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(54) **Scroll compressor with reverse rotation prevention**

(57) A scroll type compressor is employed in a heat pump system having a solenoid actuated four way flow reversing valve. A processor monitors a system parameter that is indicative that a flow reversal has taken place or is about to take place, at which time the compressor motor is shut down for a predetermined period of time during which the compressor produces objectionable noise produced by separation of the scroll element due to a low pressure differential over the compressor. At the end of the period, the compressor motor is reenergized. The processor is arranged to cycle the compressor at the beginning and end of each defrost cycle or when the system undergoes a change in its operational mode.

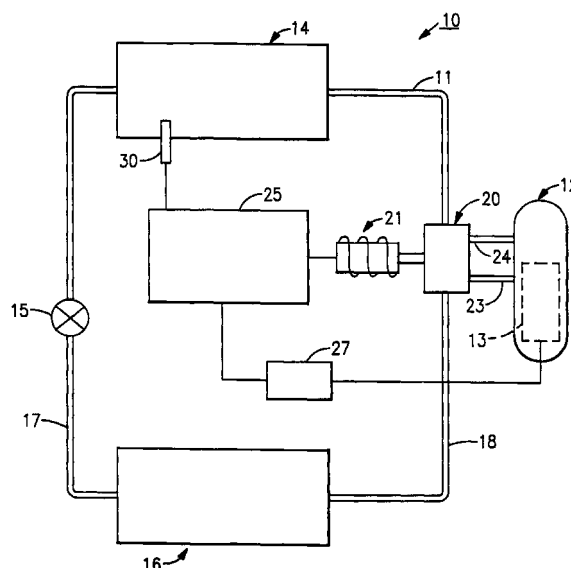


FIG.1

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Description

[0001] This invention relates to a heat pump, and in particular to a heat pump system that utilizes a scroll compressor.

[0002] The use of a scroll compressor is well known and widely accepted in the art because of the many advantages afforded by this type of compressor. Although the scroll compressor operates well in the heat pump system, the compressor can produce noise when the mode of operation of the system is changed. This occurs most frequently during the heating mode of operation when the system controller calls for a defrost cycle.

[0003] Testing has identified that compressor noise is produced when the pressure differential between the orbiting scroll and the stationary scroll of the compressor becomes low enough to permit the scroll element to separate. This occurs during a short period of time after the four-way reversing valve is cycled to reverse the direction of refrigerant flow through the system. After a flow reversal has taken place, it takes the system about twenty or thirty seconds to stabilize, after which it will return to its normal, relatively quiet operation.

[0004] It is therefore an object of the present invention to improve heat pumps.

[0005] This object is attained in a heat pump system that employs a scroll type compressor to eliminate unwanted noise during periods when the flow of refrigerant through the system is reversed and, in particular, when the system is undergoing a defrost cycle during the heating mode of operation. A processor is programmed to sense when the system's four way reversing valve is cycled indicating a reversal in refrigerant flow. The sensed signal is analyzed and processed and if a flow reversal is about to start or is in progress, the processor will shut down the compressor for a sufficient period of time to permit the system to become stabilized, thus eliminating unwanted compressor noise that is usually generated during the start of a flow reversal period.

[0006] For a better understanding of the these and other objects of the present invention, reference will be made to the following detailed description of the invention which is to be read in association with the accompanying drawings, wherein:

FIG. 1 is a schematic drawing showing a heat pump employing a scroll compressor which embodies the teachings of the present invention;

Figs. 2A-2D illustrate the fixed relationship of the scroll element of the compressor employed in the system shown in Fig. 1 showing how compression is achieved; and

Fig. 3 is a flow diagram outlining the steps in controlling the operation of the compressor to eliminate unwanted compressor noise when the direction of refrigerant flow through the system is reversed.

Detailed Description of the Invention

[0007] Turning initially to Fig. 1, there is shown, in schematic form, a heat pump system, generally referenced 10, that embodies the teachings of the present invention. The system employs a scroll compressor for delivering refrigerant to an outdoor heat exchanger or coil 14 via line 11 when the system is in a cooling mode of operation. In this mode, the outdoor coil acts as a condenser and condensed refrigerant is passed to the indoor heat exchanger or coil 16 through means of a refrigerant line 17. An expansion device 15 is mounted in the refrigerant line which throttles the high pressure refrigerant passing through the line to a lower pressure. In the cooling mode, the indoor coil acts as an evaporator to draw heat from the indoor air to provide cooling. Refrigerant vapor generated by the indoor coil is then passed to the inlet side of the compressor via line 18.

[0008] The suction line 24 and the discharge line 23 of the compressor both are connected to a four way flow reversing valve 20 that is cycled by means of a solenoid actuator 21 to reverse the flow of refrigerant through the system when the mode of operation of the system is changed. The solenoid actuator is under the control of a processor 25 which, among other things, cycles the valve when the system goes into a heating mode of operation. At this time, the high pressure refrigerant from the compressor is sent to the indoor coil 16 which now acts as a condenser in the system to heat the indoor air. The outdoor coil, in turn, acts as an evaporator to draw heat from the surrounding ambient. The expansion device 15 is arranged so that it is capable of automatically throttling refrigerant that is moving in either direction through the refrigerant line.

[0009] A heat sensor 30 is associated with the outdoor coil 14 which provides temperature related data to the system processor 25. The temperature data is processed and analyzed when the system is in a heating mode to determine when a defrost cycle should be initiated. As is well known in the art, during a defrost cycle the system is thermodynamically reversed and the outdoor coil acting as a condenser causes the heat exchanger coils to be heated thus, melting frost or ice from the coil surface, which reduces the efficiency of the system.

[0010] As will be explained in greater detail below, the processor is programmed to provide an input signal to the solenoid actuator 21 when it determines that a defrost cycle should be initiated. This, in turn, causes the four way valve to cycle, reversing the flow of refrigerant through the system.

[0011] As noted above, it has been determined that the reversal of flow through a heat pump can produce objectionable noise in a scroll compressor. The scroll type compressor operates as shown in Figs. 2A-2D by moving a sealed pocket 34 of refrigerant from a low pressure region as illustrated in Fig. 2A to a high pressure region as illustrated in Fig. 2D. The sealed pocket

of fluid is bound by two end plates and a fixed scroll element 40 and a moving scroll element 41. One plate 37 supports the fixed scroll element 40 while the other plate (not shown) supports an orbiting scroll element 41. The scroll elements are aligned along parallel axes so that the sealed pocket moves as illustrated to entrap the refrigerant within a constantly diminishing volume as the orbiting scroll is moved in rolling contact with the stationary scroll. Although not shown, entry and exit ports are provided for carrying refrigerant into and out of the moving pocket region.

[0012] It has been found that the scroll elements of the compressor, both orbiting and fixed can separate when a low pressure differential is experienced over the compressor. All scroll compressors are inherently susceptible to temporary scroll separation when subjected to a low pressure differential. Experimentation has shown that as soon as the four way flow reversing valve is cycled, as for example at the beginning and end of a defrost cycle, a period of low pressure differential occurs which lasts about twenty (20) seconds. It is during this period that the scroll elements undergo separation due to flow instability resulting in the creation of unwanted noise.

[0013] As noted above, the processor 25 is programmed to accept temperature related data regarding the outdoor coil 14 from sensor 30 and process the information to determine when a defrost cycle is to be initiated and terminated. To initiate a defrost cycle when the heat pump system is operating in the heating mode, a signal is sent to the solenoid actuator 21 which cycles the four way valve 20, thus reversing the refrigerant flow through the system. At this time, the outdoor coil operates as a condenser without air flow and any frost build up on the coil is melted. Upon completion of the defrosting process, the processor again signals the solenoid actuator to cycle the four way valve whereupon the system again returns to a normal heating mode.

[0014] Accordingly, during each flow reversal period, at the beginning and end of a defrost cycle, the pressure differential over the compressor becomes low, and unwanted noise is created. The processor is further programmed to shut down the compressor motor 13 (Fig. 1) for a given period of time at the initiation or termination of each defrost cycle. The processor, once it determines that a defrost cycle is beginning or ending, sends a signal to the motor switch 27 (Fig. 1) to shut down the compressor motor for about thirty seconds. At the completion of this thirty second shut down period, the processor again signals the motor switch to place the compressor motor back on line. By shutting down the compressor for a short period of time at the beginning and end of each defrost cycle, objectionable generation of noise during this period of instability is eliminated.

[0015] Turning now to Fig. 3, there is illustrated a flow diagram showing the steps the processor carries out at the beginning and end of each defrost cycle or

anytime the flow of refrigerant through the system is reversed. The processor reads and stores data relating to solenoid actuator voltage to determine when the system is in a heating mode. When in a heating mode, the four way valve is set in a first position and the solenoid actuator is deenergized. Accordingly, zero volts is applied over the terminals of the solenoid. At the beginning of a defrost cycle, for example, 24 volts is applied across the solenoid terminals and the solenoid is energized to cycle the four way valve.

[0016] The stored data is used to determine when the directional flow of refrigerant through the four way valve 20 is reversed. The processor 25 senses the value of the voltage level of the input signal across the input terminals of the solenoid 21 and compares the sensed voltage level of the input signal to the voltage level of the input signal of the previous operating mode. For example, when the heat pump system 10 is operating in a heating mode, the input signal to the solenoid 21 has a voltage level of 0 volts. This value is stored in memory by the processor 25 as shown in block 80. The processor 25 continuously monitors the input signal as shown in block 82. When the processor 25 senses a change in the voltage level of the input signal as shown in block 84, the processor 25 performs a sampling on the input signal for 0.5 seconds to confirm that a change in the voltage level of the input signal has occurred. (see blocks 86 and 88). So, in this example, the processor 25 reads the voltage level of the input signal N times in 0.5 seconds and compares the sampled voltage level to the voltage level of the input signal stored in memory, in this case 0 volts. If the processor 25 determines that M out of N samples indicate that a change in the voltage level of the input signal has occurred, the input signal now being 24 volts, then the processor 25 knows that a defrost cycle has begun or the system's mode of operation has changed, and it deactivates the compressor motor 13 for a predetermined amount of time, typically 30 seconds. These steps are shown in blocks 90, 92 and 94. The above described procedure is also used for determining when to deactivate the compressor motor 13 when going from the cooling or defrost mode back to the heating mode. It should be understood that the input signal could have different voltage levels than those described in the present embodiment.

[0017] As illustrated in block 96, after the compressor motor 13 has been deactivated for the predetermined amount of time, the processor 25 automatically reactivates the compressor motor 13, thereby placing it back on line. Next, the processor 25 resets the 30 second timer, shown in block 98, and stores the new input voltage value in memory as shown in block 80.

[0018] Other methods may be employed to determine when to deactivate the compressor 12 as may be apparent to one skilled in the art. For instance, as described above there is a sudden change in discharge and suction pressure when the heat pump system 10 changes modes. Therefore, it is possible to monitor the

discharge and suction pressures for determining when to deactivate the compressor SW12. Additionally, the voltage drawn by the compressor motor 13 changes when the discharge pressure changes. Therefore, it is possible to monitor the voltage drawn by the compressor motor 13 for determining when to deactivate the compressor 12, similarly, the temperature of the outdoor coil could also provide sufficient input data to the processor upon which the activation and reactivation of the compressor motor can be made.

[0019] According to a more particular feature, the present invention improves heat pump systems that employ scroll type compressors. Yet a further feature of the present invention is to reduce the amount of noise produced by a scroll compressor that is used in a heat pump system. Another feature of the present invention is to control the operation of the scroll compressor that is used in the heat pump system to eliminate unwanted compressor noise, particularly when the system calls for a defrosting cycle during the heating mode of operation.

Claims

1. A method of reducing the noise produced by a scroll compressor that is employed in a heat pump system having a four way flow reversing valve, said method characterized by the steps of,

sensing a system parameter indicative that a change in direction of refrigerant flow through the system has or is about to occur, and deactivating the scroll compressor for a predetermined period of time after a change in refrigerant flow has or is about to occur.

2. The method of claim 1 wherein the sensing step includes sensing a change in the positioning of the system four way flow reversing valve.

3. The method of claim 1 that includes the further step of providing a solenoid actuator for controlling the four way flow reversing valve and said sensing step includes the step of sensing the voltage change over the input terminals of said solenoid actuator.

4. The method of claim 2 that includes the further steps of providing a temperature sensor for monitoring the temperature of the system's outdoor coil and providing an output signal indicative of said sensed temperature, and cycling the four way valve when said output signal reaches one or more threshold levels.

5. The method of claim 1 that includes the further step of reactivating the compressor motor at the conclusion of said predetermined period of time.

6. The method of claim 1 wherein said predetermined

period of time lasts about thirty (30) seconds.

7. Apparatus for controlling a scroll compressor that is employed in a heat pump having a solenoid actuated four way refrigerant flow reversing valve that is characterized by,

a processor for monitoring at least one system parameter that is indicative of a change in the direction of refrigerant flow through the heat pump, and

means for deactivating the compressor motor for a predetermined period of time when said processor detects a change in said system parameter has occurred or is about to occur.

8. The apparatus of claim 7 that further includes a sensing means for detecting a change in the positioning of the system's four way valve and sending an output signal to said processor indicating a reversal in refrigerant flow through the system.

9. The apparatus of claim 8 wherein said sensing means further includes means for detecting the input voltage over the solenoid actuator of said four way valve.

10. The apparatus of claim 9 wherein said processor further includes a timer means for reactivating said compressor motor after said predetermined period.

11. The apparatus of claim 10 wherein said predetermined period is about thirty (30) seconds.

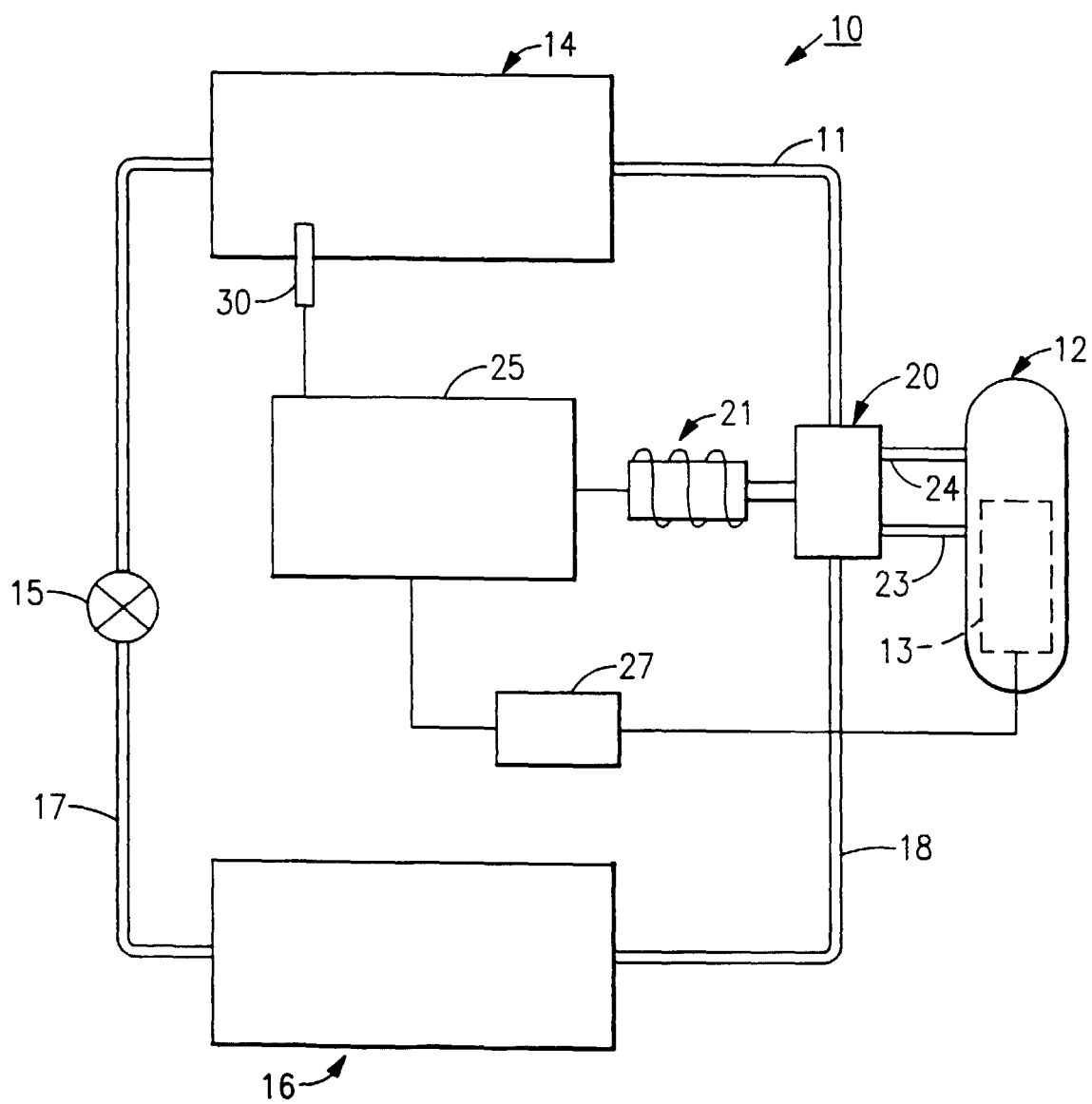


FIG.1

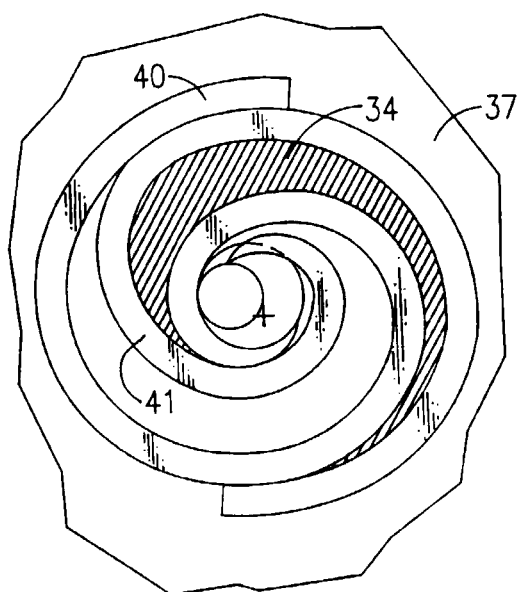


FIG. 2A

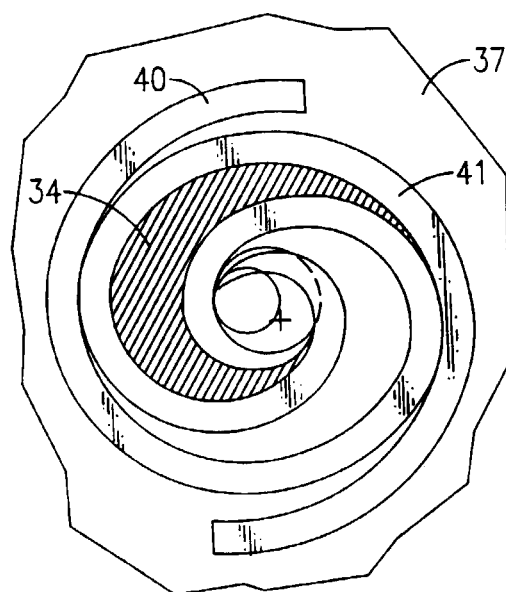


FIG. 2B

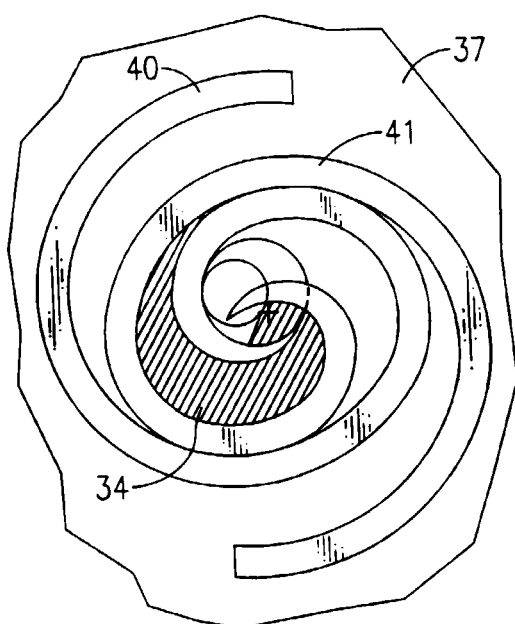


FIG. 2C

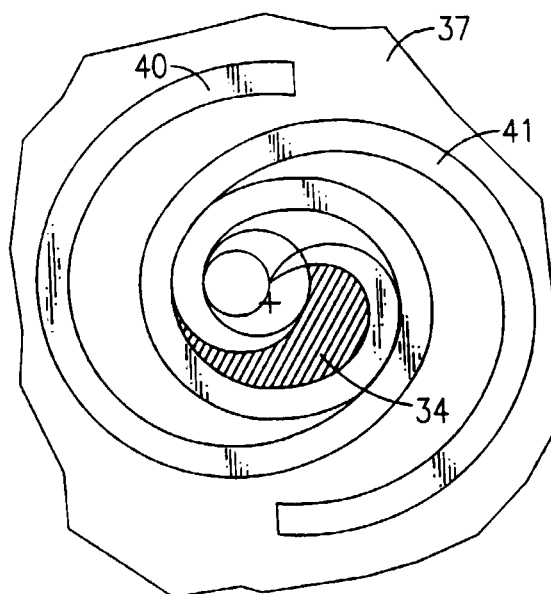


FIG. 2D

