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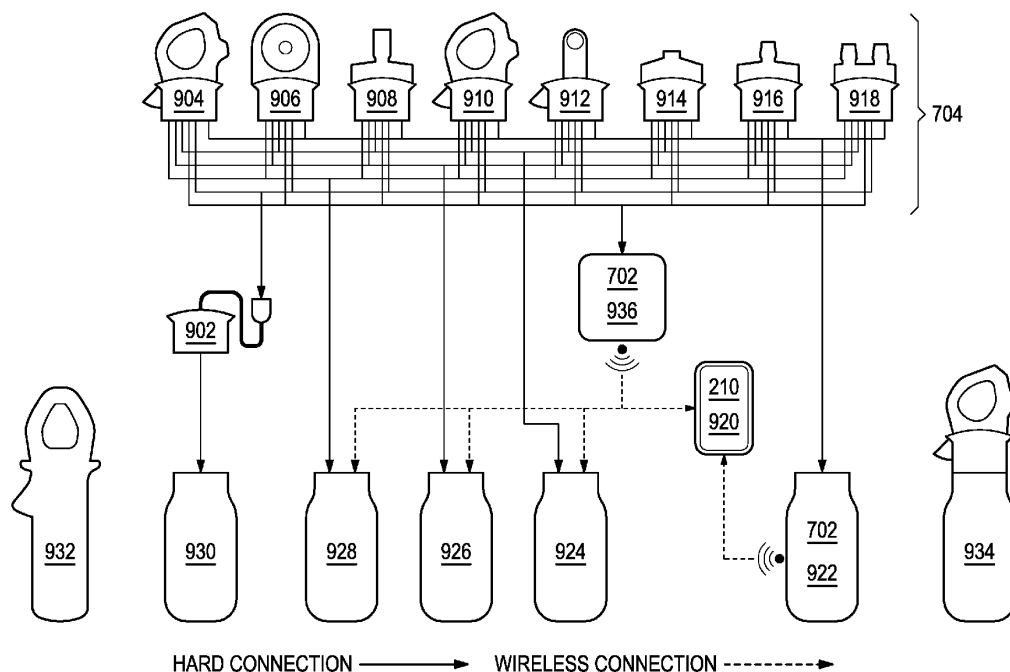
(19) **United States**(12) **Patent Application Publication**
Kane et al.(10) **Pub. No.: US 2013/0245965 A1**(43) **Pub. Date: Sep. 19, 2013**(54) **HANDHELD HVAC/R TEST AND MEASUREMENT INSTRUMENT****Publication Classification**(71) Applicants: **Michael John Kane**, Portland, OR (US);
David Lauren Wheaton, Sherwood, OR (US); **Sean Patrick Tierney**, Milwaukie, OR (US)(51) **Int. Cl.**
G01D 7/00 (2006.01)(52) **U.S. Cl.**
CPC **G01D 7/00** (2013.01)
USPC **702/33**(72) Inventors: **Michael John Kane**, Portland, OR (US);
David Lauren Wheaton, Sherwood, OR (US); **Sean Patrick Tierney**, Milwaukie, OR (US)(57) **ABSTRACT**

A method of HVAC/R test and measurement using a plurality of test and measurement sensor heads, at least one power source and transmitter unit adapted to physically connect with any of the sensor heads and wirelessly transmit data to an external handheld-sized field use display and analysis instrument, including the steps of connecting the power source and transmitter unit a sensor head; performing a test and measurement by positioning the sensor head to sense and measure the desired parameter; transmitting data to the display and analysis instrument; and receiving the transmitted data on the display and analysis instrument. The display and analysis instrument may be connected to a sensor head, and preferably may receive wired or wirelessly transmitted test and measurement data from any number of communicably connected sensor heads. Wirelessly transmitted data may be received by another external display device such as a smartphone or similar computing device.

(21) Appl. No.: **13/875,683**(22) Filed: **May 2, 2013****Related U.S. Application Data**

(63) Continuation-in-part of application No. 13/072,636, filed on Mar. 25, 2011.

(60) Provisional application No. 61/768,546, filed on Feb. 25, 2013.



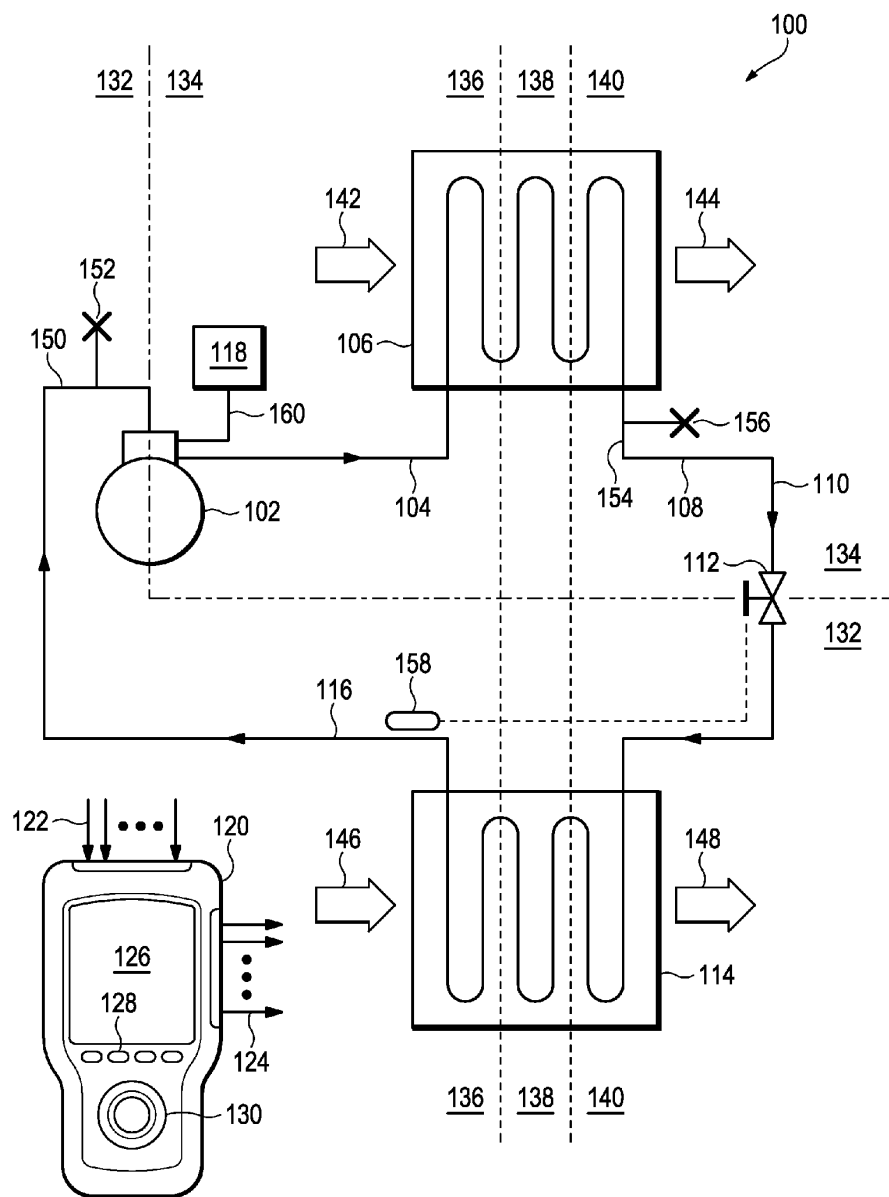


FIG. 1

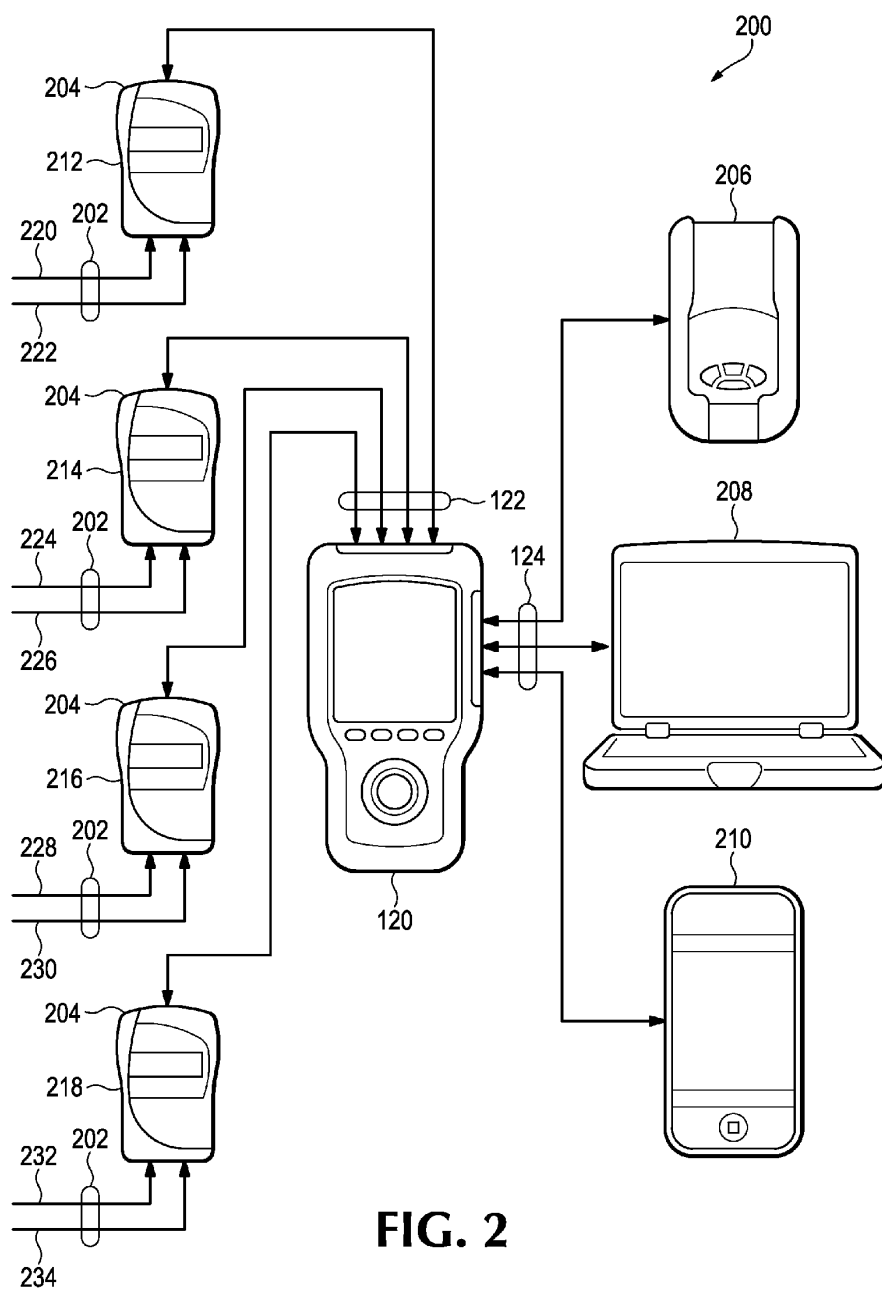


FIG. 2

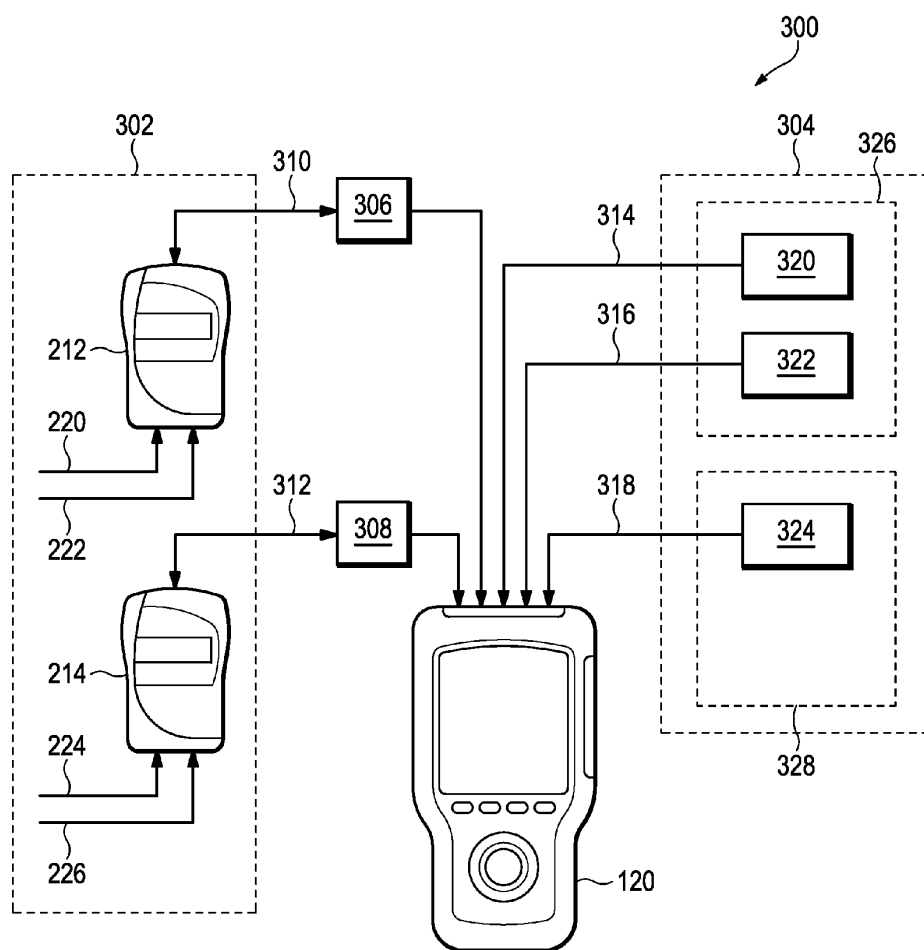


FIG. 3

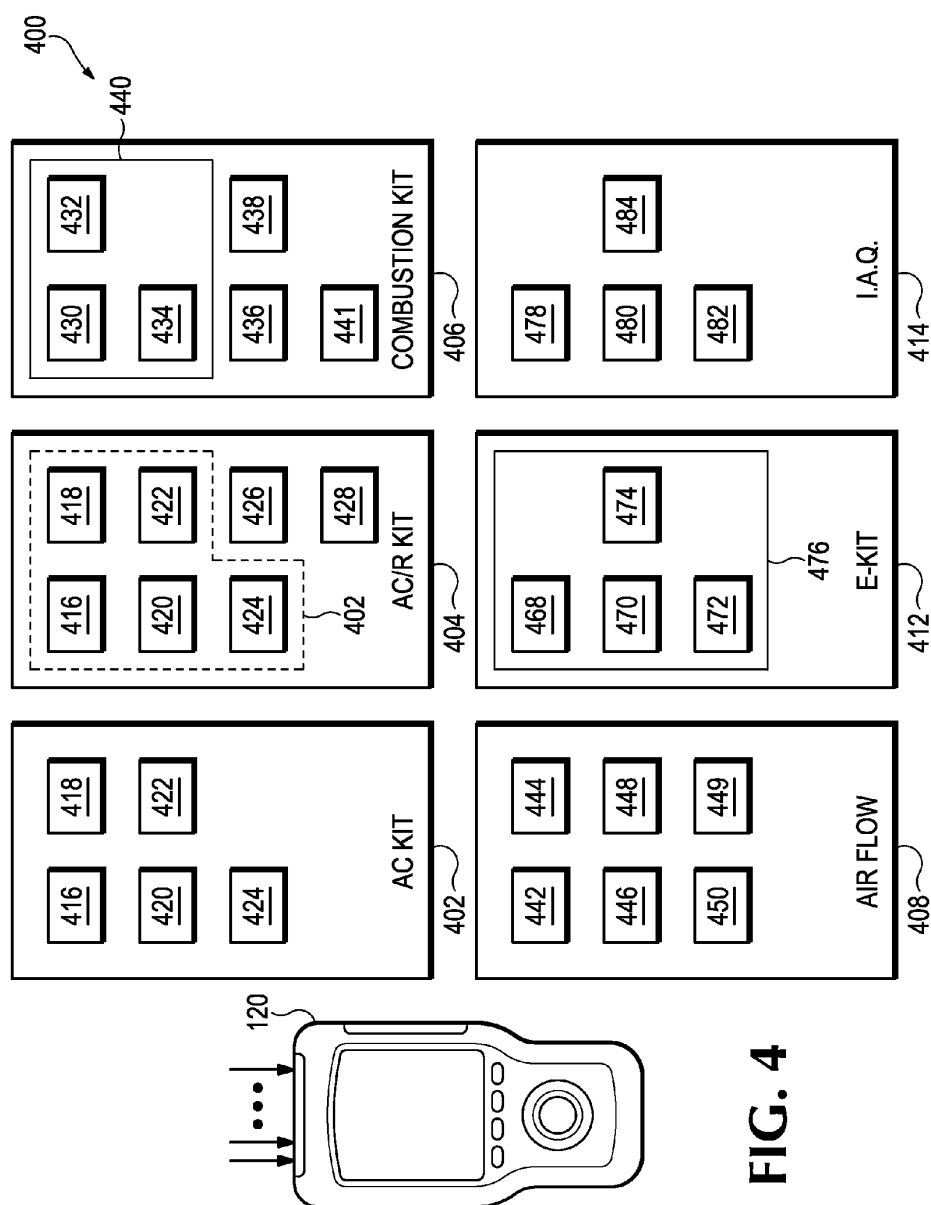


FIG. 4

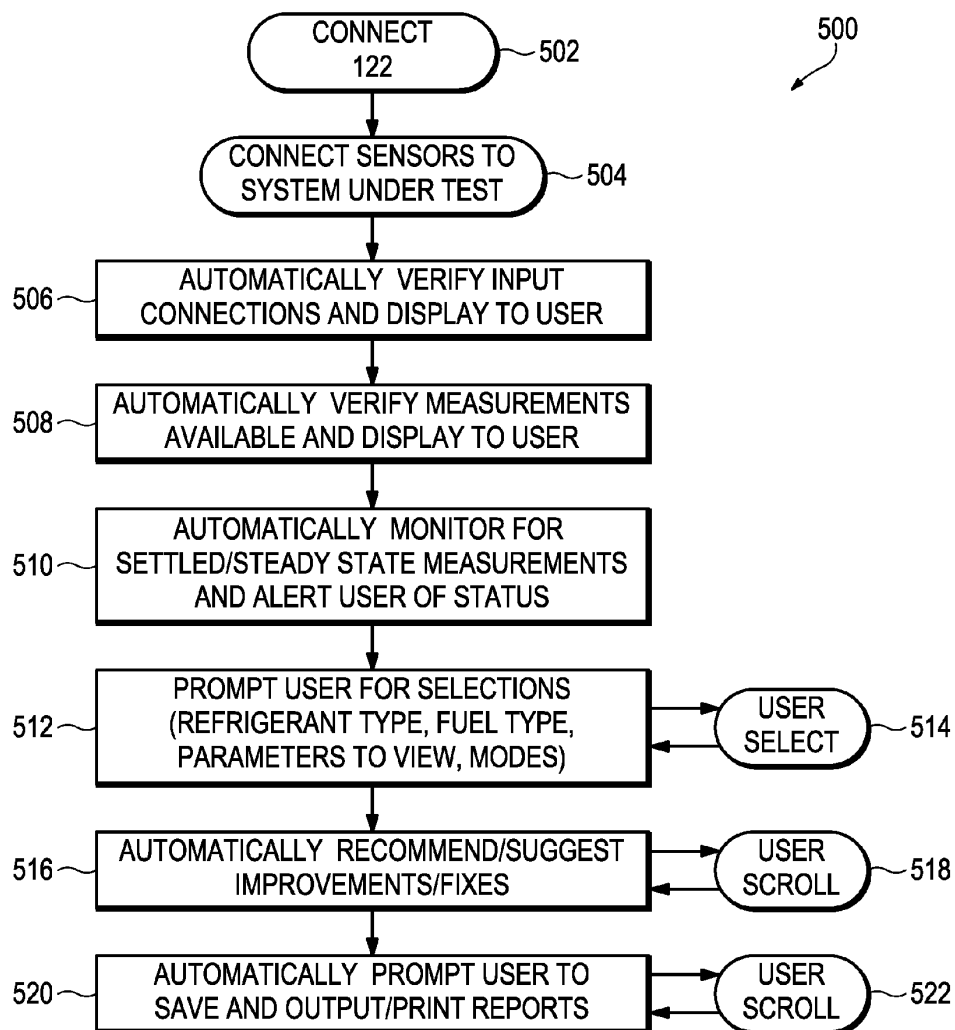


FIG. 5

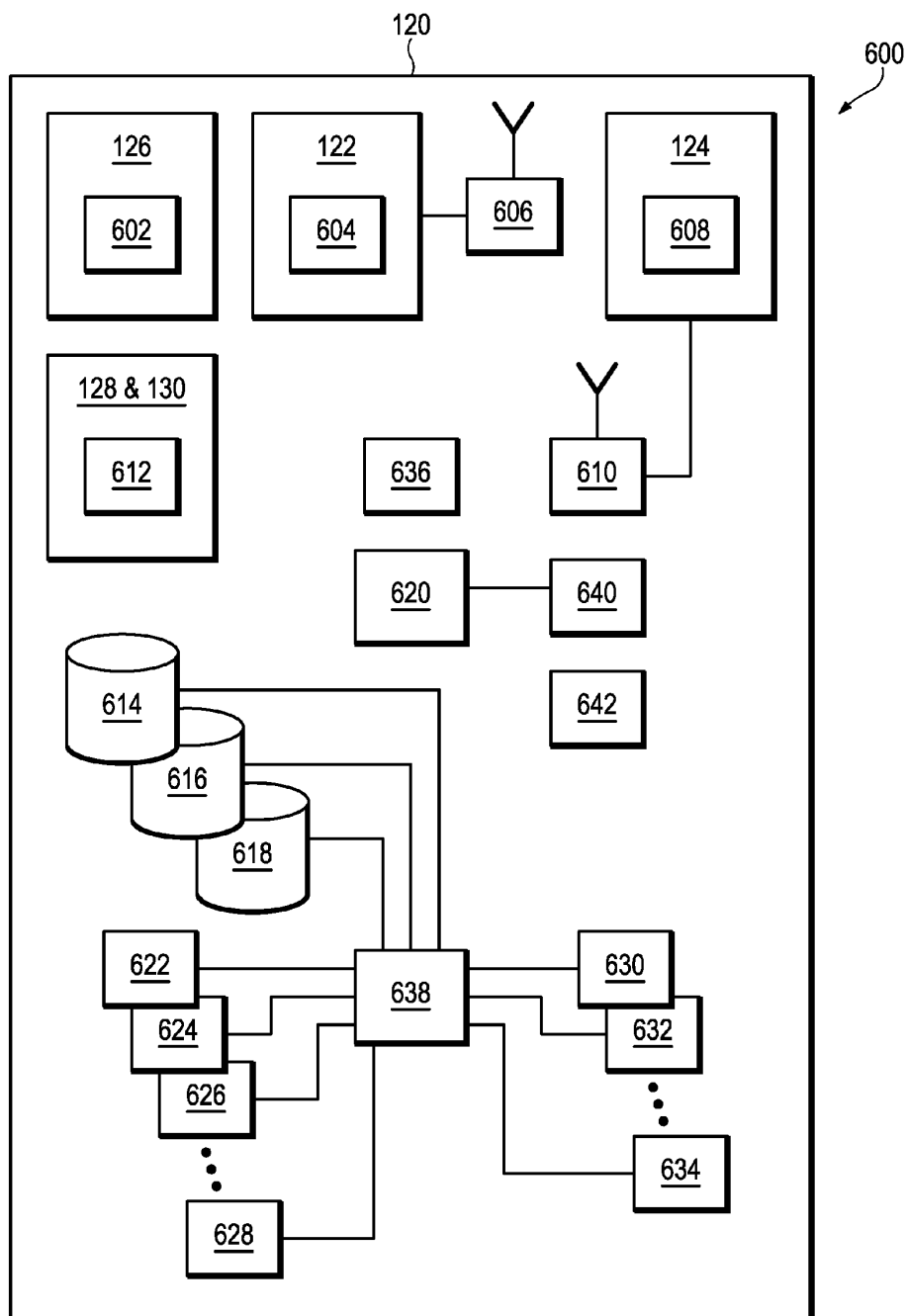


FIG. 6

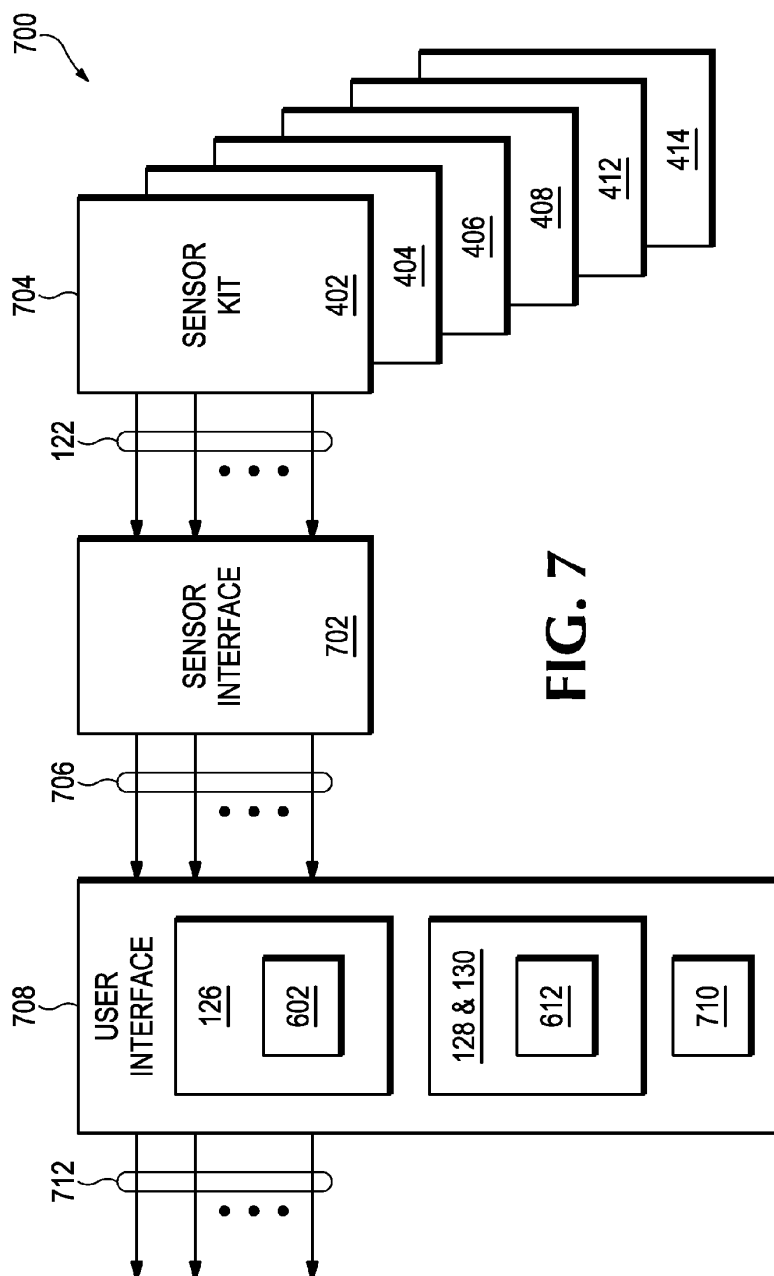


FIG. 7

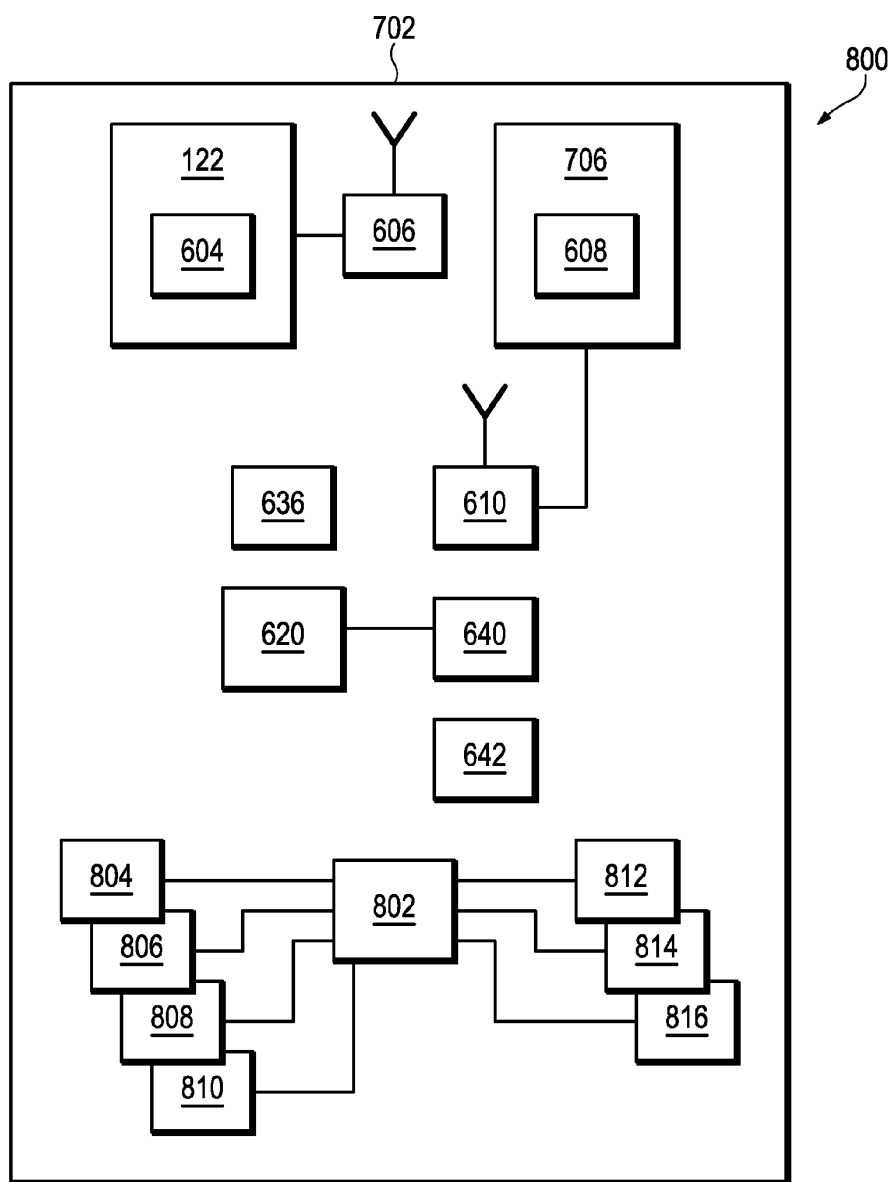


FIG. 8

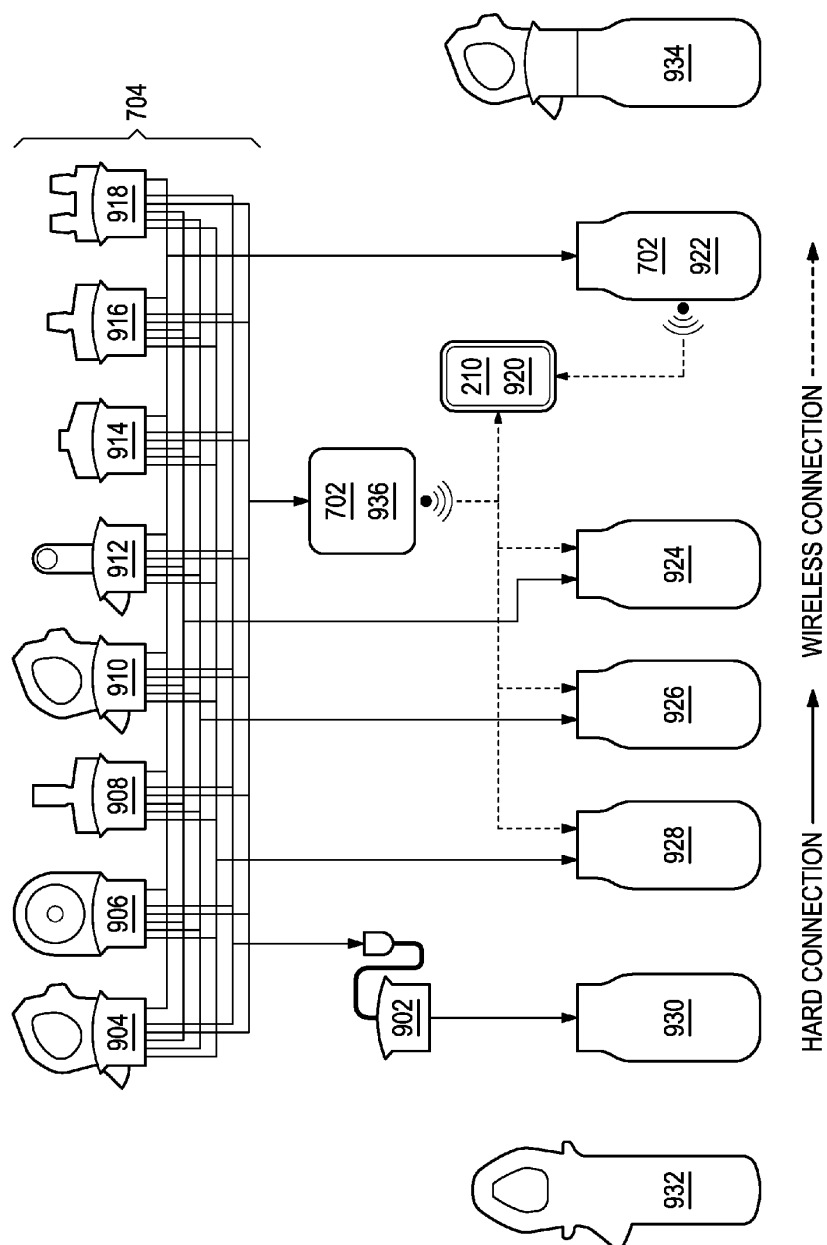


FIG. 9

HANDHELD HVAC/R TEST AND MEASUREMENT INSTRUMENT

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This is a continuation-in-part of U.S. patent application Ser. No. 13/072,636 filed on Mar. 25, 2011, and claims the benefit of U.S. provisional application Ser. No. 61/768,546 filed on Feb. 25, 2013.

BACKGROUND OF THE INVENTION

[0002] The invention involves servicing and testing equipment used in the heating, ventilating, air conditioning, and refrigeration (HVAC/R) field and, more particularly to handheld test and measurement devices useful for HVAC/R technicians for the performance of their vocation.

[0003] HVAC/R (or, sometimes referred to simply as HVAC) technicians employ a wide variety of servicing and testing equipment in the daily and routine performance of their vocation. Some of the electrical measuring and test instruments include: voltmeters to measure electric potential differences (volts, V; volts AC, VAC; volts DC, VDC); ohmmeters to measure electric resistance (ohms, S2); ammeters to measure electric current (amperes, A; alternating current, AC; direct current, DC); capacitance meters to measure electric capacitance (farads); thermocouples to measure temperature (degrees F.); wattmeters to measure electric power (Watts, W); and data logging instruments to capture and store measurement data over time.

[0004] Exemplary refrigerant system servicing and testing equipment include: various types of thermometers—dial thermometers, digital thermometers, thermocouples, infrared thermometers; gage manifold sets for measuring operating pressures (kilopascals, kPa; pounds per square inch, psi) in one of three ways—atmospheric (psi), gage (psig), or absolute (psia) pressure—and for adding or removing refrigerant; superheat and subcool meters that measure low side (suction line) pressure and temperature (for determining superheat) and high side (condenser discharge line) pressure and temperature (for determining subcool); psychrometers for measuring wet bulb and dry bulb temperatures to determine relative humidity; and leak detectors such as electronic leak detectors or ultrasonic-type leak detectors for detecting refrigerant leaks.

[0005] Heating system servicing and testing equipment may include: draft gages for measuring the amount of draft in inches of water column in the flue pipe opening and in the furnace inspection port (to compare flue draft with manufacturer specifications and to detect leaks); flue gas analyzers for measuring carbon monoxide (CO), carbon dioxide (CO₂), oxygen (O₂), nitrous oxide (NO), and flue pressure; refrigerant and gas identifiers and monitors; and oxygen-depletion alarms for warning technicians of dangerous conditions in enclosed or confined equipment areas.

[0006] Pressure measuring devices include: manometers for measuring small pressures (under one inch water column); and Bourdon tube gages for measuring higher pressures in psig.

[0007] Air speed and air volume measuring devices such as rotating vane anemometers, thermal anemometers, and flow hoods are used for measuring air speed (feet per minute, fpm) and air volume (cubic feet per minute, CFM).

[0008] Indoor air quality (IAQ) test and measurement devices may include particle counters, infrared cameras, thermal imagers, and various pollutant sampling kits, devices, and sensors—for detecting mold, lead, asbestos, radon, CO, nitrogen dioxide (NO₂), mercury, volatile organic compounds (VOC's) such as ketones and hydrocarbons, and ozone (O₃)—in addition to instruments to measure CO₂ percentage, temperature, and relative humidity percentage.

[0009] Numerous techniques are used by HVAC/R technicians to service a wide variety of different types of systems, requiring the technician to acquire, learn to use, and maintain several separate servicing and testing devices as well as accompanying technical reference materials such as refrigerant pressure-temperature charts and calculation algorithms and methods. HVAC/R test and measurement instruments are needed that reduce the number of separate instruments and technical reference materials needed to install and service HVAC/R systems. HVAC/R test and measurement instruments are needed that incorporate greater flexibility, versatility, portability, and functionality than those which are presently available.

[0010] What is needed, therefore, are improved techniques and devices designed to help HVAC/R technicians in their vocation by reducing the number and complexity of devices, systems, and technical materials needed to perform various servicing and testing procedures. A handheld sized device or family of related, interconnectable, or multi-purpose devices that may be used for a wide variety of HVAC/R system servicing and testing applications, and that provide the technician with real-time system performance information, guidance in system analysis and troubleshooting, is needed.

[0011] The foregoing and other objectives, features, and advantages of the invention will be more readily understood upon consideration of the following detailed description of the invention taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE SEVERAL DRAWINGS

[0012] For a more complete understanding of the present invention, the drawings herein illustrate examples of the invention. The drawings, however, do not limit the scope of the invention. Similar references in the drawings indicate similar elements.

[0013] FIG. 1 illustrates an exemplary air conditioning and refrigeration system with a handheld HVAC/R test and measurement instrument, according to one embodiment.

[0014] FIG. 2 illustrates various embodiments of the handheld HVAC/R instrument shown in FIG. 1 connected with sensor module inputs and external output and peripheral devices.

[0015] FIG. 3 illustrates various embodiments of inputs connectable to a handheld HVAC/R instrument as in FIGS. 1 and 2.

[0016] FIG. 4 illustrates optional sensor kits for use with a handheld HVAC/R instrument as in FIGS. 1-3, according to various embodiments.

[0017] FIG. 5 depicts a partial, generalized operational flow chart of a handheld HVAC/R instrument and sensor kit, according to various embodiments.

[0018] FIG. 6 shows an exemplary functional block diagram of a handheld HVAC/R instrument as in FIGS. 1-3, according to various embodiments.

[0019] FIG. 7 illustrates various embodiments of a handheld sized test and measurement data interface unit for receiving sensor inputs from sensor kits and providing received sensor input information to a handheld sized user interface.

[0020] FIG. 8 shows an exemplary functional block diagram of a handheld sized data interface unit as in FIG. 7, according to various embodiments.

[0021] FIG. 9 illustrates various embodiments of a handheld-sized test and measurement instrument with one or more associated sensor head attachments and multiple wired and wireless communicating configurations.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

[0022] In the following detailed description, numerous specific details are set forth in order to provide a thorough understanding of the preferred embodiments. However, those skilled in the art will understand that the present invention may be practiced without these specific details, that the present invention is not limited to the depicted embodiments, and that the present invention may be practiced in a variety of alternate embodiments. In other instances, well known methods, procedures, components, and systems have not been described in detail.

[0023] Rather than use several different test and measurement instruments when servicing a system such as that shown in FIG. 1, the present inventors invented a handheld central or main field test and measurement instrument that is capable of receiving inputs from sensors or sensor modules to perform typical tests and measurements associated with installation and maintenance of HVAC/R systems. FIG. 1 shows an example air conditioning and refrigeration system 100 with a handheld central or main field test and measurement instrument (hereinafter, "main unit") 120, according to one embodiment. The main unit 120 comprises: a handheld-sized instrument with means for receiving a plurality of (ex. 1 through n) inputs 122 via physically wired connections to sensors or sensor modules, via wireless communications with sensor or sender units or sensor modules, or via a combination of the two; means for sending/transmitting a plurality of (ex. 1 through m) outputs 124 via wireless and/or wired connections with various external output devices; a display 126; and control buttons 128 and/or up, down, right, left, scroll, and select navigation controls 130.

[0024] The exemplary HVAC/R system 100, or system under test, shown in FIG. 1 may be any of a wide variety of systems, such systems being described and illustrated more thoroughly in HVAC/R systems treatises, for example the Air-Conditioning, Heating, and Refrigeration Institute's published reference text, Fundamentals of HVAC/R, by Carter Stanfield and David Skaves, copyright 2010, Prentice Hall, which is incorporated herein by reference. The system 100 shown in FIG. 1 is presented as a typical HVAC/R system under test, having a compressor 102, a condenser 106, a metering device 112, and an evaporator 114. Refrigerant (and some lubricating oil) generally flows through piping, as indicated in FIG. 1, in a clockwise direction from the compressor 102, through the condenser 106, through a metering device 112 (which may, for instance, be a capillary tube type structure or a thermal expansion valve (TEV) device), through an evaporator 114, and back to the compressor 102. Not all components are shown. For example, an oil separator may be positioned immediately after (i.e. downstream from) the compressor 102 along hot gas line 104 with an oil return line

from the oil separator back to the compressor; a receiver may be positioned after the condenser 106 between the condensate line 108 and the liquid line 110 leading to (i.e. upstream from) the metering device 112; and an accumulator may be positioned along the suction (vapor) line 116 after the evaporator 114 and before the compressor 102.

[0025] Generally, the compressor 102 and metering device 112 delineate a low side (or low pressure side) 132 and a high side (or high pressure side) 134 of the HVAC/R system 100, with the compressor 102 causing refrigerant to flow from the low side 132 to the high side 134 in response to operational controls and safeties 118 associated with the compressor via electrical control lines 160. The compressor 102 delivers pressurized refrigerant to the hot gas line 104 and condenser 106. As refrigerant flows through the condenser 106, it transitions from a vapor phase 136 where only vapor is in the lines, to a liquid plus vapor phase 138 within the condenser 102, and finally to a liquid only phase 140. Outside ambient air 142 flows into the condenser coils of the condenser 106, receives heat from the high pressure refrigerant as the refrigerant condenses from a vapor to a liquid, and leaves the condenser coils as (heated) discharge air 144.

[0026] Refrigerant flows from liquid line 110 through metering device 112, through which the line pressure drops from high pressure before the metering device 112 to low pressure following the metering device 112. The low pressure refrigerant then flows in a liquid phase 140 into the evaporator 114, transitions into a vapor plus liquid phase 138 as the refrigerant absorbs heat from return air 146 flowing through the evaporator coils (thereby cooling the intake/return air 146 to provide cooled supply air 148) and finally transitions into a vapor phase 136, leaving the evaporator 114 through suction (vapor) line 116. The low pressure suction (vapor) line 116 refrigerant then flows into the compressor 102 to complete (and repeat/restart) the cycle of refrigerant flow through the HVAC/R system 100.

[0027] Low and high side test and measurement points are shown in FIG. 1. For example, the temperature of the low side or suction line near (just before) the compressor 102 may be measured at temperature measuring point 150. The temperature of the suction line (at 150) along with the pressure measurement at the suction line port 152 near (just before) the compressor 102 is typically used to check system superheat. Superheat may be defined as (suction line temperature) minus (evaporator saturation temperature). Suction line temperature is typically measured, and evaporator saturation temperature is approximated using measured suction line pressure and pressure-temperature charts (or look-up tables) for the particular type of refrigerant used in the system under test.

[0028] The temperature of the high side or condensate line leaving the condenser 102 may be measured at temperature measuring point 154. The temperature of the condensate line (at 154) along with the pressure measurement at the condensate line port 156 near (just after) the compressor 102 are typically used to check system subcool. Subcool may be defined as (condenser saturation temperature) minus (condensate line temperature). Condensate line temperature is typically measured, and condenser saturation temperature is approximated using measured condensate line pressure and pressure-temperature charts (or look-up tables) for the particular type of refrigerant used in the system under test.

[0029] Methods for charging HVAC/R systems for proper superheat and subcooling are well established but vary in application according to the particular type of system (and

refrigerant) and require reference to manufacturer specifications, charts, graphs, or other data. Measuring the operating superheat of a thermal expansion valve (TEV) type metering device **112** to, for example, adjust the TEV, typically involves measuring suction (vapor) line temperature and pressure at the expansion valve bulb **158**, since this is where the TEV senses the suction line temperature in its operation and function to maintain a constant system superheat. A TEV type metering device **112** typically includes a thermostatic expansion valve bulb **158** with capillary tube back to the power head of the TEV metering device **112** or a thermistor at **158** electrically connected with the TEV metering device **112** if an electronically controlled TEV metering device **112** is used. Once the TEV is adjusted for the desired superheat (for example, to maintain a superheat of 8-12 degrees F.), proper charging of the system **100** having a TEV type metering device **112** may be checked by measuring system subcool (by measuring condensate line pressure at **156** and condensate line temperature at **154**) and using a subcooling charging chart (i.e. look-up table) which specifies a desired subcooling corresponding to measured outdoor ambient air temperature and measured indoor wet bulb temperature (or calculated indoor wet bulb temperature using measured relative humidity). If the measured subcooling is less than specified by the charging chart, then the system is undercharged refrigerant should be added. If the measured subcooling is greater than specified, then the system is overcharged and the excess refrigerant should be recovered.

[0030] For systems having a fixed restriction type metering device **112** (such as a capillary tube type metering device **112**), proper charging of the system may be checked by measuring system superheat (by measuring suction line pressure at **152** and suction line temperature at **150**) and using a superheat charging chart which specifies a desired superheat corresponding to measured outdoor ambient air temperature and measured indoor wet bulb temperature (or calculated indoor wet bulb temperature using measured return air temperature and relative humidity). If the measured superheat is more than specified by the manufacturer's charging chart, then the system is undercharged and refrigerant should be added. If the measured superheat is less than specified, then the system is overcharged and the excess refrigerant should be recovered.

[0031] Another method, sometimes referred to as the Liquid-Ambient method, for determining whether a system is over or undercharged is to measure the condensate line (or liquid line) temperature at **154** and subtract the measured outdoor ambient temperature at **142**. The difference is then compared with the manufacturer's specifications. If the difference is more than specified, then the system is undercharged. If the difference is less than specified, then the system is overcharged.

[0032] In various embodiments, the main unit **120** may be connected, as shown in FIG. 2, as a system **200** with its 1 through n inputs **122** comprising wired or wireless communication between sensor sender units (or sender modules) **204** and the main unit **120**, and with its 1 through m outputs **124** comprising wired or wireless communication between the main unit **120** and various external output and peripheral devices **206, 208, 210**. Exemplary external output and peripheral devices may include any of a wide variety of devices, such as IR printer or other printing devices **206**, laptop or other computing device connected with the main unit **120** via IR, USB, or other means, and/or smartphone or PDA devices communicating with the main unit **120** via Bluetooth, mini

USB, or other means. Each of the sender units **204**, as shown, receive sensor inputs **202** from sensors suitably applied to a system under test such as the system **100** in FIG. 1, and communicate, preferably in real-time, the sensor input information to the main unit **120**, which in turn preferably monitors in real-time and receives the transmitted sensor input information.

[0033] The sender units **212, 214, 216, 218** may, for example, comprise sender units with circuitry adapted for particular types or groupings of sensor inputs **202**. The sender unit **212** may, for example, be adapted for location outside at the condenser **106** for measuring system subcool. For example, such a sender unit **212** may be connected to a pressure sensor via connection **220** and a temperature sensor via connection **222** for receiving, respectively, signal information representing high side pressure at condensate line pressure port **156** and signal information representing high side temperature at the condensate line temperature measuring point **154**. In similar fashion, the sender unit **214** may be adapted for location outside at the compressor **102** for measuring superheat, with connections to a pressure sensor via connection **224** and a temperature sensor via connection **226** for receiving, respectively, signal information representing low side (suction line) pressure at **152** and signal information representing low side temperature at the low side temperature measuring point **150**.

[0034] The sender unit **216** may be adapted for location inside at the evaporator **114** duct work for taking return air **146** temperature and relative humidity measurements, with connections to a temperature sensor via connection **228** and a humidity sensor via connection **230** for receiving, respectively, signal information representing return air **146** temperature and signal information representing return air **146** humidity.

[0035] The sender unit **218** may be adapted for location outside at the condenser **106** for taking outside ambient air **142** temperature, with connection to a temperature sensor via connection **232** for receiving signal information representing outside ambient air **142** temperature, to, for example, use the Liquid-Ambient method for checking system refrigerant charge. In such application the sender **218** may also be adapted for taking condensate line (or liquid line) temperature at **154**, with connection to a temperature sensor via connection **234** for receiving signal information representing condensate (liquid) line temperature at **154**. Configuring a sender with both temperature sensing inputs needed for use of the Liquid-Ambient method of charging allows for calibration within the sender or main unit **120** of the two temperature sensors to permit more accurate measurement of the temperature difference between the (higher) liquid line temperature and the (lower) outside ambient air temperature, since calibration differences between the two sensors (if two different temperature sensors are used instead of separate measurements using a single sensor) would likely adversely influence system charging.

[0036] The sender unit **218** may be adapted instead for location inside at the evaporator **114** for taking temperature and pressure measurements near the TEV bulb **158**. In such an application, the sender unit **218** may have connection to a temperature sensor via connection **232** and a pressure sensor via connection **234** for receiving, respectively, signal information representing suction line temperature at **158** and signal information representing suction line pressure at **158**.

[0037] Instead of configuring the sender units **212**, **214**, **216**, **218** as above, i.e. having sensor inputs grouped according to typical application needs such as (one sender configured for) measuring high side pressure and temperature for measuring superheat, the sender units may be configured to support particular types of sensor inputs. For example, sender unit **212** may be adapted for taking refrigerant line temperatures, with connections to temperature sensors via connections **220** and **222** for receiving signal information representing refrigerant line temperatures, and sender **214** may be adapted for taking refrigerant line pressures, with connections to pressure sensors via connections **224** and **226** for receiving signal information representing refrigerant line pressures.

[0038] Preferably, each of the sender units **204** include circuitry adapted to permit wireless transmission of sensor information characterizing sensor inputs **202** for wireless reception by circuitry incorporated in the main unit **120** for wirelessly receiving the sensor information from the sender units **204**. In other embodiments, the sender units **204** may include sender units with such wireless transmitting means and/or sender units requiring physically wired communication with the main unit **120**.

[0039] In still other embodiments, the main unit **120** may not include circuitry adapted to wirelessly receive sensor input information directly. As shown in FIG. 3, some sensors and sender units **302** may be in wireless communication with the main unit **120** via wireless transceivers **306**, **308**, and other sensors and sensor modules **304** may be in directly wired communication with the main unit **120**. For example, sender units **212**, **214** as previously described may be located outside at the compressor **102** and condenser **106** and communicate wirelessly to wireless transceivers **306**, **308** via wireless channels **310**, **312**. The transceivers **306**, **308** in turn provide the main unit **120** with sensor information via wired inputs **122**. Other sensors **320**, **322**, **324** may be located inside at the evaporator and return air duct work and communicate directly via respective wired connections **314**, **316**, **318** to the inputs **122** of the main unit **120**.

[0040] In one embodiment, sensor and sender units **302** comprise wireless sender units **212**, **214** as previously described for providing sensor input information needed for checking superheat and subcool. The wireless transceivers **306**, **308** enable the main unit **120** to receive sensor information from the sender units **212**, **214** wirelessly so that the main unit **120** may be located remotely from the compressor **102** and condenser **106** of the system under test **100**. Sensor and sensor modules **304** include a temperature probe or temperature probe module **320** adapted for receiving signal information representing return air **146** temperature; a humidity sensor or humidity sensing module **322** adapted for receiving signal information representing return air **146** humidity; and a temperature probe or temperature probe **324** adapted for receiving signal information representing suction line temperature at the TEV bulb **158**. In one embodiment, the temperature probe modules **320** and **322** together (shown as **326** in FIG. 3) provide the functionality of sender unit **216** and the temperature/humidity probe **228/230** shown in FIG. 2. In one embodiment, the temperature probe module **324** (shown as **328** in FIG. 3) provides the functionality of sender unit **218** insofar as the temperature sensor **232** shown in FIG. 2.

[0041] As shown in FIG. 4, the handheld HVAC/R test and measurement instrument **120** may be combined with a range of optional sensor/module kits **402**, **404**, **406**, **408**, **412**, **414** as

a complete HVAC/R test and measurement system **400**, according to various embodiments. In one embodiment, a technician may use the central, main unit **120** with one or more of the optional sensor kits depending upon the application. Other sensor kits may be used, and the kits described are exemplary of typical HVAC/R test and measurement applications and may include different sensors, sender units, probes, or modules than those shown and described. Each kit preferably includes the appropriate probes, sensor attachments, wiring leads, cabling, sensor signal senders/transmitters, transceivers/receivers (if needed) for attachment to the main unit **120**, and other equipment and circuitry for physically taking the desired system measurement (i.e. suction line pressure) and providing sensed measurement signal information (referred to as sensor inputs) receivable by the main unit **120** sensor inputs **122**.

[0042] The AC kit **402** includes the sensors, sender units, probes, or modules needed to provide the main unit **120** with sensor input information for measuring outdoor ambient temperature, indoor return air temperature, indoor relative humidity, and either the low side (suction line) temperature and pressure needed for measuring superheat or the high side (discharge/condensate/liquid line) temperature and pressure needed for measuring subcool. In one embodiment, AC kit **402** includes a pressure sensor **416** and temperature sensor **418** for measuring pressure and temperature, respectively, of typical refrigerant lines in HVAC/R systems such as system **100** in FIG. 1. The pressure and temperature sensors **416**, **418** are preferably equipped with Schrader or other standard refrigerant line pressure test port fittings, pipe engaging sensor clamps for quality transducer contact for measuring refrigerant (line) temperature, adequate wire/cable lengths, and other features for convenient measurement of superheat and subcool (an similar measurements for adjusting a thermal expansion valve). The pressure sensor **416** and temperature sensor **418** may be as described and shown in FIG. 2 for either of the sensor inputs **220** and **222** described for measuring subcool and **224** and **226** described for measuring superheat. AC kit **402** preferably also includes indoor temperature probe **420**, humidity probe **422**, and outdoor temperature sensor **424**, which may be as described for indoor temperature probe, humidity sensor, and outdoor temperature sensor inputs **228**, **230**, and **232**, respectively, described and shown in FIG. 2.

[0043] The AC/R kit **404** includes everything in the AC kit **402** plus the additional sensors, sender units, probes, or modules needed to provide the main unit **120** with the sensor input information needed for measuring both superheat and subcool. For example, AC/R kit **404** preferably includes all the sensors and probes **416**, **418**, **420**, **422**, **424** in the AC kit **402** plus an additional pressure sensor **426** (which may be substantially similar to pressure sensor **416**) and an additional temperature sensor **428** (which may be substantially similar to temperature sensor **418**). The AC/R kit **404** may include a combination of wired and wireless sensors, sender units, and transceivers/receivers as described and shown in FIG. 3, to provide a combination of wired and wireless remote sensor test and measurement means using a central/main unit **120**.

[0044] The Combustion kit **406** includes the sensors, sender units, probes, or modules needed to provide the main unit **120** with sensor input information for measuring CO₂ percentage, carbon monoxide (CO) percentage, CO ppm, inlet or ambient temperature, flue temperature, draft pressure, and gas pressure. For example, Combustion kit **406** preferably includes an oxygen (O₂) sensor **430**, a carbon monoxide

(CO) sensor **432**, a differential pressure sensor module **434** (for measuring draft and gas line pressures), a temperature probe **436** (for measuring temperature inlet combustion air entering the combustion chamber for ducted inlet combustion equipment or ambient air for ambient combustion air equipment), and a second temperature probe **438** (for measuring flue gas temperature past the heat exchanger, in the chimney of the heating system). The Combustion kit **406** preferably further includes an external unit **440** attachable to (for example, the back of) the main unit **120** and having its own power supply, the external unit **440** including, in one embodiment, the oxygen sensor **430**, the carbon monoxide sensor **432**, and the differential pressure sensor module **434**. The Combustion kit **406** preferably includes a flue gas sample probe **441**, for sampling flue gas in the chimney.

[0045] The Air Flow kit **408** includes the sensors, sender units, probes, or modules needed to provide the main unit **120** with sensor input information for measuring air flow velocity, air temperature, relative humidity, wet bulb temperature (calculated), dew point (calculated), change in dew point, and pressure differential. The Air Flow kit **408** preferably includes an air vane **442** for sensing air flow velocity, a low pressure probe **444** adapted to sense return air static pressure, another low pressure probe **446** to sense supply air static pressure (for differential pressure measurements across the blower), and indoor temperature and humidity probes **448**, **450** as described for indoor temperature probe **228** and humidity sensor **230**, respectively, described and shown in FIG. 2. In one embodiment, low pressure probes **444**, **446** provide measurement of return air static pressure plus supply air static pressure, the combined total being comparable with equipment specifications for determining proper system functioning and system performance. The Air Flow kit **408** may include an additional temperature probe **449** for measuring the temperature rise through the furnace and using the temperature difference to estimate air flow (CFM). Temperature probe **448** may be used to measure return air temperature, temperature probe **449** may be used to measure supply air temperature, and the difference between the two is the temperature rise/difference (TD). The air flow (CFM) may then be approximated as (the furnace output in Btu/hour) divided by (TD times **1.08**).

[0046] The Electrical kit (E-kit) **412** includes the sensors, sender units, probes, or modules needed to provide the main unit **120** with sensor input information for measuring voltage, current, resistance, and other common electrical measurements (i.e. capacitance, frequency, duty cycle, diode function, temperature). The E-kit **412** preferably includes a voltage probe **468**, a current probe **470**, a resistance probe **472**, other probes such as, for example, capacitance, frequency, or temperature probes, and an external device **476** capable of converting measured parameters to a signal having sensor input information receivable by the main unit **120**. The external device **476** may also include common leads and attachments (such as, for example, a common ground lead), high impedance circuitry for voltage measurements, low impedance circuitry for current measurements, and circuitry for selecting between AC and DC measurements. The E-kit **412** may substantially comprise the functionality and features of a digital multi-meter combined with circuitry adapted to provide test and measurement information to the main unit **120** via sensor inputs **122**.

[0047] The Indoor Air Quality (I.A.Q.) kit **414** includes the sensors, sender units, probes, or modules needed to provide

the main unit **120** with sensor input information for measuring CO₂, air temperature, relative humidity, and pollutant concentration/detection. The I.A.Q. kit **414** may include an oxygen (O₂) sensor **478** for measuring carbon dioxide percentage, a temperature probe **480**, a humidity probe **482**, and one or more pollutant sensors **484**.

[0048] A partial, generalized operational flow chart of a handheld HVAC/R test and measurement instrument **120** with kits **400**, according to various embodiments, is shown in FIG. 5. Other steps may be added, and steps may be omitted. However, operation of the main unit **120** preferably includes the following general steps, functionality, and features. Generally, sensor inputs **122** from a chosen kit of sensors (from a range of optional kits **400**) are connected (step **502**) with the main unit **120**, and the sensors (probes, sender units, etc.) associated with the chosen kit are connected to the system under test (step **504**). Upon power up of the main unit **120** and any components of the chosen kit requiring power, and once the sensors are connected to the system under test and sensor inputs **122** connected with the main unit **120**, the main unit **120** automatically detects and verifies what is connected to it and (step **508**) the tests, measurements, and analysis functions that may be performed using the sensor information available. That is, preferably, the main unit **120** automatically verifies the sensor inputs **122** (in terms of what type of sensor are connected and, also preferably, whether such sensors are working properly). The sensor input **122** information (i.e. sensor connections, sensor functioning status, sensor information being transmitted/received in real-time) is then provided to the main unit **120** for display to the technician/user. The main unit **120** preferably automatically monitors (step **510**) the sensor inputs **122** for settled/steady state sensor measurement information and alerts the technician (visually, audibly, and/or tactilely) of the status of the connected sensors, status of the system **100** (for example, the settling of subcool or superheat measurements following a change in refrigerant charge, the presence of hazardous gas concentrations near the furnace warranting improved ventilation, whether the sensed measurement information is within typical/expected operating ranges), and the status of analysis or tests in-process or to be performed (for example, the status of data-logging). In one embodiment, the main unit **120** automatically monitors sensor inputs **122** and provides the technician with alerts and indications regarding safety conditions of workspaces, for example, alerting the technician if refrigerant is detected or if oxygen levels are becoming too low (or trending downward) so as to present workspace safety concerns.

[0049] The main unit **120** preferably provides the user/technician with real-time display of the sensor inputs **122** so the technician can watch the measurements/sensor inputs change in real-time. In preferred embodiments, the main unit **120** also provides the user/technician with real-time display of the (computed/calculated/estimated) output values (such as, for example, superheat, subcool, combustion efficiency, etc.) as those output values change in response to dynamically changing sensor input values. That is, the main unit **120** allows a technician to not only view all sensor inputs simultaneously, but also to view outputs/results/computations in real-time. In one embodiment, the main unit **120** allows the technician/user to enter "what if" input values or other parameters (such as, for example, a temperature value, refrigerant type, manufacturer model number, or other measured or referenced value that may influence calculated or estimated

measurements such as superheat) to determine what impact, if any, such hypothetical input or reference value or parameters, if different, would have on the real-time displayed output values and results.

[0050] In most superheat or subcool measurements, it is recommended to start the HVAC/R system and let it run for 10-30 minutes to allow the temperatures and pressures to stabilize before taking measurement values. In preferred embodiments, as described previously, the main unit **120** includes programming instructions and circuitry adapted to monitor sensor inputs **122** in real-time and detect when system **100** temperatures and pressures have settled/stabilized (step **510**). In one embodiment, the main unit **120** also provides the technician with an indication of the expected time that will be needed to reach such settled/stabilized system temperatures and pressures, enabling the technician to multi-task or focus on another activity during waiting periods. In one embodiment, the main unit **120** alerts the technician of settled sensor inputs (step **510**). In preferred embodiments, the main unit **120** provides alerts to the technician when predetermined target values are reached. For example, the main unit **120** preferably provides the technician with step-by-step guidance for tests such as target evaporator exit temperature in addition to common testing for superheat, subcooling, and combustion. Once the target evaporator exit temperature (i.e. once supply air **148** exiting evaporator **114** in system **100** reaches a target value) the main unit **120** provides an alert to the technician.

[0051] The main unit **120** preferably automatically prompts the technician/user for user-input selections **514** such as refrigerant type, fuel type, parameters to view/display, or modes of operation of the main unit **120** depending upon the automatically detected sensor inputs **122** and automatically determined available measurements and analysis available to the user. The main unit **120** preferably (step **516**) includes sufficient programming instructions to provide recommendations, suggestions for system performance improvement, troubleshooting guidance, and so forth, based upon the real-time monitoring of the sensor inputs **122**. Preferably, the user is able to scroll **518** through such automatically provided troubleshooting and analysis guidance information to select and drill down through menu information to access additional information and suggestions and to perform the desired system analysis.

[0052] In one embodiment, the main unit **120** provides the user access to not only suggested testing and measurement procedures and troubleshooting assistance, but also access to reference information and underlying practical application principles and best practices so as to present the user with the depth of vocational training and information available from technical handbooks commonly carried by field technicians, or, preferably, the in-depth reference information available from treatises such as the aforementioned Air-Conditioning, Heating, and Refrigeration Institute's published reference text. Such technical reference and training information may be stored on-board the main unit **120** or accessed by the main unit **120** via wi-fi, Ethernet, cell, or other network connection. For example, technical reference information may be accessed through a smartphone application designed for retrieval and mobile presentation to a field technician. Preferably, main unit **120** provides the user/technician access and prompts to relevant technical reference information that is in response to the main unit's determination of the kit of sensors **400** being used, the automatically detected and verified sen-

sor input information being received, monitored, and presented for display to the user in real-time, and the automatically determined recommendation/troubleshooting/system analysis information. In preferred embodiments, main unit **120** provides the user with technical database information with possible causes for erroneous readings/measurements.

[0053] In one embodiment, the main unit **120** automatically saves into memory test and measurement information useful for typical system testing and analysis, and that is most commonly used when reporting system performance. The main unit **120** then alerts the user of the automatically saved data, providing the user options whether continue retaining the data in memory or allow the automatically saved data to be overwritten as additional memory is needed. The main unit **120** preferably (step **520**) automatically prompts the user to save pertinent test and measurement results (in memory on-board the main unit **120** or storage accessible to the main unit **120**) and provides the user with output options such as printing on a networked or connected printer, export data to a laptop or other device, or send data via email or to a smartphone, PDA, or other external device. The main unit **120** preferably prompts the user to save pertinent data and output typically used service and system performance reports, allowing the user to scroll (step **522**) through such saving and reporting/output options.

[0054] Although different circuitry, hardware, and software arrangements/architectures may be used, an exemplary functional block diagram **600** of a handheld HVAC/R instrument (or main unit) **120** is illustrated in FIG. 6, in accordance with various embodiments. The main unit **120** preferably includes drivers and circuitry **602** for the display **126** and drivers and circuitry **612** for the key pad **130** and function/selection buttons **128**. Drivers and circuitry **604** and **608** are provided for the physical inputs **122** and physical outputs **124**, respectively. Physical inputs **122** may be any of a wide variety of configurations—USB, mini-USB, DIN, or other wired signal transmitting/receiving means. The main unit **120** is preferably equipped with drivers and circuitry **606** and **610** for wirelessly transmitting/receiving, respectively, sensor inputs **122** and main unit outputs **124**. The main unit **120** also includes an internal power supply **636** and audio drivers and circuitry **642**.

[0055] Databases **614**, **616**, **618** are preferably included in main unit **120** for providing troubleshooting, system analysis, improvements, possible causes of erroneous readings, user guidance steps/functions, and other technical reference information. Memory **622**, **624**, **626**, **628** is preferably included for look-up tables (LUTs) and calculation algorithms needed to support the sensor kits **400**. On-board memory **630**, **632**, **634** that is writable by external devices such as, for example, laptop **208** or smartphone **210**, and via SD card, flash drive devices, etc. may be included in main unit **120** for loading additional or updated LUTs, software, customer ID information, and other data. Memory, LUT, and database management circuitry **638** is preferably included for handling software changes, updates, and operation of the main unit **120**.

[0056] Microprocessor **620** and supporting circuitry preferably provides the main unit **120** with processing means for executing stored programming instructions, access to on-board and accessible databases and memory, calculations, execution of algorithms, and other computing needs. Additional processing capacity **640** is preferably included for real-

time monitoring and display of input data, preferably real-time monitoring of all inputs simultaneously or substantially simultaneously.

[0057] Instead of the main unit 120 receiving sensor inputs 122 and directly providing outputs 124, in other embodiments of the present invention the function and capabilities of the central/main unit 120 may be divided, as shown (as system 700) in FIG. 7, into a handheld sized test and measurement data interface unit 702 for receiving sensor inputs 122 from sensor kits 704 and providing received sensor input information 706 to a handheld sized user interface 708, which in turn provides outputs 712 in the same way as described herein for the outputs 124 from main unit 120. The sensor kits 704 are as in FIG. 4, including kits 400, as shown as kits 402, 404, 406, 408, 412, 414. The interface unit 702, in one embodiment, provides all functionality of the main unit 120 (for receiving sensor inputs from sensor kits 704) except for display 126, key pad 130 and buttons 128 (i.e. most user interface functions) which are provided by the user interface 708. The user interface 708 may also include databases 614, 616, 618 for providing troubleshooting, system analysis, improvements, possible causes of erroneous readings, user guidance steps/functions, and other technical reference information. In some embodiments the user interface 708 includes displays, key pad or user input features, and data processing capabilities. Functional components 710 in the user interface 708 may include a power supply (such as 636), memory/memory management circuitry (such as 638), databases 614, 616, 618, and wired/wireless transmission/reception circuitry (such as 604, 606, 608, 610).

[0058] In one embodiment, the sensor interface 702 provides means for receiving sensor inputs 122 (from sensor kits 704) and transmitting sensor information 706 configured and arranged for reception by a user interface 708 such as a field portable tablet computing device, netbook, or smartphone device which can receive the transmitted sensor information and perform the data processing and user interface and feedback capabilities described herein provided by the main unit 120. In another embodiment, the sensor interface 702 comprises all functionality and capabilities (and databases, data processing means, etc.) as main unit 120, with the display 126 and user input features such as control buttons 128 and/or up, down, right, left, scroll, and select navigation controls 130 may be omitted in lieu of those user interface capabilities provided by an external device such as smartphone 210. In such fashion the housing and components required for such a sensor interface 702 may be reduced in cost, size, and complexity, and a greater variety of devices may be used to provide the physical user interface for the technician. For example, the technician may choose to use a particular tablet computing device as a preferred user interface in combination with sensor interface 702 and sensor kits 704. In such an embodiment, sensor interface 702 and sensor kits 704 provide all the functionality and capabilities described for main unit 120 herein, with the technician's choice of user interface device either substituting for display and physical user interface features not included with sensor interface 702 or complementing the display and physical user interface features and capabilities of sensor interface 702.

[0059] FIG. 8 shows an exemplary functional block diagram 800 of a handheld sized data interface unit 702 as in FIG. 7, according to various embodiments. Preferably, functionally and physically, the combination of sensor interface 702 and the user interface 708 include all features and capa-

bilities of the main unit 120 described previously. That is, in preferred embodiments, the sensor inputs 122 shown in FIG. 7 and in FIGS. 1-3 (and in all figures described herein) work in basically the same way, and, likewise, the user interface outputs 712 shown in FIG. 7 work in basically the same way as main unit 120 outputs 124 in FIGS. 1-3 (and all figures described herein). Drivers and circuitry 604 and 608 are provided for the physical inputs 122 and physical outputs 706, respectively. Physical inputs 122 may be any of a wide variety of configurations—USB, mini-USB, DIN, or other wired signal transmitting/receiving means. The interface unit 702 is preferably equipped with drivers and circuitry 606 and 610 for wirelessly transmitting/receiving, respectively, sensor inputs 122 and outputs 706. The interface unit 702 also includes an internal power supply 636 and audio drivers and circuitry 642.

[0060] Memory 804, 806, 808, 810 is preferably included for data pertaining to function/operation of the sensor kits 400. On-board memory 812, 814, 816 that is writable by external devices such as, for example, user interface 708, and via SD card, flash drive devices, etc. may be included in interface unit 702 for loading additional or updated software and other data. Memory management circuitry 802 is preferably included for handling software changes, updates, and operation of the interface unit 702.

[0061] Microprocessor 620 and supporting circuitry preferably provides the interface unit 702 with processing means for executing stored programming instructions, access to on-board and accessible memory, and other computing needs. Additional processing capacity 640 is preferably included for real-time monitoring and transmission of input data, preferably real-time monitoring of all inputs simultaneously or substantially simultaneously.

[0062] As mentioned above, the user interface 708 may comprise a smartphone (such as smartphone or PDA device 210 shown in FIG. 2) with sensor interface 702 and any of a variety of sensors 704, and the sensor interface 702 may be, in some embodiments, reduced in complexity to merely include means for receiving information from one or more sensors 704 and transmitting pertinent sensor information to a user interface 708.

[0063] As shown in FIG. 9, a user interface 708 may comprise a Blue Tooth device 920 (for example, a Blue Tooth enabled smartphone) and may be used to wirelessly communicate with a sensor interface 702 that may comprise a power source and transmitter unit 936 adapted to receive sensor information from any of a variety of sensors 704 and transmit pertinent sensor information to the user interface 708. In a preferred embodiment, the sensors 704 comprise any one or more attachment heads 904, 906, 908, 910, 912, 914, 916, 918, or another sensor attachment head not shown, each of which preferably interconnects with the sensor interface 702. The types of sensor attachment heads 704 shown in FIG. 9 are exemplary. Other types of attachment heads may be used. Clamp head 904 may be used to sense current flow. Airflow head 906 may be used to sense air flow. RH/wet bulb/temp head 908 may be used to sense/determine relative humidity, wet bulb temperature, and/or general temperature. AC/DC amp clamp head 910 may be used to sense AC and/or DC current. Automotive DC clamp head 912 may be used to sense DC current. Carbon monoxide detector head 914 may be used to detect CO levels. And single pressure head 916 and dual pressure head 918 may be used to sense single and dual pressures, respectively.

[0064] In one embodiment, a sensor interface 702 comprises a base unit 922 adapted to receive any one or more sensor head attachments 704 and having wireless transmit and receive capabilities for wireless communications with a user interface 708. The base unit 922 may be configured, for example, as a category III (CAT III) rated device (i.e. safety rated for use on permanently installed loads such as distribution panels, motors, and 3-phase appliance outlets) with display and user input functionality provided by a separate wirelessly connected user interface 708 such as handheld device/smartphone 920.

[0065] As an example of a base unit 922 in combination with a sensor unit 704, an IP67 rated meter 934 is shown in FIG. 9 comprising a clamp-on type head 904. Such meter 934 operates, according to a preferred embodiment, with a wirelessly connected user interface 708 such as a Blue Tooth enabled device 920 (or smartphone 210). Other types of base units may be used. An IP67 unit is safety rated for ingress protection—the “6” indicating total dust protection, and the “7” indicating protection in water submersion to a depth of 1 meter for at least a predetermined amount of time, typically 30 minutes.

[0066] As shown in FIG. 9, base unit 922 and IP67 meter 934 are exemplary configurations operable with a wirelessly connected device 920 whereby the device 920 preferably provides a display and other functionality of a user interface 708. In other embodiments, the base unit 924, 926, 928 as indicated in FIG. 9 include means for wirelessly communicating with a wireless device 920 which may comprise a user interface 708, and/or means for communicating with a sensor interface 702 such as the power source and transmitter unit 936. In preferred embodiments, any of the base units 924, 926, 928 may be attached to a particular sensor 704 (i.e. attachment head 904, 906, 908, etc.) and wirelessly communicate with one or more device 920/user interface 708 and/or wirelessly communicate with one or more sensor 704 via its associated sensor interface 702.

[0067] For example, a base unit 924 may comprise a CAT IV rated device (i.e. a device rated for use in locations where fault current levels can be very high, such as supply service entrances, main panels, supply meters, and primary over-voltage protection equipment), such as a G3 Phoenix refrigeration instrument (manufactured by Universal Enterprises Inc.) with single display and wireless communications circuitry for wireless communication with either or both a Blue Tooth device 920 (such as an iPhone or other smartphone, for example) and one or more wireless power source and transmitter 936 with its connected sensor head 704. If the G3 unit 924 is connected to a single pressure sensor head 916, for example, the G3 unit 924 preferably provides functionality of a user interface 708 for both its own directly (wired) connected sensor head 916 as well as, for instance, a power source/transmitter 936 attached to a carbon monoxide detector 914, with the CO detector 914 capable of being remotely located from the G3 unit 924. Further, a separate wireless device 920 may also be used by the technician as a user interface 708. The technician may use the wireless device 920 to monitor both the CO detector 914 via its transmitter 936 and also the single pressure sensor 916 via the G3 unit 924 and its wireless transmitter.

[0068] In similar fashion, in preferred embodiments, the technician may use the wireless device 920 to simultaneously and/or selectively monitor additional wireless enabled base units with respective attached sensor heads, additional base

units in wireless communication with other remotely located (wirelessly enabled) sensor units/sensor interface units, and/or other wirelessly enabled base unit devices. In preferred embodiments, any of the wireless capable units 924, 926, 928 may, as illustrated in FIG. 9, communicate wirelessly (such wireless communication shown in FIG. 9 in dashed line) with one or more transmitter 936 equipped sensor heads 704 (i.e. 904, 906, 908, 910, etc.) and with one or more wireless device 920, or even (not shown) other wireless capable units 924, 926, 928.

[0069] As shown in FIG. 9, unit 926 may comprise a CAT III rated G3 Phoenix-type device with two displays, true RMS, and equipped with wireless communications capabilities/circuitry. Unit 928 may comprise a CAT III rated G3 Phoenix-type device with two displays and wireless communications capabilities/circuitry. Other configurations for the units 924, 926, 928 may be used, which preferably include user interface 708 functionality and means for wirelessly communicating with a transmitter 936 and/or wireless device 920.

[0070] In preferred embodiments, each of the units 922, 924, 926, 928, 930 may be directly (wired) connected with any of the sensor attachment heads 904, 906, 908, 910, 912, 914, 916, 918. Unit 930 is illustrated as an exemplary user interface unit that does not include wireless communications means. Unit 930 may comprise, for example, a CAT III rated G3 Phoenix-type test and measurement instrument with two displays, temperature, but no wireless communications means. Preferably, such unit 930 may be configured to receive and directly (wired) connect with any one of the sensor attachment heads 904, 906, 908, 910, etc. (as indicated for units 922, 924, 926, 928). In one embodiment, a wired adapter 902 may be used to directly (wired) connect unit 930 or any unit 922, 924, 926, 928 with any of the sensor attachment heads 904, 906, 908, etc. The wired adapter 902, in preferred embodiments, allows for physical separation between the unit 930 (or other base unit 922, 924, 926, 928) and the sensor 704. For instance, a technician holding a G3 unit 930 may use a wired adapter 902 to connect the G3 unit 930 to an air flow head 906 that may be positioned in a hard-to-reach area (eg. air duct space) at a distance (substantially the length of the wired adapter 902) away from the technician holding the G3 unit 930.

[0071] By way of comparison with meters having greater features and capabilities, the clamp-on meter 932 shown in FIG. 9 is illustrated as a low cost current and temperature meter without a capability for accepting (attaching to) different sensor attachment heads 904, 906, 908, 910, etc. and without any wireless communications mean/circuitry. The unit 932 is shown as a “UTL” brand low cost meter. UTL meters such as the UTL 260 Digital Clamp-on meter are distributed by Universal Enterprises Inc. (UEI).

[0072] The terms and expressions which have been employed in the foregoing specification are used therein as terms of description and not of limitation, and there is no intention in the use of such terms and expressions of excluding equivalents of the features shown and described or portions thereof, it being recognized that the scope of the invention is defined and limited only by the claims which follow.

What is claimed is:

1. A method of HVAC/R test and measurement using a plurality of test and measurement sensor heads, at least one power source and transmitter unit adapted to physically connect with any of said plurality of sensor heads, provide power

thereto, and wirelessly transmit data to an external handheld-sized display and analysis instrument adapted for field use, the method comprising a field technician:

- (a) connecting said power source and transmitter unit to one of a plurality of test and measurement sensor heads;
- (b) performing a test and measurement using said connected sensor head by positioning said sensor head so as to sense and measure a desired parameter;
- (c) transmitting data from said power source and transmitter unit to said external display and analysis instrument; and
- (d) receiving said transmitted data on said external display and analysis instrument.

2. The method of claim 1 further comprising said technician performing a second test and measurement and receiving test and measurement data from a second one of said plurality of test and measurement sensor heads physically connected to said external display and analysis instrument.

3. The method of claim 2 further comprising said technician performing a third test and measurement and wirelessly receiving test and measurement data from a third one of said plurality of test and measurement sensor heads physically connected to a second power source and transmitter unit.

4. The method of claim 3 further comprising said technician wirelessly receiving test and measurement data from said first, second, and third ones of said plurality of test and measurement sensor heads on a handheld wireless device such as a smartphone or single-hand sized tablet wireless display and computing device.

5. The method of claim 1 further comprising said technician physically connecting a second one of said plurality of test and measurement sensor heads with said external display and analysis instrument using a wired adaptor unit for extending the distance between the sensor head and a handgrip portion of said external display and analysis instrument, and performing a second test and measurement and receiving test and measurement data from said second sensor head.

6. The method of claim 5 further comprising said technician performing a third test and measurement and wirelessly receiving test and measurement data from a third one of said

plurality of test and measurement sensor heads physically connected to a second power source and transmitter unit.

7. The method of claim 6 further comprising said technician wirelessly receiving test and measurement data from said first, second, and third ones of said plurality of test and measurement sensor heads on a handheld wireless device such as a smartphone or single-hand sized tablet wireless display and computing device.

8. The method of claim 1 wherein said external display and analysis instrument is adapted to connect to any of said plurality of sensor heads using the same physical connection as for said power source and transmitter unit.

9. The method of claim 8 further comprising said technician using said external display and analysis instrument to receive test and measurement data from any number of said plurality of sensor heads.

10. The method of claim 9 further comprising said technician using said external display and analysis instrument to determine at least relative positions of sensor heads transmitting test and measurement data to said external display.

11. The method of claim 10 further comprising said technician using said external display and analysis instrument to display a visual map of the relative positions of said transmitting sensor heads.

12. The method of claim 8 wherein said external display and analysis instrument includes circuitry adapted to automatically identify each one of said plurality of sensor heads by type of sensor and transmitted test and measurement data received, and automatically verify the tests and measurements that are available to be performed by the technician.

13. The method of claim 12 wherein said external display and analysis instrument automatically monitors each one of said plurality of sensor heads for settled/steady state measurements, and automatically alerts the technician as to settled/steady state status.

14. The method of claim 13 wherein said external display and analysis instrument automatically provides to the technician a suggested test or measurement, or a recommended improvement needed based on received test and measurement data from said plurality of sensor heads.

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