United States Patent Office 3,443,394
Patented May 13, 1969

3,443,394

WATER CHILLER WITH IMPROVED FREEZE-UP PROTECTION

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Filed Aug. 23, 1967, Ser. No. 662,606
Int. Cl. F25d 17/00
U.S. Cl. 62—139 10 Claims

ABSTRACT OF THE DISCLOSURE

A water chiller with improved freeze-up protection device comprising a positive flow switch arranged in series in the coolant circuit to deactivate the refrigerant compressor when the coolant flow falls below a minimum level, which is constantly maintained in the absence of coolant demand by a by-pass circuit. A feature of the invention is to locate the flow switch downstream from the coolant circulator pump at least five pipe diameters from the closest pipe discontinuity on the upstream side.

This invention relates to fluid chiller apparatus, and in particular to a fluid chiller with an improved freeze-up protection device.

Fluid chillers, specifically water chillers, perform important duties in various industrial applications, for example, special cooling of solution temperatures in chemical processing, temperature control of laminating machine rolls, and plastic mold and extrusion cooling. These applications require coolant temperatures from, for example, −10° F. to +60° F., to close tolerances in capacities ranging from, say, 0 up to 40 gals./min. When the coolant temperature requirement is approximately +40° F. or below, an anti-freeze substance, as for example ethylene glycol, is mixed in with the water to prevent freezing and enable the coolant to remain in the liquid state.

It is imperative that the coolant be prevented from freezing in the system, for several reasons. First, the coolant is chilled in a so-called chiller unit comprising a finned heat exchanger in which the gaseous refrigerant expands and absorbs heat from the water while the latter flows through small diameter pipes to increase the heat transfer efficiency. Should any icing occur in the water pipes in the chiller unit, even in relatively tiny amounts, the water flow is retarded, accentuating the freezing even more, with the possible consequence of causing a build-up of ice within the narrow tubes cracking them and destroying the chiller unit. Second, any reduction or loss of coolant can cause serious damage to the equipment depending on the coolant for proper operation. For example, without proper cooling of plastic molds or extrusion equipment, which frequently requires coolants at +20° F. or lower, excessive temperatures may result causing burning and gumming of the plastic material, plastic material back-up, mold damage, and other destruction. In addition, inoperativeness of the water chiller equipment means inoperative production equipment and the financial loss attendant thereon.

The standard solution to this vexing problem in commercial water chillers is to include a freezestat protective device in the equipment. This is simply a thermostat located in the chiller unit at the discharge water outlet. Normally the safety thermostat is set to operate 10° below the expected coolant temperature. However, this has not been a fully satisfactory solution to the problem. Since the freezestat only senses temperature at one point, should conditions arise causing the temperature at a different point in the chiller to be lower, then freeze-up can still occur at the latter point. Also, when operating with anti-freeze in the system, if for one reason or another, such as loss of liquid when changing lines, the anti-freeze concentration falls, then freeze-up will occur even at the expected coolant temperature.

An object of the invention is fluid chiller apparatus incorporating an improved freeze-up protection device.

A further object of the invention is water chiller apparatus incorporating a highly-sensitive, fast-acting safety device providing fail-safe deactivation of the refrigeration whenever freezing conditions prevail anywhere in the system regardless of the reasons therefor.

Still another object of the invention is water chiller apparatus provided with a safety device to protect against freeze-up of the coolant which does not depend for its operation on the temperature of the coolant.

These and other objects of the invention as will appear hereinafter are attained with my novel chiller apparatus which incorporates as the freeze-up protection device a positive-acting flow switch arranged in series in the coolant line to respond instantly to any retarding of the coolant flow. To prevent the flow switch from being activated when the demand is reduced to a low level or completely interrupted, I provide a by-pass line in the system which is related to the main discharge line in such a manner as to maintain a minimum flow of the coolant constantly through the chiller irrespective of the user demand. Because of the sensitivity of the series flow switch, I have found it necessary to mount the flow switch downstream of the circulator pump at least a minimum distance from the nearest pipe discontinuity upstream of the flow switch which could be causing turbulence in the coolant capable of activating the flow switch even though no freezing conditions are present. This prevents unnecessary deactivation of the refrigerator which increases the downtime of the chiller and the equipment dependent thereon.

An exemplary embodiment of the invention will now be described in detail, reference being had to the accompanying drawing wherein:

FIG. 1 is a schematic view of one form of water chiller apparatus in accordance with my invention;

FIG. 2 is an electrical wiring diagram of the water chiller apparatus illustrated in FIG. 1.

I will now describe with reference to FIGS. 1 and 2 one embodiment of my invention actually reduced to practice as a commercial water chiller, though I wish it to be understood that it is merely illustrative of my invention and the principles outlined below can be used in any form of fluid chiller or refrigeration apparatus operated under conditions under which the fluid may freeze causing damage to the system.

The chiller according to my invention comprises a coolant circuit comprising a chiller unit **10** wherein the coolant fluid is brought into intimate heat exchange relationship with a refrigerant which upon evaporation absorbs heat from the coolant. The refrigerant circuit comprises the traditional refrigeration system including a compressor **11** operated by a motor not shown in which the gaseous refrigerant is compressed and then passed to a condenser **12** wherein the compressed gas is converted back into the liquid state. The liquid refrigerant is then passed through a standard expansion valve **13** and the expanding gas passed through the refrigerant tubes **14** in the chiller **10**.

The chiller **10** also contains a set of tubes **16** for the coolant circuit. The coolant returned from the load or user **17** is passed through the chiller unit **10** wherein it is cooled down to the desired temperature and then passed into an insulated storage tank **20**. Fluid from the outlet of the storage tank **20** is conveyed via a conduit **21** to the circulator pump **22** which drives the coolant through the system, to the load **17** and back. The discharge outlet of the apparatus is a conduit **23** which may

be shut off by a shut-off valve **24**. The return or inlet line is a conduit **26** also provided with a shut-off valve **27**.

The chiller **10** is of a type in wide commercial use because of its high heat exchange efficiency. It comprises, as described above, a bundle or assembly of chiller tubes **16** all connected at one end to a common coolant inlet **31** and at the opposite end to a common coolant outlet **32**. Within the chiller tubes **16** are a series of radial copper fins **33** in intimate contact with the coolant. The refrigerant passes through an inner coaxial tube **14** within each of the chiller tubes **16**. In a typical unit commercially available from Dunham-Bush, the chiller tubes **16** are only ¼ inch O.D. With the inner-fin construction, it will be evident that the coolant passages are extremely small. As a result, even the slightest amount of ice formation immediately reduces very sharply the coolant flow to a low level, which has the effect of augmenting the freezing condition producing quite rapidly ice build up in the small coolant passageways leading very rapidly to cracking of the copper tubes by the expanding ice and destruction of the unit. Thus, with these highly efficient heat exchangers it is imperative that the freezing condition wherever it arises be sensed quickly and the compressor **11** deactivated.

I have found that sensing temperature is not a fully satisfactory method of overcoming the problem. I have further found that the existence of an icing condition anywhere in the system instantly manifests itself as a sharp reduction in coolant flow through the system. My invention is to sense the water flow rate, not the temperature, to provide fail-safe freeze-up protection. In my invention, I arrange a positive-acting flow switch **35** in series in the system to detect coolant flow rates and to deactivate the compressor motor when the flow rate falls below a preset level. I have found that satisfactory results are obtained with a paddle type flow switch of the type manufactured by McDonnell & Miller as the FS4 series flow switch. This flow switch incorporates a paddle extended directly into the coolant flow and designed to keep electrical switch contacts closed only while at least a minimum flow rate exists. Should the flow rate fall below the preset minimum, the switch contacts open.

Such flow switches are fast-acting, dependable and highly sensitive. I have further found that they respond to water turbulence and will operate even though the minimum flow rate is exceeded. A further feature of my invention is to locate the flow switch **35** downstream of the circulator pump **22** and at least five pipe diameters from the nearest discontinuity on the upstream side. As noted in FIG. 1, the coolant discharged by the pump passes through an elbow **36** from whence it travels in a straight pipe section **37** to the flow switch **35**, located a distance **38** of at least five pipe diameters from the elbow **36**. For instance, with 1⅛ inches piping **37**, I locate the flow switch at least 5⅝ inches from the elbow **36** to ensure that coolant turbulence due to the pump **22** or the elbow **36** is minimized when the flow switch **35** is reached.

In order to render the chiller apparatus independent of user demand and to assure that the minimum flow rate to keep the flow switch contacts closed is maintained, I provide a by-pass line **40** connecting the outlet and inlet of the system. The diameter **41** of the by-pass conduit must bear a certain relationship to the diameter **42** of the outlet and inlet pipes to assure the minimum desired flow rate independent of user demand but without sacrificing unduly the equipment capacity. The size of the by-pass line is determined by the desirability of maintaining the chiller temperature as close as possible to the coolant temperature, generally not more than 5° F. difference, to optimize efficiency, which establishes a minimum flow rate. It also depends on the minimum flow rate specification of the flow switch, and it further depends on the user demand capacity which tends to withdraw coolant from the by-pass line. With the type FS4 paddle type flow switch above described and 1⅛ inch O.D. discharge and return lines in the equipment, I have found a suitable diameter for the by-pass line to be ½ inch O.D. All of the piping mentioned has a 0.032 inch wall thickness. The particular flow switch mentioned opened its contacts when the flow rate fell below about 6 gals./min. The system above described operated extremely well without freeze-up under the usual operating conditions and without false shut-offs leading to short cycling due to coolant turbulence. Attempts to locate the flow switch downstream of the storage tank **20** or closer to the pump **22** proved unsatisfactory due to the high coolant turbulence. A further advantage of my invention is that the continuous coolant flow via the by-pass line, independent of user demand, providing a constant liquid flow over the heat exchanger surfaces in the chiller unit **10** assures a close temperature relationship between the refrigerant and the coolant optimizing efficiency of the system.

FIG. 2 shows the electrical wiring diagram of the system. The 3-phase power input from the line is fed directly to the circulator pump **22** via a manual pump start-stop switch **50**. This enables the pump to be activated apart from the refrigeration circuit. Across two of the phases is connected via a coupling transformer **51** a control circuit comprising the normally-closed contacts **52** of the usual temperature controlling thermostat, the normally closed contacts **53** of a standard pressure switch, and the contacts **55** of the series flow switch **35**. The circuit also includes a relay coil **56** which when energized closes normally-open contacts **57** connecting the 3-phase line to the compressor motor **11**. With the pump activated, and nothing in the system to retard the coolant flow, the flow switch contacts **55** are closed. Until the coolant is brought down to the desired operating temperature, the thermostat contacts remain closed, and the pressure switch contacts remain closed when normal pressure conditions prevail. As a result, the relay **56** is energized supplying power to the compressor **11**. Should the coolant flow be retarded, the flow switch contacts **55** open immediately terminating the electrical power to the compressor.

Although the present invention has been illustrated in connection with a water chiller, it will be appreciated that it is also applicable to chiller equipment for liquids other than water.

While there has been shown and described a preferred embodiment of the invention which has been found in actual commercial structures to give entirely satisfactory and reliable results, it will be obvious to those skilled in the art that various changes, modifications, additions and subtractions may be made therein without departing from the spirit of the invention.

What is claimed is:

1. Chiller apparatus comprising a heat exchanger, a refrigerant circuit for passing a heat absorbable medium through the heat exchanger, said refrigerant circuit including a compressor, a coolant circuit for passing fluid coolant through the heat exchanger for cooling thereof, said coolant circuit including a circulator pump for driving the coolant through the coolant circuit, said apparatus being capable of reducing the temperature of the coolant to a point where a freezing condition may occur in the system causing a reduction in the rate of flow of the coolant, means in the coolant circuit and activated by the coolant flow rate to directly respond to a reduction in the coolant flow rate and coupled to the compressor for deactivating same when the flow rate falls below a minimum level, and means including a by-pass line in the coolant circuit for maintaining a constant coolant flow rate therein above the said minimum level irrespective of user demand and in the absence of the occurrence of a freezing condition.

2. Chiller apparatus as set forth in claim **1** wherein the coolant flow rate responsive means comprises a flow switch connected in series in the coolant circuit and having electrical contacts which are normally closed when the flow rate exceeds the said minimum level and which

contacts open when the flow rate falls below the said minimum level, said contacts being in an electrical circuit coupling the power line to the compressor.

3. Chiller apparatus as set forth in claim 2 wherein the flow switch comprises a paddle-type flow switch directly activated by the coolant flow.

4. Chiller apparatus as set forth in claim 2 wherein the heat exchanger comprises a bundle of tubes within the coolant circuit including inner-finned tubes forming small passageways, the occurrence of the freezing condition immediately reducing the cross-section of the passageways reducing the flow rate.

5. Chiller apparatus as set forth in claim 2 wherein the by-pass line is connected in parallel with the user load, said by-pass line having a diameter so related to the diameter of the coolant circuit outlet line as to maintain a constant coolant flow through the heat exchanger independent of user demand, said constant coolant flow exceeding the said minimum level in the absence of a freezing condition.

6. Chiller apparatus as set forth in claim 5 wherein the outlet line has a diameter of about 1⅛", and the by-pass line has a diameter of about ½".

7. Chiller apparatus as set forth in claim 2 wherein the circulator pump is connected directly to the power line via a start-stop switch, the flow switch contacts are included in an electrical circuit energized when the pump is energized and further including a relay whose contacts are included in the compressor electrical circuit, whereby upon opening of the flow switch contacts due to retardation of the coolant flow, the relay is deenergized and the compressor circuit opened.

8. Chiller apparatus as set forth in claim 1 wherein the heat exchanger comprises passageways of smaller size than that of the coolant circuit, and the coolant flow rate responsive means comprises a flow switch directly activated by the coolant flow and having electrical contacts in an electrical circuit coupling the power line to the compressor.

9. Chiller apparatus as set forth in claim 8 wherein the flow switch is arranged in the coolant circuit downstream of the circulator pump.

10. Chiller apparatus as set forth in claim 9 wherein the flow switch is located at least five pipe diameters from the nearest upstream discontinuity in the coolant circuit.

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