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Jayanth

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(54) **REMOTE DATA ACQUISITION SYSTEM AND METHOD**

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Related U.S. Application Data

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B60H 1/00 (2006.01)
G05B 15/00 (2006.01)

(52) **U.S. Cl.** **62/129**; 62/230; 165/11.1; 236/94; 700/276

(58) **Field of Classification Search** 621/125, 621/126, 127, 129, 130, 230; 165/11.1, 11.2; 236/51, 94; 700/276, 277, 278; 702/182, 702/183, 184, 185

See application file for complete search history.

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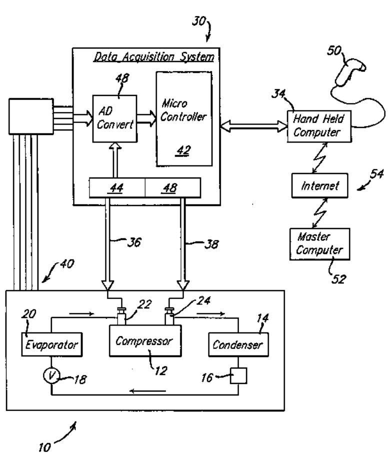
(57) **ABSTRACT**

An apparatus for diagnosing a cooling system includes a first sensor for sensing a first operating parameter, a second sensor for sensing a motor operating parameter, a controller in communication with the sensors for receiving a signal from each of the sensors, and a computer in communication with the controller. The computer includes a memory storing normal operating parameters for a plurality of cooling systems, and is operable to compare the first and motor operating parameters with the normal parameters of one of the plurality of cooling systems to diagnose the cooling system.

54 Claims, 2 Drawing Sheets



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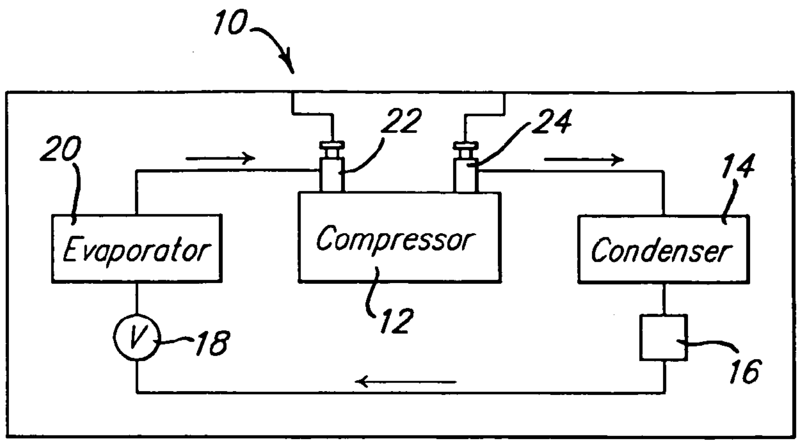

10
22
24
20
14
Evaporator
Compressor
Condenser
V
18
12
16

FIG. 1.

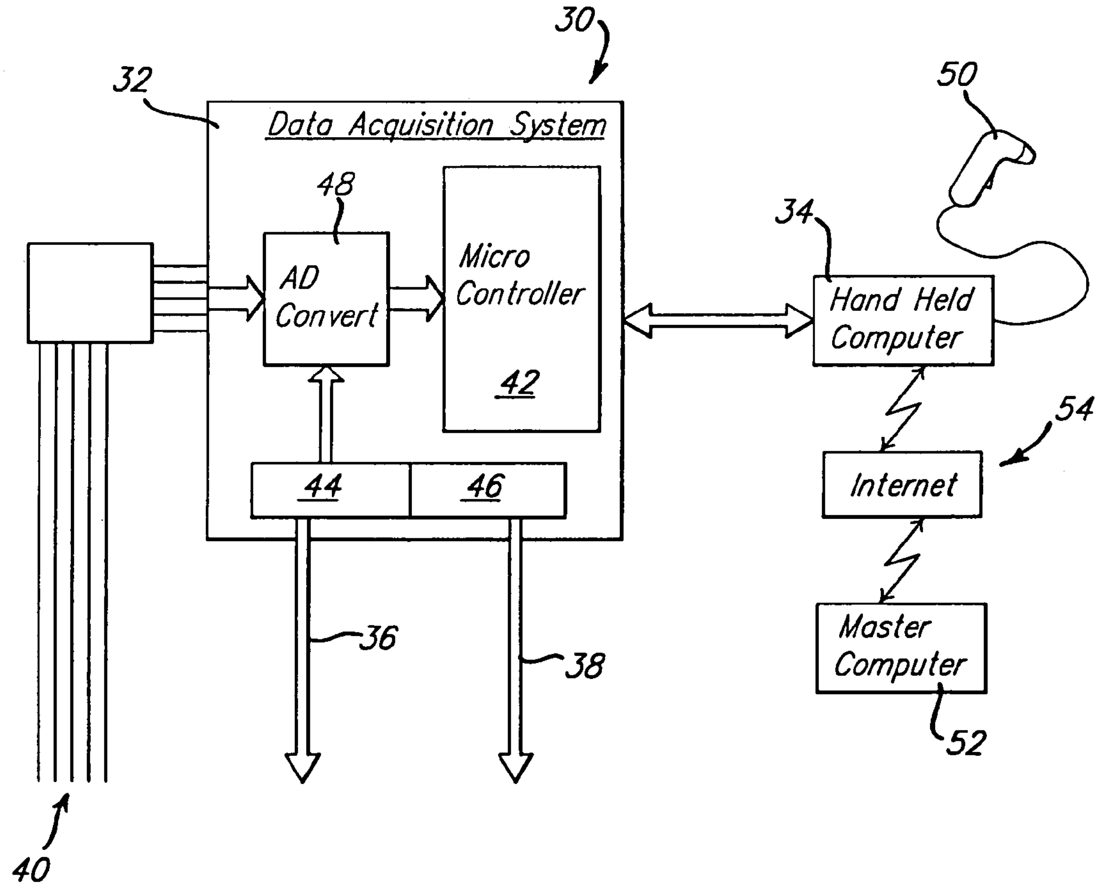
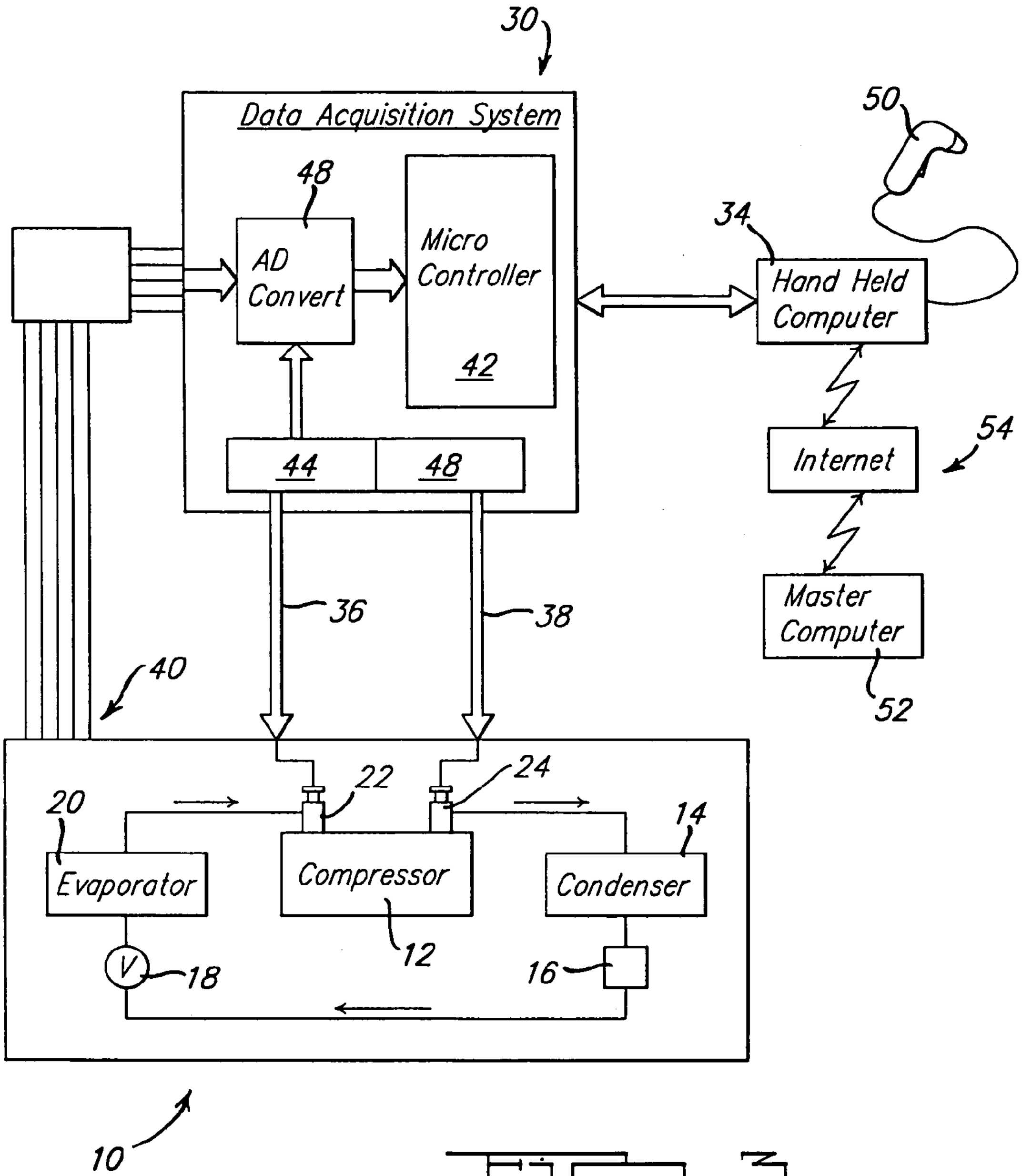

30
32
Data Acquisition System
48
AD Convert
Micro Controller
42
44
46
36
38
40
50
34
Hand Held Computer
54
Internet
Master Computer
52

FIG. 2.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Evaporator
Compressor
Condenser
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FIG. 3.

REMOTE DATA ACQUISITION SYSTEM AND METHOD

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a continuation of U.S. patent application Ser. No. 10/280,774 filed on Oct. 25, 2002, which is a continuation of U.S. patent application Ser. No. 10/012,631 filed on Dec. 7, 2001, which is a continuation of U.S. patent application Ser. No. 09/721,594 filed on Nov. 22, 2000 (now U.S. Pat. No. 6,324,854), which are incorporated herein by reference.

FIELD OF THE INVENTION

The present invention relates generally to an apparatus and a method for servicing an air-conditioning system. More particularly, the present invention relates to an apparatus and a method for servicing an air-conditioning system which utilizes a data acquisition system for communicating with the air-conditioning system and a hand held computer which analyzes the information received from the data acquisition system.

BACKGROUND AND SUMMARY OF THE INVENTION

Several air-conditioning service units are available to assist a trained technician in servicing an air-conditioning system. Some prior art units are adapted to be connected to the high- and low-pressure sides of the air-conditioning system and these units include gauges for measuring the high and low side pressures of the system under the appropriate operating conditions. These measured values are then manually compared with known standards for the particular air-conditioning system being tested. From this manual comparison and other observable characteristics of the system, the technician decides whether or not the system is operating properly. If a system malfunction is indicated, the technician determines the possible causes of the malfunction and decides how the system should be repaired.

Expensive and high-end large commercial air-conditioning systems are typically provided with their own sophisticated electronics and a host of internal sensors. The sophisticated electronics and the host of sensors for these large commercial systems simplify the diagnosis for these systems. However, the costs associated with these electronics and the sensors is too much for cost sensitive systems like residential air-conditioning systems and small commercial installations. In these smaller systems, the servicing efficiency is still dependent upon the skill of the technician. The tools that the technician typically uses to help in the diagnosis are pressure gauges, service units which suggest possible fixes, common electronic instruments like multi-meters and component data books which supplement the various service units that are available. Even though these tools have improved over the years in terms of accuracy, ease of use and reliability, the technician still has to rely on his own personal skill and knowledge in interpreting the results of these instruments. The problems associated with depending upon the skill and knowledge of the service technician is expected to compound in the future due in part to the introduction of many new refrigerants. Thus, the large experience that the technicians have gained on current day refrigerants will not be adequate for the air-conditioning systems of the future. This leads to a high cost for training and a higher incident of misdiagnosing which needs to be addressed.

During the process of this diagnosis by the technician, he typically relies on his knowledge and his past experience. Thus, accurate diagnosis and repair require that the technician possess substantial experience. The problem of accurate diagnosis is complicated by the large number of different air-conditioning systems in the marketplace. While each air-conditioning system includes a basic air-conditioning cycle, the various systems can include components and options that complicate the diagnosis for the system as a whole. Accordingly, with these prior art service units, misdiagnosis can occur, resulting in improperly repaired systems and in excessive time to complete repairs.

Although service manuals are available to assist the technician in diagnosing and repairing the air-conditioning systems, their use is time-consuming and inefficient. In addition, the large number of manuals require valuable space and each manual must be kept up to date.

In order to improve over the above described diagnosis procedures, service units have been designed which employ electronic processing means for initially diagnosing the air-conditioning system and, thereafter, if tests or repairs are needed, for guiding the mechanic to correction of its defective operation. When using these prior art service units, the technician identifies what type of system is being diagnosed. The service units are then capable of receiving signals which are indicative of the high and low side pressures of the air-conditioning system. Based upon the observed pressures in relation to the programmed standards for the type of air-conditioning system being tested, the service unit indicates whether or not the system is functioning properly. If the air-conditioning system is not functioning properly, a list of possible defective components and/or other possible causes of the system malfunction are identified. This list could range from a complete self-diagnosis where the problem is clearly identified to interactive dialog that narrows down the possible causes of the problem. The systems that monitor only the high and low pressure side pressures of the air-conditioning system are thus inherently limited in their diagnostic ability. What is needed is an air-conditioning service system which monitors not only the system's pressures, but the system should monitor other conditions such as various temperatures within the system as well as operating parameters of the motor driving the system in order to enable a more accurate diagnosis.

The present invention provides the art with a diagnostic system which is applicable to the present day air-conditioning systems as well as being adaptable to the air-conditioning systems of the future. The present invention provides a data acquisition system which includes a judicious integration of sensors. The sensors monitor the system's pressures, various temperatures within the system as well as operating parameters for the motor driving the system. By incorporating these additional sensors and specifically the motor operating sensors, the data acquisition system can provide better diagnostic results for the air-conditioning system. The data acquisition system coupled with a hand held computer using sophisticated software provides a reasonable cost diagnostic tool for a service technician. In the very cost sensitive systems like residential air-conditioning systems, this diagnostic tool eliminates the need for having each system equipped with independent sensors and electronics, yet they will still have the capability to assist the technician to efficiently service the air-conditioning system when there is a problem. The diagnostic tool also includes a wireless Internet link with a master computer which contains the service information on all of the various systems in use. In this way, the hand held computer can be constantly updated with new information as well as not being required to maintain files on every system. If the technician encounters a system not on file in his hand held computer, a wireless Internet link to the master computer can identify the missing information.

Other advantages and objects of the present invention will become apparent to those skilled in the art from the subsequent detailed description, appended claims and drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

In the drawings which illustrate the best mode presently contemplated for carrying out the present invention:

FIG. **1** schematically illustrates a typical air-conditioning system in accordance with the present invention;

FIG. **2** schematically illustrates an air-conditioning service system in accordance with the present invention; and

FIG. **3** schematically illustrates the air-conditioning service system shown in FIG. **2** coupled with the air-conditioning system shown in FIG. **1**.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now to the drawings in which like reference numerals designate like or corresponding parts throughout the several views, there is shown in FIG. **1** an air-conditioning system for use with the service system in accordance with the present invention and which is designated generally by the reference numeral **10**. Air-conditioning system **10** comprises a compressor **12** which compresses refrigerant gas and delivers it to a condensor **14** where the compressed gas is converted to a liquid. Condensor **14** discharges through a sight glass **16** which provides visual observation of the fill level of refrigerant in the system during operation. Sight glass **16** also normally includes a reservoir for storing liquid refrigerant under conditions of large load fluctuations on the system, and includes a high-pressure filter and desiccant to trap and hold any moisture or solid particles which may be present in the system. From sight glass **16**, the refrigerant is delivered through an expansion valve **18** to an evaporator **20** where the refrigerant is evaporated into gaseous form as the system provides cooling in a well known manner. From evaporator **20**, the refrigerant returns to compressor **12** to again start the above described refrigeration cycle.

For purposes of initial charging system **10** and for periodic servicing of system **10**, compressor **12** has a pair of refrigerant ports **22** and **24**. Port **22** is located at or near the low pressure suction port for compressor **12** and port **24** is located at or near the high pressure discharge port for compressor **12**. Ports **22** and **24** provide connections for pressure gauge readings and for the addition of refrigerant and/or lubricating oil at either the suction side or the discharge side of compressor **12**.

Referring now to FIGS. **2** and **3**, an air-conditioning service system or apparatus **30** is illustrated. Apparatus **30** comprises a data acquisition system **32**, a hand held computer **34**, a pair of pressure hoses **36** and **38**, and a plurality of sensors **40**. Data acquisition system **32** includes a micro-controller **42**, a pair of pressure sensors **44** and **46** and an Analog to Digital converter **48**. Pressure hose **36** is adapted to be attached to port **22** to monitor the pressure at or near the suction port of compressor **12**. Pressure hose **38** is adapted to be attached to port **24** to monitor the pressure at or near the discharge port of compressor **12**. Each hose **36** and **38** is in communication with sensors **44** and **46**, respectively, and each sensor **44** and **46** provides an analog signal to A/D converter **48** which is indicative of the pressure being monitored. A/D converter **48** receives the analog signal from sensors **44** and **46**, converts this analog signal to a digital signal which is indicative of the pressure being monitored and provides this digital system to micro-controller **42**.

Sensors **40** are adapted to monitor various operating characteristics of compressor **12**. Several sensors **40** monitor specific temperatures in the system, one sensor monitors compressor supply voltage, one sensor monitors compressor supply amperage and one sensor monitors the rotational speed (RPM) for compressor **12**. Typical temperatures that can be monitored include evaporator refrigerant temperature, condensor refrigerant temperature, ambient temperature and conditioned space temperature. The analysis of parameters like compressor voltage, compressor current, compressor RPM and discharge temperature can provide valuable information regarding the cause of the problem. Each sensor **40** is connected to A/D converter **48** and sends an analog signal indicative of its sensed parameter to A/D converter **48**. A/D converter **48** receives the analog signals from sensors **40** and converts them to a digital signal indicative of the sensed parameter and provides this digital signal to micro-controller **42**.

Micro-controller **42** is in communication with computer **34** and provides to computer **34** the information provided by micro-controller **42**. Once computer **34** is provided with the air-conditioning system configuration and the sensed parameters from sensors **40**, **44** and **46**, a diagnostic program can be performed. The air-conditioning system configuration can be provided to computer **34** manually by the technician or it can be provided to computer **34** by a bar code reader **50** if the air-conditioning system is provided with a bar code label which sufficiently identifies the air-conditioning system.

In order for the diagnostic program to run, computer **34** must know what the normal parameters for the monitored air conditioning system should be. This information can be kept in the memory of computer **34**, it can be kept in the larger memory of a master computer **52** or it can be kept in both places. Master computer **52** can be continuously updated with new models and revised information as it becomes available. When accessing the normal parameters in its own memory, computer **34** can immediately use the saved normal parameters or computer **34** can request the technician to connect to master computer **52** to confirm and/or update the normal parameters. The connection to the master computer **52** is preferably accomplished through a wireless Internet connection **54** in order to simplify the procedure for the technician. Also, if the particular air conditioning system being monitored is not in the memory of computer **34**, computer **34** can prompt the technician to connect to master computer **52** using wireless Internet connection **54** to access the larger data base which is available in the memory of master computer **52**. In this way, computer **34** can include only the most popular systems in its memory but still have access to the entire population or air-conditioning systems through connection **54**. While the present invention is being illustrated utilizing wireless Internet connection **54**, it is within the scope of the present invention to communicate between computers **34** and **52** using a direct wireless or a wire connection if desired.

The technician using apparatus **30** would first hook up pressure hose **36** to port **22** and pressure hose **38** to port **24**. The technician would then hook up the various temperature sensors **40**, the compressor supply voltage and current sensors **40** and the compressor RPM sensor **40**. The technician would then initialize computer **34** and launch the diagnostics application software. The software on start-up prompts the technician to set up the test session. The technician then picks various options such as refrigerant type of the system and the system configuration, like compressors and system model number, expansion device type or other information for the configuration system. Optionally this information can be input into computer **34** using a barcode label and barcode reader **50** if this option is available. The software then checks to see if the operating information for the system or the compressor model exists within its memory. If this information is not within its memory, computer **34** will establish a wireless connection to master computer **52** through wireless Internet connection **54** and access this information from master computer **52**. Also, optionally, computer **34** can prompt the technician to update the existing information in its memory with the information contained in the memory of master computer **52** or computer **34** can prompt the technician to add the missing information to its memory from the memory of master computer **52**.

Once the test session is set up, the software commands micro-controller **42** to acquire the sensed values from sensors **40**, **44** and **46**. Micro-controller **42** has its own custom software that verifies the integrity of the values reported by sensors **40**, **44** and **46**. An example would be that micro-controller **42** has the ability to detect a failed sensor. The sensors values acquired by micro-controller **42** through A/D converter **48** are reported back to computer **34**. This cycle of sensor data is acquired continuously throughout the test session. The reported sensed data is then used to calculate a variety of system operating parameters. For example, superheat, supercooling, condensing temperature, evaporating temperature, and other operating parameters can be determined. The software within computer **34** then compares these values individually or in combination with the diagnostics rules programmed and then based upon these comparisons, the software derives a set of possible causes to the differences between the measured values and the standard operating values. The diagnostic rules can range from simple limits to fuzzy logic to trend analysis. The diagnostic rules can also range from individual values to a combination of values.

For example, the current drawn by compressor **12** is related to the suction and discharge pressures and is unique to each compressor model. Also, the superheat settings are unique to each air-conditioning system. Further, the diagnostic rules are different for different system configurations like refrigerant type, expansion device type, compressor type, unloading scheme, condensor cooling scheme and the like. In some situations, the application of the diagnostic rules may lead to the requirement of one or more additional parameters. For example, the diagnostic system may require the indoor temperature which may not be currently sensed. In this case, the technician will be prompted to acquire this valve by other means and to input its value into the program. When the criteria for a diagnostic rule have been satisfied, then a cause or causes of the problem is displayed to the technician together with solutions to eliminate the problem. For example, a high superheat condition in combination with several other conditions suggests a low refrigerant charge and the solution would be to add refrigerant to the system. The technician can then carry out the suggested repairs and then rerun the test. When the system is again functioning normally, the test results and the sensed values can be saved for future reference.

While sensors **40** are disclosed as being hard wired to A/D converter **48**, it is within the scope of the present invention to utilize wireless devices to reduce the number of wiring hookups that need to be made.

Also, while apparatus **30** is being disclosed as a diagnostic tool, it is within the scope of the present invention to include an automatic refrigerant charging capability through hoses **36** and **38** if desired. This would involve the addition of a control loop to meter refrigerant into the system from a charging cylinder. Accurate charging would be accomplished by continuously monitoring the system parameters during the charging process.

While the above detailed description describes the preferred embodiment of the present invention, it should be understood that the present invention is susceptible to modification, variation and alteration without deviating from the scope and fair meaning of the subjoined claims.

What is claimed is:

1. A cooling system diagnostic apparatus comprising:

a first sensor operable to sense a first cooling system parameter;

a second sensor operable to sense a motor operating parameter;

a controller in communication with said first and second sensors and operable to receive first sensor data from said first sensor and second sensor data from said second sensor

a master computer having a memory storing a plurality of data sets containing normal operating parameters for a plurality of systems; and

a computer in communication with said master computer to acquire one of said plurality of datasets from said master computer and in communication with said controller to receive said first sensor data and said second sensor data, said computer comparing said first sensor data and said second sensor data with said normal operating parameters to provide a diagnosis.

2. The apparatus of claim **1**, wherein said first operating parameter is a low-side pressure and said motor operating parameter is a compressor motor supply voltage.

3. The apparatus of claim **2**, further comprising a third sensor operable to detect high-side pressure.

4. The apparatus of claim **2**, wherein said first operating parameter is a low-side pressure and said motor operating parameter is a compressor motor rotational speed.

5. The apparatus of claim **4**, further comprising a third sensor operable to detect high-side pressure.

6. The apparatus of claim **1**, wherein said first operating parameter is a low-side pressure measurement and said motor operating parameter is a compressor motor supply amperage.

7. The apparatus of claim **6**, further comprising a third sensor operable to detect high-side pressure.

8. The apparatus of claim **1**, further comprising a third sensor operable to detect an evaporator refrigerant temperature.

9. The apparatus of claim **1**, further comprising a third sensor operable to detect a condenser refrigerant temperature.

10. The apparatus of claim **1**, wherein said computer and said master computer are in communication through the Internet.

11. The apparatus of claim **1**, wherein said computer and said master computer are in wireless communication.

12. The apparatus of claim **1**, wherein said computer is operable to output repair instructions.

13. The apparatus of claim **1**, further comprising a barcode reader in communication with said computer.

14. A method comprising:

measuring a first cooling system operating parameter;

measuring a second cooling system operating parameter;

measuring a compressor motor operating parameter;

communicating said first cooling system parameter, said second cooling system operating parameter, and said compressor motor operating parameter to a controller;

communicating said first cooling system parameter, said second cooling system parameter, and said compressor motor operating parameter from said controller to a computer;

selecting a dataset of normal operating parameters from a master computer located remotely from said computer;

downloading said normal operating parameters from said master computer to said computer;

comparing said set of normal operating parameters to said provided operating parameters at said computer; and

outputting diagnostic results.

15. The method of claim **14**, further comprising storing said system types in said computer.

16. The method of claim **14**, wherein said selecting includes inputting a system identifier.

17. The method of claim **14**, wherein said selecting includes communicating a selection between said computer and said master computer.

18. The method of claim **17**, wherein said downloading a selection includes communicating through the Internet.

19. The method of claim **14**, wherein said outputting diagnostic results includes providing instructions for cooling system repair.

20. A data acquisition system comprising:

a master computer storing predefined operating parameters for a plurality of system types;

a first sensor operable to sense a first cooling system operating parameter;

a second sensor operable to sense a compressor motor operating parameter;

a controller in communication with said first sensor and said second sensor and operable to receive first sensor data from said first sensor and second sensor data from said second sensor; and

a computer selecting said predefined operating parameters from said master computer and including an input for receiving said first cooling system operating parameter and said second cooling system operating parameter from said controller, said computer comparing said first cooling system operating parameter and said second cooling system operating parameter to said predefined operating parameters to diagnose the cooling system.

21. The data acquisition system of claim **20**, further comprising a third sensor operable to sense a second cooling system operating parameter and communicate said second cooling system operating parameter to said computer, wherein said monitored operating parameters include said first cooling system operating parameter, said second cooling system operating parameter, and said compressor motor operating parameter.

22. The data acquisition system of claim **21**, wherein said first cooling system operating parameter is low-side pressure, said second cooling system operating parameter is high-side pressure, and said compressor motor operating parameter is compressor motor supply voltage.

23. The data acquisition system of claim **21**, wherein said first cooling system operating parameter is low-side pressure, said second cooling system operating parameter is high-side pressure, and said motor operating parameter is compressor motor supply amperage.

24. The data acquisition system of claim **21**, wherein said first cooling system operating parameter is low-side pressure, said second cooling system operating parameter is high-side pressure, and said compressor motor operating parameter is compressor motor rotational speed.

25. The data acquisition system of claim **21**, wherein said first cooling system operating parameter is low side pressure, said second cooling system operating parameter is high side pressure, and further comprising a fourth sensor operable to sense an evaporator refrigerant temperature, wherein said monitored operating parameters further include said evaporator refrigerant temperature.

26. The data acquisition system of claim **21**, wherein said first cooling system operating parameter is low side pressure, said second cooling system operating parameter is high side pressure, and further comprising a fourth sensor operable to sense a condenser refrigerant temperature, wherein said monitored operating parameters further include said condenser refrigerant temperature.

27. The data acquisition system of claim **20**, wherein said computer includes a memory for storing said predefined operating parameters.

28. The data acquisition system of claim **20**, wherein said computer and said master computer are in communication through the Internet.

29. The data acquisition system of claim **20**, wherein said computer and said master computer are in wireless communication.

30. The data acquisition system of claim **20**, wherein said computer is operable to provide repair instructions.

31. The data acquisition system of claim **20**, wherein said computer is a hand-held computer.

32. A method for monitoring a system including a refrigerant compressor, evaporator, and condenser, said method comprising:

measuring a first operating parameter of the monitored system;

measuring a second operating parameter of the monitored system;

measuring a motor operating parameter of the monitored system;

communicating said first operating parameter, said second operating parameter, and said motor operating parameter to a controller;

providing at least one of said first operating parameter, said second operating parameter, and said motor operating parameter from said controller to a computer;

retrieving a dataset of predefined operating parameters for the monitored system from a plurality of predetermined operating parameters from a master computer;

comparing said predefined operating parameters from said selected dataset with said at least one provided operating parameter of the monitored system at said computer; and

providing diagnostic results based on said comparing.

33. The method for monitoring a system in accordance with claim **32**, wherein said retrieving includes inputting an identifier of the monitored system.

34. The method for monitoring a system in accordance with claim **33**, wherein said inputting includes reading said identifier with a barcode reader.

35. The method for monitoring a system in accordance with claim **32**, wherein said retrieving includes communicating through the Internet.

36. The method for monitoring a system in accordance with claim **32**, wherein said retrieving includes wirelessly communicating.

37. The method for monitoring a system in accordance with claim **32**, wherein said providing diagnostic results includes providing repair instructions.

38. The method for monitoring a system in accordance with claim **32**, further comprising performing a test session prior to comparing said set of predefined operating parameters with said provided operating parameters of the monitored system.

39. A system comprising:

a master computer including predefined operating parameters for a plurality of cooling systems;

a microcontroller in communication with a first sensor monitoring a motor operating parameter of a monitored cooling system and a second sensor monitoring a temperature or pressure parameter of said monitored cooling system; and

a computer in communication with the microcontroller to receive at least one of said motor parameter and said temperature or pressure parameter, in communication with and remotely located from said master computer to receive said predetermined operating parameters from said master computer and to compare said motor, temperature or pressure parameter with said predefined operating parameters of one of the plurality of cooling systems, and operable to diagnose said monitored cooling system based on comparing said at least one motor, temperature or pressure parameter to said predefined operating parameters.

40. The system of claim **39**, wherein said microcontroller receives said motor parameter and at said temperature or pressure parameter of said monitored cooling system.

41. The system of claim **39**, wherein said microcontroller receives said motor parameter and both of said temperature or pressure parameters.

42. The system of claim **39**, wherein said computer is a hand-held computer.

43. The system of claim **39**, wherein said communication between said master computer and said computer includes communication via the Internet.

44. The system of claim **39**, wherein said communication between said master computer and said computer includes wireless communication.

45. The system of claim **39**, further comprising a diagnostic program executed by said master computer to diagnose said monitored cooling system.

46. The system of claim **39**, wherein said motor operating parameter includes at least one of compressor supply voltage, compressor supply amperage and compressor rotational speed.

47. The system of claim **39**, wherein said temperature or pressure parameter includes at least one of evaporator refrigerant temperature, condenser refrigerant temperature, ambient temperature, conditioned space temperature, superheat temperature, super cooling temperature, compressor discharge temperature, compressor suction pressure, and compressor discharge pressure.

48. The system of claim **39**, further comprising a diagnostic program executed by said computer to diagnose said monitored cooling system.

49. The system of claim **39**, wherein said plurality of cooling systems are differentiated by system configurations including at least one of refrigerant type, expansion device type, compressor type, unloading scheme, and condenser cooling scheme.

50. The system of claim **39**, wherein said first operating parameter is a low-side pressure measurement and said motor operating parameter is a compressor motor supply amperage.

51. The system of claim **39**, wherein said first operating parameter is a low-side pressure and said motor operating parameter is a compressor motor rotational speed.

52. The system of claim **39**, further comprising a third sensor operable to detect an evaporator refrigerant temperature.

53. The system of claim **39**, further comprising a third sensor operable to detect a condenser refrigerant temperature.

54. The system of claim **39**, wherein said computer is operable to output repair instructions.

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