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Thomas, Jr.

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[54] **AIR-CONDITIONING SIMULATION SYSTEM AND METHOD**

[75] Inventor: **Sanford E. Thomas, Jr.**, Houston, Tex.

[73] Assignee: **Dyna-Kool Corporation**, Houston, Tex.

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[51] **Int. Cl.** **G09b 25/02**

[58] **Field of Search** ..... 35/13, 49, 9 D

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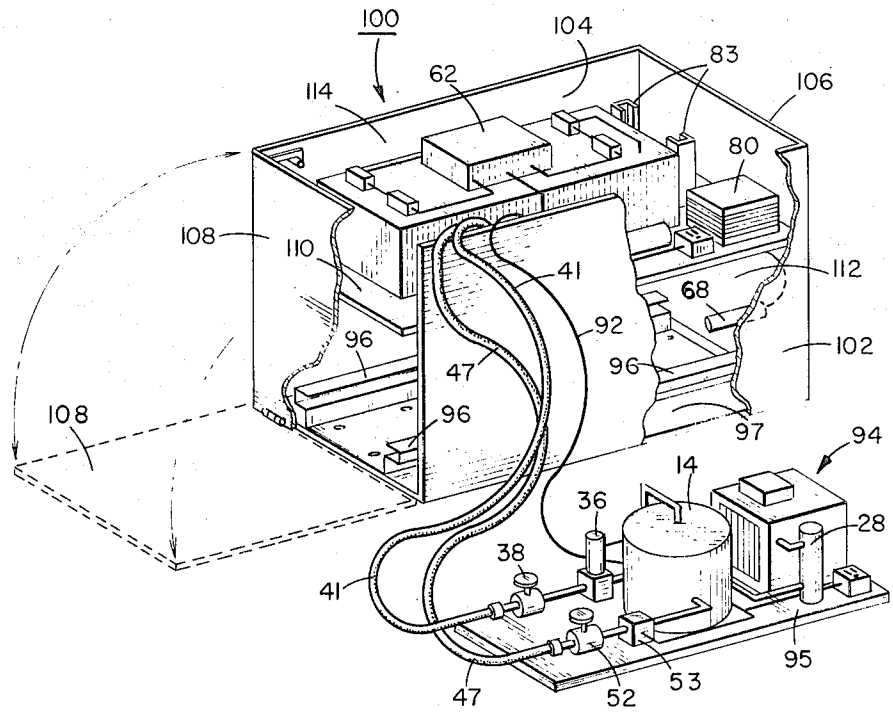
Primary Examiner—Wm. H. Greib

Attorney—Michael P. Breston

[57] **ABSTRACT**

A method and apparatus for simulating the normal and abnormal operating conditions in an air-conditioning system comprising a plurality of mechanically and electrically operated working units functionally interconnected into a thermodynamic loop, including a plurality of simulating components responsive to control signals from a central control station for simulating desired conditions. The station includes a female receptacle for receiving a programmed plug-in board thereby automatically and simultaneously affecting the state of energization of certain of the simulating components and working units whereby certain of the working units will operate in an abnormal mode.

7 Claims, 5 Drawing Figures



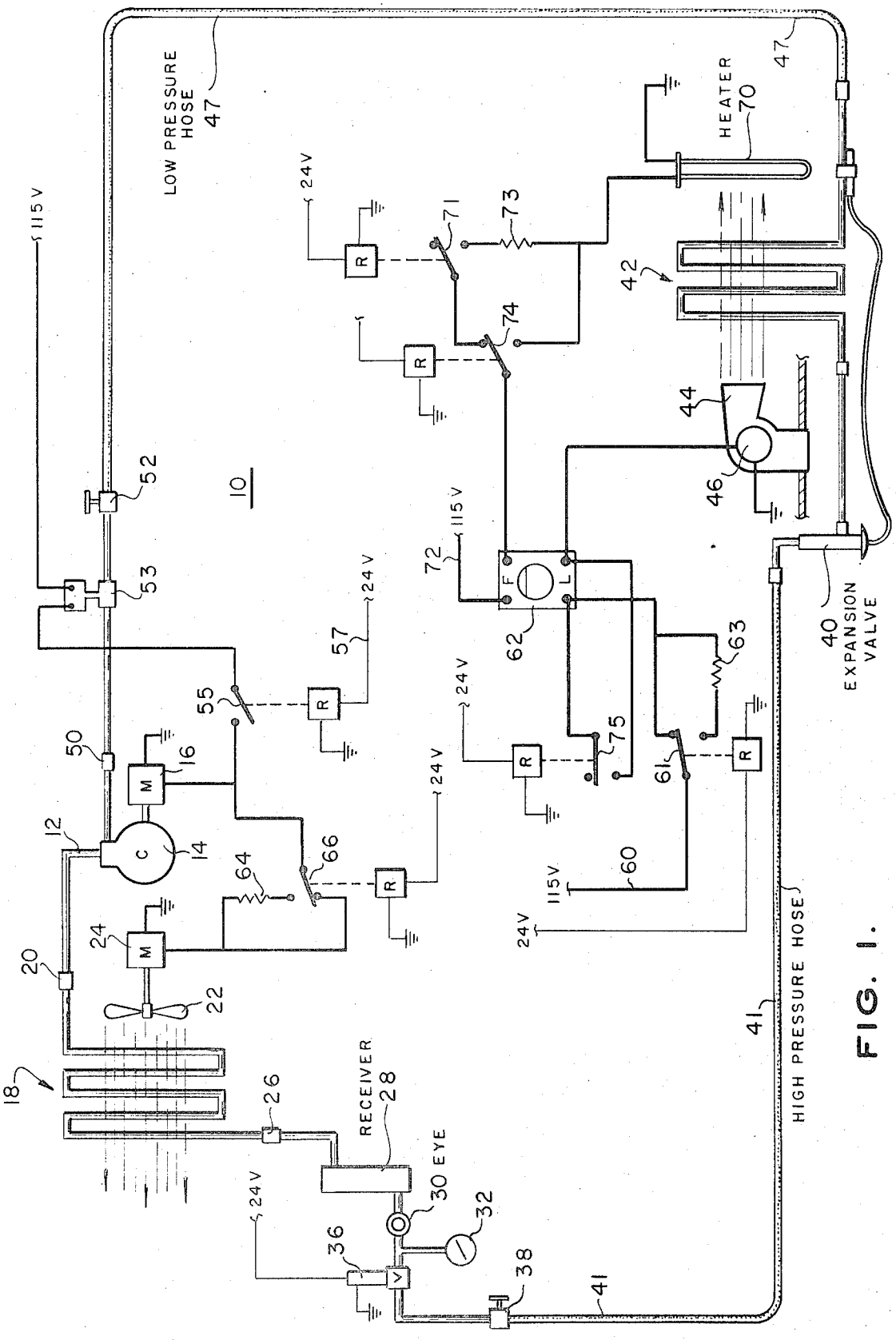

LOW PRESSURE HOSE
47
HEATER
70
47
115 V
24 V
71
73
74
42
44
46
10
52
53
72
115 V
F
L
62
63
40
EXPANSION VALVE
57
24 V
55
R
50
16
M
12
C
14
64
66
24
20
22
18
26
RECEIVER
28
30 EYE
32
36
V
38
41
HIGH PRESSURE HOSE
75
61
60

FIG. 1.

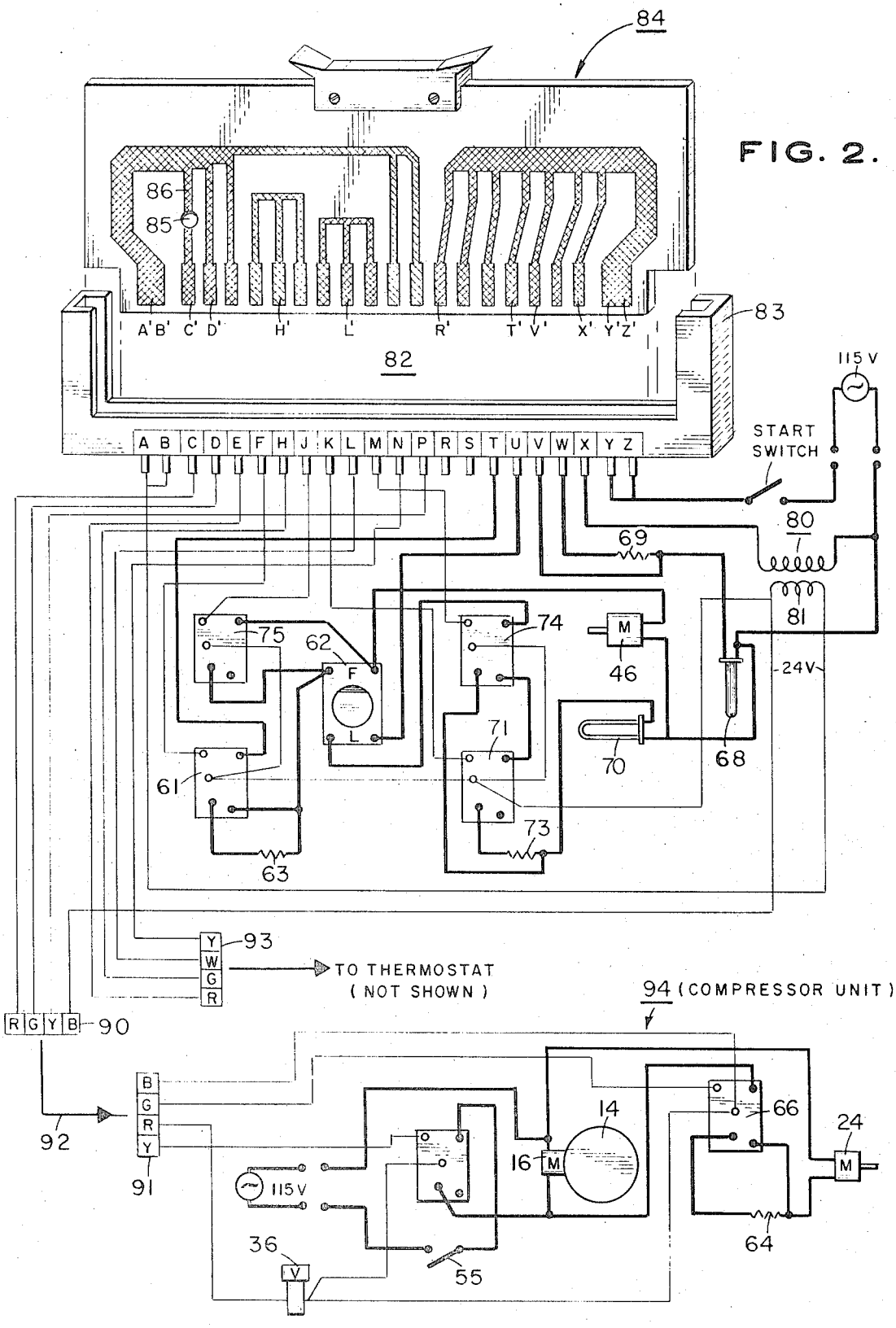

84
86
85
A' B' C' D' H' L' R' T' V' X' Y' Z'
82
83
A B C D E F H J K L M N P R S T U V W X Y Z
115 V
START SWITCH
80
69
81
75
62
F
L
74
M
46
24V
71
70
68
61
73
63
Y
W
G
R
93
TO THERMOSTAT
(NOT SHOWN)
94 (COMPRESSOR UNIT)
R G Y B
90
92
B
G
R
Y
91
115V
14
16
M
66
24
M
64
36
V
55

FIG. 2.

FIG. 3.

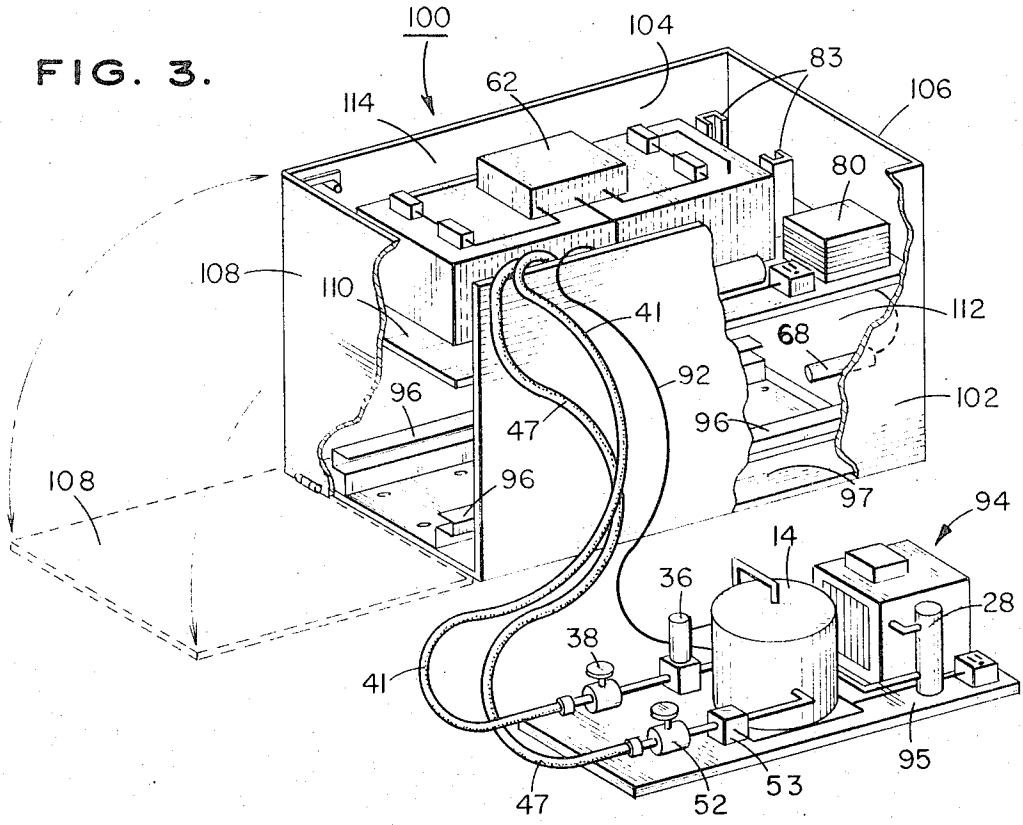


FIG. 4.

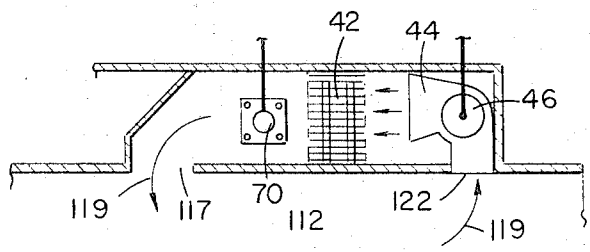
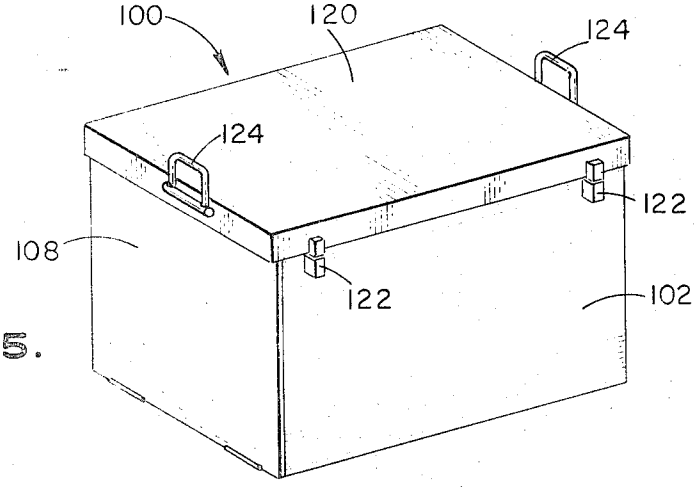


FIG. 5.



AIR-CONDITIONING SIMULATION SYSTEM AND METHOD

BACKGROUND OF THE INVENTION

Air-conditioning systems can be classified in several ways. According to their purpose, they can be described as winter, summer or all-year systems. Such systems are now generally referred to as central air-conditioners. Some of the units employed in air-conditioning equipment are also used in refrigeration and heating systems. As used herein, an "air-conditioner" refers to a heating, cooling or refrigeration system. In the most widely used central air-conditioning system for hot, humid climates, the air is cooled and dehumidified by passing it through a finned cooling coil. The coil serves as an evaporator for the refrigerant.

The basic working units in a central air-conditioning system are: (1) a thermostat which senses changes in temperature, (2) actuator units which operate valves to regulate the flow of air or refrigerant used in the system; and (3) limit and safety control units which change their state only when a potentially dangerous condition develops in the system. Some units are operated electrically, mechanically, thermally, or are fluid-pressure responsive.

In a typical refrigeration cycle in a mechanical compression system, a super-heated, high-pressure refrigerant vapor is discharged from the compressor into a heat exchanger or condenser. There the refrigerant vapor is condensed, essentially at constant pressure, by giving up its heat to the cooling water flowing through tubes or to the surrounding atmosphere, as in the case of small-sized, air-cooled machines. From the condenser, the saturated liquid refrigerant is collected into a receiver tank from which it is allowed to pass through an expansion valve followed by an evaporator coil, wherein, simultaneously with the reduction in pressure, an associated reduction in temperature takes place. The actual mechanism accounting for the lowering of the liquid refrigerant's temperature consists of the flashing into vapor of a portion of the liquid for which, the energy of evaporation is supplied by the liquid refrigerant itself, thus causing its temperature to drop. The liquid refrigerant is also evaporated by heat transferred to it from the warm conditioned air from the space being refrigerated or cooled. The flow rate of the refrigerant is automatically adjusted by the thermally operated expansion valve.

At the exit of the evaporator substantially all of the liquid refrigerant is in its saturated vapor state. The vapor leaving the evaporator enters the suction side of the compressor wherein it is compressed to a higher pressure. The work done by the compressor raises both the pressure and temperature of the refrigerant vapor so that it is discharged in the superheated vapor state and ready to repeat the entire thermodynamic or refrigeration cycle over again.

At any one point in this thermodynamic cycle, the refrigerant's condition, that is, its flow-rate, temperature, pressure, etc., do not change with time, while heat and work are received by the refrigerant in the evaporator and compressor, respectively, and heat is rejected in the condenser. The high-pressure half of this cycle extends from the discharge of the compressor to the inlet of the expansion valve, and the low-pressure half extends from the discharge of the expansion valve to the inlet of the compressor.

To teach a student to fully understand the performance of the various working units of the air-conditioner requires theoretical considerations with which maintenance personnel are not generally familiar. Basically, however, considering the condenser, the refrigerant receives no external work and only heat is exchanged between the condensing refrigerant and the cooling medium, water or air. The evaporator is a similar unit and again there is no work involved. The flow through the expansion valve involves neither the exchange of heat nor work. In the case of the compressor, a definite amount of work is delivered to the refrigerant vapor being compressed. The work of compression depends primarily on the pressure ratio of compression and not on the absolute values of the inlet or discharge pressures.

The compressed and superheated refrigerant vapor leaves the compressor at a temperature T_1 and pressure P_1 and enters the condenser. As heat is transferred in the condenser to the cooling water or air, the superheated vapor is cooled at constant pressure and its temperature drops from T_1 to T_2. The saturated vapor begins to condense and upon further heat transfer, condensation continues with the vapor giving up its latent heat of condensation until all of the vapor is completely liquified. It is collected in the lower part of the condenser or receiver as saturated liquid. From there it enters the expansion valve, and its pressure is reduced from P_1 to P_2. As a result of this pressure drop, the temperature of the refrigerant is further reduced to T_3 at the expense of some of the liquid flashing into vapor.

As the refrigerant enters the evaporator and absorbs heat from the conditioned space and its contents, it continues to evaporate at constant pressure and temperature until all of the refrigerant is completely evaporated and leaves the evaporator as saturated vapor. As it leaves the evaporator, it is dried and the dry saturated vapor enters the compressor, wherein by means of external work, it is compressed and discharged to repeat the cycle.

The cycle just described is somewhat simplified in that it was assumed that the refrigerant entering the expansion valve and the compressor consists of saturated liquid and saturated vapor, respectively. In actual practice, it is always nearly the case that the liquid refrigerant leaving the condenser is somewhat sub-cooled and the vapor leaving the evaporator is somewhat superheated.

With the knowledge of the above basic considerations, the maintenance technician can now best be taught the art of air-conditioning by simulating in a model the normal and abnormal modes of operation of the working units forming the thermodynamic loop.

Accordingly, it is a general object of the present invention to provide a method and apparatus for selectively simualting normal and abnormal operating modes of such working units in a manner especially adapted for individual or group training of air-conditioning maintenance personnel.

While various training machines have been developed for training maintenance personnel in such systems, most of them were bulky and impractical for home study. They were based on a teaching method which lacked the desired incentive to the trainee for self-discovery of the cause of the simulated malfunc-

tion by observing its measurable or visual manifestations.

SUMMARY OF THE INVENTION

In accordance with the teaching method of this invention, the student unknowingly but consciously simulates a malfunction in a model which is compact, lightweight portable and capable of being operated from an available conventional power supply outlet. The model is relatively simple and economical to fabricate, operate and maintain. It is designed to cool, heat or refrigerate a confined space or "room." Some of the units are mounted on a base which easily slides in and out of the room for visual observation. Other working units and simulating components are mounted in a compartment which simulates an equipment room or "attic."

The invention allows the trainee to receive a guided program of training in the maintenance of the working units in an air-conditioning system. By simultaneously establishing a simulated mode of operation, the trainee does not waste time in reading pages of instructions, and need not fear that he might damage the system by improperly following them. He then must diagnose the problem and compare his diagnosis with the solution, the delivery of which can be delayed to him.

The model of the invention employs simulating components, such as electrically-operated relays and resistors for closing a normally open, or opening a normally closed, or introducing a resistor into the, path of current flowing to a working unit. Signal lights may be included to warn of abnormal working conditions.

Each energizing circuit for various simulating components relays and resistors, and for the working units, has a terminal at a central control station having a receptacle adapted to receive one of a plurality of preprogrammed, printed circuit boards. Each board has a number of terminals corresponding to the number of said circuits.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a schematic representation of a thermodynamic loop including conventional working units and simulating components arranged in accordance with this invention;

FIG. **2** is a wiring diagram of a preferred model of the invention;

FIG. **3** is an isometric view, partly in section, of the model in its dis-assembled form;

FIG. **4** shows the air circulation mode; and

FIG. **5** is an isometric view of the housing.

Referring to FIG. **1,** there is schematically shown a model of a cooling, refrigeration, and heating loop, generally indicated as **10,** wherein a high-pressure refrigerant vapor is discharged at **12** from a compressor **14** driven by an electric motor **16.** The high-pressure refrigerant vapor enters a condenser unit **18** at inlet **20.** There the refrigerant vapor is condensed into liquid by giving up its heat to the cooling air blown over the condenser by a fan **22** driven by an electric motor **24.** From outlet **26** of the condenser, the refrigerant liquid is collected by a receiver unit **28** wherein the vapor, if any, is housed near the top and the liquid at the bottom. The refrigerant from the receiver flows through an "eye" **30** to allow visual inspection of its liquid phase. The pressure of the liquid refrigerant can be measured by a pressure gauge **32** connected to the output of the eye **30.** The flow of the liquid refrigerant may be controlled by a normally closed, solenoid-operated valve **36** and by a manually operated valve **38.** The high-pressure liquid refrigerant flows through a flexible line **41** and is allowed to pass through a thermally operated expansion valve **40** wherein it sustains a considerable reduction in pressure and an associated reduction in temperature.

The relatively-low pressure liquid refrigerant now flows through an evaporator unit **42** wherein the temperature of the liquid drops still further as it delivers energy of evaporation. In the evaporation process, heat energy is also used up by the refrigerant from the conditioned and warm air blown over the evaporator by a fan **44** energized by a motor **46.** The flow rate of the refrigerant is automatically adjusted by the expansion valve **40,** so that substantially all of the refrigerant leaving the evaporator is in a saturated vapor state.

In a suction line **47,** a portion of which is flexible, between the evaporator **42** and the suction inlet **50** of the compressor **14,** is provided a manually controlled valve **52** and a pressure-operated switch **53** for controlling the main electric line **54** feeding motors **16** and **24.** Line **54** also includes a thermostatically controlled switch **55** for starting the cooling cycle of loop **10.** The actual thermostatic circuit is not shown in the drawings since it is conventional.

Motor **46** of fan **44** is normally energized from a line **60** through a thermally responsive, double switch **62.** Near the evaporator's coil **42** is positioned a heating coil **70** which, in field use, can be an electrically-operated or a gas heater. The main electric line **72** feeding coil **70** also goes through the switch **62** and through a thermostatically-controlled switch **74.**

The working units **14, 18, 28, 40, 42** and **70,** and their associated electrical working circuits are conventional.

To simulate malfunctions and abnormal modes of operation in the working units of loop **10,** there are provided in accordance with the invention a plurality of simulating circuits including simulating components, as resistors and preferably relays (R), a description of which will now follow.

For simulating the abnormal mode of operation of evaporator **42,** there is provided a relay-operated switch **61** for energizing motor **46** either directly or through a resistor **63.** Similarly, motor **24** of fan **22** in the condenser unit **18** can be selectively operated through a resistor **64** by a relay-operated switch **66.** A relay-operated switch **71** selectively couples the main line **72** to heater coil **70** through a resistor **73.** A relay-operated switch **75** can selectively by-pass the thermally operated switch **62** in line **60.** A heat load simulator **68** (FIG. **2**) can be energized directly or through a resistor **69.**

In FIG. **2** is shown an actual wire diagram used in a preferred model of the invention in which the same reference characters are used to designate the same or similar parts as in FIG. **1.** The previously described working units in the working circuits (represented by the heavy lines) are energized from a conventional power source of 115 volts, whereas the simulating components in the simulating cirucits (represented by the light lines) are energized with 24 volts obtained from the secondary winding **81** of a power transformer **80.**

The simulating and working circuits are respectively arranged so that each one of them has a terminal originating at a control station, generally designated as **82.**

Station 82 includes a receptacle 83 adapted to consecutively receive a plurality of pre-programmed, plug-n, printed-circuit (PC) boards generally designated as 84. The terminals in receptacle 83 are marked A' through Z' and each PC board includes a corresponding number of matching terminals A–Z. If no hole 85 is punched in a line 86 electrically interconnecting a pair of terminals, say A and C on PC board 84, then the mating terminals A' and C' in the receptacle 83 would be electrically interconnected. By punching such a hole 85 in line 86, the electrical connection between terminals A and C in the control station 82 is interrupted. In this manner, it is possible to pre-program a plurality of such boards to achieve a desired mode of operation by the working units and the simulating components.

Each such board 84 after being inserted into receptacle 83 will automatically, fully or partially, energize or de-energize certain of the working units and/ or simulating components to cause certain ones of them to operate in a desired mode for simulating a field condition or an abnormal mode of operation.

A male plug 90, to which are attached four colored wires (red, green, yellow and blue), detachably connects to a mating plug 91 through a flexible line 92. Another group of four colored wires (red, green, white and yellow) are connected through a connector 93 to a mating connector (not shown) of the thermostat circuit. The working units and simulating components energized by or through plug 91 constitute a network, generally designated as 94, which is mounted on a removable base 95, slidably mounted on a pair of parallel rails 96 secured to the floor 97 of a housing, generally designated as 100.

Housing 100 has two lateral walls 102, 104, an end wall 106, and a hingedly secured end wall 108. Between the ends of walls 102, 104 there is positioned a shelf 110 which separates the inside volume of housing 100 into two compartments 112 and 114. Compartment 112 simulates the conditioned space previously referred to as the "room," and compartment 114 simulates the equipment room, previously referred to as the "attic." It will be appreciated that the equipment room could be the basement or a closet.

As shown in FIG. 4, the conditioned air is circulated in the direction of the arrows 119 from room 112 to the attic 114 through openings 117, 122 in the shelf 110.

The compressor network 94 on board 95 is detachably coupled to the attic via high-pressure flexible line 41, low-pressure line 47, and electric cord 92.

In FIG. 5 the housing 100 is shown with its wall 108 in the erected position and with its cover 120 secured by locks 122. The housing can be readily carried by one person with the aid of handles 124.

To operate the model, the compressor base 95 is removed from the rails 96. For a normal cooling mode, PC board 84 is inserted into receptacle 83 located near the top of end wall 106, as shown in FIG. 3. This basic board will hereinafter be referred to as the C-1 board. It simulates a normal cooling operation in room 112 when wall 108 is raised.

A thermostat (not shown) in room 112 was preset to a desired cooling temperature. In the normal cooling mode, the load simulator 68 is energized to provide a heat load for the room. When the temperature of the room reaches the setting of the thermostat, switch 55 will close, motors 16 and 24 will start running, and valve 36 will open to allow the high-pressure liquid refrigerant to flow from the condensing unit 18. Motor 46 is energized by the by-pass switch 75. The thermostat will in due time open switch 55 and stop the cooling cycle.

The student can observe the normal function of the loop 10 by removing the base 95 from the room 112 and positioning it adjacent to the housing, as shown in FIG. 3. After the student becomes acquainted with the normal mode of operation brought about by the insertion of a C-1 board into receptacle 83, he will unplug the board and insert a C-2 board (not shown) which makes the same electric connections as the C-1 board, except that now switch 61 will cause resistor 63 to be in the energizing line 60 leading to the evaporator fan 46. The size of resistor 63 is such as to reduce the speed of fan 44 by about 75 percent. Since an insufficient volume of air flows through the evaporator coil 42, the pressure in suction line 47 will drop appreciably, as the student can observe by connecting a pressure gauge to inlet 50. As a result, coil 42 will begin to frost-up. The abnormal C-2 mode of operation simulates a dirty air filter (not shown) in the evaporator unit, a dirty evaporator coil, a defective fan belt between the shaft of motor 46 and the fan 44, an insufficient volume of refrigerant, a restriction in a refrigerant line, a defective motor 46, etc.

By removing the C-2 board and inserting a C-3 board, the same connections are made as with the C-1 board except that now switch 66 will bring resistor 64 in the line energizing motor 24. The speed of fan 22 will be sharply reduced with a corresponding decrease in the volume of air blown through condenser coil 18. As a consequence, the pressure at the discharge outlet 12 of compressor 14 will rapidly increase thereby causing the compressor to over heat and its internal thermal protector contacts (not shown) to cut-off motor 16. The abnormal C-3 cooling mode simulates a dirty condenser coil 18, a defective motor 22, a defective fan belt in the condenser unit, a restriction in the condenser coil, an abnormally high heat load, a defective expansion valve 40, etc.

By inserting a C-4 PC board the student establishes the same connection as with the C-1 board, except that now no current is provided to the solenoid-valve 36, blocking the flow of refrigerant from the receiver 28. This will cause the pressure in the suction line 47 to drop sharply. The pressure drop is sensed by the pressure-operated switch 53 thereby opening line 54 and stopping motors 16 and 24. The C-4 abnormal cooling mode simulates a plugged-up refrigerant dryer, usually found in the suction line 47 but not shown in the drawings, a defective expansion valve 40, a low amount of refrigerant, etc.

To simulate a normal heating cycle, a H-1 board is inserted into receptacle 83 which allows the thermostat to close switch 74 thereby heating coil 70. The heat responsive switch 62 will respond to the heat increase to close its terminals thereby energizing motor 46. When the conditioned air in room 112 reaches the temperature prescribed by the thermostat, the thermostat will open switch 74 to de-energize coil 70.

To simulate an abnormal heating cycle, a H-2 board is inserted into receptacle 83. In this H-2 abnormal heating mode, switch 71 brings resistor 73 into the energizing line 72 thereby reducing the electric energy supplied to coil 70. Switch 62 will now remain open and motor 46 will not run. This mode simulates defec-

tive relay contacts, an incorrectly operating switch **62,** insufficient energy provided to the heater coil **70,** etc.

By inserting a H-3 board into receptacle **83,** line **60** is not energized and consequently fan **44** will not operate. Since no air blows through coil **70,** the air surrounding coil **70** will heat up until the heat-responsive switch **62** will open to break the energizing line **72** thereby stopping the heating cycle. This H-3 mode simulates a defective or incorrectly operating switch **62,** defective relay contacts, a broken energizing line **60,** etc.

To simulate a normal refrigeration cycle, a R-1 board is inserted to establish the same connections as the C-1 board, except that line **57** (FIG. 1) leading to the relay-operated switch **55,** will be energized irrespective of the setting of the thermostat. Accordingly, switch **55** will close, and motors **16** and **24** will start running. In this R-1 refrigeration mode, motor **46** is energized through resistor **63,** thereby reducing the amount of air blown by fan **44.** Evaporator coil **42** will now frost-up. Since the thermostat is effectively by-passed, the compressor's motor **16** will continue to run but the pressure in the suction line **47** will continue to drop. When the pressure falls below the preset pressure for the pressure-operated switch **53,** it will open line **54** to stop motors **16** and **24.** This R-1 mode represents a normal refrigeration cycle.

By inserting a R-2 board into receptable **83,** an abnormal refrigeration cycle is simulated. The same connections are established as with the R-1 board, except that now no power is supplied to the primary winding of transformer **80.** This has the effect of rendering inoperative all working units and simulating components. The student is faced with a real challenge in that he must test each component, each working unit, and each circuit.

While a plurality of plug-in PC boards have been described, it will be appreciated that many other abnormal operating conditions could be simulated to provide the student with an ever increasing challange for diagnosis.

In summary, the method and apparatus of this invention allow the student, by inserting a single member, to simultaneously affect the condition of a plurality of circuits in an air-conditioning loop. This pre-programmed operation avoids the student from having to read, sometimes in a language of which he has little working knowledge, several pages of instructions, with the inherent danger that he might open or close a wrong switch thereby possibly damaging an expensive working unit or simulating component.

What is claimed is:

1. A method for training air-conditioning students in simulating normal and abnormal operating modes in an air-conditioning system, comprising the steps of:

interconnecting a plurality of working units and simulating components to form an operative thermodynamic loop, said simulating and working units being arranged in respective simulating electric circuits and working electric circuits and each circuit having a terminal originating at a control station including a receptacle;

electrically energizing said loop;

consecutively inserting programmed members into said receptacle, each programmed member having circuit arrangements thereon; and

transmitting control signals from said receptacle to thereby simultaneously control the operating conditions of said simulating and working electric circuits whereby a simulated mode of operation is created for a particular one of said working units to allow the trainee an opportunity to diagnose the nature of said normal and abnormal modes of operation as well as the resulting manifestations thereof.

2. An air conditioning training apparatus for simulating normal and abnormal operating modes, unknown to the trainee in an air-conditioning system comprising:

a plurality of working units functionally interconnected to form an operative thermodynamic loop when energized by a source of electric power, said loop including a plurality of suitably arranged, simulating components responsive to control signals for simulating the abnormal mode of operation of certain ones of said working units;

a central control station for generating such control signals including a receptacle,

said simulating and working units being arranged in respective simulating and working circuits each of which having a terminal originating at said control station;

at least one programmed member matingly engageable with said receptacle and having circuit arrangements thereon adapted to simultaneously control the operating conditions of said simulating and working electric circuits whereby a simulated mode of operation is created for a particular one of said working units to allow the trainee an opportunity to diagnose the nature of said unknown abnormal mode of operation as well as the resulting manifestations thereof.

3. The apparatus of claim **2** and further including:

a portable housing defining a conditioned room and an equipment room,

a base unit removably supported in said conditioned room, certain of said working units being mounted on said base unit and being flexibly interconnected with the other working units in the equipment room.

4. The apparatus of claim **2** wherein,

said circuit means include a receptacle in said control station for removably accepting said member.

5. The apparatus of claim **4** wherein said member is a printed circuit board.

6. The apparatus of claim **5** wherein certain of said simulating components are resistors.

7. The apparatus of claim **6** wherein certain of said simulating components are relays.

* * * * *