



US 20060225445A1

(19) **United States**(12) **Patent Application Publication**
Lifson et al.(10) **Pub. No.: US 2006/0225445 A1**(43) **Pub. Date: Oct. 12, 2006**(54) **REFRIGERANT SYSTEM WITH VARIABLE
SPEED COMPRESSOR IN TANDEM
COMPRESSOR APPLICATION****Publication Classification**(51) **Int. Cl.***F25B 7/00* (2006.01)*F25D 17/02* (2006.01)*F25B 1/00* (2006.01)*F25B 49/00* (2006.01)*F25B 1/10* (2006.01)*F25B 41/00* (2006.01)(52) **U.S. Cl.** 62/175; 62/228.4; 62/510;
62/513(75) Inventors: **Alexander Lifson**, Manlius, NY (US);
Michael F. Taras, Fayetteville, NY
(US)

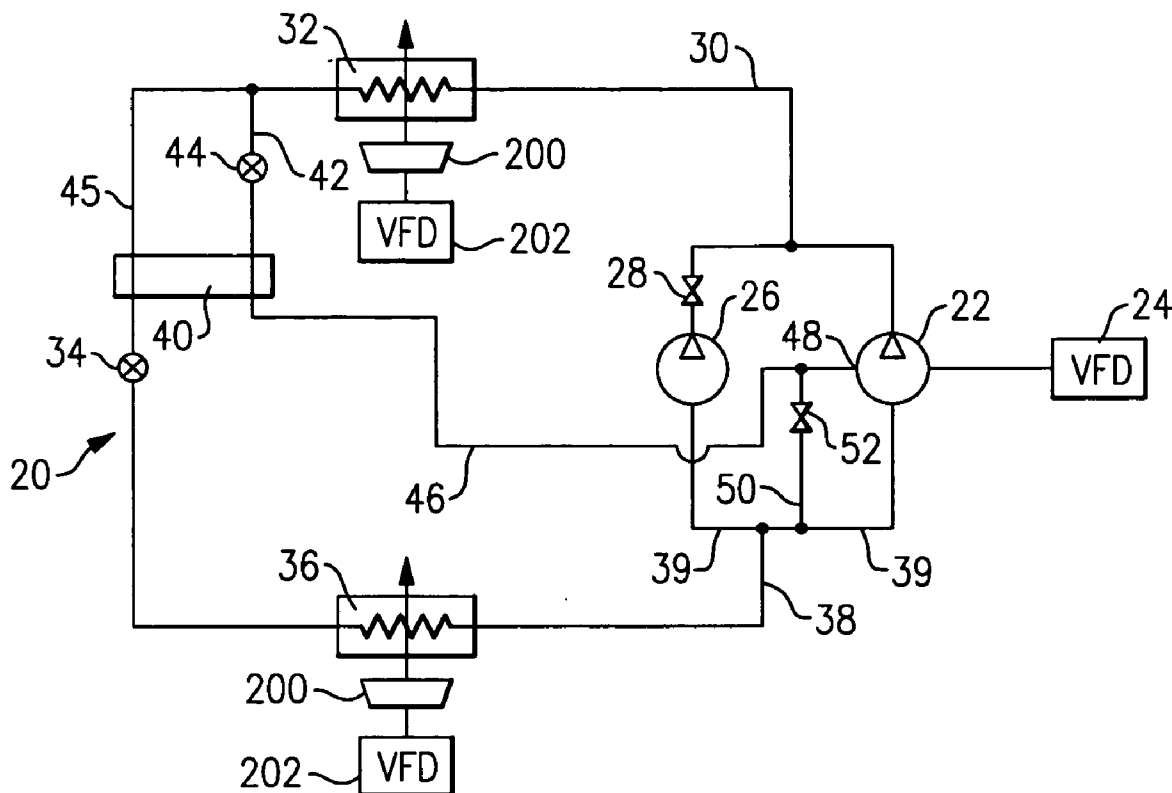
Correspondence Address:

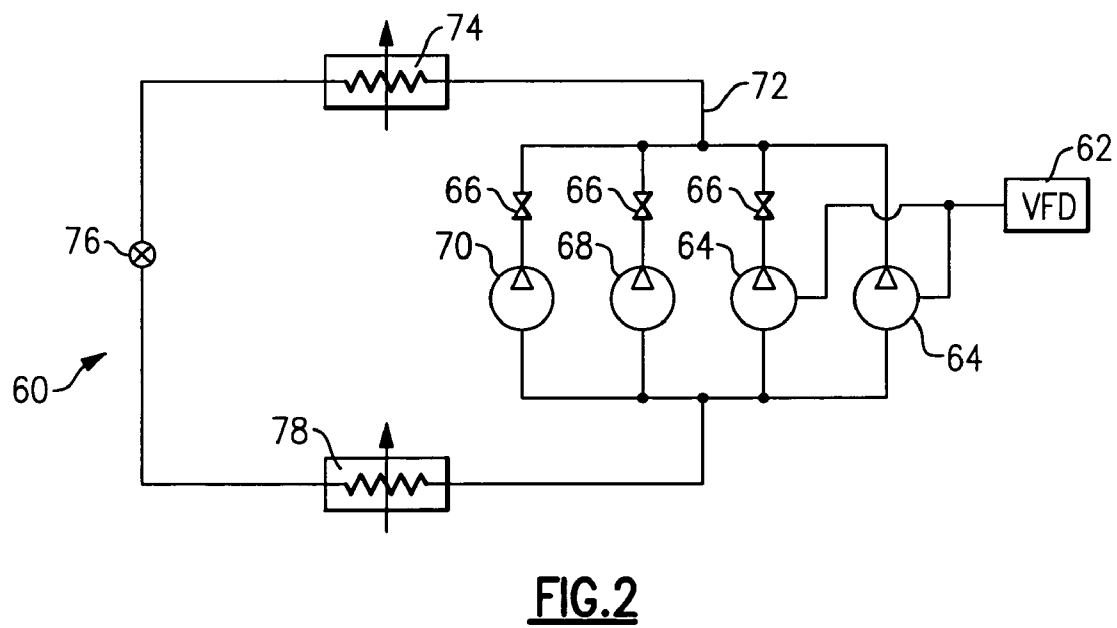
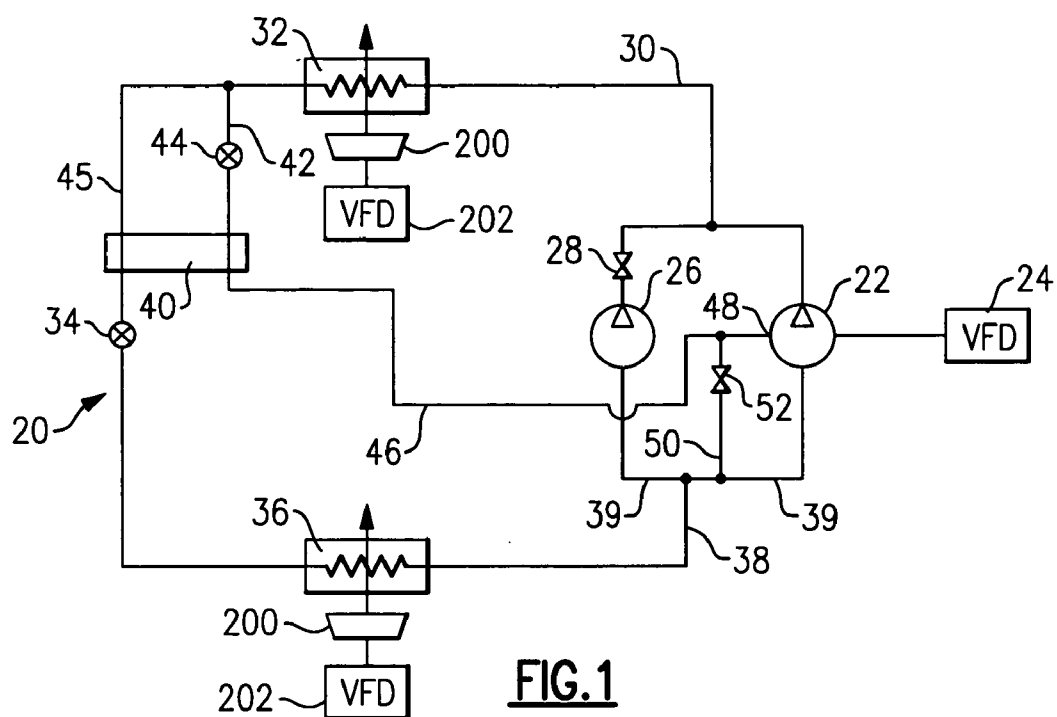
CARLSON, GASKEY & OLDS, P.C.
400 WEST MAPLE ROAD
SUITE 350
BIRMINGHAM, MI 48009 (US)(73) Assignee: **Carrier Corporation**(21) Appl. No.: **11/101,347**(22) Filed: **Apr. 7, 2005**

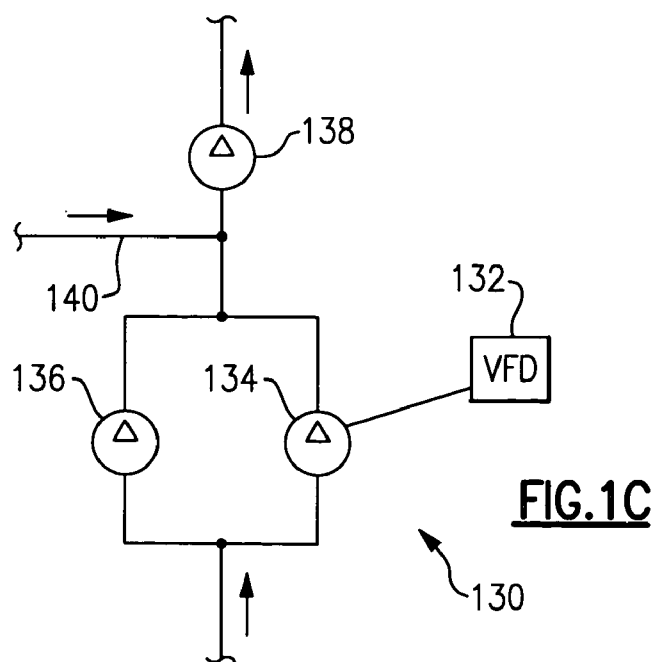
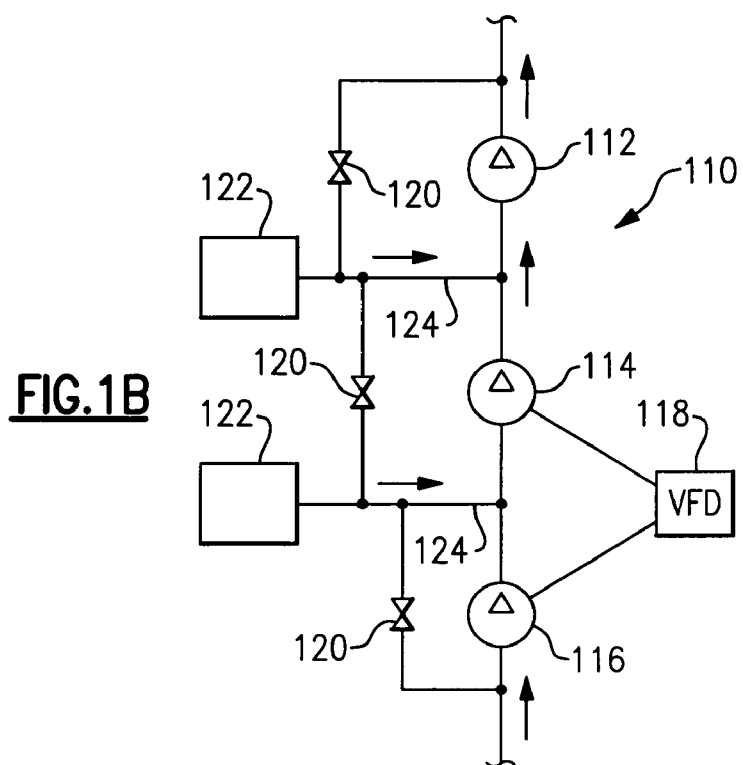
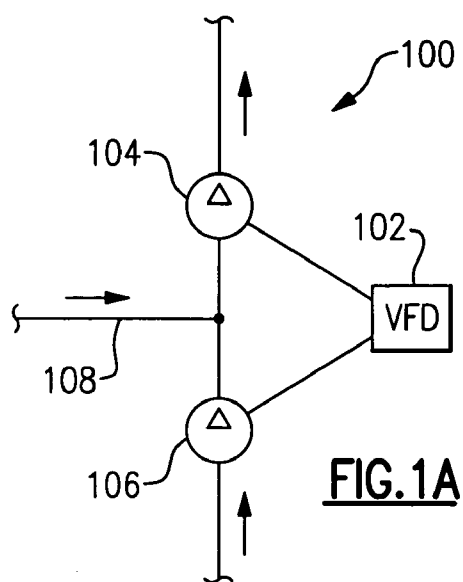
(57)

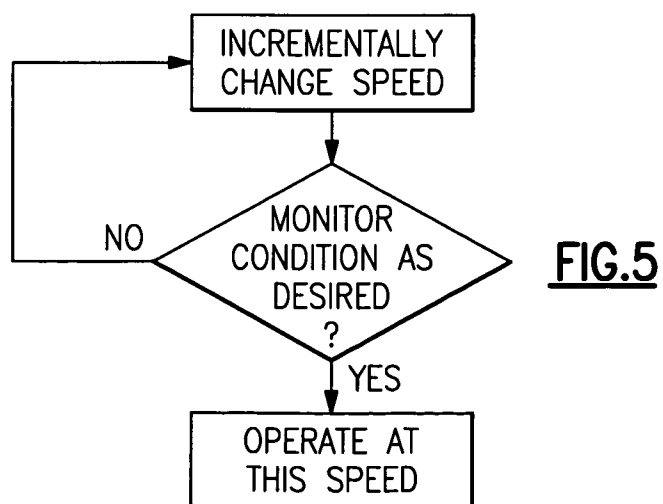
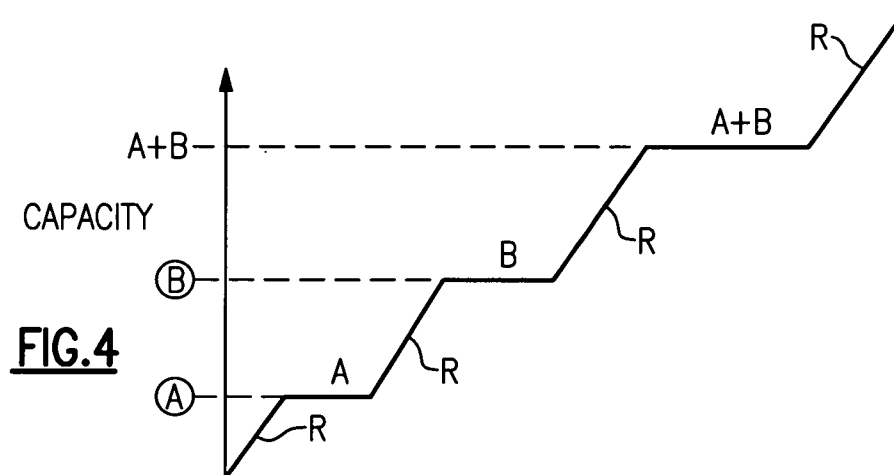
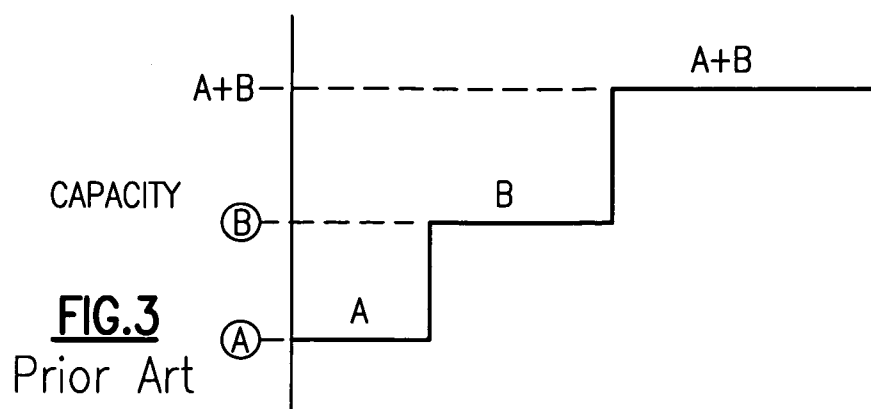
ABSTRACT

A refrigerant system is provided with tandem compressors. As is known, tandem compressors operate in parallel to provide a refrigerant system designer with the ability to achieve a stepped capacity control of the refrigerant system. At least one of the tandem compressors is provided with a variable speed drive. Further, at least one of the tandem compressors may be provided with the economizer and/or unloader functions. System configurations with multiple compression stages and multiple injection ports are disclosed. In this manner, the stepless capacity control can be achieved.









REFRIGERANT SYSTEM WITH VARIABLE SPEED COMPRESSOR IN TANDEM COMPRESSOR APPLICATION

BACKGROUND OF THE INVENTION

[0001] This invention relates to a variable speed motor for driving a compressor that is incorporated into a refrigerant system with tandem compressors.

[0002] Refrigerant systems are utilized in many air conditioning and heat pump applications for cooling and/or heating the air entering an environment. The cooling or heating load on the environment may vary with ambient conditions, and as the temperature and/or humidity levels demanded by an occupant of the building change.

[0003] In some refrigerant systems, a single compressor is utilized to compress the refrigerant and move the refrigerant through the cycle connecting indoor and outdoor heat exchangers in a closed loop. However, under many circumstances, it would be desirable to have the ability to vary the capacity, or amount of cooling or heating provided by the refrigerant system. Thus, known refrigerant systems may be provided with tandem compressors. Tandem compressors are essentially at least two compressors operating in parallel, where the compressors are interconnected with each other via common suction and/or discharge manifolds. For instance, a control for the two-compressor system may actuate both of the compressors or either one of the two compressors. The two compressors may have different sizes to provide distinct stages of capacity during part-load operation. Rather than having a single level of capacity, a refrigerant system provided with tandem compressors would have several discrete levels of capacity.

[0004] In the prior art, controls can be programmed to optionally actuate the tandem compressors. However, the capacity control provided by the tandem compressors is increased or decreased in large discrete steps. It would be desirable to provide the ability to improve system control capability to continuously vary capacity between these discrete steps to precisely match external load demands at a wide spectrum of environmental conditions.

[0005] Variable speed drives are known for driving compressors at a variable speed in a refrigerant system. By driving the compressor at a higher or lower speed, the amount of refrigerant that is compressed per unit of time changes, and thus the system capacity can be adjusted.

[0006] Variable speed drives have not been utilized in refrigerant systems incorporating tandem compressors, where a selected number of the tandem compressors is driven by a variable speed drive, for the purpose of varying the system capacity to control temperature and humidity levels within the conditioned space.

SUMMARY OF THE INVENTION

[0007] In the disclosed embodiment of this invention, a variable speed drive is provided into at least one compressor in a refrigerant system having tandem compressors. By selectively controlling this one compressor, capacity adjustment between the discrete steps provided by tandem compressor operation can be achieved.

[0008] A control identifies a desired cooling capacity, and then achieves this desired capacity by first actuating the

tandem compressors to accurately approximate the necessary capacity in the most efficient and reliable manner. Then, the speed of the at least one compressor provided with variable speed is changed incrementally. The capacity is then monitored. When a desired level is finally achieved, the at least one compressor is operated at that new speed. If the capacity still needs to be adjusted, then the speed is again adjusted incrementally, and the resulting condition is again monitored.

[0009] In disclosed embodiments, one of the tandem compressors may be provided with the variable speed drive while the other is not. In other embodiments, plural compressors are provided with a variable speed drives.

[0010] Embodiments are disclosed which incorporate economizer cycles and unloader cycles into the schematic along with the variable speed drive.

[0011] 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

[0012] **FIG. 1** shows a first embodiment refrigerant system.

[0013] **FIG. 1A** shows other possible circuit schematics.

[0014] **FIG. 1B** shows other possible circuit schematics.

[0015] **FIG. 1C** shows other possible circuit schematics.

[0016] **FIG. 2** shows a second embodiment refrigerant system.

[0017] **FIG. 3** shows the capacity control provided by the prior art.

[0018] **FIG. 4** shows the capacity control provided by the present invention.

[0019] **FIG. 5** is a flowchart of a control algorithm according to the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

[0020] A refrigerant system **20** is illustrated in **FIG. 1**. A compressor **22** is provided with a variable speed drive **24**. A second compressor **26** is not provided with a variable speed drive, and operates in tandem with the compressor **22**. As shown, a shut-off valve **28** may allow the compressor **26** to be isolated from the discharge manifold, should a control for the system determine that only the compressor **22** is necessary for achieving a given capacity. As is known, the compressors **22** and **26** deliver refrigerant to a common discharge line **30** leading to a condenser **32**. While the system **20** is illustrated as an air conditioning system, it should be understood that the present invention would also apply to heat pumps and chillers.

[0021] As is known, the two compressors **22** and **26** may preferably be provided with distinct capacities such that varying total levels of capacity can be achieved by operating one or the other, or both of the compressors **22** and **26**. In this case, it is at the system designer's discretion to select whether a larger or smaller compressor is provided with a variable speed drive. The decision will depend on many factors including (but not limited to) application require-

ments, cost, system operation efficiency, etc. An expansion device **34** is positioned downstream of the condenser **32**, and an evaporator **36** is located downstream of the expansion device **34**. A common suction line **38** leads to distinct suction lines **39** for returning refrigerant to the compressors **22** and **26**.

[0022] As also shown, an economizer circuit can be incorporated into the **FIG. 1** schematic. An economizer heat exchanger **40** receives a tapped refrigerant from a line **42** having passed through an economizer expansion device **44**. As is known, by passing the tapped refrigerant through the expansion device **44**, its pressure and temperature are lowered. Thus, in the economizer heat exchanger **40**, this tapped refrigerant subcools a refrigerant in a main liquid line **45**, which also passes through the economizer heat exchanger **40**. The economizer function is known in the prior art, and allows increased capacity and/or efficiency of the refrigerant system **20**.

[0023] As shown, the tapped refrigerant is returned through a line **46** to an intermediate compression point **48** in at least one of the compressors, here illustrated as compressor **22**. While refrigerant in the tap line **42** is shown flowing through the economizer heat exchanger **40** in the same direction as refrigerant in the main liquid line **45**, it should be understood that in a preferred embodiment, the two flows would actually be in counter-flow arrangement.

[0024] A bypass line **50** is also incorporated, and allows a portion of refrigerant from the intermediate compression point **48** in the compressor **22** to be returned to the suction line **39**. When it is desired to have unloaded operation, a valve **52** is opened while the expansion device **44** is preferably (but not necessarily) closed. In this way, refrigerant that has been partially compressed by the compressor **22** will be returned to the suction line **39**, thus providing the unloading function.

[0025] It has to be understood that the economized compressor **22** may have more than one injection port **48** and more than one associated economizer heat exchanger **40**. Also, as known, the economizer heat exchanger arrangement can be substituted by a flash tank. Further, multi-stage compression system may be employed instead of a single economized compressor. In such multi-stage compressor system, one or several of the stages may be provided with a variable speed drive.

[0026] As shown, electric motors **200** are associated with fans for blowing the air over the condenser **32** and evaporator **36**. One or other of these electric motors **200** may be provided with a variable speed drive **202**. A worker of ordinary skill in the art would recognize when the variable speed control of the fan, or other components such as a secondary loop pump, motors associated with the refrigerant system might be desirable.

[0027] **FIG. 1A** shows another circuit schematic **100** wherein one of the two compressors, e.g. compressor **22**, is replaced by two compressor stages **104** and **106**. While both of the compressor stages **104** and **106** are shown connected to the variable speed drive **102**, only one stage or the other could be connected instead. As shown, the return line **108** from the economizer heat exchanger extends simply between the two stages, rather than into compression chambers in either of the stages.

[0028] **FIG. 1B** shows another embodiment **110** wherein there are three compressor stages **112**, **114** and **116**. The

variable speed drive **118** controls both stages **114** and **116**. Each of the stages is shown associated with an unloader valve **120**. Two separate economizer heat exchangers **122** selectively deliver refrigerant through lines **124** back to points between the compressor stages. It is well known to a person ordinarily skilled in the art that a number of compression stages (as well as a number and particular position of compression stages operating at variable speeds), a number of unloader valves and a number of economizer heat exchangers are at a designer freedom and depend on a particular application.

[0029] **FIG. 1C** shows another embodiment **130** wherein a first stage of the compressor is provided by a pair of tandem compressors **134** and **136** feeding a second compressor stage **138**. As shown, an intermediate pressure refrigerant return line **140** extends between the stages. A variable speed drive **132** is associated with the compressor **134** only. Of course, many other schematics would come within the scope of this invention, including (but not limited to) a varying number of tandem and variable speed compressors.

[0030] **FIG. 2** shows a distinct embodiment **60**, wherein the two tandem compressors are replaced by a bank of four compressors. As shown, compressors **64** are each provided with a variable speed drive **62**. Shut-off valves **66** are placed on the discharge lines for three compressors **64**, **68** and **70** to isolate those compressors when they are stopped by the system control. A common discharge manifold **72** leads to a condenser **74**, an expansion device **76**, and an evaporator **78**. A control for this refrigerant system **60** is configured to operate the two compressors **64** at variable speeds, and the two compressors **68** and **70** at fixed speed to achieve desired capacity.

[0031] A control for either refrigerant system **20** and **60** is able to identify a desired cooling capacity, and operate the tandem compressors and/or the economizer and unloader functions as necessary. Thus, as shown in **FIG. 3**, a prior art system that incorporated the **FIG. 1** schematic without the variable speed drive could provide at least three stages A, B, and A+B of capacity control. In fact, the schematic shown in **FIG. 1** would have even more stages, in that the operation of the unloader valve and economizer function would provide additional capacity steps. However, for purposes of understanding the remainder of this invention, the simplified schematic of **FIG. 3** will suffice. As can be seen, there are several values between values A, B, and A+B that cannot be provided by this prior art system. This is, of course, an oversimplification of the system, yet this does provide a good basis for understanding the present invention. The **FIG. 2** embodiment would have many other levels of capacity control available as well.

[0032] **FIGS. 3 and 4** are an oversimplification of the **FIG. 1** embodiment and the capacity levels it can provide. As mentioned, by operating the unloader valve and economizer function, additional capacity steps can be achieved. However, a control for this system would operate one of the compressors (e.g., compressor **26**) that may be smaller than the compressor **22** to provide the level A. The other compressor **22** can be operated to provide the level B, with the compressor **26** stopped. By operating both compressors **22** and **26**, the level A+B can be achieved. Within each of these levels, by increasing the speed of the motor for the compressor **22**, a ramp R above the step A, B, or A+B can be achieved. On the other hand, by slowing the speed, the opposite can occur to move a ramp downwardly from these

values. A decision of switching between the compressor speed adjustment and moving to a different mode of operation is usually based on the amount of required cooling, efficiency and reliability considerations. For instance, it may be unsafe to operate the compressor below certain speed due to inadequate lubrication provided to compressor elements. On the other hand, running compressor at a relatively high speed may be inefficient in comparison to switching to an economizer mode of operation.

[0033] FIG. 5 shows how the ramps would typically be achieved with a standard variable speed motor control as is known in the prior art. Ramps R as shown in FIG. 4 are an oversimplification. In fact, the control typically moves in incremental steps, and then monitors the operation of the refrigerant cycle after that incremental change. Thus, there would be a plurality of step changes along each ramp R, rather than the infinite number of changes as is illustrated in FIG. 4. However, FIG. 4 does provide a good illustration of the power of the present invention to provide varying capacity.

[0034] It has to be noted that variable speed tandem compressors can be utilized in conjunction with other system components such as fans or pumps also operated at variable speeds.

[0035] Although preferred embodiments 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:

at least two tandem compressors operating in parallel, with at least one compressor having a variable speed drive for varying a speed of said at least one compressor;

a condenser downstream of said compressor and an evaporator downstream of said condenser; and

a control for selectively varying said speed of said at least one compressor.

2. The refrigerant system as set forth in claim 1, wherein an economizer heat exchanger is positioned intermediate to said condenser and said evaporator, said economizer heat exchanger selectively receiving a tapped refrigerant to sub-cool a main refrigerant flow passing through said economizer heat exchanger, and said tapped refrigerant being returned to least one of said compressors and said control being operable to vary the speed of at least said one compressor to provide variation in capacity control between a level with said economizer heat exchanger operational, and a level without said economizer heat exchanger operational.

3. The refrigerant system as set forth in claim 2, wherein there are a plurality of intermediate ports where said tapped refrigerant is returned to said at least one of said compressors.

4. The refrigerant system as set forth in claim 1, wherein at least one of said two tandem compressors is provided by a multi-stage compressor.

5. The refrigerant system as set forth in claim 1, wherein said control changing said speed of said at least one compressor in incremental steps.

6. The refrigerant system as set forth in claim 1, wherein at least one of said at least two compressors is provided with an unloader function.

7. The refrigerant system as set forth in claim 1, wherein at least one of said at least two compressors is not provided with a variable speed drive.

8. The refrigerant system as set forth in claim 1, wherein there are more than two of said at least two compressors, and at least two of said compressors are provided with a variable speed drive.

9. The refrigerant system as set forth in claim 1, wherein a fan or pump associated with a component other than the compressor is also provided with the variable speed drive.

10. The refrigerant system as set forth in claim 1, wherein said at least two compressors have different capacities.

11. A method of controlling a refrigerant system comprising the steps of:

(1) providing at least two tandem compressors operating in parallel, with at least one compressor having a variable speed drive for varying a speed of said at least one compressor, providing a condenser downstream of said compressor and an evaporator downstream of said condenser, and a control for selectively varying said speed of said at least one compressor to achieve varying levels of capacity control; and

(2) determining a desired capacity, and operating one or the other, or both of said at least two compressors, and varying a speed of said at least one compressor to achieve said determined desired capacity.

12. The method as set forth in claim 11, wherein an economizer function is provided with the refrigerant system, and selectively actuating said economizer function to provide additional capacity or increase operation efficiency if necessary to achieve the desired capacity of step 2.

13. The method as set forth in claim 12, wherein refrigerant from corresponding economizer heat exchangers is returned to a plurality of ports associated with said at least two tandem compressors.

14. The method as set forth in claim 11, wherein at least one of said at least two compressors is provided by a multi-stage compressor.

15. The method as set forth in claim 11, wherein said control changes said speed of said at least one compressor in incremental steps.

16. The method as set forth in claim 11, wherein an unloader function is provided to unload at least one of said at least two compressors to achieve the desired capacity of step 2.

17. The method as set forth in claim 11, wherein at least one of said at least two compressors is not provided with a variable speed drive.

18. The method as set forth in claim 11, wherein there are more than two of said at least two compressors, and at least two of said compressors being provided with a variable speed drive, and said control varying the speed of said at least two variable speed driven compressors.

19. The method as set forth in claim 11, wherein said at least two compressors are provided with different capacities.

20. The method as set forth in claim 11, wherein at least one fan or pump associated with another component in said refrigerant system is provided with a variable speed drive.