Chapter 2 – Professional Air-conditioning Systems

EXPERIMENT 2.1 – INTRODUCTION TO PROFESSIONAL AIR-CONDITIONING SYSTEMS

Name	Class/Period	Date

1. Objectives:

At the end of this experiment session, you will be able to:

- Explain the general principle of air-conditioning.
- Explain the reverse thermal cycle procedure.
- Explain the use of psychrometric diagrams.
- Explain the motors control.
- Explain the results of pressure drop.
- Explain the cooling procedure.
- Explain the heating procedure.
- Explain the humidification and drying of air.
- Explain the operation of the cooling unit with various relaxation devices.

2. Equipment Required:

- Main Platform Unit
- Professional Air Conditioning Panel

3. Discussion: **General principles of cooling and air-conditioning**

The general principle of cooling, air-conditioning and the thermodynamic terms can be found in chapter 1. In experiment 1.1 of this book all the basic principle and terms such as: basic air-conditioning cycle, basic operation of air-conditioning system, basic component of air-conditioning system, basic cooling, air-conditioning and thermodynamic principles and terms and the p-h diagram.

4. Discussion: Reverse thermal cycle procedure

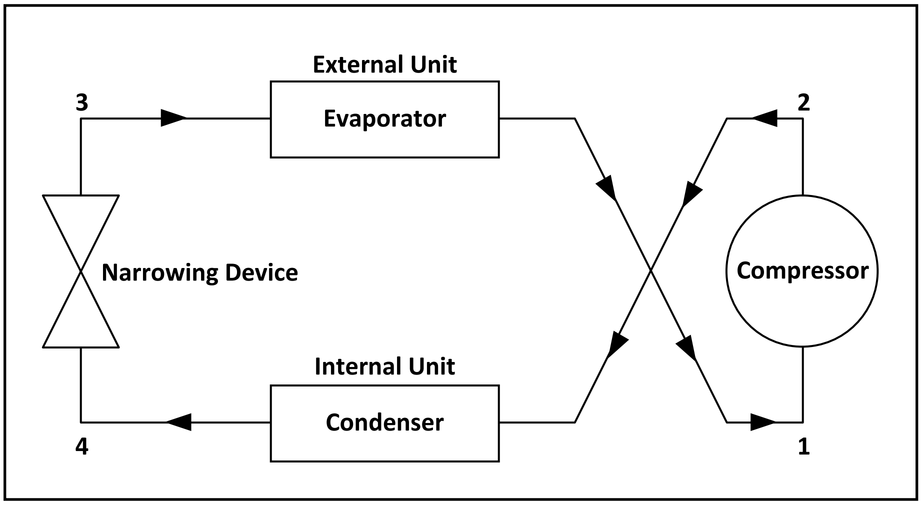


Figure 2-1 Reverse thermal cycle

The Reverse thermal cycle procedure is a function to enables the air-conditioning system to heat the air. Working in the heating state, the cooling material exits the compressor and flows towards the internal battery instead of toward the external battery, making the internal battery (the evaporator) becomes a condenser.

The cooling material continues to flow through the narrowing device from point 3 to point 4 and undergoes a process similar to the narrowing process in a cooling working state. From point 4, the cooling material goes on to the external battery, which turns from a condenser to an evaporator. At the end of the evaporation process, the cooling material flows back to the compressor.

When the heating pump is working, the evaporation and condensation processes exchange places. The condensation process, which took place in the external battery and caused heat convection to the external environment now occurs in the internal battery and causes heat convection to the air-conditioned center. The evaporation process, which took place in the internal battery and caused heat reception from the air-conditioned center now occurs in the external battery and causes heat reception from the external environment.

5. Discussion: Use of psychrometric diagrams

Psychrometric is a science, which deals with the thermodynamic characteristics of humid air in various conditions. This section includes theoretical explanations of these characteristics as shown in the psychrometric diagram, and description on the various procedures and the coefficients defining the procedures.

The airflow in the air-conditioned center and in the Air Treatment Unit is a cyclic flow. The air is sucked from the air-conditioned center to the Air Treatment Unit, and flows from the Air Treatment Unit to the center. The air's thermodynamic characteristics change during this cycle and this change can be described in the psychrometric diagram.

The psychrometric diagram is the most important basis for understanding the air's behavior in the treatment unit, and is the basis for various planning conditions.

How to read the psychrometric chart?

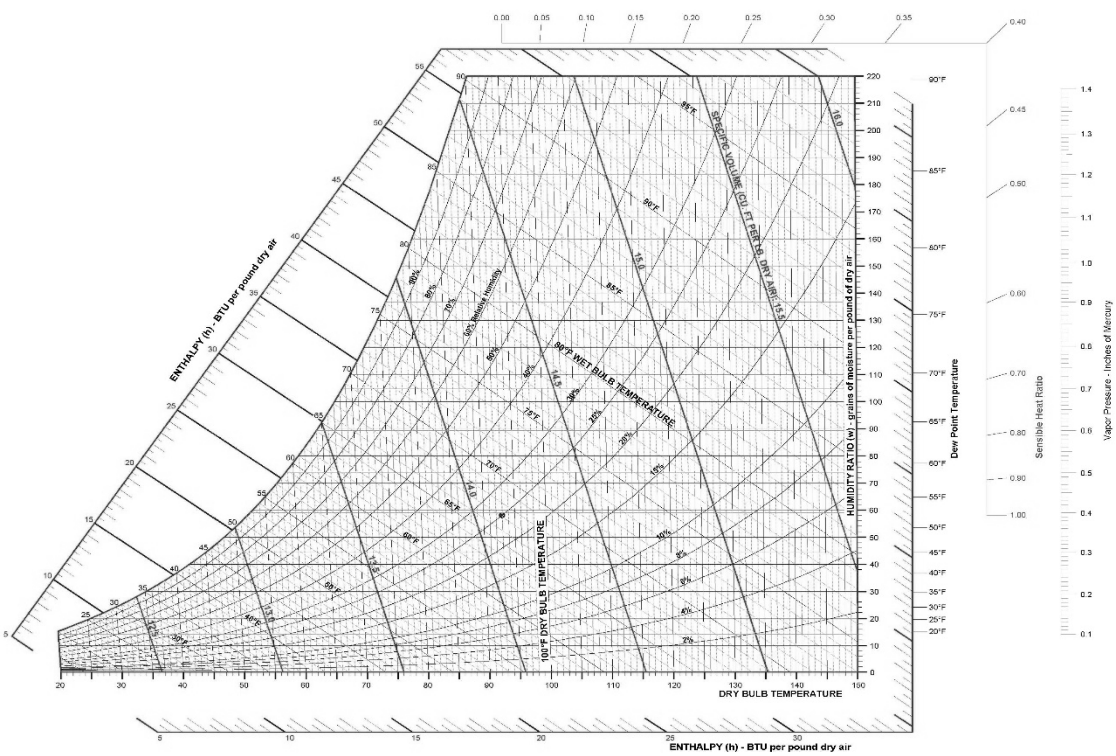


Figure 2-2

The dry-bulb temperature scale can be read from the boundary of the vertical axis, a humidity ratio (moisture content) scale on the vertical axis, and an upper curved boundary which represents saturated air or 100% moisture holding capacity. The chart shows other important moist air properties as, wet-bulb temperature; enthalpy; dew point or saturation temperature; relative humidity; and specific volume. Moist air can be described by finding the intersection of any two of these properties and from that point all the other properties can be read. The key is to determine which set of lines on the chart represent the air property of interest.

An understanding of the shape and use of the psychrometric chart will help to diagnose air temperature and humidity problems. Note that cooler air will not hold as much moisture as warm air.

6. Discussion: **Motors control**

Two types of motors control are used in these air-conditioning systems: thermostatic and pressure controls. Systems with more than one evaporator use pressure motor control because:

1. Low side pressure indicates the evaporator's temperature.
2. A single motor control works better without the need to rely on the evaporators connected to it.

When motors with high power start working, they consume high current (more than the control system can hold). The starter system is needed to solve this problem. This system activates a relay that disconnects the starter after it finishes its work.

7. Discussion: **Results of pressure drop**

When the gas pressure is too low, the compressor can over-heat because not enough gas reaches the motor head, which can cause the motor to burn. To avoid this, when the pressure drops below the desired level, the protection system disconnects the compressor from the electricity.

A properly designed air-conditioning system should have a pressure loss of much less than 10% of the compressor's discharge pressure.

Extreme pressure drop will result in poor system performance and excessive energy consumption. Flow restrictions of any type in a system require higher operating pressures than are needed, resulting in higher energy consumption. Minimizing differentials in all parts of the system is an important part of efficient operation. Pressure drop upstream of the compressor signal requires higher compression pressures to achieve the control settings on the compressor. The most typical problem areas include the after cooler, lubricant separators, and check valves. This particular pressure rise resulting from resistance to flow can involve increasing the drive energy on the compressor by 1% of the connected power for each 2 psi of differential.

8. Discussion: **Pressure regulation valve**

Professional air-conditioning systems use many types of pressure regulation valves. Here are some examples:

- Evaporator pressure (two temperature valves).
- Crankcase pressure.
- Head pressure control valve.

9. Discussion: **Compressor protection safety devices**

The reciprocating compressors may be damaged when air-conditioning liquid accidently flows to it from the suction line. The refrigerant must be in a steam state. The steam temperature must be higher than the temperature in the evaporator. A rise in temperature means that the evaporator is superheated.

There are many devices which prevent or minimize the liquid flow from the suction line to the compressor:

- Accumulator in the suction line.
- Warm gas bypass valve to remove the warm gas to the suction line.
- Temperature sensing device.
- Electrical heating for heating the liquid in the suction line.
- Evaporator in the suction line.

10. Discussion: **Manual service valve**

In air-conditioning systems the manual service valve is used for:

- Filling or emptying the cooling liquid from the system.
- Determining the work pressure.

Manual and service valves must be durable against corrosion. They also need to be in good quality in order to withstand many openings and closings without leaking. Steam valves must be taken care of carefully.

11. Discussion: **Cooling procedure**

Air-conditioning systems absorb heat from the air in the air-conditioned area and discharges the heat somewhere else. This is done with the use of a fluid called refrigerant, to move heat from one place to another.

When refrigerant absorbs heat it evaporates (boils). As such, mechanical refrigeration is accomplished through the latent heat of vaporization.

So that refrigerant can be reused (evaporated each time it cycles through the system,) it has to be condensed. When condensed, the refrigerant rejects latent heat (and some sensible heat) and returns to a liquid state. This cyclical evaporation and condensation necessitates a pressure differential in the system and usually some type of pumping mechanism.

12. Discussion: **Manual service valve**

In the heating procedure-working state, the cooling material exits the compressor and flows towards the internal battery instead of toward the external battery, such that the internal battery (the evaporator) becomes a condenser.

The cooling material keeps flowing through the narrowing device from point 3 to point 4 and undergoes a process similar to the narrowing process in a cooling working state. From point 4, the cooling material goes on to the external battery, which turns from a condenser to an evaporator. At the end of the evaporation process, the cooling material flows back to the compressor.

When the heating pump is working, the evaporation and condensation processes change places. The condensation process, which took place in the external battery and caused heat convection to the external environment now occurs in the internal battery and causes heat convection to the air-conditioned center. The evaporation process, which took place in the internal battery and caused heat reception from the air-conditioned center now occurs in the external battery and causes heat reception from the external environment.

13. Discussion: **Humidification and drying of air procedure**

The drying and humidification processes as explained in chapter 1 exercise 1.3, are a major factor in the process of air-conditioning. The cooling and drying processes occur in the air-condition unit. The air cools down and creates condensed water drops. These water drops drain into a drainage pool located in the air-conditioner, and flow outside the structure. The air-conditioner manages to squeeze water vapor from the air using a cold body installed inside it. This cold body has a lower temperature than the air's dew point, and the air flows through this body.

The process of heating and humidification also occurs in the air-conditioned unit. The air outside the air-conditioner unit flows through the center's space meets the heat loads there. They then heat up and absorb moisture from the air in the center space.

The Humidification and drying of air procedure and test will be practiced in the procedure in this exercise.

14. Discussion: **Operation of the cooling unit with various relaxation devices**

In order to protect the compressor from damage caused by high pressure, the cooling unit must not be activated immediately after shut down (mainly in professional cooling systems and air-conditioning systems). 5 minutes must be waited before re-activation in order to allow pressure comparison between the condenser and the evaporator.

A number of electronic system delays exist today. Their function is to delay the activation of the compressor for 3.5-5 minutes, even if the air-conditioning cooling unit were shut down and activated immediately. This delay is good mainly when there are voltage drops or momentary electrical blackout.

The air-conditioning system is equipped with the following relaxation devices:

- **Pressure** – The system checks the pressure values and waits until they reach the safe operating pressures.
- **Timer** – Another method of relaxation device is with a timer that does not allow the system to operate until 5 minutes have expired.

15. Discussion: **Description of the operation of the system**

The professional air-conditioning system is composed of MAIN PLATFORM UNIT and PROFESSIONAL AIR CONDITIONING PANEL as described in the following circuit:

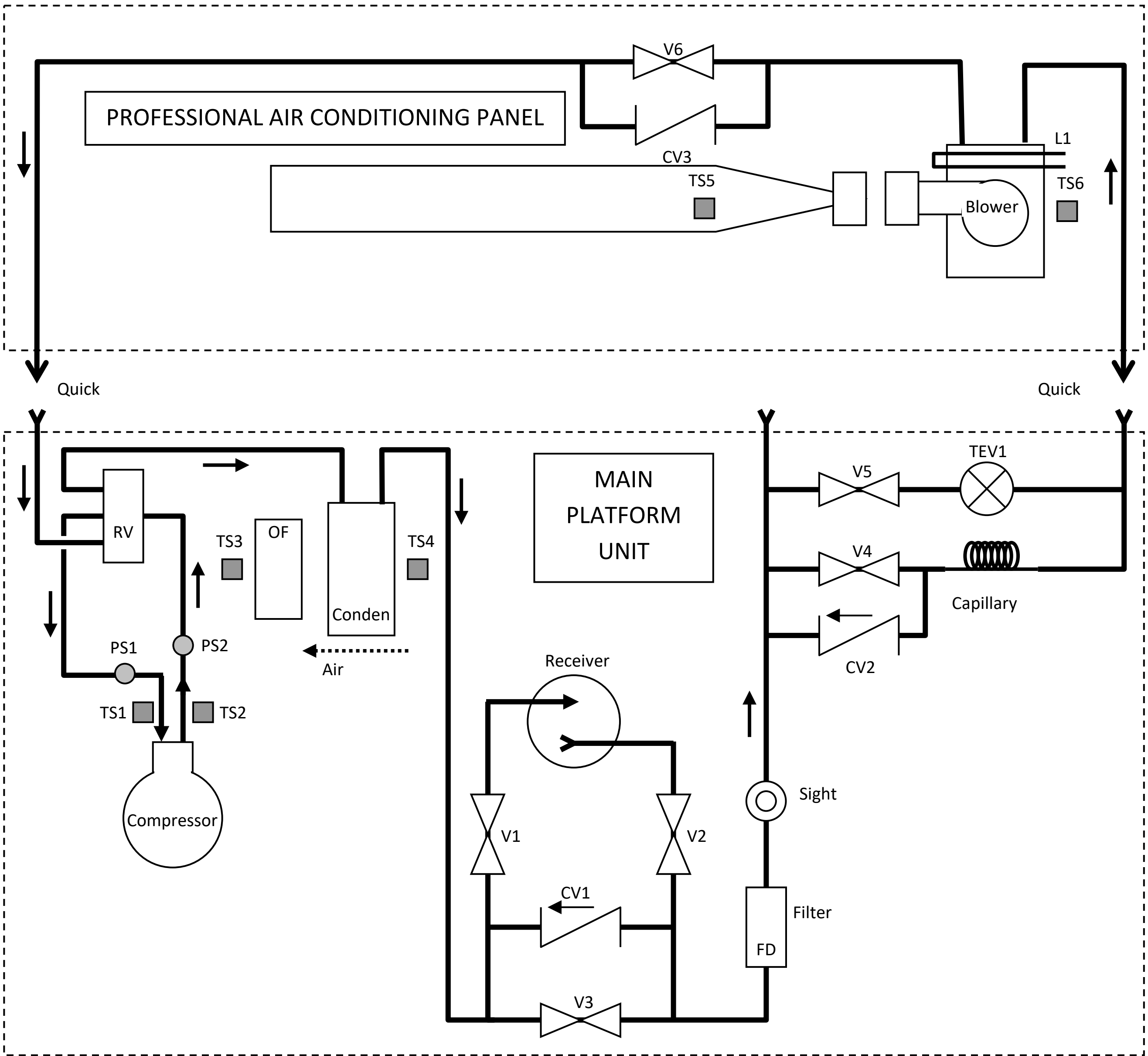


Figure 2-3

The system includes two cooling chambers intended for two different temperatures. The right chamber is for low temperature and the left one is for higher temperature.

Every chamber includes an evaporator, a fan, temperature sensor, and an electric valve which controls the gas supply to the evaporator.

The evaporator may be operated in series or in parallel.

The two chambers are located in the PROFESSIONAL AIR CONDITIONING PANEL and are connected to MAIN PLATFORM UNIT by quick fasteners.

The MAIN PLATFORM UNIT is the base unit for the basic air-conditioning and professional air-conditioning system. It includes the air-conditioning elements (besides the evaporator components on the panel) – a compressor, a condenser and its fan, a thrilling elements, TEV (Thermostatic Expansion Valve), reversing valve and capillary tube.

Additionally, the system is equipped with accessories and controls, which help the system to operate efficiently and protect the main components from various problems. They are the following:

- **Receiver-Drier** – A container that contains a desiccant to remove moisture and is used to store and filter liquid refrigerant. The receiver-drier is located in the liquid line between the condenser outlet and the expansion valve inlet.
- **Sight Glass ("Eye")** found on the liquid line. This unit checks if the cooling liquid level is satisfactory. Bubbles usually signal lack of cooling liquid in the system.
- **Filter Drier** – A device used to remove moisture from an air-conditioning system.

The MAIN PLATFORM UNIT has two modes of operations: TEV mode and Capillary mode. Valves are installed in the system in order to enable these two modes.

These valves direct the refrigerant according to the required air-conditioning circuit. The system monitor operates the valves.

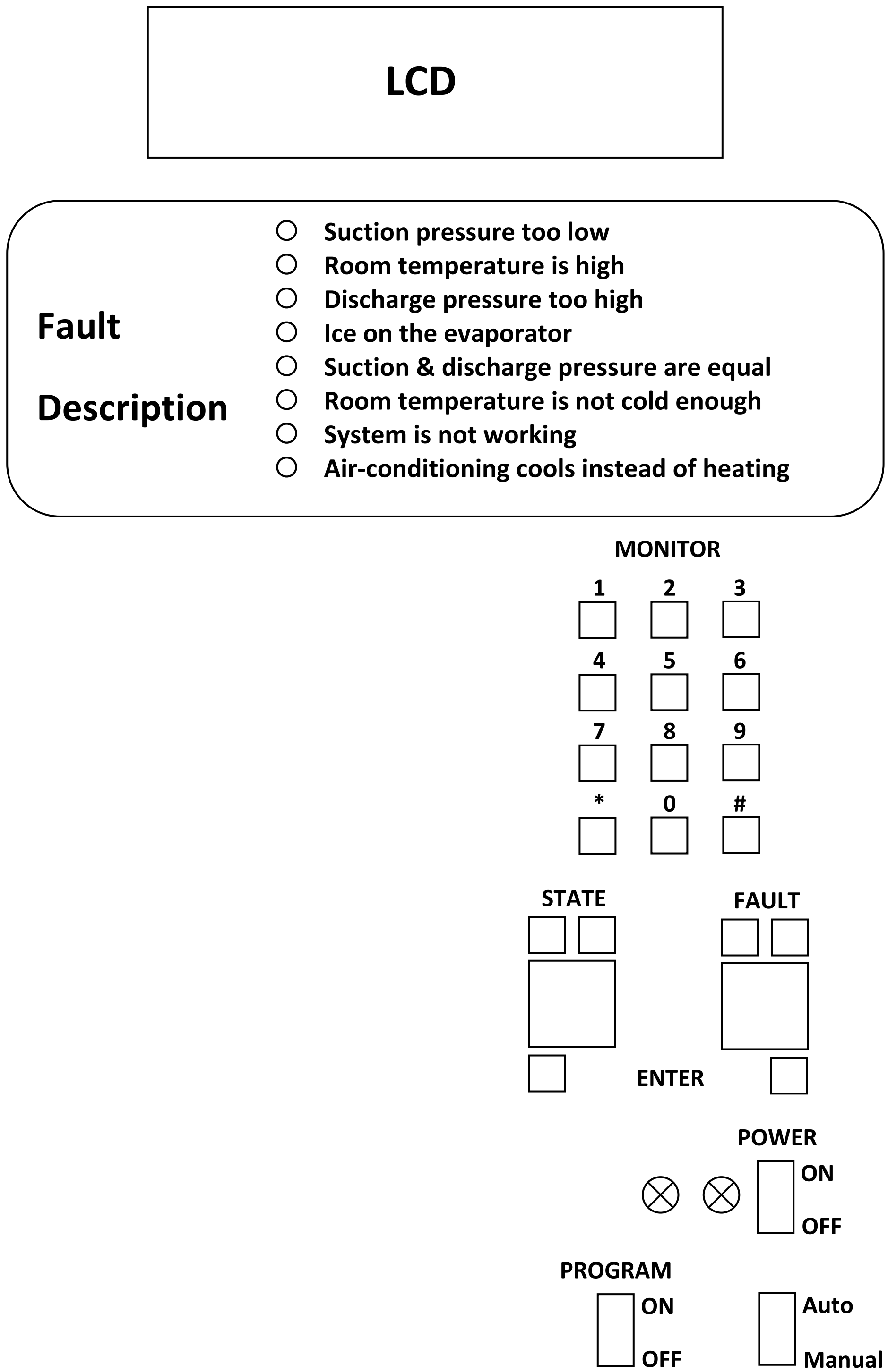
Because MAIN PLATFORM UNIT is also aimed for air-conditioning, it includes a 4-way valve (the RV). This valve enables changing the system from a cooling system to a heating system.

In the air-conditioning system, the RV stage is always at its normal position, which forms a cooling system only. The compressor sucks gas from the evaporator and compresses it to the condenser.

The system also includes Temperature Sensors (TS1-TS8) and Pressure Sensors (PS1 and PS2).

The evaporators include heaters acting as a thermal loads or as a defrost device.

The system is operated by the monitor controller helped by the switches, keys and LCD display as follows:



It is most recommended to perform the following experiments after doing the basic air-conditioning experiment but it is not mandatory.

16. Procedure:

Step 1: Check that the PROFESSIONAL AIR CONDITIONING PANEL is properly installed on the refrigeration and air-conditioning general system MAIN PLATFORM UNIT according to the instructions described in the book preface.

Step 2: Check that the MAIN PLATFORM UNIT monitor POWER and PROGRAM switches are at OFF position.

A ground leakage relay, a semi-automatic circuit breaker, and a main power switch are installed in a main power box located on the rear panel.

Step 3: Check that the high voltage ground leakage relay and the semi-automatic circuit breaker are ON.

Step 4: Connect the MAIN PLATFORM UNIT power supply cable to the Mains.

Step 5: Set the Auto/Manual switch (located on the bottom left of the simulator) to the Manual position.

Step 6: Turn ON the main POWER switch located on the main power box on the rear panel.

Step 7: Turn ON the monitor power switch.

Step 8: The FAULT display should display the number 00. If not, use the keys above the FAULT display to display the number 00 (no fault condition) on the FAULT 7-SEG. display and press the ENTER key beneath this display.

Step 9: The STATE display should display the number 00 (no operation program).

The air-conditioning devices (with the PROFESSIONAL AIR CONDITIONING PANEL basic air-conditioning panel) are as follows:

No.	Symbol	Description
1.	V1	Receiver's input valve (for TEV mode)
2.	V2	Receiver's output valve (for TEV mode)
3.	V3	Receiver's by-pass valve (for capillary mode)

4.	V4	Transfers gas to the capillary unit
5.	V5	Transfers gas to the TEV unit
6.	V6	Transfers gas from the evaporator to the compressor
7.	CM	Compressor
8.	OF	Out fan (the base condenser fan)
9.	E1	Evaporator fan (the panel evaporator fan)
10.	L1	Evaporator 1 thermal load

These components are controlled by the system's controller.

Step 10: On the LCD display you should find the following table:

V1	V2	V3	V4	V5	V6	V7	RV	CM	OF

TEV mode:

The TEV (Thermostatic Expansion Valves) are used to gauge the liquid refrigerant's flow upon entering the evaporator, at a rate equivalent to the amount of refrigerant being evaporated in the evaporator. The valve provides a pressure drop in the system, separating the high-pressure side of the system from the low-pressure side of the system, allowing the low-pressure refrigerant to absorb heat.

Use the keys above the STATE display to show the number 11 (Basic air-conditioning TEV Experiment Program) on the STATE 7-segment display and press the ENTER key beneath the number 11.

In this operation setting the air-conditioning system is operated on TEV mode.

Step 11: Changing the STATE number does not start the operating program (even after pressing the ENTER key).

The STATE number after pressing the ENTER key only displays the required operating program and state.

Step 12: Lower the PROGRAM switch and raise it.

The TEV mode states are 11-46.

Note: You can move from one TEV state to another without lowering and raising the PROGRAM switch. If you lower and raise the PROGRAM switch, the system acts as a relaxation device for safety operation.

The TEV programs are:

State 11 – TEV operation with °C display.

State 12 – TEV operation with °F display.

State 13 – TEV operation with graphic display.

State 14 – TEV operation with °C display and thermal load.

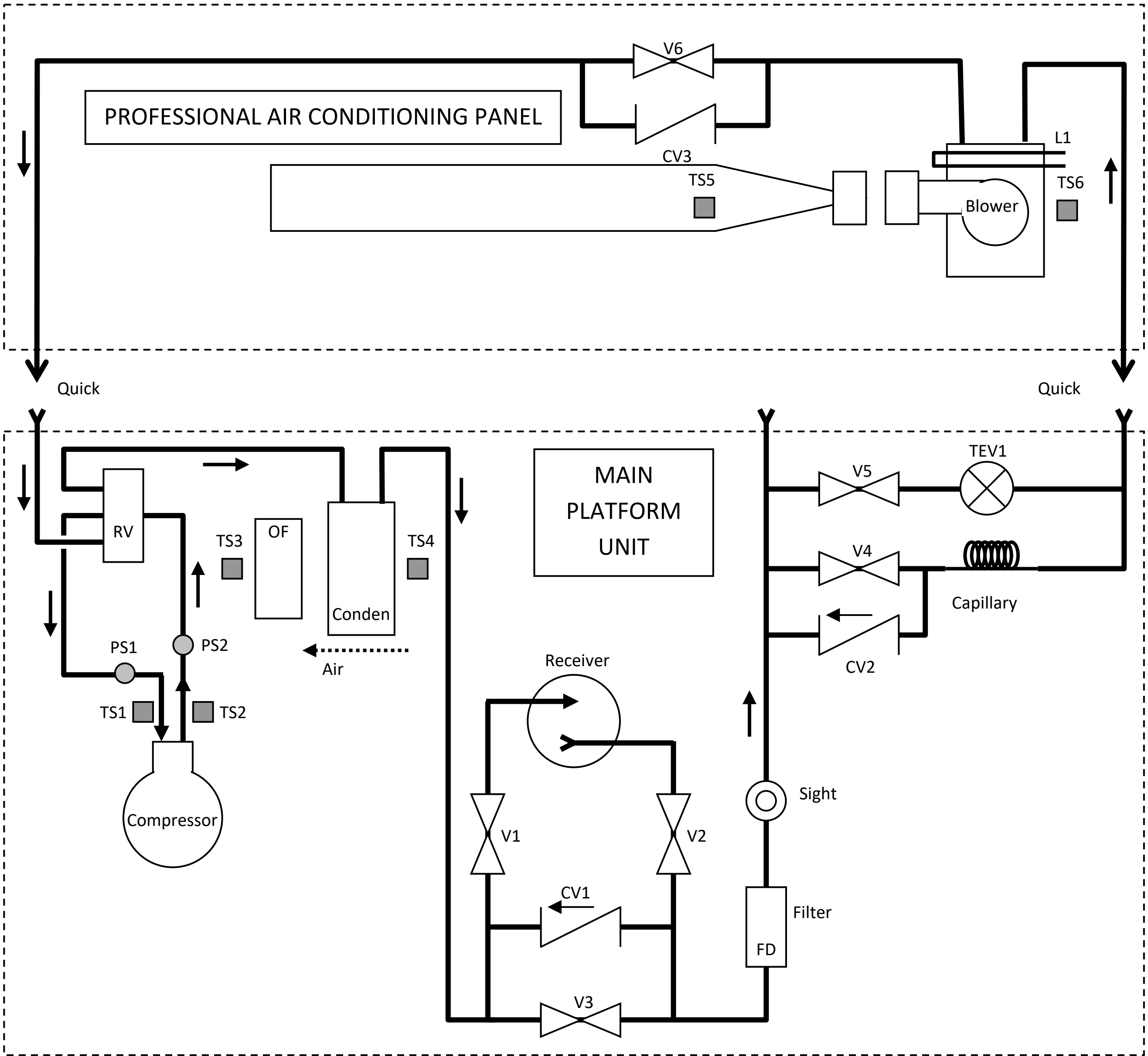
State 15 – TEV operation with °F display and thermal load.

State 16 – TEV operation with graphic display and thermal load.

Step 13: On the LCD display you should find the following table:

V1	V2	V3	V4	V5	V6	V7	RV	CM	OF
ON	ON			ON	ON			ON	ON

Step 14: Copy the following circuit to your notebook and mark the refrigerant path on it.


PROFESSIONAL AIR CONDITIONING PANEL
V6
CV3
TS5
Blower
L1
TS6
Quick
Quick
MAIN
PLATFORM
UNIT
RV
TS3
OF
TS4
Conden
PS1
PS2
Air
TS1
TS2
Compressor
V5
TEV1
V4
Capillary
CV2
Receiver
Sight
V1
V2
CV1
Filter
FD
V3

Step 15: The LCD also displays the system pressures and temperature as follows:

LP – Low Pressure (the suction pressure measured by PS1)

HP – High Pressure (the compression pressure measured by PS2)

T1 – The compressor inlet temperature (measured by TS1)

T2 – The compressor outlet temperature (measured by TS2)

T3 – The condenser outlet air temperature (measured by TS3)

T4 – The condenser inlet air temperature (measured by TS4)

T5 – The evaporator outlet air temperature (measured by TS5)

T6 – The evaporator inlet air temperature (the cooling chamber temperature measured by TS6)

HU – Humidity sensor

T8 – Not relevant to this panel

The values are displayed in a table as follows:

LP	HP	T1	T2	T3	T4	T5	T6	HU	T8

Identify the sensors in the drawing and in the system.

Step 16: Another table that appears on the LCD display is the control parameters:

S1 – Room temperature setup

D1 – Room temperature difference

S1	D1	S2	D2	SP	PD	E1	L1	E2	RT
20°C	5°C					LO			

The setup temperature is the required temperature. When the cooling chamber temperature goes below this temperature, the air-conditioning system should stop cooling and this is done by stopping the compressor.

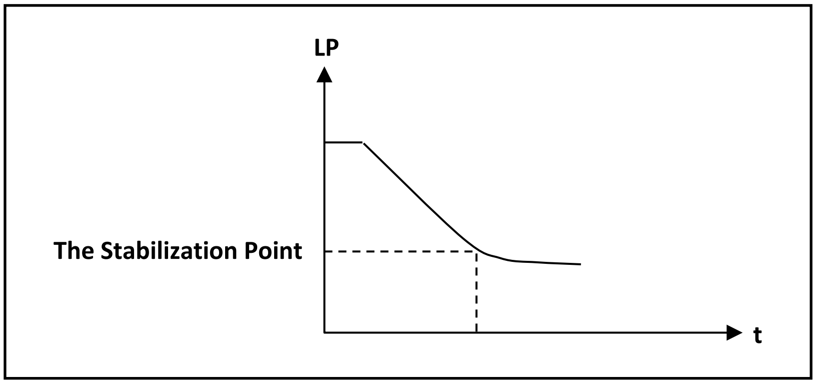
The compressor turns ON when the cooling chamber temperature is above S1 + D1. D1 is determined in order to avoid the system to oscillate.

There is a linear relationship between the temperature and pressure. This is why the cooling chamber temperature can be controlled according to the system's low pressure or the system's high pressure. This subject will be described later.

The TEV mode is controlled by temperature and this is why a dash appears in the pressure squares.

Identify the system's default values of S1 and D1.

Step 17: Immediately after operating the air-conditioner, the suction pressure should be high and going down while the system is cooling according to the following graph.



At the stabilization point the suction pressure (LP) is almost unchanged.

The stabilization point, which is the operation point, is the point where the pressures in the system are the right ones for cooling and are appropriate for the system's devices, the refrigerant, the fan speed and the environment.

The system includes a sight glass (an "eye") that enables observation of the refrigerant.

The refrigerant at that point should be liquid without bubbles.

If there are bubbles after a long period of operation, it indicates a faulty air-conditioning system.

Observe this sight glass and check that there are no bubbles.

At the stabilization point there should not be bubbles at all.

Step 18: Change the STATE no. to 12 and press ENTER.

This state does not change the system's operation; it only changes the display from °C to °F.

Observe that.

Step 19: When the LP is stable at the stabilized point, record the temperature and pressure values of the stabilization point in the table at step 44.

The cooling chamber temperature should continue to go down.

Step 20: Change the STATE no. to 13 and press ENTER.

This state does not change the system's operation; it only changes the display to the graphic display.

The monitor samples and displays the LP and T6 every 2 seconds and displays them graphically on the screen.

Observe that.

Step 21: The chamber temperature T6 goes down as long as the system is cooling (the compressor works).

On the 11-16 experiment states the air-conditioning's control is according to the temperature.

The compressor should turn OFF when the chamber temperature reaches the S1 (Setup Point) and should turn ON when the chamber temperature goes over S1+ D1.

The default value of S1 is 20°C (68°F) and the default value of D1 is 5°C (9°F).

Check that.

Step 22: See what happens when the cooling chamber temperature reaches the S1 point.

Step 23: Wait until the compressor turns ON again.

Step 24: The evaporator speed can be changed by the '*' key.

Press the '*' key and check that the evaporator fan (E1) changes to HI.

Step 25: Wait until the system reaches the stabilized point.

Record the stabilization values.

Step 26: Press the '*' key again and check that E1 is changed into 'LO'.

Step 27: Change the STATE no. to 16 and press ENTER.

This state operates the thermal load to the evaporator (1 minute ON and 2 minutes OFF alternately).

The suction pressure should go up slowly.

Step 28: Wait until the system is stable.

Identify the new stabilization point.

Step 29: Change the E1 speed to high and record the new stabilization point values.

Step 30: Change the E1 speed back to low.

Step 31: Change the STATE no. to 14 (°C) and press ENTER.

Record the stabilization values.

Step 32: Change the STATE no. to 15 (°F) and press ENTER.

Record the stabilization values.

Step 33: The system at 11-16 states allows you to change the S1 value in a certain range.

Step 34: Key in the number 18 (if you are in °C) or 65 (if you are in °F) and key '#'.

Step 35: Change the state no. to 11 or 12 accordingly.

Step 36: Wait until the compressor stops working.

Step 37: Record the pressures and temperatures.

Step 38: Open the cooling chamber window.

Step 39: Wait until the compressor turns ON.

Step 40: Record the pressures and temperatures.

Step 41: Change the STATE no. to 00 and press ENTER.

Lower the PROGRAM switch and raise it.

All the devices should shut OFF.

Step 42: Open the cooling chamber window and let the environment air to enter inside.

Step 43: Wait about 5 minutes.

Step 44: Fill in the following table with the stabilization point's values you have recorded.

No.	Comp.	Load	E1	LP	HP	T1	T2	T3	T4	T5	T6
1.	ON	OFF	LO								
2.	ON	OFF	HI								
3.	OFF	OFF	LO								
4.	OFF	OFF	HI								
5.	ON	ON	LO								
6.	ON	ON	HI								
7.	OFF	ON	LO								
8.	OFF	ON	HI								

Capillary mode:

The capillary tube is designed to lower the cooling liquid pressure at the same measure the compressor raised it during the compression process.

The pressure drop on the tube depends on:

- The internal diameter of the tube.
- The tube length.
- The flow speed.
- The cooling material specific weight.
- The friction coefficient between the cooling material and the tube.

This is a fix control element, which depends on its dimensions and material.

Step 45: Change the STATE no. to 21 and press ENTER.

Step 46: Lower the PROGRAM switch and raise it.

The capillary mode states are 21-26.

You can move from one capillary state to another without lowering and raising the PROGRAM switch. If you lower and raise the PROGRAM switch, the system acts as a relaxation device for safety operation.

The capillary programs are:

State 21 – capillary operation with °C display.

State 22 – capillary operation with °F display.

State 23 – capillary operation with graphic display.

State 24 – capillary operation with °C display and thermal load.

State 25 – capillary operation with °F display and thermal load.

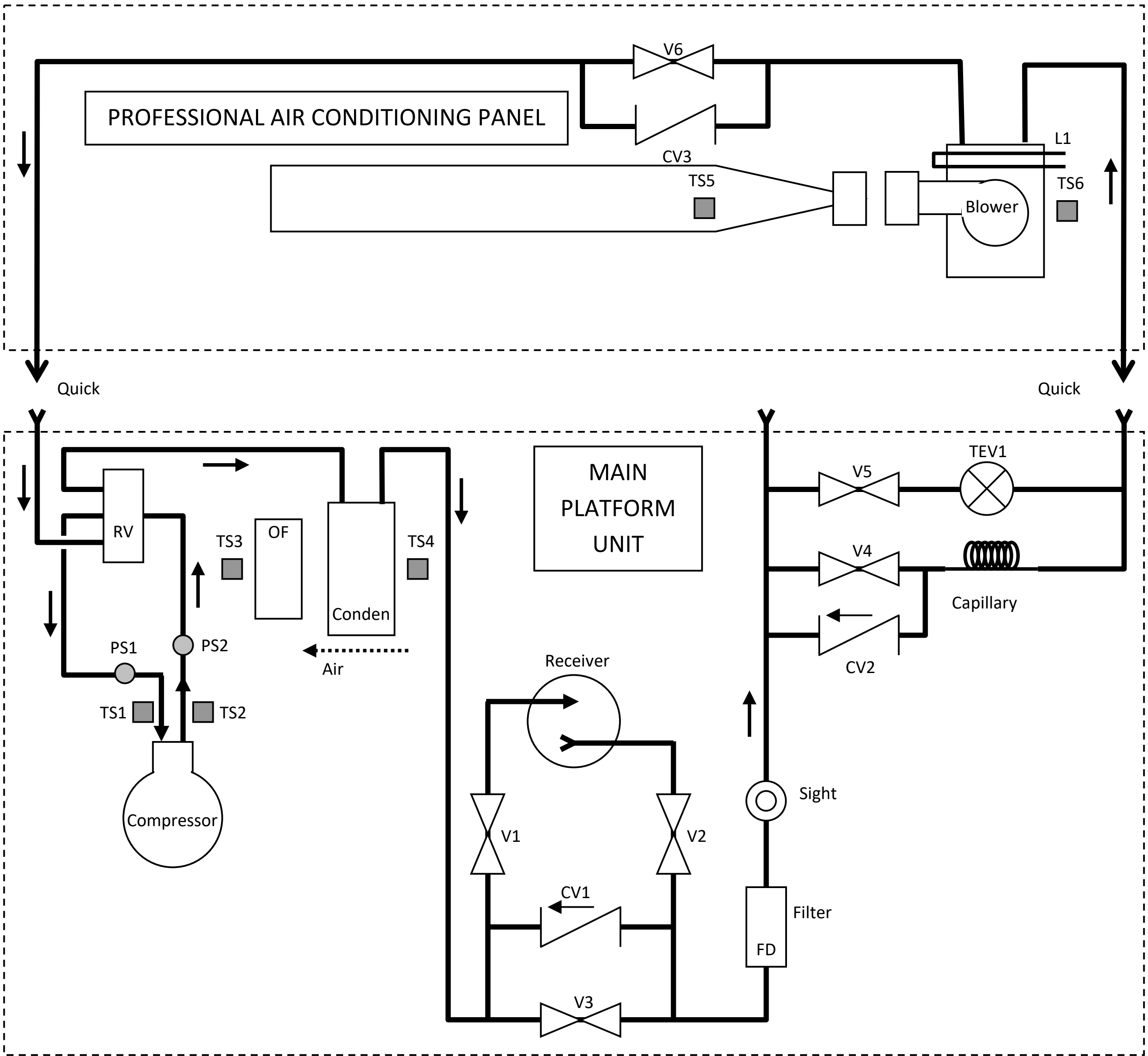
State 26 – capillary operation with graphic display.

Step 47: On the LCD display you should find the following table:

V1	V2	V3	V4	V5	V6	V7	RV	CM	OF
		ON	ON		ON			ON	ON

If "on" (lowercase) appears on the CM and OF columns, it means that the compressor is in a 3 minutes delay state before it starts to work. This delay protects the compressor.

Step 48: Copy the following circuit to your notebook and mark the refrigerant path on it.



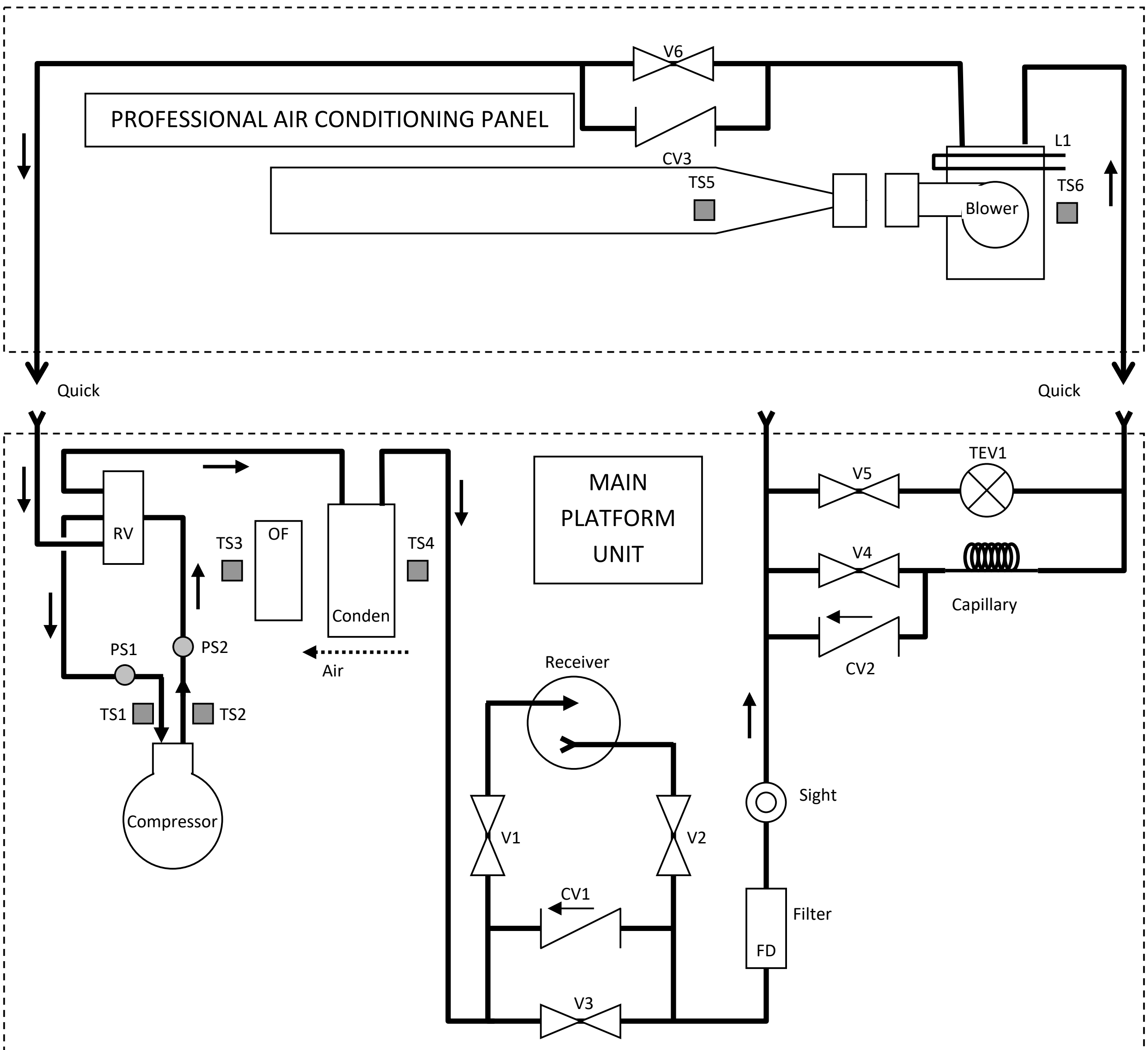
Step 49: The sensor table is the same as the TEV experiment.

LP	HP	T1	T2	T3	T4	T5	T6	HU	T8

Step 50: On the LCD display you should find the following table:

V1	V2	V3	V4	V5	V6	V7	RV	CM	OF
		ON	ON		ON			ON	ON

Step 51: Copy the following circuit to your notebook and mark the refrigerant path on it.



Step 52: The sensor table is the same as the TEV experiment.

LP	HP	T1	T2	T3	T4	T5	T6	HU	T8

Step 53: The control table is a little different. In this experiment the control is made according to the low pressure.

The table is as follows:

S1	D1	S2	D2	SP	PD	E1	L1	E2	RT
				33	17	LO			

Step 54: Change the STATE no. to 22 and press ENTER.

This state does not change the system's operation; it only changes the display from °C to °F.

Observe that.

Step 55: Observe the temperature and pressure values and wait for the system to stabilize.

Step 56: When LP is at a stable point, record the temperature and pressure values at the stabilization point in the table at step 75.

The cooling chamber temperature should continue to go down.

Step 57: Change the STATE no. to 23 and press ENTER.

This state does not change the system's operation; it only changes the display to graphic display.

The monitor samples and displays the LP and T6 every 2 seconds and displays them graphically on the screen.

Observe that.

Step 58: Change the STATE no. to 26 and press ENTER.

This state operates the thermal load to the evaporator (1 minute ON and 2 minutes OFF alternately).

The suction pressure should go up slowly.

Step 59: Change the E1 speed (by keying '*') to high and record the new stabilization point values.

Step 60: Change the E1 speed back to low.

Step 61: Wait until the system is stable.

Identify the new stabilization point.

Step 62: Change the STATE no. to 24 (°C) and press ENTER.

Record the stabilization values.

Step 63: Change the E1 speed to high and record the new stabilization point values.

Step 64: Change the E1 speed back to low.

Step 65: Change the STATE no. to 25 (°F) and press ENTER.

Record the stabilization values.

Step 66: The system at 21-26 states allows you to change the S1 value in a certain range.

Step 67: Key in the number 20 and key '#'.

Step 67: Change the state no. to 11 or 12.

Step 69: Wait until the compressor stops working.

Step 70: Record the pressures and temperatures.

Step 71: Open the cooling chamber window.

Step 72: Wait until the compressor turns ON.

Step 73: Record the pressures and temperatures.

Step 74: Change the STATE no. to 00 and press ENTER.

Lower the PROGRAM switch and raise it.

All the devices should shut OFF.

Step 75: Fill in the following table with the stabilization point's values.

No.	Comp.	Load	E1	LP	HP	T1	T2	T3	T4	T5	T6
1.	ON	OFF	LO								
2.	ON	OFF	HI								
3.	OFF	OFF	LO								
4.	OFF	OFF	HI								
5.	ON	ON	LO								
6.	ON	ON	HI								
7.	OFF	ON	LO								
8.	OFF	ON	HI								