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(54) START-UP PROCEDURE FOR REFRIGERANT SYSTEMS HAVING MICROCHEMICAL CONSENSOR AND REHEAT CYCLE

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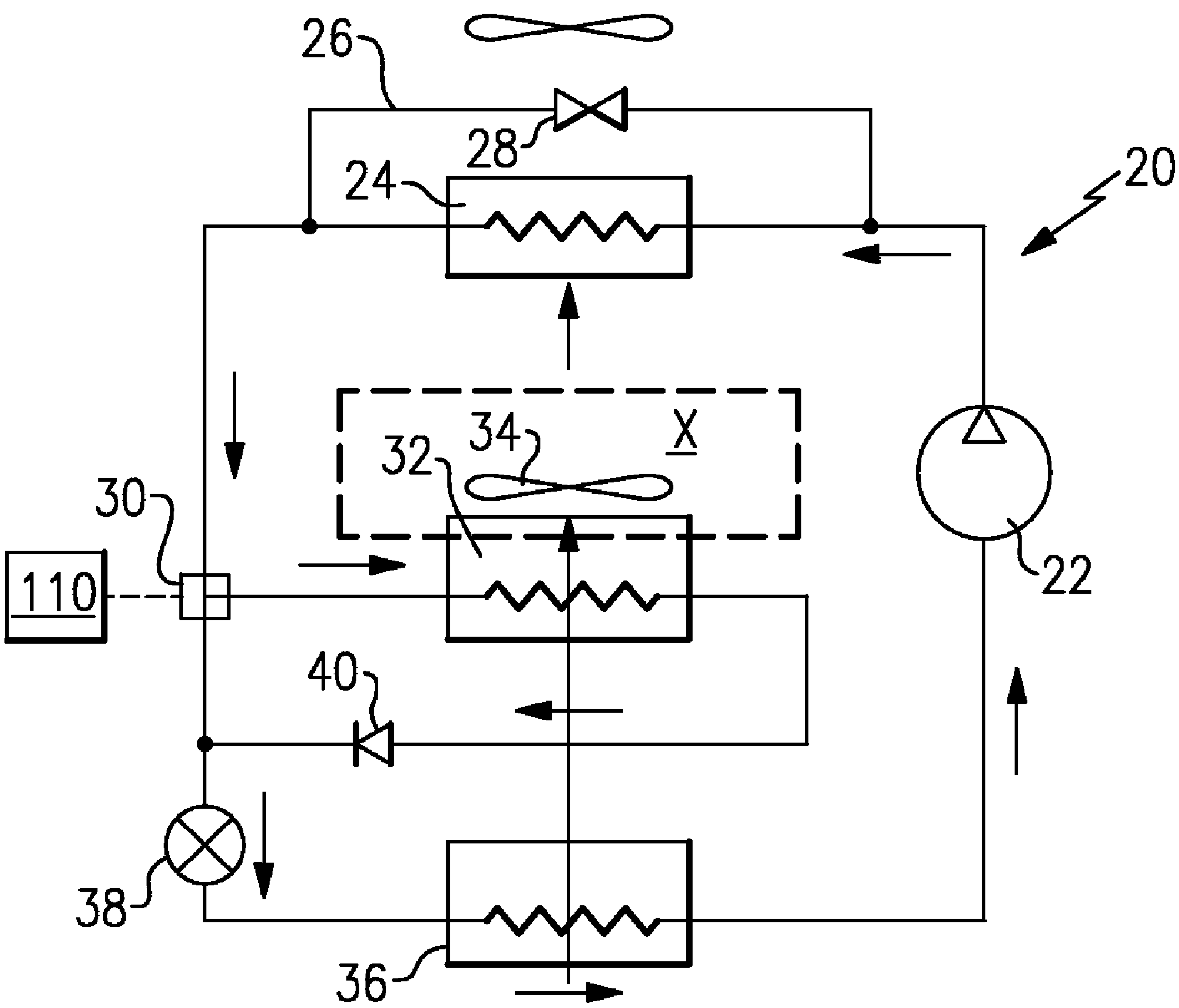
(57) **ABSTRACT**

A refrigerant system has a condenser of microchannel design and construction and includes a reheat cycle. The reheat cycle includes a refrigerant flow control device, such as a three-way valve, for selectively routing at least a portion of refrigerant through a reheat heat exchanger from a location between a compressor and expansion device. A control for the refrigerant system selectively actuates this refrigerant flow control device to route at least a portion of refrigerant through the reheat heat exchanger at system start-up.



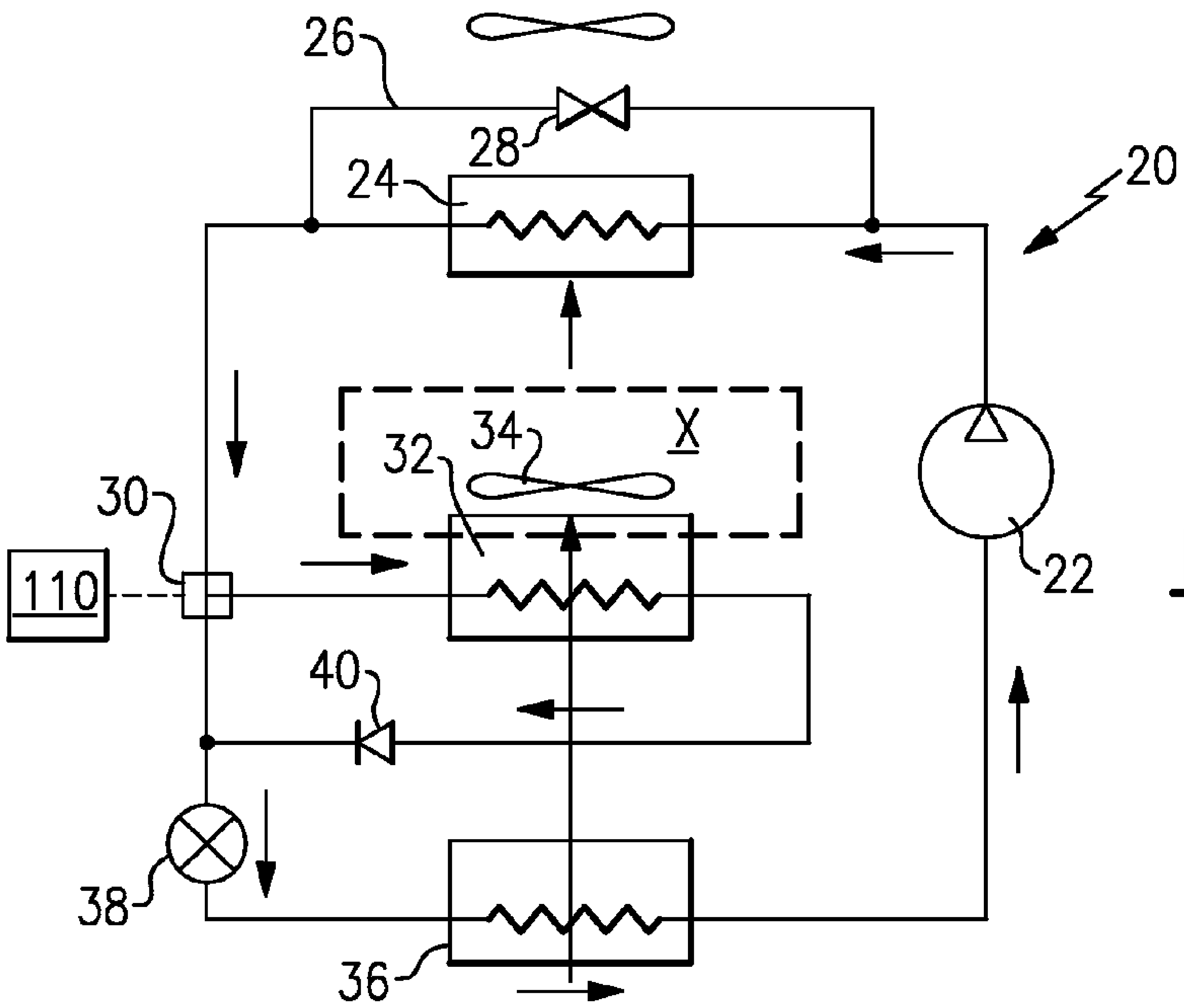


FIG.1A

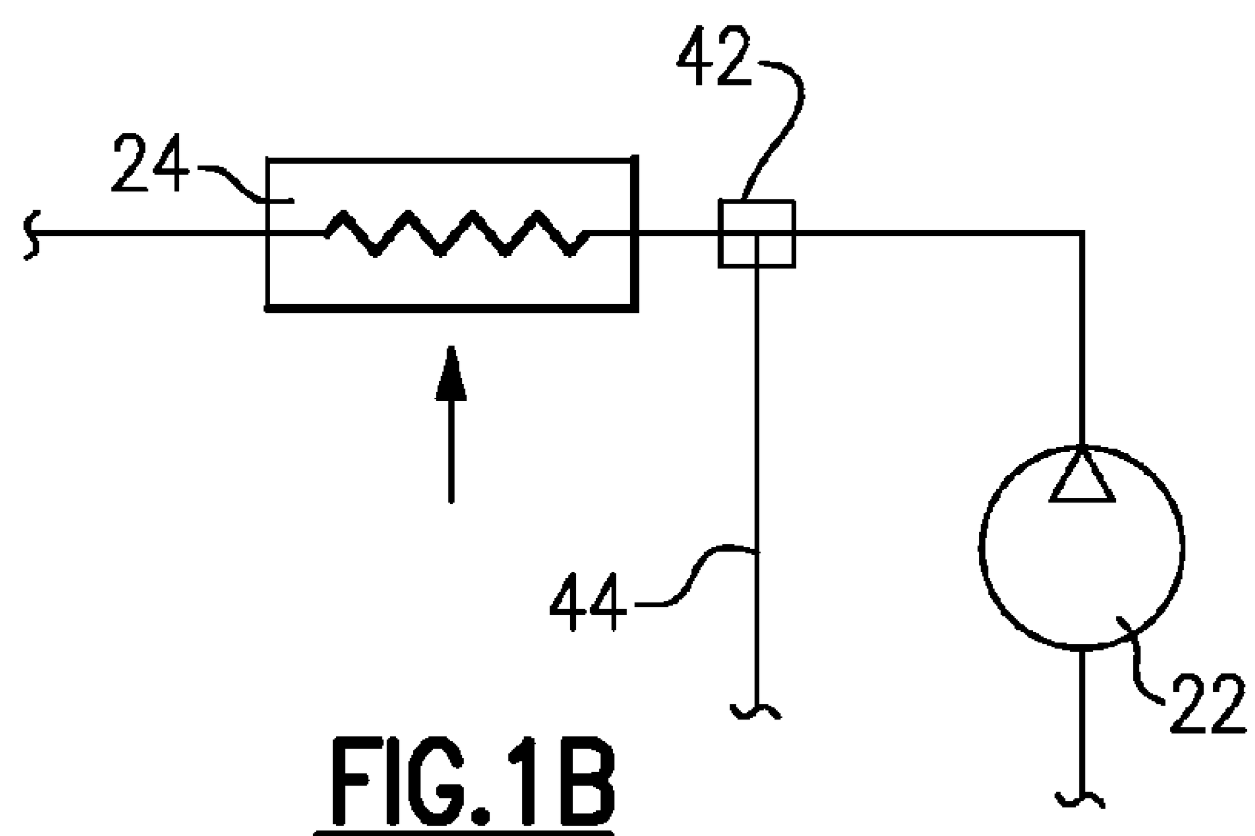


FIG.1B

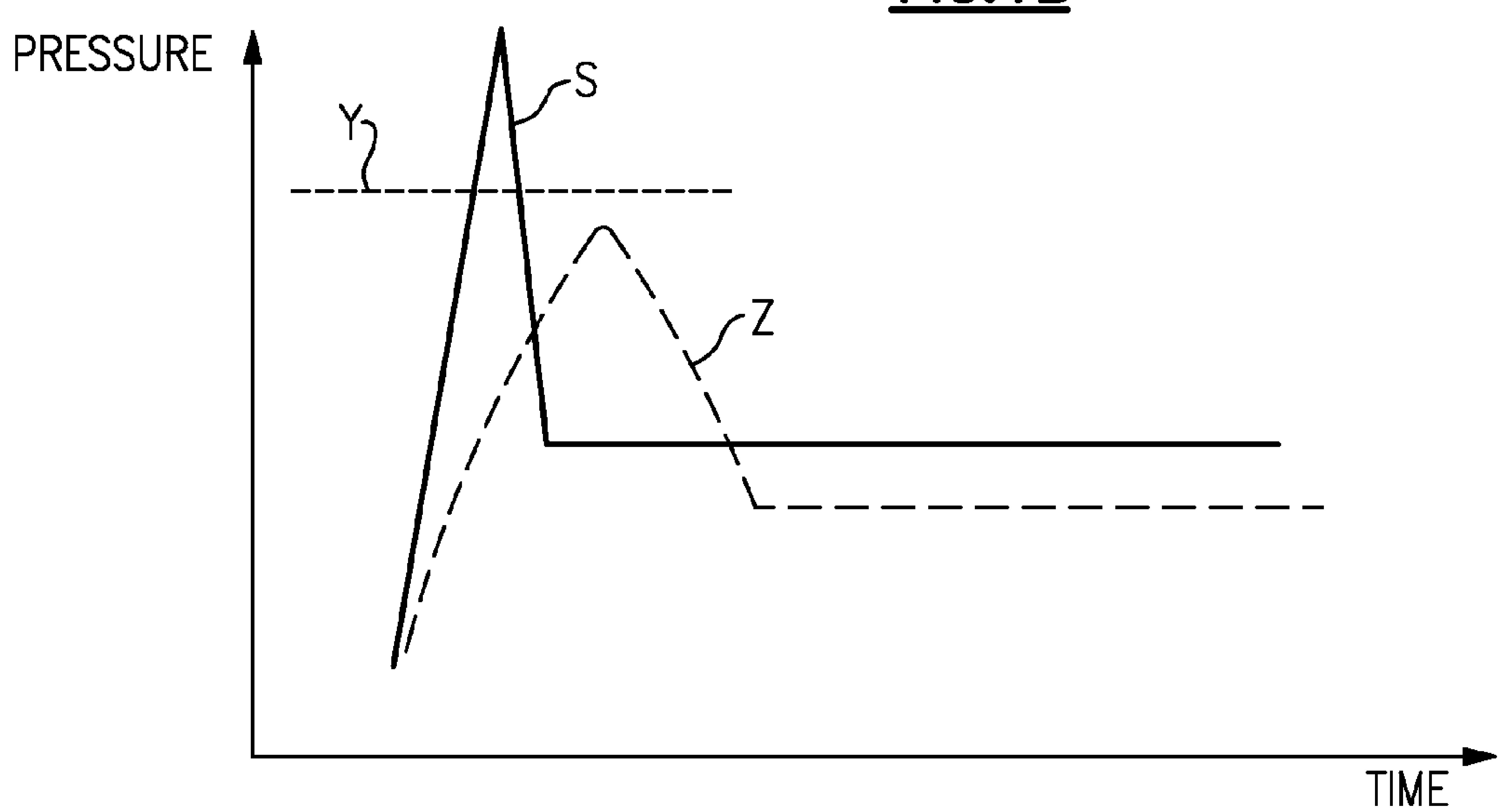


FIG.3

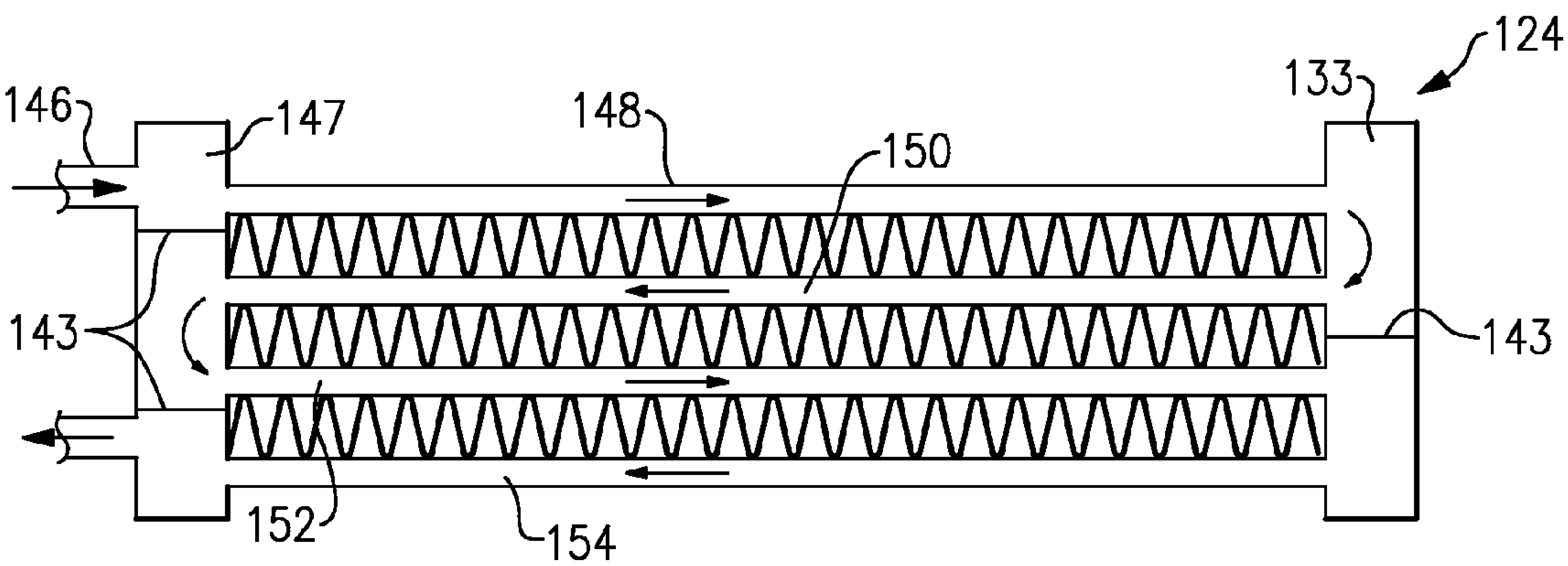


FIG.2A

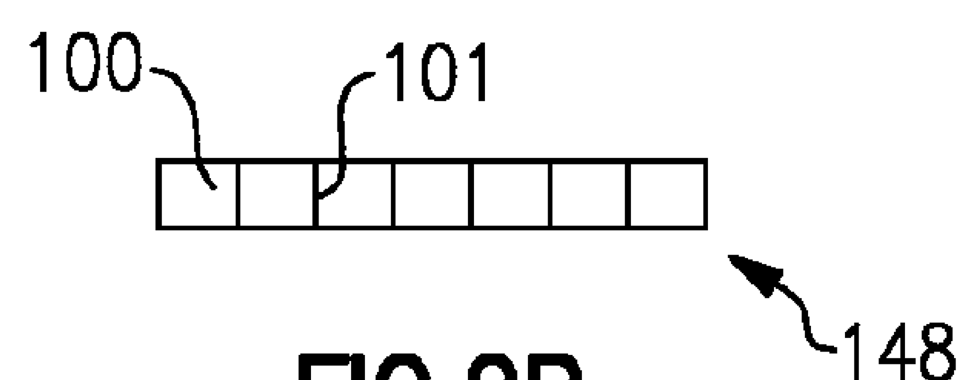


FIG.2B

START-UP PROCEDURE FOR REFRIGERANT SYSTEMS HAVING MICROCHEMICAL CONSENSOR AND REHEAT CYCLE

RELATED APPLICATIONS

[0001] This application claims priority to U.S. Provisional Patent Application No. 61/061,142, which was filed Jun. 13, 2008.

BACKGROUND OF THE INVENTION

[0002] Refrigerant systems utilize a refrigerant to condition a secondary fluid, such as air, delivered to a climate-controlled space. In a basic refrigerant system, the refrigerant is compressed in a compressor, and flows downstream to a condenser in a subcritical refrigerant cycle or to a gas cooler in a transcritical refrigerant cycle, where heat is typically rejected from the refrigerant to ambient environment, during heat transfer interaction with this ambient environment. Then refrigerant flows through an expansion device, where it is expanded to a lower pressure and temperature, and to an evaporator, where during heat transfer interaction with a secondary fluid (e.g., indoor air), the refrigerant is evaporated and typically superheated, while cooling and often dehumidifying this secondary fluid.

[0003] In recent years, much interest and design effort has been focused on the efficient operation of the heat exchangers (condenser and evaporator) of the refrigerant systems. One relatively recent advancement in heat exchanger technology is the development and application of parallel flow, or so-called microchannel or minichannel, heat exchangers (these two terms will be used interchangeably throughout the text), as the condensers and evaporators.

[0004] These heat exchangers are provided with a plurality of parallel heat exchange tubes, typically of a non-round shape, among which refrigerant is distributed and flown in a parallel manner. The heat exchange tubes are orientated generally substantially perpendicular to a refrigerant flow direction in the inlet, intermediate and outlet manifolds that are in flow communication with the heat exchange tubes. The heat exchange tubes typically have a multi-channel construction, with refrigerant distributed and flowing within these multiple channels in a parallel manner. Heat transfer fins are interdisposed in between and rigidly attached to heat exchange tubes. The primary reasons for the employment of the parallel flow heat exchangers, which usually have aluminum furnace-brazed construction, are related to their superior performance, high degree of compactness, structural rigidity, lower weight, lower refrigerant charge and enhanced resistance to corrosion.

[0005] One concern with utilizing microchannel heat exchangers, also related to their advantage, is their low internal volume. Due to low internal volume, microchannel heat exchangers are more susceptible to refrigerant pressure variations due to instantaneous changes in refrigerant flow throughout the refrigerant circuit. Microchannel heat exchangers are also very sensitive to refrigerant charge amounts, with even a small amount of extra refrigerant charge in the system leading to higher than desirable discharge operating pressures and instantaneous pressure spikes. These problems are especially pronounced during start-ups. Nuisance interruptions of the refrigerant system operation can be a result of emergency shutdown by control software on a high pressure alarm or by mechanical safety, such as a high pressure switch, leading to complete inability to operate the refrigerant system, if a discharge pressure spike exceeded predetermined allowable safe limit (typically for a preset number of times). This consequently would results in a failure to keep a climate-controlled environment within desirable temperature and humidity ranges, leading to occupant discomfort and liability claims. Under certain circumstances, repeated starts and shutdowns in short periods of time can potentially lead to a compressor failure.

[0006] Another refrigerant cycle component is a reheat cycle utilizing primary refrigerant circulating throughout the main refrigerant circuit. In the reheat cycle, at least a portion of refrigerant passes through a reheat heat exchanger which is positioned in the path of air flowing across the evaporator. The reheat heat exchanger is typically positioned in the path of the air downstream of the evaporator. With a reheat cycle actuated, air can be cooled in the evaporator below normally desirable temperature, allowing for a greater amount of moisture removal from the air stream. The air then passes over the reheat heat exchanger and is heated back toward the target temperature. Typically, reheat cycles are provided with a refrigerant flow control device, such a three-way valve, that can selectively route at least a portion of refrigerant through the reheat heat exchanger when reheat is desired. The reheat cycle has not been operated at system start-up, in order to prevent high pressure spikes and nuisance refrigerant system shutdowns.

SUMMARY OF THE INVENTION

[0007] A refrigerant system has a compressor delivering a compressed refrigerant to a condenser. Refrigerant from the condenser passes through an expansion device and an evaporator. From the evaporator it is returned to the compressor. The condenser is a microchannel heat exchanger. A reheat cycle includes a refrigerant flow control device for selectively routing at least a portion of refrigerant through a reheat heat exchanger. The reheat heat exchanger is positioned in a path of air that has passed over the evaporator. A control for the refrigerant system selectively actuates a switch to route refrigerant through a reheat heat exchanger at system start-up.

[0008] In one embodiment, the reheat cycle may also be actuated at certain environmental and operating conditions, when high pressure spikes are expected to occur. Such conditions may include, for instance, high ambient temperatures, higher operating speeds of variable speed compressors and a higher number of active tandem compressors. These environmental and operating conditions may be pre-programmed and stored in the memory of the refrigerant system controller.

[0009] These and other features of the present invention can be best understood from the following specification and drawings, the following of which is a brief description.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] FIG. **1**A shows a first embodiment schematic.

[0011] FIG. **1**B shows an alternative embodiment.

[0012] FIG. **2**A shows an exemplary microchannel heat exchanger.

[0013] FIG. **2**B is a cross-section through a portion of FIG. **2**A.

[0014] FIG. **3** is a graph showing start-up utilizing the disclosed method.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

[0015] A refrigerant system **20** is illustrated in FIG. **1**A and includes a compressor **22** delivering refrigerant into a discharge line heading to a condenser **24**. The condenser **24** is a parallel flow heat exchanger, and in one disclosed embodiment is a microchannel or minichannel heat exchanger. As mentioned above, these terms are used interchangeably here.

[0016] Heat is transferred in the condenser **24** from the refrigerant to a secondary fluid, such as ambient air. The high pressure, desuperheated, condensed and typically subcooled, refrigerant passes from the condenser **24** into an expansion device **38**, where it is expanded to a lower pressure and temperature. Downstream of the expansion device **38**, refrigerant flows through an evaporator **36** and back to the compressor **22**. As known, the heat exchanger **24** operates as a condenser in subcritical applications and as a gas cooler in transcritical applications. Nevertheless, although both applications are within the scope of the invention, the heat exchanger **24** will be referred throughout the text as a condenser.

[0017] A reheat cycle is incorporated into the refrigerant system **20**. As known, a refrigerant flow control device such as a three-way valve **30** selectively routes at least a portion of refrigerant downstream of the condenser **24** and through a reheat heat exchanger **32**. An air-moving device such as a fan **34** blows air over an evaporator **36**, and over the reheat heat exchanger **32**. That is, the reheat heat exchanger **32** is positioned indoors, along with the evaporator **36**, and downstream, with respect to the air flow, of the evaporator **36**. As mentioned above, essentially, the reheat cycle is selectively actuated by opening (fully or partially) the three-way valve **30** to direct at least a portion of refrigerant through the reheat heat exchanger **32** when dehumidification in a climate-controlled environment X is desired. Under such circumstances, the refrigerant system is controlled such that the evaporator **36** cools the air to a temperature below that is desired in the environment to be conditioned X, which allows removing an additional amount of moisture from the air to be delivered to the conditioned environment X. As the air passes over the reheat heat exchanger **32**, it is reheated toward the target temperature. As a result, temperature and humidity control are achieved in the climate-controlled environment X.

[0018] Downstream of the reheat heat exchanger **32**, there is an optional check valve **40**. Further, as shown, a condenser bypass line **26** selectively bypasses at least a portion of refrigerant around the condenser **24** and includes a refrigerant flow control device such as a valve **28**. This allows for achieving variable dehumidification capability, or variable sensible heat ratios. The valve **28** can be adjustable (through modulation or pulsation) or of an on/off type.

[0019] FIG. **1**B shows an alternative embodiment wherein the reheat cycle three-way valve **42** is positioned upstream of the condenser **24** and delivers at least a portion of refrigerant through a reheat refrigerant line **44** to a reheat heat exchanger (not shown). For purposes of this application, the exact location of the three-way valve **42** and the reheat heat exchanger **32** is not critical, provided they are both located on the high pressure side of the refrigerant system **20**. Also, as known, the three-way valves **30** and **42** can be replaced by a pair of conventional valves performing identical refrigerant routing function.

[0020] As shown in FIG. **2**A, an inlet line **146** downstream of the compressor **22** delivers refrigerant into a first bank of parallel heat exchange tubes **148**, and then across the condenser core to a first chamber of an intermediate manifold structure **133**. From the intermediate manifold structure **133**, the refrigerant passes back through a second bank of parallel heat exchange tubes **150** to an intermediate chamber in the manifold **147**. Refrigerant then passes through yet another bank of parallel heat exchange tubes **152**, returning to the intermediate manifold **133**. From the intermediate manifold **133**, the refrigerant passes through another bank of heat exchange tubes **154** back to the manifold **147**, and an outlet refrigerant line. Of course, this is simply one illustrated embodiment. It should be noted that, in practice, there may be more or less refrigerant passes than the four illustrated passes **148**, **150**, **152**, and **154**. Further, it should be understood that, although for simplicity purposes, each refrigerant pass is represented by a single heat exchange tube, typically there are many heat exchange tubes within each pass amongst which refrigerant is distributed while flowing within the pass. In condenser applications, a number of the heat exchange tubes within each bank may decrease in a downstream direction, with respect to refrigerant flow. For instance, there could be 12 heat exchange tubes in the first bank, 8 heat exchange tubes in the second bank, 5 heat exchange tubes in a third bank and only 2 heat exchange tubes in the last forth bank. Separator plates **143** are placed within the manifolds **133** and **147** to separate the chambers positioned within the same manifold structure.

[0021] As shown in FIG. **2**B, the heat exchange tubes within the tube banks **148**, **150**, **152**, and **154** may consist of a plurality of parallel channels **100** separated by walls **101**. The FIG. **2**B is a cross-sectional view of the heat exchange tubes shown in FIG. **2**A. The channels **100** allow for enhanced heat transfer characteristics and assist in improved structural rigidity of the heat exchanger. The cross-section of the channels **100** may take different forms, and although illustrated as a rectangular in FIG. **2**B, may be, for instance, of triangular, trapezoidal, oval or circular configurations. The size of the channels **100** in a microchannel heat exchanger is quite small. As disclosed, the channels could have a hydraulic diameter of less than or equal to 5 mm, and more narrowly, less than or equal to 3 mm. Notably, the use of "hydraulic diameter" does not imply the channels are circular.

[0022] As mentioned above, when microchannel heat exchangers are utilized as condensers, pressure spikes which can be particularly observed at the refrigerant system start-up, can provide a challenge to a refrigerant system designer. One concern with microchannel heat exchangers is that their internal volume is relatively small, and thus they are particularly susceptible to pressure spikes and extremely sensitive to refrigerant charge amounts. Although pressure spikes are particularly pronounced at refrigerant system start-up, they can be also observed at changes of operating conditions such as, for instance, a sharp increase of the compressor speed or activating a larger number of tandem compressors, in order to satisfy thermal load demands in the conditioned space X.

[0023] In this invention, the reheat circuit is actuated at refrigerant system start-up. Now, when the refrigerant is passing through both the condenser **24**, and through the reheat heat exchanger **32**, there is a larger combined internal volume on a high pressure side of the refrigerant system, and the amplitude of the pressure spike is thus reduced. In some instances, all of the refrigerant could pass through the reheat heat exchanger **32**.

[0024] As shown in FIG. **3**, with a conventional start-up S, and without the reheat circuit being actuated, a pressure spike can be relatively high, and may exceed the safety limit Y. With the present application, and as shown at Z in FIG. **3**, the amplitude of the pressure spike is greatly reduced, due to the combined internal volume of the heat exchangers **24** and **32**. In this manner, the pressure spike may well be below the safety limit Y, and nuisance shutdowns, caused by control software operating on a high pressure alarm or by mechanical safety, such as a high pressure switch, can be avoided. This provides uninterrupted control of temperature and humidity within the desired ranges and occupant comfort in the climate-controlled environment. Furthermore, repeated starts and shutdowns of the refrigerant system in short periods of time will be avoided, leading to improved compressor reliability and temperature/humidity variation reduction in the conditioned space.

[0025] The reheat heat exchanger **32** can be any type of a heat exchanger, including standard heat exchangers or a microchannel heat exchanger.

[0026] A control **110** for the refrigerant system may be of any appropriate electronic control type, as is known in the art. The control would typically control all system components, and not only the three-way valve **30** that can be adjustable (through modulation or pulsation) or of an on/off type. The control **110** can actuate the reheat cycle at certain environmental and operating conditions, when high pressure spikes are likely to occur. Such conditions may include, for instance, high ambient temperatures, higher operating speeds of variable speed compressors and a higher number of active tandem compressors. These environmental and operating conditions may be pre-programmed and stored in the memory of the refrigerant system control **110**. Further, under some environment and operating conditions, it may be that there is less likelihood of a pressure spike at system start-up. Thus, the control may be programmed to not actuate the reheat cycle in these instances.

[0027] In addition, after some period of time following refrigerant system start-up, the three-way valve **30** is deactivated to block flow of refrigerant through the reheat heat exchanger **32**, unless dehumidification mode of operation is desired. This period of time can be on the order of 15 seconds to 3 minutes.

[0028] Although an embodiment of this invention has been disclosed, a worker of ordinary skill in this art would recognize that certain modifications would come within the scope of this invention. For that reason, the following claims should be studied to determine the true scope and content of this invention.

What is claimed is:

1. A refrigerant system comprising:

a compressor for delivering a compressed refrigerant to a condenser, refrigerant from said condenser passing through an expansion device, and from said expansion device through an evaporator, and from said evaporator being returned to said compressor; and

said condenser being a microchannel heat exchanger;

a reheat cycle including a refrigerant flow control device for selectively routing at least a portion of refrigerant through a reheat heat exchanger, said refrigerant flow control device being positioned to route said at least portion of refrigerant through said reheat heat exchanger from a location between said compressor and said expansion device, and said reheat heat exchanger being positioned in a path of air that has passed over said evaporator; and

a control for the system selectively actuating said switch to route at least a portion of refrigerant through said reheat heat exchanger at refrigerant system start-up.

2. The refrigerant system as set forth in claim **1**, wherein said control is also routing said at least a portion of refrigerant through said reheat heat exchanger when at least one of a start-up, compressor speed change, tandem compressor activation or high ambient temperature conditions occur.

3. The refrigerant system as set forth in claim **2**, wherein said conditions are programmed in the control to identify when to selectively actuate said refrigerant flow control device to route refrigerant through said reheat heat exchanger.

4. The refrigerant system as set forth in claim **1**, wherein a bypass is provided around said condenser to selectively bypass at least a portion of refrigerant around said condenser.

5. The refrigerant system as set forth in claim **1**, wherein said refrigerant flow control device routes said at least portion of refrigerant from a location between said compressor and said expansion device, and downstream of said compressor.

6. The refrigerant system as set forth in claim **1**, wherein said refrigerant flow control device is actuated to selectively allow for refrigerant flow through the reheat heat exchanger for at least a predetermined period of time after said condition is identified.

7. The refrigerant system as set forth in claim **6**, wherein said predetermined period of time is preferably from 15 seconds to 3 minutes.

8. The refrigerant system as set forth in claim **1**, wherein said refrigerant flow control device is one of adjustable type through modulation or pulsation or of an on/off type.

9. The refrigerant system as set forth in claim **1**, wherein said microchannel heat exchanger includes a plurality of heat exchange tube each having a plurality of parallel refrigerant channels.

10. The refrigerant system as set forth in claim **9**, wherein said microchannel heat exchanger having flow channels with a hydraulic diameter less than or equal to 5 mm.

11. The refrigerant system as set forth in claim **1**, wherein all of the refrigerant passes through said reheat heat exchanger.

12. A method of operating a refrigerant system comprising the steps of:

a) delivering a compressed refrigerant to a condenser, refrigerant from said condenser passing through an expansion device, and from said expansion device through an evaporator, and from said evaporator being returned to said compressor;

b) said condenser being a microchannel heat exchanger;

c) selectively routing at least a portion of refrigerant through a reheat heat exchanger from a location between said compressor and said expansion device, and passing at least a portion of air over said reheat heat exchanger after the air has passed over said evaporator; and

d) selectively actuating a refrigerant flow control device to route said at least portion of refrigerant through said reheat heat exchanger at system start-up.

13. The method as set forth in claim **12**, further comprising the step of routing said at least a portion of refrigerant through said reheat heat exchanger when at least one of a start-up, compressor speed change, tandem compressor activation or high ambient temperature occurs.

14. The method as set forth in claim **12**, further comprising the step of selectively allowing refrigerant flow through the reheat heat exchanger for at least a predetermined period of time after refrigerant system start-up.

15. The method as set forth in claim **12**, wherein all of the refrigerant passes through said reheat heat exchanger.

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