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(54) **SYSTEM AND METHOD FOR EVALUATING PARAMETERS FOR A REFRIGERATION SYSTEM WITH A VARIABLE SPEED COMPRESSOR**

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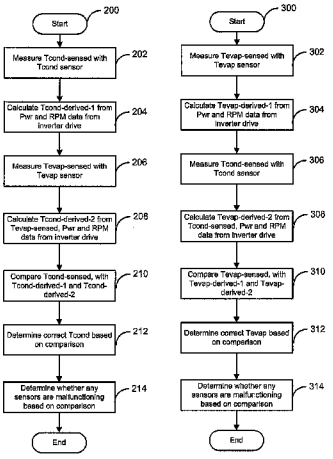
(57) **ABSTRACT**

A system and method for evaluating parameters for a refrigeration system having a variable speed compressor is provided. A compressor is connected to a condenser and an evaporator. A condenser sensor and an evaporator sensor are provided. An inverter drive modulates a frequency of electric power delivered to the compressor to modulate a speed of the compressor. A monitor module receives compressor power data and compressor speed data from the inverter drive, determines a measured condenser temperature based on the condenser signal, determines a measured evaporator temperature based on the evaporator signal, calculates a first derived condenser temperature based on the compressor power data and the compressor speed data, calculates a second derived condenser temperature based on the measured evaporator temperature, the compressor power data and the compressor speed data, and compares the measured condenser temperature with the first and second derived condenser temperatures to determine whether any of the measured condenser temperature and the first and second derived condenser temperatures are inaccurate.

18 Claims, 9 Drawing Sheets



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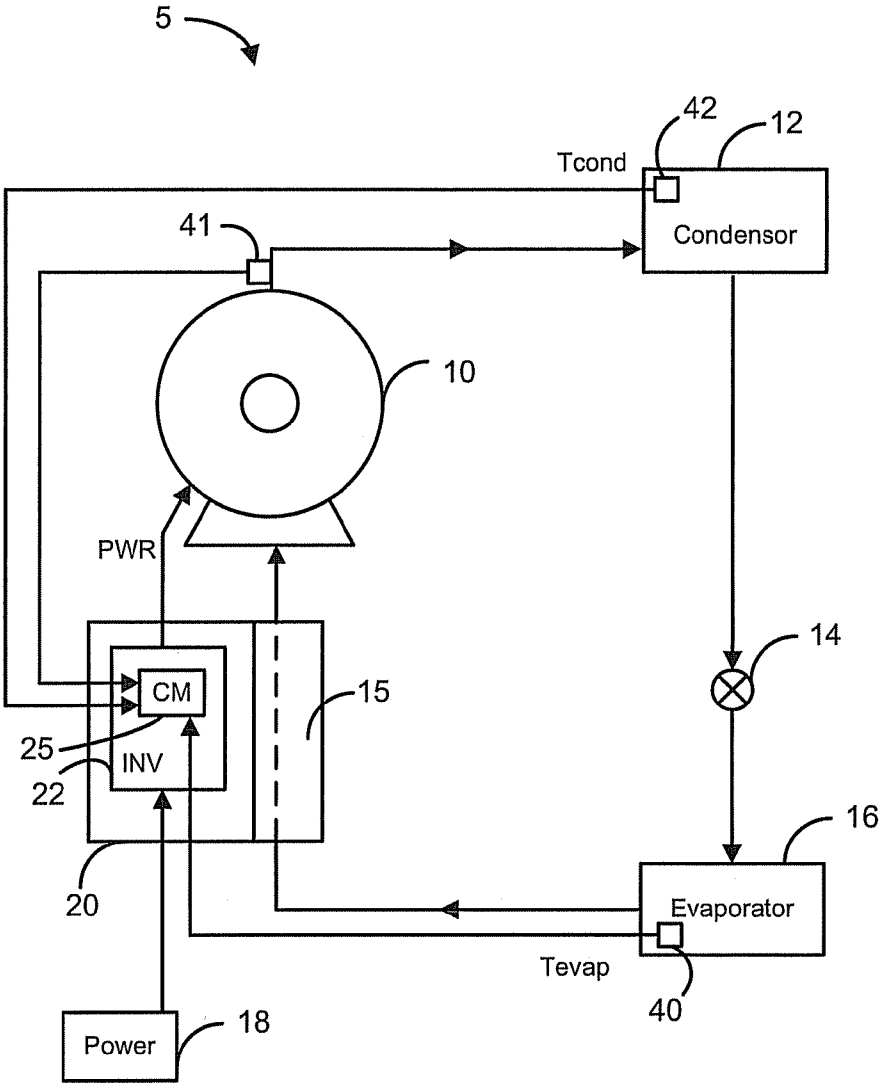

5
42
12
Tcond
Condensor
41
10
PWR
14
CM
15
25
INV
22
16
20
Evaporator
Tevap
40
Power
18

Fig - 1

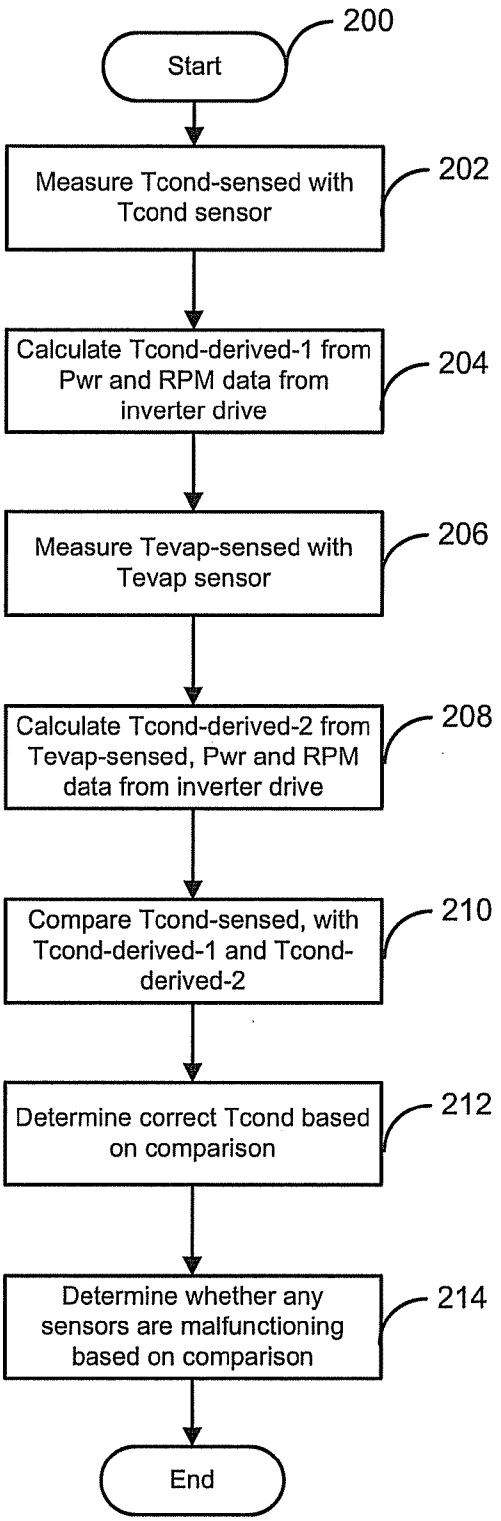

200
Start
Measure Tcond-sensed with Tcond sensor
202
Calculate Tcond-derived-1 from Pwr and RPM data from inverter drive
204
Measure Tevap-sensed with Tevap sensor
206
Calculate Tcond-derived-2 from Tevap-sensed, Pwr and RPM data from inverter drive
208
Compare Tcond-sensed, with Tcond-derived-1 and Tcond-derived-2
210
Determine correct Tcond based on comparison
212
Determine whether any sensors are malfunctioning based on comparison
214
End

Fig - 2

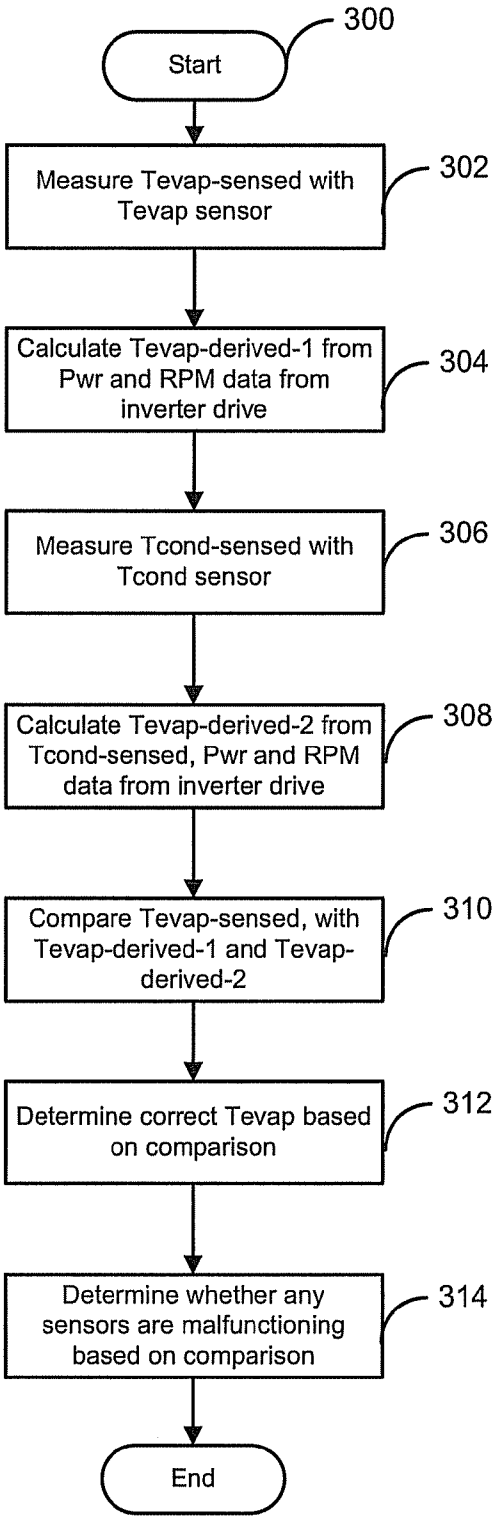

300
Start
Measure Tevap-sensed with Tevap sensor
302
Calculate Tevap-derived-1 from Pwr and RPM data from inverter drive
304
Measure Tcond-sensed with Tcond sensor
306
Calculate Tevap-derived-2 from Tcond-sensed, Pwr and RPM data from inverter drive
308
Compare Tevap-sensed, with Tevap-derived-1 and Tevap-derived-2
310
Determine correct Tevap based on comparison
312
Determine whether any sensors are malfunctioning based on comparison
314
End

Fig - 3

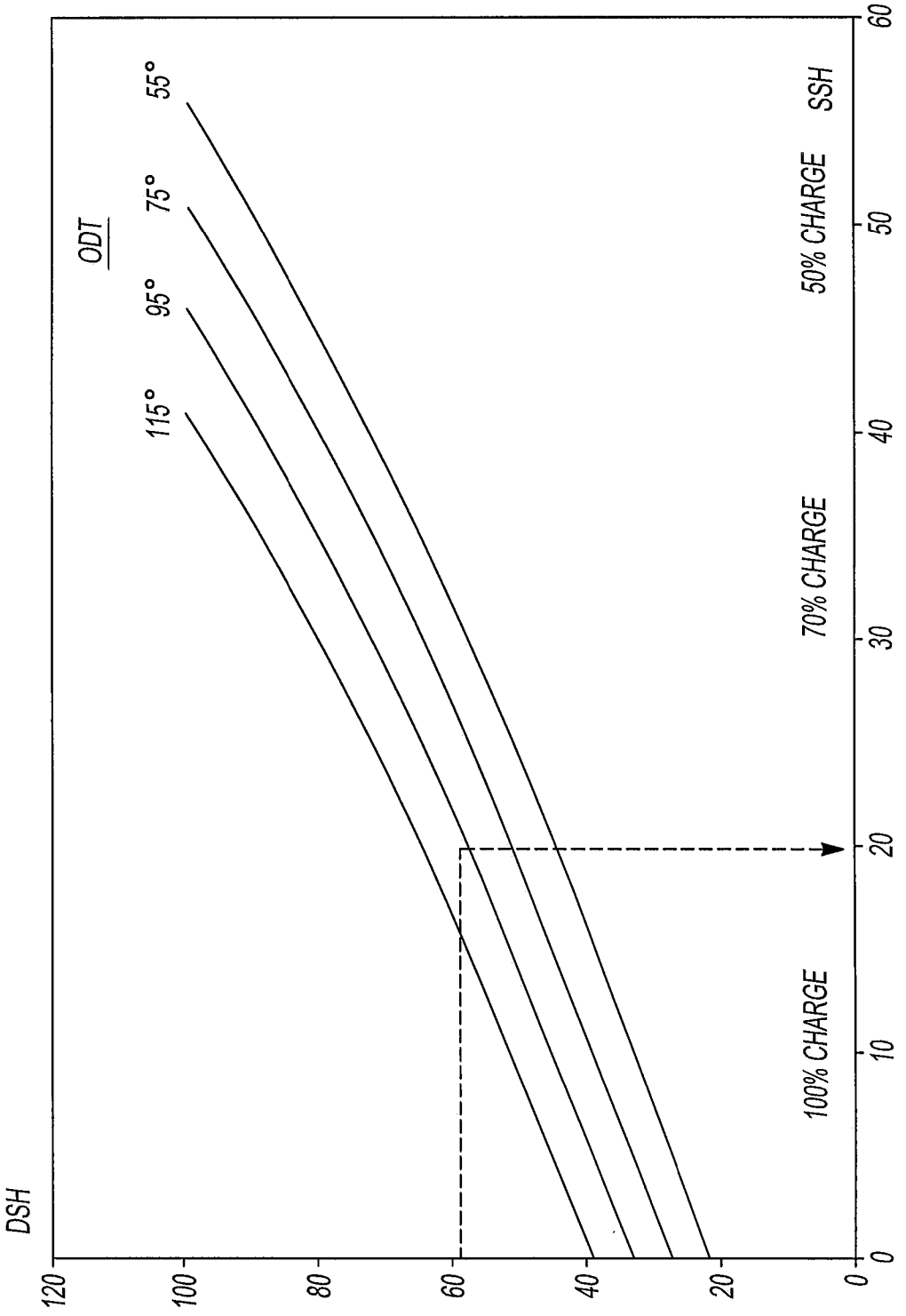

DSH
120
100
80
60
40
20
0
ODT
115°
95°
75°
55°
100% CHARGE
70% CHARGE
50% CHARGE
SSH
0
10
20
30
40
50
60

Fig - 4

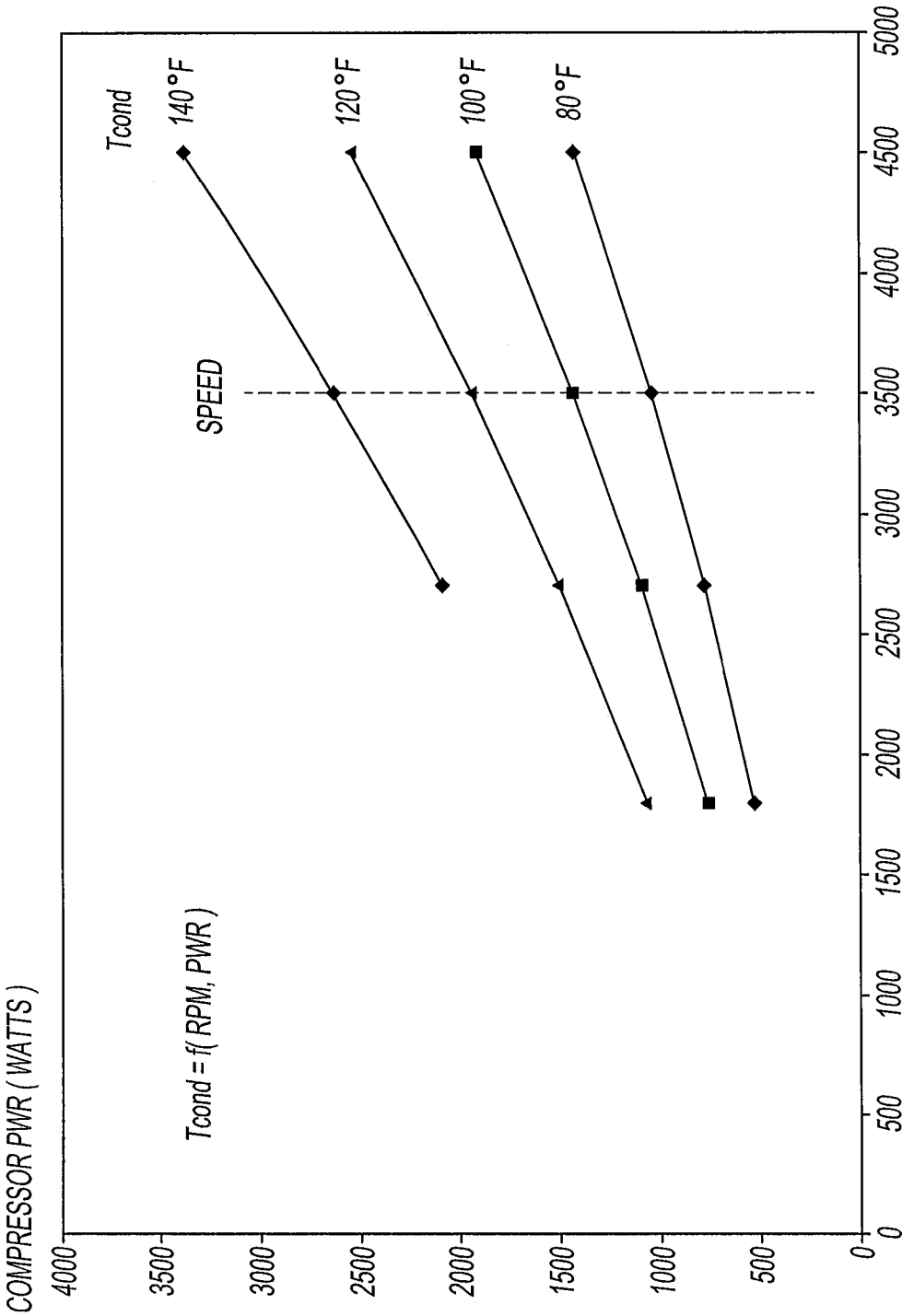
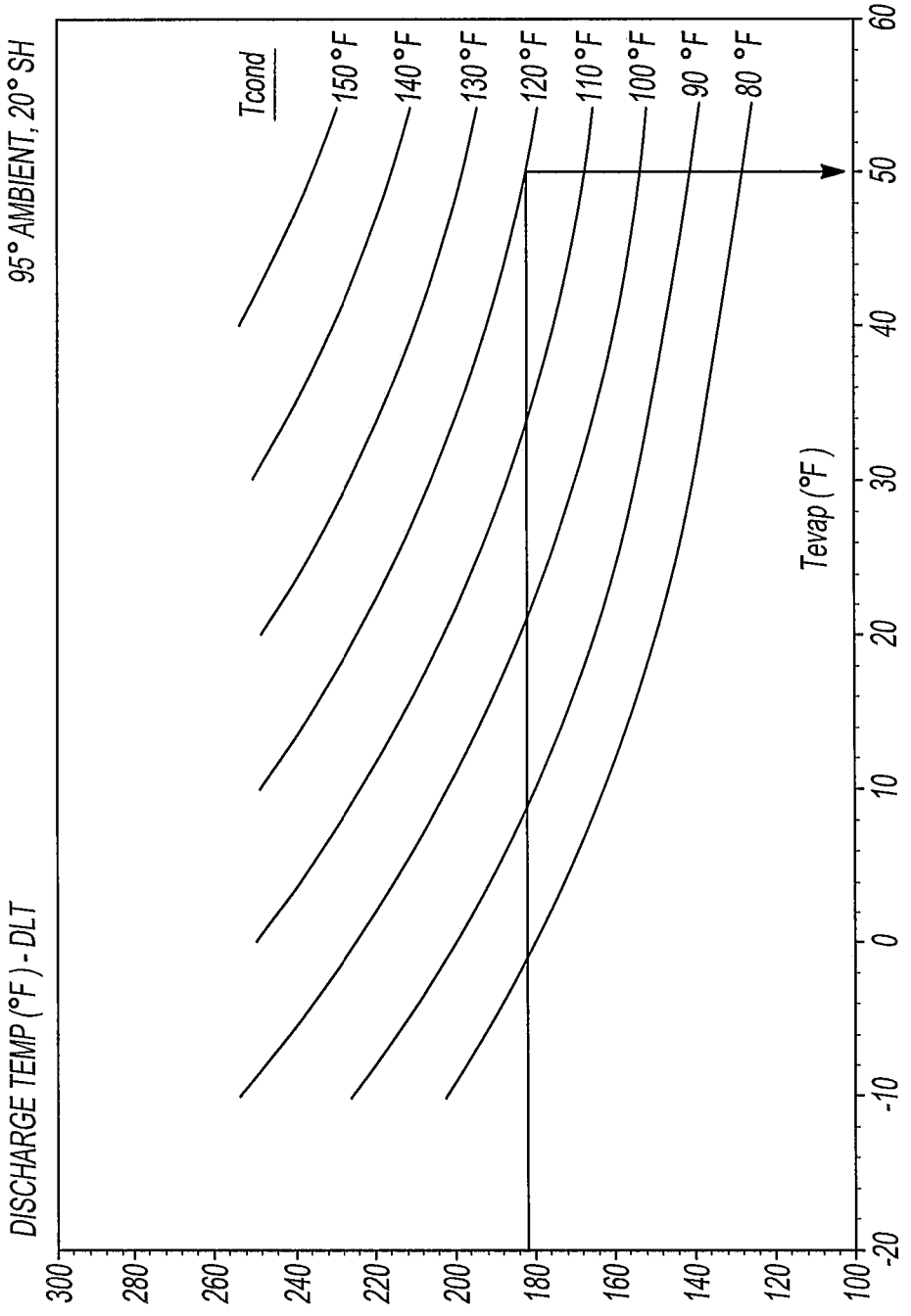

COMPRESSOR PWR (WATTS)
4000
3500
3000
2500
2000
1500
1000
500
0
Tcond = f(RPM, PWR)
Tcond
140 °F
120 °F
100 °F
80 °F
SPEED
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
COMPRESSOR RPM

Fig - 5



Tevap DERIVED FROM DLT AND Tcond

Fig - 6

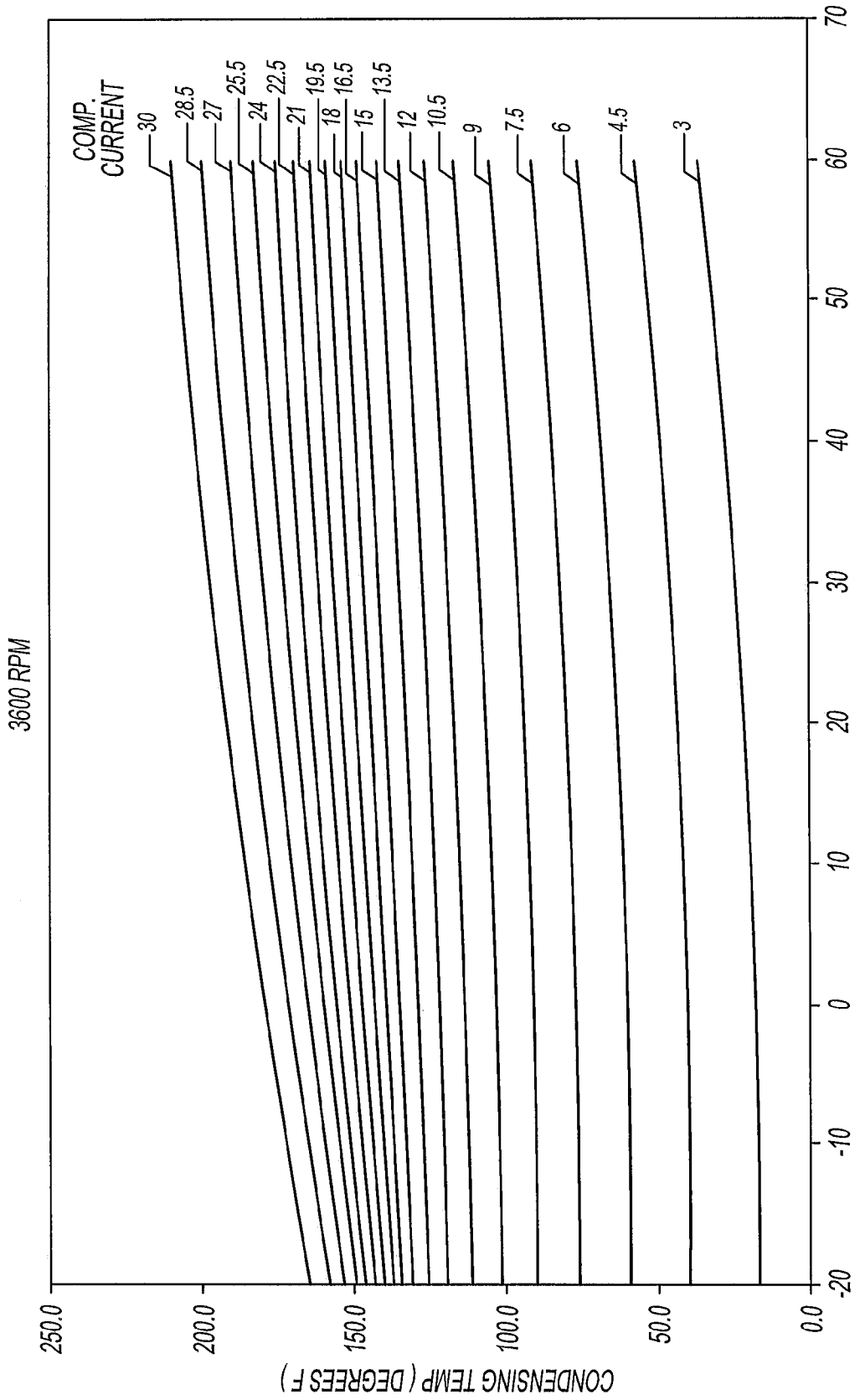

3600 RPM
COMP. CURRENT
30
28.5
27
25.5
24
22.5
21
19.5
18
16.5
15
13.5
12
10.5
9
7.5
6
4.5
3
CONDENSING TEMP (DEGREES F)
250.0
200.0
150.0
100.0
50.0
0.0
EVAP TEMP
-20
-10
0
10
20
30
40
50
60
70

Fig - 7

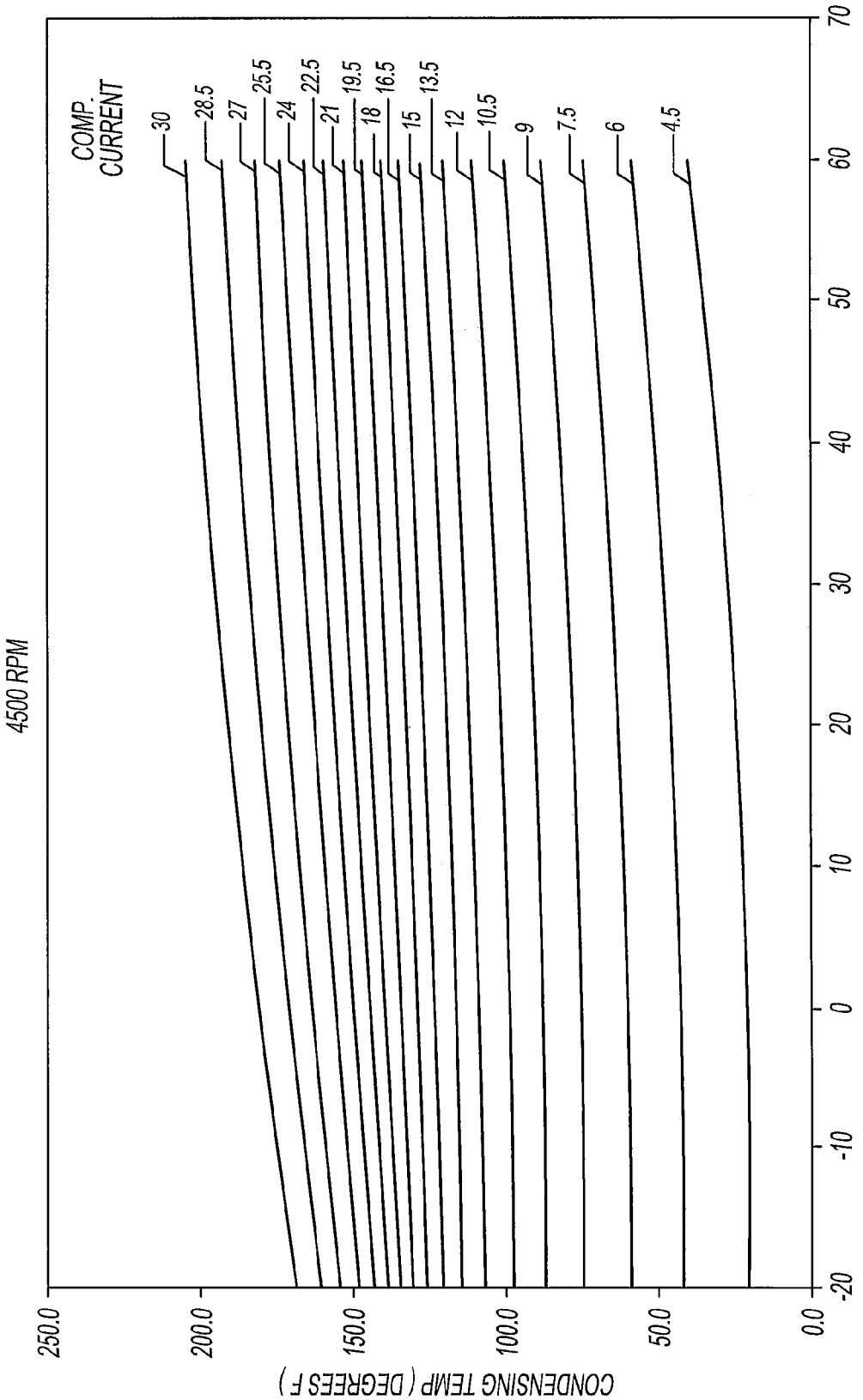

4500 RPM
COMP. CURRENT
30
28.5
27
25.5
24
22.5
21
19.5
18
16.5
15
13.5
12
10.5
9
7.5
6
4.5
250.0
200.0
150.0
100.0
50.0
0.0
CONDENSING TEMP (DEGREES F)
-20
-10
0
10
20
30
40
50
60
70
EVAP TEMP

Fig - 8

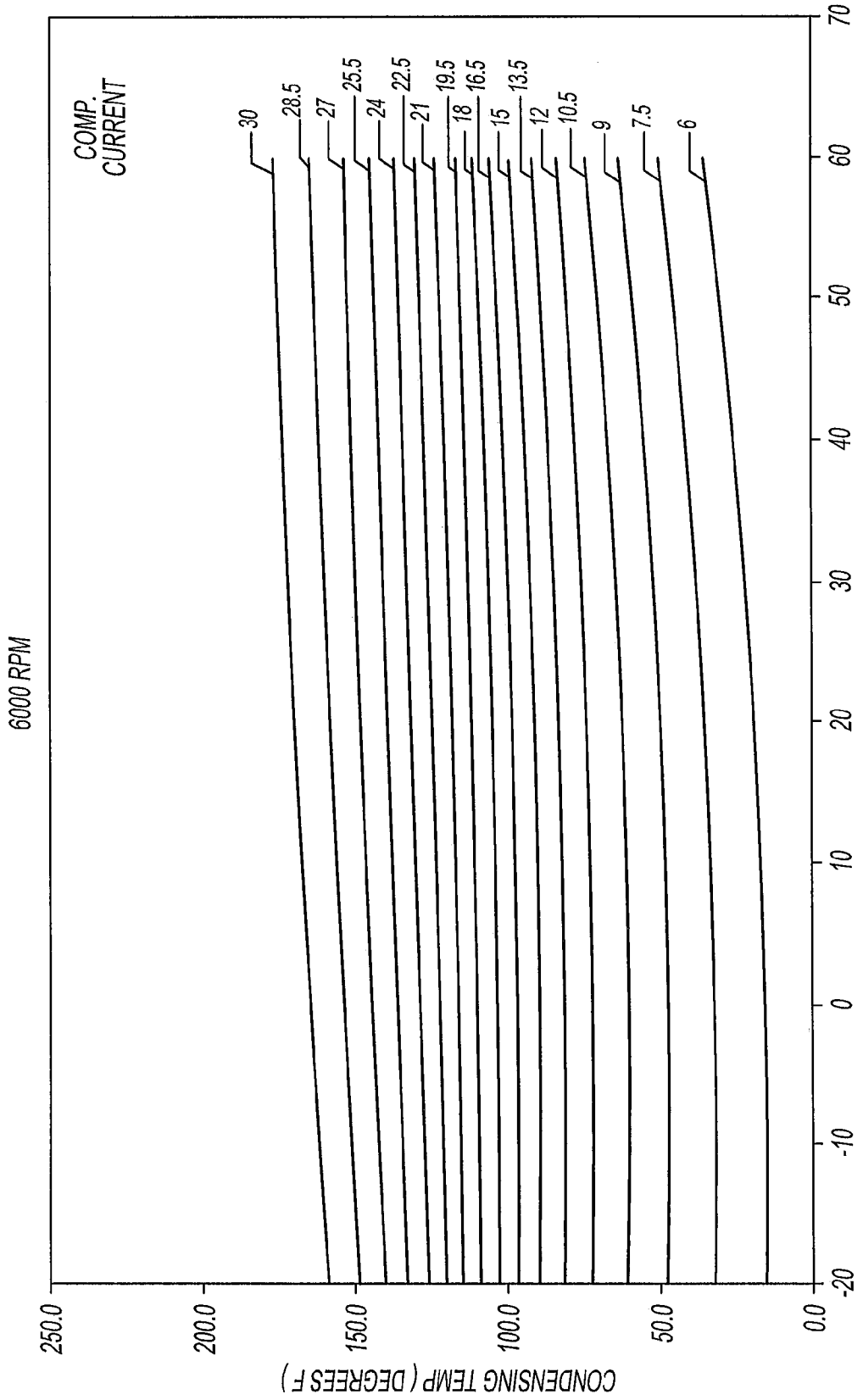

6000 RPM
COMP. CURRENT
30
28.5
27
25.5
24
22.5
21
19.5
18
16.5
15
13.5
12
10.5
9
7.5
6
250.0
200.0
150.0
100.0
50.0
0.0
CONDENSING TEMP (DEGREES F)
-20
-10
0
10
20
30
40
50
60
70
EVAP TEMP

Fig - 9

SYSTEM AND METHOD FOR EVALUATING PARAMETERS FOR A REFRIGERATION SYSTEM WITH A VARIABLE SPEED COMPRESSOR

CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims the benefit of U.S. Provisional Application No. 60/978,324, filed on Oct. 8, 2007. The application also claims the benefit of U.S. Provisional Application No. 60/978,258, filed on Oct. 8, 2007. The application also claims the benefit of U.S. Provisional Application No. 60/978,296, filed on Oct. 8, 2007. The entire disclosures of each of the above applications are incorporated herein by reference.

FIELD

The present disclosure relates to compressors and more particularly to a system and method for evaluating the parameters of a refrigeration system with a variable speed compressor.

BACKGROUND

The statements in this section merely provide background information related to the present disclosure and may not constitute prior art.

Compressors may be used in a wide variety of industrial and residential applications to circulate refrigerant within a refrigeration, heat pump, HVAC, or chiller system (generically "refrigeration systems") to provide a desired heating or cooling effect. In any of the foregoing applications, the compressor should provide consistent and efficient operation to insure that the particular application (i.e., refrigeration, heat pump, HVAC, or chiller system) functions properly. A variable speed compressor may be used to vary compressor capacity according to refrigeration system load. Operating parameters of the compressor and of the refrigeration system may be used by protection, control, and diagnostic systems to insure optimal operation of the compressor and refrigeration system components. For example, evaporator temperature and/or condenser temperature may be used to diagnose, protect, and control the compressor and other refrigeration system components.

SUMMARY

A system is provided and may comprise a compressor connected to a condenser and an evaporator, a condenser sensor that outputs a condenser signal corresponding to at least one of a condenser pressure and a condenser temperature, an evaporator sensor that outputs an evaporator signal corresponding to at least one of an evaporator pressure and an evaporator temperature, an inverter drive that modulates a frequency of electric power delivered to the compressor to modulate a speed of the compressor, a monitor module that receives compressor power data and compressor speed data from the inverter drive, determines a measured condenser temperature based on the condenser signal, determines a measured evaporator temperature based on the evaporator signal, calculates a first derived condenser temperature based on the compressor power data and the compressor speed data, calculates a second derived condenser temperature based on the measured evaporator temperature, the compressor power data and the compressor speed data, and compares the measured condenser temperature with the first and second derived condenser temperatures to determine whether any of the measured condenser temperature and the first and second derived condenser temperatures are inaccurate.

In other features, the control module may determines whether each of the first and second derived condenser temperatures and the measured condenser temperature are within a predetermined temperature range.

In other features, when one of the first and second derived condenser temperatures and the measured condenser temperature are outside of the predetermined temperature range, the control module may disregard the one of the first and second derived condenser temperatures and the measured condenser temperature.

In other features, the control module may generate an alarm when one of the first and second derived condenser temperatures and the measured condenser temperature are outside of the predetermined temperature range.

In other features, the alarm may indicate that at least one of the condenser sensor, the evaporator sensor, the discharge temperature sensor, a voltage sensor within the inverter drive, and a current sensor within the inverter drive are malfunctioning.

In other features, the control module may average the first and second derived condenser temperatures and the measured condenser temperature.

A system is provided and may comprise a compressor connected to a condenser and an evaporator, a condenser sensor that outputs a condenser signal corresponding to at least one of a condenser pressure and a condenser temperature, an evaporator sensor that outputs an evaporator signal corresponding to at least one of an evaporator pressure and an evaporator temperature, a discharge temperature sensor that outputs a discharge temperature signal corresponding to a temperature of refrigerant exiting the compressor, an inverter drive that modulates a frequency of electric power delivered to the compressor to modulate a speed of the compressor, a monitor module that receives compressor power data and compressor speed data from the inverter drive, determines a measured condenser temperature based on the evaporator signal, determines a measured evaporator temperature based on the evaporator signal, calculates a first derived evaporator temperature based on the compressor power data, the discharge temperature signal, and the compressor speed data, calculates a second derived evaporator temperature based on the measured condenser temperature, the compressor power data, the compressor speed data, and the discharge temperature signal, and compares the measured evaporator temperature with the first and second derived evaporator temperatures to determine whether any of the measured evaporator temperature and the first and second derived evaporator temperatures are inaccurate.

In other features, the control module may determine whether each of the first and second derived evaporator temperatures and the measured evaporator temperature are within a predetermined temperature range.

In other features, when one of the first and second derived evaporator temperatures and the measured evaporator temperature are outside of the predetermined temperature range, the control module may disregard the one of the first and second derived evaporator temperatures and the measured evaporator temperature.

In other features, the control module may generate an alarm when one of the first and second derived evaporator temperatures and the measured condenser temperature are outside of the predetermined temperature range.

In other features, the alarm may indicate that at least one of the condenser sensor, the evaporator sensor, the discharge temperature sensor, a voltage sensor within the inverter drive, and a current sensor within the inverter drive are malfunctioning.

In other features, the control module may average the first and second derived evaporator temperatures and the measured condenser temperature.

The method may comprise receiving an evaporator signal corresponding to at least one of an evaporator pressure and an evaporator temperature corresponding to an evaporator connected to a condenser and a compressor, receiving a condenser signal corresponding to at least one of a condenser pressure and a condenser temperature corresponding to the condenser, receiving compressor power data and compressor speed data from an inverter drive that drives the compressor, determining a measured condenser temperature based on the condenser signal, determining a measured evaporator temperature based on the evaporator signal, calculating a first derived condenser temperature based on the compresor data and the compressor speed data, calculating a second derived condenser temperature based on the measured evaporator temperature, the compressor power data, and the compressor speed data; comparing the measured condenser temperature with the first and second derived condenser temperatures to determine whether any of the measured condenser temperature and the first and second derived condenser temperatures are inaccurate.

In other features, the method may include determining whether each of the first and second derived condenser temperatures and the measured condenser temperature are within a predetermined temperature range.

In other features, the method may include, when one of the first and second derived condenser temperatures and the measured condenser temperature are outside of the predetermined temperature range, disregarding the one of the first and second derived condenser temperatures and the measured condenser temperature.

In other features, the method may include generating an alarm when one of the first and second derived condenser temperatures and the measured condenser temperature are outside of the predetermined temperature range.

In other features, the alarm may indicate that at least one of the condenser sensor, the evaporator sensor, the discharge temperature sensor, a voltage sensor within the inverter drive, and a current sensor within the inverter drive are malfunctioning.

In other features, the method may include averaging the first and second derived condenser temperatures and the measured condenser temperature.

Further areas of applicability will become apparent from the description provided herein. It should be understood that the description and specific examples are intended for purposes of illustration only and are not intended to limit the scope of the present disclosure.

DRAWINGS

The drawings described herein are for illustration purposes only and are not intended to limit the scope of the present disclosure in any way.

FIG. **1** is a schematic view of a refrigeration system.

FIG. **2** is a flow chart showing steps performed according to the present teachings.

FIG. **3** is a flow chart showing steps performed according to the present teachings.

FIG. **4** is a graph showing discharge super heat correlated with suction super heat and outdoor temperature.

FIG. **5** is a graph showing condenser temperature correlated with compressor power and compressor speed.

FIG. **6** is a graph showing discharge line temperature correlated with evaporator temperature and condenser temperature.

FIG. **7** is a graph of evaporator temperature and condenser temperature.

FIG. **8** is a graph of evaporator temperature and condenser temperature.

FIG. **9** is a graph of evaporator temperature and condenser temperature.

DETAILED DESCRIPTION

The following description is merely exemplary in nature and is not intended to limit the present disclosure, application, or uses. It should be understood that throughout the drawings, corresponding reference numerals indicate like or corresponding parts and features.

As used herein, the terms module, control module, and controller refer to one or more of the following: An application specific integrated circuit (ASIC), an electronic circuit, a processor (shared, dedicated, or group) and memory that execute one or more software or firmware programs, a combinational logic circuit, or other suitable components that provide the described functionality. As used herein, computer readable medium refers to any medium capable of storing data for a computer. Computer-readable medium includes, but is not limited to, memory, RAM, ROM, PROM, EPROM, EEPROM, flash memory, CD-ROM, floppy disk, magnetic tape, other magnetic medium, optical medium, or any other device or medium capable of storing data for a computer.

With reference to FIG. **1**, an exemplary refrigeration system **5** includes a compressor **10** that compresses refrigerant vapor. While a specific refrigeration system is shown in FIG. **1**, the present teachings are applicable to any refrigeration system, including heat pump, HVAC, and chiller systems. Refrigerant vapor from compressor **10** is delivered to a condenser **12** where the refrigerant vapor is liquefied at high pressure, thereby rejecting heat to the outside air. The liquid refrigerant exiting condenser **12** is delivered to an evaporator **16** through an expansion valve **14**. Expansion valve **14** may be a mechanical or electronic valve for controlling super heat of the refrigerant. The refrigerant passes through expansion valve **14** where a pressure drop causes the high pressure liquid refrigerant to achieve a lower pressure combination of liquid and vapor. As hot air moves across evaporator **16**, the low pressure liquid turns into gas, thereby removing heat from evaporator **16**. The low pressure gas is again delivered to compressor **10** where it is compressed to a high pressure gas, and delivered to condenser **12** to start the refrigeration cycle again.

Compressor **10** may be driven by an inverter drive **22**, also referred to as a variable frequency drive (VFD), housed in an enclosure **20**. Enclosure **20** may be near compressor **10**. Inverter drive **22** receives electrical power from a power supply **18** and delivers electrical power to compressor **10**. Inverter drive **22** includes a control module **25** with a processor and software operable to modulate and control the frequency of electrical power delivered to an electric motor of compressor **10**. Control module **25** includes a computer readable medium for storing data including the software executed by the processor to modulate and control the frequency of electrical power delivered to the electric motor of compressor and the software necessary for control module **25** to execute

and perform the protection and control algorithms of the present teachings. By modulating the frequency of electrical power delivered to the electric motor of compressor **10**, control module **25** may thereby modulate and control the speed, and consequently the capacity, of compressor **10**.

Inverter drive **22** includes solid state electronics to modulate the frequency of electrical power. Generally, inverter drive **22** converts the inputted electrical power from AC to DC, and then converts the electrical power from DC back to AC at a desired frequency. For example, inverter drive **22** may directly rectify electrical power with a full-wave rectifier bridge. Inverter driver **22** may then chop the electrical power using insulated gate bipolar transistors (IGBT's) or thyristors to achieve the desired frequency. Other suitable electronic components may be used to modulate the frequency of electrical power from power supply **18**.

Electric motor speed of compressor **10** is controlled by the frequency of electrical power received from inverter driver **22**. For example, when compressor **10** is driven at sixty hertz electric power, compressor **10** may operate at full capacity operation. When compressor **10** is driven at thirty hertz electric power, compressor **10** may operate at half capacity operation.

Control module **25** may generate data corresponding to compressor current and/or compressor power during the routines executed to modulate the electric power delivered to the electric motor of compressor **10**. Control module **25** may utilize data corresponding to compressor current and/or compressor power to calculate and derive other compressor and refrigeration system parameters.

As described in the disclosure titled "VARIABLE SPEED COMPRESSOR PROTECTION SYSTEM AND METHOD", U.S. Application Ser. No. 60/978,258, which is incorporated herein by reference, suction super heat (SSH) and discharge super heat (DSH) may be used to monitor or predict a flood back condition or overheat condition of compressor **10**. As described therein, condenser temperature (Tcond) may be used to derive DSH. Likewise, evaporator temperature (Tevap) may be used to derive SSH.

A compressor floodback or overheat condition is undesirable and may cause damage to compressor **10** or other refrigeration system components. Suction super heat (SSH) and/or discharge super heat (DSH) may be correlated to a flood back or overheating condition of compressor **10** and may be monitored to detect and/or predict a flood back or overheating condition of compressor **10**. DSH is the difference between the temperature of refrigerant vapor leaving the compressor, referred to as discharge line temperature (DLT) and the saturated condenser temperature (Tcond). Suction super heat (SSH) is the difference between the temperature of refrigerant vapor entering the compressor, referred to as suction line temperature (SLT) and saturated evaporator temperature (Tevap).

SSH and DSH may be correlated as shown in FIG. **4**. The correlation between DSH and SSH may be particularly accurate for scroll type compressors, with outside ambient temperature being only a secondary effect. As shown in FIG. **4**, correlations between DSH and SSH are shown for outdoor temperatures (ODT) of one-hundred fifteen degrees Fahrenheit, ninety-five degrees Fahrenheit, seventy-five degrees Fahrenheit, and fifty-five degrees Fahrenheit. The correlation shown in FIG. **4** is an example only and specific correlations for specific compressors may vary by compressor type, model, capacity, etc.

A flood back condition may occur when SSH is approaching zero degrees or when DSH is approaching twenty to forty degrees Fahrenheit. For this reason, DSH may be used to detect the onset of a flood back condition and its severity. When SSH is at zero degrees, SSH may not indicate the severity of the flood back condition. As the floodback condition becomes more severe, SSH remains at around zero degrees. When SSH is at zero degrees, however, DSH may be between twenty and forty degrees Fahrenheit and may more accurately indicate the severity of a flood back condition. When DSH is in the range of thirty degrees Fahrenheit to eighty degrees Fahrenheit, compressor **10** may operate within a normal range. When DSH is below thirty degrees Fahrenheit, the onset of a flood back condition may be occur. When DSH is below ten degrees Fahrenheit, a severe flood back condition may occur.

With respect to overheating, when DSH is greater than eighty degrees Fahrenheit, the onset of an overheating condition may occur. When DSH is greater than one-hundred degrees Fahrenheit, a severe overheating condition may be present.

In FIG. **4**, typical SSH temperatures for exemplar refrigerant charge levels are shown. For example, as the percentage of refrigerant charge in refrigeration system **5** decreases, SSH typically increases.

As further described in the disclosure titled "VARIABLE SPEED COMPRESSOR PROTECTION SYSTEM AND METHOD", U.S. Application Ser. No. 60/978,258, which is incorporated herein by reference, Tcond may be a function of compressor power and compressor speed. Control module **25** may derive Tcond based on compressor power or current and compressor speed. As further described in the attached disclosure, Tevap may be a function of compressor power, compressor speed, and DLT. Control module **25** may derive Tevap based on compressor power or current, DLT, and compressor speed. As further described, control module **25** may use Tcond and/or Tevap to derive other parameters including compressor capacity, power, energy efficiency, ratio, load, Kwh/Day, etc.

Tcond may be derived from other system parameters. Specifically, Tcond may be derived from compressor current and voltage (i.e., compressor power), compressor speed, and compressor map data associated with compressor **10**. A method for deriving Tcond based on current, voltage and compressor map data for a fixed speed compressor is described in the commonly assigned application for Compressor Diagnostic and Protection System, U.S. application Ser. No. 11/059,646, Publication No. U.S. 2005/0235660. Compressor map data for a fixed speed compressor correlating compressor current and voltage to Tcond may be compressor specific and based on test data for a specific compressor type, model and capacity.

In the case of a variable speed compressor, Tcond may also be a function of compressor speed, in addition to compressor power.

A graphical correlation between compressor power in watts and compressor speed is shown in FIG. **5**. As shown, Tcond is a function of compressor power and compressor speed. In this way, a three-dimensional compressor map with data correlating compressor power, compressor speed, and Tcond may be derived for a specific compressor based on test data. Compressor current may be used instead of compressor power. Compressor power, however, may be preferred over compressor current to reduce the impact of any line voltage variation. The compressor map may be stored in a computer readable medium accessible to control module **25**.

In this way, control module **25** may calculate Tcond based on compressor power data and compressor speed data. Control module **25** may calculate, monitor, or detect compressor power data during the calculations performed to convert elec-

trical power from power supply **18** to electrical power at a desired frequency. In this way, compressor power and current data may be readily available to control module **25**. In addition, control module **25** may calculate, monitor, or detect compressor speed based on the frequency of electrical power delivered to the electric motor of compressor **10**. In this way, compressor speed data may also be readily available to control module **25**. Based on compressor power and compressor speed, control module **25** may derive Tcond.

After measuring or calculating Tcond, control module **25** may calculate DSH as the difference between Tcond and DLT, with DLT data being receiving from external DLT sensor **28** or internal DLT sensor **30**.

Tevap may be derived as a function of Tcond and DLT, as described in commonly assigned U.S. application Ser. No. 11/059,646, U.S. Publication No. 2005/0235660. For variable speed compressors, the correlation may also reflect compressor speed. In this way, Tevap may be derived as a function of Tcond, DLT and compressor speed.

As shown in FIG. **6**, Tevap is shown correlated with DLT, for various Tcond levels. For this reason, compressor map data for different speeds may be used.

Tcond and Tevap may be calculated based on a single derivation.

In addition, iterative calculations may be made based on the following equations:

$$Tcond=f(\text{compressor power, compressor speed, } Tevap) \quad \text{Equation 1}$$

$$Tevap=f(Tcond, \text{ DLT, compressor speed}) \quad \text{Equation 2}$$

Multiple iterations of these equations may be performed to achieve convergence. For example, three iterations may provide optimal convergence. As discussed above, more or less iteration, or no iterations, may be used.

Tevap and Tcond may also be determined by using compressor map data, for different speeds, based on DLT and compressor power, based on the following equations:

$$Tevap=f(\text{compressor power, compressor speed, DLT}) \quad \text{Equation 3}$$

$$Tcond=f(\text{compressor power, compressor speed, DLT}) \quad \text{Equation 4}$$

As described in the disclosure titled "SYSTEM AND METHOD FOR CALCULATING PARAMETERS FOR A REFRIGERATION SYSTEM WITH A VARIABLE SPEED COMPRESSOR", U.S. Application Ser. No. 60/978,296, which is incorporated herein by reference, Tcond may be calculated based on Tevap and compressor current and compressor speed. Likewise, Tevap may be derived from Tcond and compressor current and compressor speed.

Control module **25** may receive Tevap and, as described above, may receive compressor speed and compressor current data as a result of operating inverter drive **22** and modulating the frequency of power delivered to compressor **10**.

Control module **25** may calculate Tcond from Tevap, compressor speed, and compressor current based on compressor map data derived from field tests for a particular compressor type, model, and capacity. The compressor map data may correlate Tcond with Tevap, compressor current, and compressor speed.

As shown in FIGS. **7**, **8** and **9**, Tcond is graphically correlated with Tevap and compressor current for various compressor speeds. Specifically, FIG. **7** shows Tcond related to Tevap and compressor current for compressor speed of 3600 RPM. FIG. **8** shows Tcond related to Tevap and compressor current for compressor speed of 4500 RPM. FIG. **9** shows Tcond related to Tevap and compressor current for compressor speed of 6000 RPM. FIGS. **7**, **8** and **9** are exemplary. Additional compressor map data, spanning a range of compressor speeds and compressor currents may be used by control module **25** and stored in a computer readable medium accessible to control module **25**.

FIGS. **7**, **8** and **9** graphically relate Tcond, Tevap and various compressor currents for a particular compressor speed. For example in FIG. **8**, compressor currents are shown for various amperage levels between 4.5 and 30. Corresponding Tcond vs. Tevap curves are shown for each compressor current at the compressor speed of 4500 RPM.

In this way, control module may derive Tcond from Tevap, as measured by evaporator temperature sensor **40**, compressor speed and compressor current data from operating inverter drive **22**.

As shown in FIG. **1**, condenser **12** may include a condenser temperature sensor **42**, which may sense Tcond and communicate Tcond to control module **25**. Alternatively, a condenser pressure sensor may be used. Based on Tcond as measured by condenser temperature sensor **42**, control module **25** may calculate Tevap from Tcond, DLT, compressor current, and compressor speed according to compressor map data as shown in FIGS. **7**, **8** and **9**, and as described above.

In this way, control module **25** may derive Tevap from Tcond, as measured by condenser temperature sensor **42**, DLT as measured by DLT sensor **41**, and compressor current and compressor speed data from operating inverter drive **22**. Likewise, control module **25** may derive Tcond from Tevap, as measured by evaporator temperature sensor **40**, and compressor current and compressor speed data from operating inverter drive **22**.

Thus, there are multiple and various ways to calculate and derive Tcond and Tevap based on the various sensors and data available. In this way, control module may function as, or include, a monitor module that compares and evaluates Tcond or Tevap data that is calculated, measured or derived from multiple sources.

As shown in FIG. **1**, condenser **12** may include a condenser temperature sensor **42** that determines Tcond and communicates Tcond to control module **25**. Evaporator **16** may include an evaporator temperature sensor that measures Tevap and communicates Tevap to control module **25**. Alternatively, pressure sensors may be used.

Based on Tcond as sensed by condenser temperature sensor **42** and Tevap as sensed by evaporator temperature sensor **40**, and based on compressor speed and compressor power as indicated by inverter drive **22**, control module may calculate and measure Tcond and Tevap multiple different ways. Control module **25** may then function as a monitor module to compare and evaluate the various calculations against each other. Alternatively, control module **25** may be connected to a separate monitor module within inverter drive **22**, within enclosure **20**, or within a system controller for refrigeration system **5**. In addition, a monitor module may be separate from control module **25** and the refrigeration system controller and may be located remotely from refrigeration system **5**.

As shown in FIG. **2**, an algorithm for evaluating refrigeration system data may be executed by control module **25** and begin in step **200**. In step **202**, control module **25** may measure Tcond with Tcond sensor (Tcond-sensed). In step **204**, control module **25** may calculate Tcond from compressor power and compressor speed data from inverter drive **22** (Tcond-derived-**1**). In step **206**, control module **25** may measure Tevap with Tevap sensor (Tevap-sensed). In step **208**, control module **25** may calculate Tcond from Tevap-sensed, and compressor power and compressor speed data from inverter drive **22**. In step **210**, control module **25** may compare Tcond-sensed with Tcond-derived-**1** and Tcond-de-

rived-2. In step 212, control module 25 may determine a correct Tcond based on the comparison. In step 214, control module 25 may determine whether any sensors are malfunctioning based on the comparison.

As an example, control module 25 may determine whether all three Tcond values (i.e., Tcond-sensed, Tcond-derived-1, and Tcond-derived-2) are within a similar predetermined range. If, for example, two of the Tcond values are within a similar range and a third Tcond value is outside of the range, control module 25 may disregard the Tcond value outside of the predetermined range, and rely only on the two Tcond values within the predetermined range. In this way control module 25 may allow the various Tcond values to "vote" on a correct Tcond value.

In addition, control module 25 may average the various Tcond values to arrive at an averaged Tcond value.

When control module 25 determines that one of the Tcond values is outside of a predetermined range, control module 25 may generate an alarm to indicate that a particular sensor associated with the out of range Tcond value may be malfunctioning. Moreover, control module 25 may rank the various sensors used to give priority to sensors that are more likely accurate. For example, voltage and current transducers used in inverter drive 22 are most likely functioning properly if compressor 10 is functioning. If the voltage and current transducers within inverter drive 22 fail, compressor 10 may also fail. Therefore, if compressor 10 is functioning it is a good indication that the voltage and current transducers within inverter drive 22 are likewise functioning properly.

For this reason, if a particular Tcond value is outside of a predetermined range, control module 25 may track the malfunctioning sensor by examining sensors other than the voltage and current transducers within inverter drive 22. In this way, voltage and current transducers within inverter drive 22 are "high priority" sensors. Control module 25 may look to sensors other than the voltage and current transducers within inverter drive to determine any malfunctioning sensors.

In this way, control module 25 may locate a system sensor that may be generating incorrect data.

With reference to FIG. 3, control module 25 may implement a similar algorithm as shown in FIG. 2, except that Tevap is evaluated instead of Tcond. For example, in step 302 control module 25 may measure Tevap (Tevap-sensed) with Tevap sensor. In step 304, control module 25 may calculate Tevap based on compressor power and compressor speed from inverter drive 22 (Tevap-derived-1). In step 306, control module 25 may measure Tcond with Tcond sensor 42 (Tcond-sensed). In step 308, control module 25 may calculate Tevap from Tcond-sensed and compressor power and compressor speed data from inverter drive 22. In step 310, control module may compare Tevap-sensed with Tevap-derived-1 and Tevap-derived-2. In step 312, control module 25 may determine correct Tevap based on the comparison. In step 314, control module may determine whether any sensors are malfunctioning based on the comparison as described above with respect to Tcond and FIG. 2.

In this way, control module 25 may determine accurate Tcond and Tevap measurements by redundantly calculating, deriving and measuring those parameters and by checking the various measurements and derivations against each other to arrive at a precise parameter. Control module 25 may also use redundancy checking between the various measured and derived parameters to determine whether any system sensors are malfunctioning and producing incorrect data.

What is claimed is:

1. A system comprising:
- a compressor connected to a condenser and an evaporator;
- a condenser sensor that outputs a condenser signal corresponding to at least one of a condenser pressure and a condenser temperature;
- an evaporator sensor that outputs an evaporator signal corresponding to at least one of an evaporator pressure and an evaporator temperature;
- an inverter drive that modulates a frequency of electric power delivered to said compressor to modulate a speed of said compressor;
- a control module that receives compressor power data and compressor speed data from said inverter drive, determines a measured condenser temperature based on said condenser signal, determines a measured evaporator temperature based on said evaporator signal, calculates a first derived condenser temperature based on said compressor power data and said compressor speed data, calculates a second derived condenser temperature based on said measured evaporator temperature, said compressor power data and said compressor speed data, and compares said measured condenser temperature with said first and second derived condenser temperatures to determine whether any of said measured condenser temperature and said first and second derived condenser temperatures are inaccurate.

2. The system of claim 1 wherein said control module determines whether each of the first and second derived condenser temperatures and the measured condenser temperature are within a predetermined temperature range.

3. The system of claim 2 wherein when one of said first and second derived condenser temperatures and said measured condenser temperature are outside of said predetermined temperature range, said control module disregards said one of said first and second derived condenser temperatures and said measured condenser temperature.

4. The system of claim 3 wherein said control module generates an alarm when one of said first and second derived condenser temperatures and said measured condenser temperature are outside of said predetermined temperature range.

5. The system of claim 4 wherein said alarm indicates that at least one of said condenser sensor, said evaporator sensor, a discharge temperature sensor, a voltage sensor within said inverter drive, and a current sensor within said inverter drive are malfunctioning.

6. The system of claim 1 wherein said control module averages said first and second derived condenser temperatures and said measured condenser temperature.

7. A system comprising:
- a compressor connected to a condenser and an evaporator;
- a condenser sensor that outputs a condenser signal corresponding to at least one of a condenser pressure and a condenser temperature;
- an evaporator sensor that outputs an evaporator signal corresponding to at least one of an evaporator pressure and an evaporator temperature;
- a discharge temperature sensor that outputs a discharge temperature signal corresponding to a temperature of refrigerant exiting said compressor;
- an inverter drive that modulates a frequency of electric power delivered to said compressor to modulate a speed of said compressor;
- a control module that receives compressor power data and compressor speed data from said inverter drive, determines a measured condenser temperature based on said condenser signal, determines a measured evaporator

temperature based on said evaporator signal, calculates a first derived evaporator temperature based on said compressor power data, said discharge temperature signal, and said compressor speed data, calculates a second derived evaporator temperature based on said measured condenser temperature, said compressor power data, said compressor speed data, and said discharge temperature signal, and compares said measured evaporator temperature with said first and second derived evaporator temperatures to determine whether any of said measured evaporator temperature and said first and second derived evaporator temperatures are inaccurate.

8. The system of claim **7** wherein said control module determines whether each of the first and second derived evaporator temperatures and the measured evaporator temperature are within a predetermined temperature range.

9. The system of claim **8** wherein when one of said first and second derived evaporator temperatures and said measured evaporator temperature are outside of said predetermined temperature range, said control module disregards said one of said first and second derived evaporator temperatures and said measured evaporator temperature.

10. The system of claim **9** wherein said control module generates an alarm when one of said first and second derived evaporator temperatures and said measured evaporator temperature are outside of said predetermined temperature range.

11. The system of claim **10** wherein said alarm indicates that at least one of said condenser sensor, said evaporator sensor, said discharge temperature sensor, a voltage sensor within said inverter drive, and a current sensor within said inverter drive are malfunctioning.

12. The system of claim **7** wherein said control module averages said first and second derived evaporator temperatures and said measured condenser temperature.

13. A method comprising;

receiving an evaporator signal corresponding to at least one of an evaporator pressure and an evaporator temperature corresponding to an evaporator connected to a condenser and a compressor;

receiving a condenser signal corresponding to at least one of a condenser pressure and a condenser temperature corresponding to said condenser;

receiving compressor power data and compressor speed data from an inverter drive that drives said compressor;

determining a measured condenser temperature based on said condenser signal;

determining a measured evaporator temperature based on said evaporator signal;

calculating a first derived condenser temperature based on said compressor data and said compressor speed data;

calculating a second derived condenser temperature based on said measured evaporator temperature, said compressor power data, and said compressor speed data;

comparing said measured condenser temperature with said first and second derived condenser temperatures to determine whether any of said measured condenser temperature and said first and second derived condenser temperatures are inaccurate.

14. The method of claim **13** determining whether each of the first and second derived condenser temperatures and the measured condenser temperature are within a predetermined temperature range.

15. The method of claim **13** further comprising, when one of said first and second derived condenser temperatures and said measured condenser temperature are outside of said predetermined temperature range, disregarding said one of said first and second derived condenser temperatures and said measured condenser temperature.

16. The method of claim **15** further comprising generating an alarm when one of said first and second derived condenser temperatures and said measured condenser temperature are outside of said predetermined temperature range.

17. The method of claim **16** wherein said alarm indicates that at least one of a condenser sensor, a evaporator sensor, a discharge temperature sensor, a voltage sensor within said inverter drive, and a current sensor within said inverter drive are malfunctioning.

18. The method of claim **13** further comprising averaging said first and second derived condenser temperatures and said measured condenser temperature.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 8,448,459 B2
APPLICATION NO. : 12/247020
DATED : May 28, 2013
INVENTOR(S) : Daniel L. McSweeney et al.

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

On the Title Page:

Page 3, Column 2, Other Publications, Line 5	After "US2008/011442", insert --,--.
Page 3, Column 2, Other Publications, Line 6	Delete "Applicatoin" and insert --Application--.
Page 4, Column 1, Other Publications, Line 10	After "Chinese", insert --Patent--.
Page 4, Column 1, Other Publications, Line 50	After "PCT/US2008/011576", insert --,--.
Page 4, Column 1, Other Publications, Line 52	After "PCT/US2008/011576", insert --,--.
Page 4, Column 1, Other Publications, Line 55	After "PCT/US2008/011464", insert --,--.
Page 4, Column 1, Other Publications, Line 57	After "PCT/US2008/011464", insert --,--.
Page 5, Column 1, Other Publications, Line 2	Delete "translation" and insert --Translation--.
Page 5, Column 1, Other Publications, Line 3	Delete "U.S." and insert --Y.S.--.
Page 5, Column 1, Other Publications, Line 5	After "Chinese", insert --Patent--.

In the Drawings:

Sheet 1 of 9, Reference Numeral 12, Fig. 1	Delete "Condensor" and insert --Condenser--.

In the Specification:

Signed and Sealed this
Seventeenth Day of September, 2013

Teresa Stanek Rea

Teresa Stanek Rea
Deputy Director of the United States Patent and Trademark Office

Column 3, Line 21	Delete "compresor data" and insert --compressor power data--.
Column 5, Line 12	Delete "driver" and insert --drive--.
Column 5, Line 18	Delete "driver" and insert --drive--.
Column 5, Line 40	Delete "floodback" and insert --flood back--.
Column 6, Line 3	Delete "floodback" and insert --flood back--.
Column 6, Line 5	After "degrees", insert --Fahrenheit--.

In the Claims:

Column 11, Line 35	In claim 13, delete "comprising;" and insert --comprising:--.
Column 12, Line 9	In claim 13, after "compressor", insert --power--.