

# Chapter 1 – Basic Cooling and Air Conditioning Systems

## **EXPERIMENT 1.1 – INTRODUCTION TO COOLING AND AIR CONDITIONING SYSTEMS**

Name	Class/Period	Date

### 1. Objectives:

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

- Explain the basic principles of air-conditioning system.
- Explain basic thermodynamics principles and terms.
- Perform basic calculations concerning an air-conditioning system.
- Explain the basic operation of air-conditioning system.
- Explain the various components of the systems, its functions and ways of usage.
- Operate the air-conditioning system at various operating conditions.
- Test the functions of the system components.
- Take measurements of the air-conditioning system.

### 2. Equipment Required:

- Main Platform Unit
- Professional Air Conditioning Panel

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

As a rule, the main function of the air-conditioning system is to remove heat from air inside a closed place and discharge the heat outside.

The two main principles for air-conditioning operation are:

- Liquids absorb heat, when they transform from liquid into gas.
- Gases emit heat, when they transform from gas into liquid.

For instance, water absorbs heat from a flame as it boils and changes into gas or vapor. When that gas or vapor condenses into a liquid, it radiates heat.

In an air-conditioning system, a liquid refrigerant absorbs heat from the air, as it changes into gas.

A temperature is kept low by removing heat from the air, faster than it is warmed up by the Sun.

In an air-conditioning system, heat is removed from the area to be cooled, to a required degree that is comfortable to the occupants. This heat must then be expelled to the outside air. This is done by utilizing the nature of heat movement.

Refrigerant is a liquid substance that flows through the air-conditioning system. It absorbs heat from the cooled down area, and emits it into the atmosphere. The refrigerant a liquid state and under both low pressure and temperature enters an **Evaporator** and absorbs heat, while changing its state into Gas.

During compression, the refrigerant is under pressure and consequently its temperature rises.

The refrigerant in its gas state (high temperature and pressure) flows into a **Condenser**, where it expands and emits heat while it changes back into liquid state. After the expansion process the refrigerant returns to the **Evaporator** in its liquid state (low temperature and pressure) in order to absorb heat again and so on.

#### 4. Discussion: Basic cooling cycle

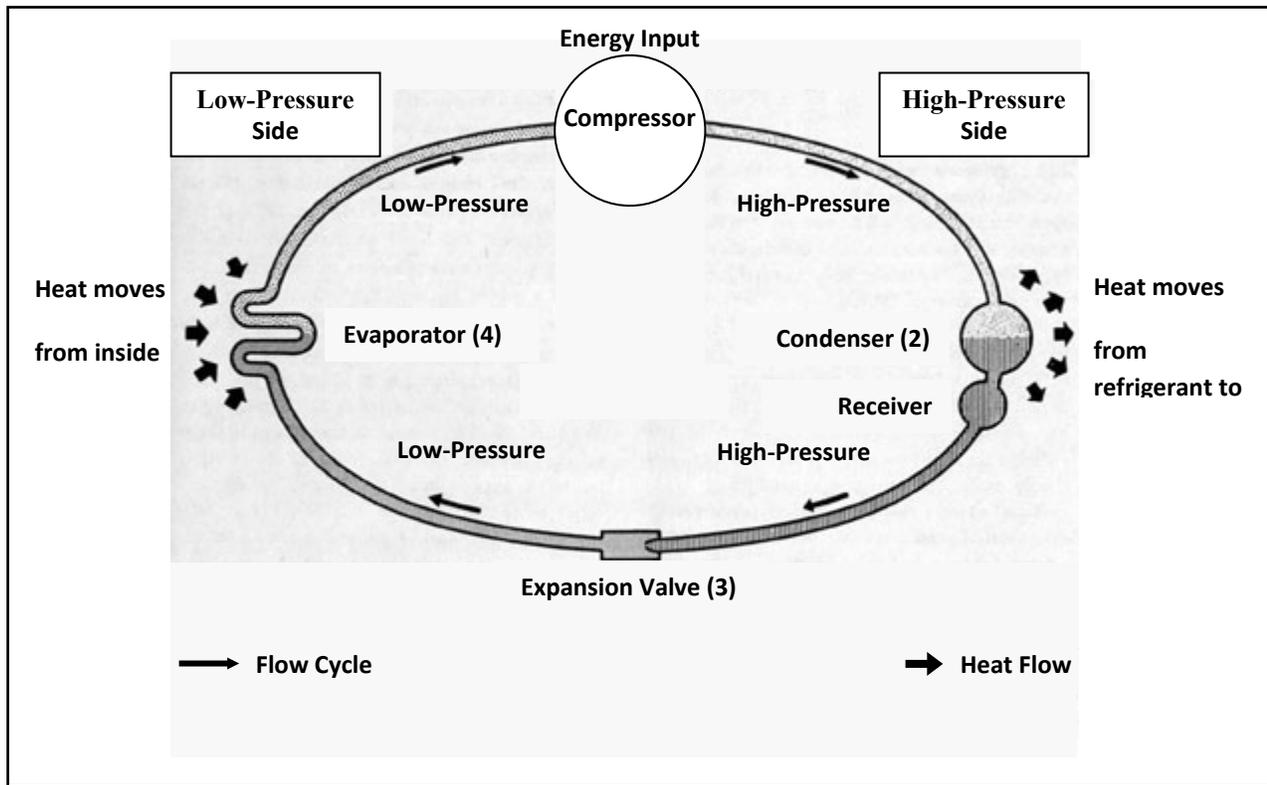
To operate economically, refrigerant is recycled. For this reason, all air conditioners are based on the same operation cycle, in a closed circuit, which is divided into four stages:

- Compression
- Condensation
- Expansion
- Evaporation

Those four stages are divided again into two parts:

- High side
- Low side

This refers to the pressures of the refrigerant in each side of the system.



**Figure 1-1 Complete Four-part Cycle of Air-conditioning**

In order to understand the basic refrigerant cycle, the first stage is at the **Compressor (1)**. The refrigerant enters into the compressor as a low-pressure gas, compresses, and moves out of the compressor as a high-pressure and high temperature gas.

At the second stage, the refrigerant gas flows into the **Condenser (2)**. Here the gas condenses into a liquid, giving off its heat to the outside air.

The third stage is when the liquid then flows under high pressure, to the **Expansion valve (3)**. This valve restricts the flow of the liquid, thus lowering its pressure as it leaves the expansion valve.

The low-pressure liquid moves then to the fourth stage, the **Evaporator (4)**, where heat from the inside air is absorbed by the liquid changing its state from liquid into gas.

As a hot low-pressure gas, the refrigerant moves back to the compressor (1) where the cycle is repeated.

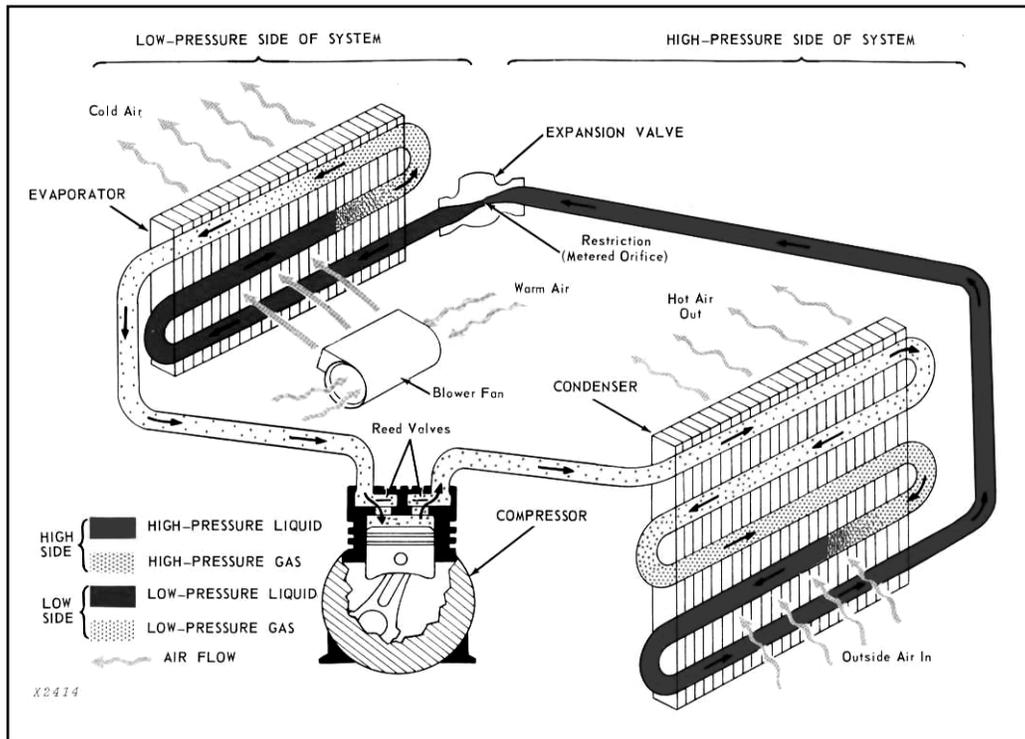
### 5. Discussion: Basic operation of the system

As described above, all air-conditioning systems must have four basic elements:

- Compressor

- Condenser
- Expansion valve or restriction orifice
- Evaporator

These are all connected with pipes and connectors



**Figure 1-2**

These four components determine the temperature, pressure and refrigerant output at each part of the circuit.

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

- Receiver-Drier (Accumulator)
- Sight Glass ("Eye")
- Pressure cut-off valves
- Temperature cut-off
- Electrical Blower
- Electrical Fan

**Review:** High-pressure gas is sent from the **Compressor** to the **Condenser**, where the heat is dissipated and the gas is condensed into liquid.

The high-pressure liquid flows to the **Expansion valve**, where it is metered and its pressure is reduced. At the **Evaporator**, the liquid absorbs heat from the air and evaporates to gas. The cycle then repeated, starting at the compressor.

## 6. Discussion: Composition of the main system

### 6.1. The compressor:

Purposes of the Compressor are to:

- Circulate the refrigerant in the circuit.
- Compress the refrigerant that leaves the evaporator and thereby raising its temperature in order to create a temperature difference that will enable heat transfer from the cooled area, toward the outside.

The pressure build-up in the system can only be accomplished by having a restriction in the high-pressure side of the system. This is a small valve located in the Expansion Valve. This metered orifice serves that purpose in the system.

Typical compressor in an air-conditioning system:



**Figure 1-3 Hermetic Compressor**

### 6.2. The condenser:

The purpose of the condenser is to receive the high-pressure and temperature gas from the Compressor and convert this gas into liquid, while emitting heat to the surroundings.

The condenser consists of pipes, usually made of copper and cooling fins usually made of aluminum.

The refrigerant in its gas state flows through the condenser pipes, while the air is forced (by the car movement + cooling fan) around the fins.

Typical condenser in the air-conditioning system:

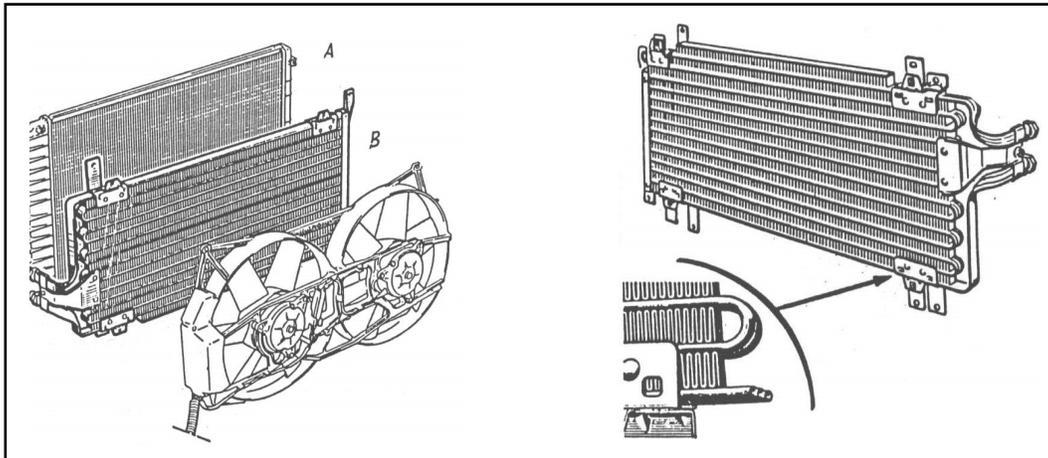


Figure 1-4

### 6.3. The expansion valve:

The expansion valve fulfills a triple function in the cooling circuit:

- It releases the pressure on the refrigerant which is in a liquid state, on its way to the evaporator. This enables the refrigerant's expansion while its temperature is reduced to the lowest value in the cooling circuit, a degree that enables efficient temperature exchange with the air in the refrigerated area.
- It determines the refrigerant flow intensity through the cooling circuit accommodating the momentary cooling request for the area to be cooled.
- It enables the compressor to accomplish its compressing action by restricting the refrigerant flow.

While the air cools in the cooled area, the expansion valve is employed to reduce the cooling output from the evaporator; otherwise it will cause ice formation on the evaporator pipes, preventing the efficient function of the air-conditioning system. The reduction of the cooling output in this case is done by means of the expansion valve. Because it controls the flow rate of the refrigerant through the evaporator, it affects the output of the air-conditioning system.

In air-conditioning systems, there are two main expansion valve types:

1. Thermostatic expansion valve.
2. Capillary (orifice) tubes.

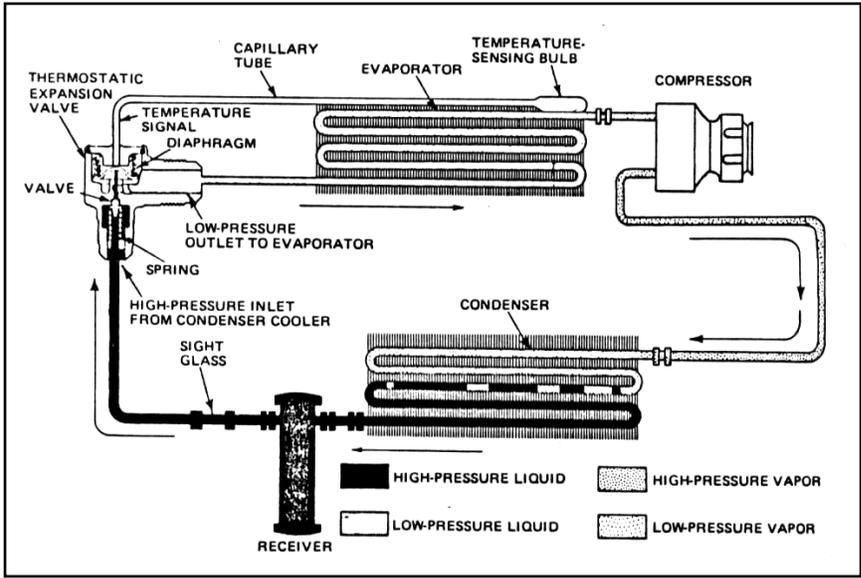


Figure 1-5

Air-conditioning circuit with an expansion valve:

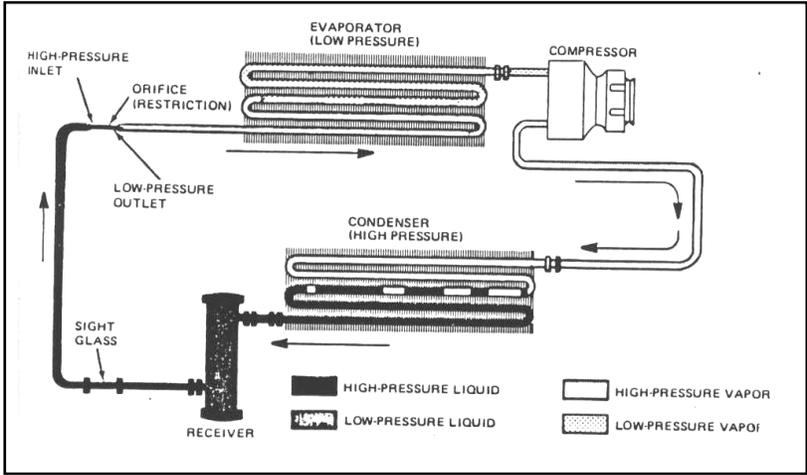


Figure 1-6 Air-conditioning Circuit with an Orifice Tube

The refrigerant fluid arrives to the expansion valve while it is very hot and under high pressure. The refrigerant, when it exits the other side of expansion valve, will be at the lowest temperature possible in the cooling circuit cycle.

During the expansion process, the refrigerant starts to evaporate, such that when the refrigerant enters the evaporator, it is already partly in a gas state.

**Note: The expansion valve size is normally characterized by the orifice diameter. The orifice size determines the system performances. Therefore, it is very important to choose the right orifice for the system requirements.**

#### **6.4. The capillary (orifice) tube:**

The capillary tube is used as an "expansion" component in the air-conditioning system. Its diameter and length are determined by the system's size.

In contrast to the expansion valve in where the capillary tube size may be adjusted, the capillary (orifice) tube is non-adjustable. Like the expansion valve, it is located inside the inlet of the evaporator. The refrigerant flow rate through the tube is determined only by the pressure differences between the high-pressure side and the low-pressure side in the cooling circuit. The capillary tube cannot be serviced and should be replaced when faulty.

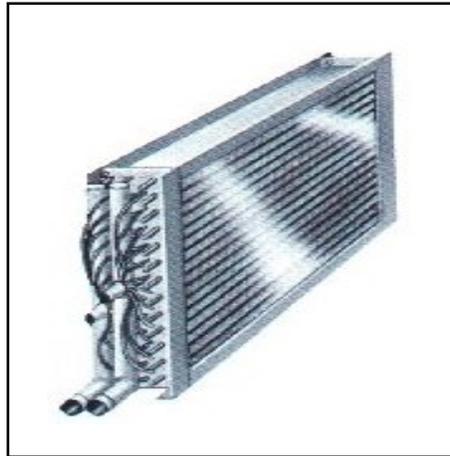
The purpose of the expansion and capillary tube is to raise the pressure on the compression side and lower the gas pressure from compression pressure to suction pressure.

#### **6.5. The evaporator:**

The function of the evaporator is the opposite of the condenser's function. In the evaporator, the refrigerant turns into gas at low pressure, while absorbing heat. The cooling down is done by the evaporator blower which sucks the air from the refrigerated area and blows it through the evaporator fins. When the air has passed through the evaporator fins and has given up its heat, it returns to the cooled area cooler and drier.

As the refrigerant evaporates, the vapor is returned to the suction side of the compressor via the suction line.

Typical evaporator in the air-conditioning system:



**Figure 1-7 Typical Evaporator**

#### **6.6. The fan:**

The fan moves the air through the evaporator or the condenser. The heat exchange depends upon the temperature difference between the air and the refrigerant. The greater the difference is, the greater the amount of heat that is exchanged between the air and the refrigerant.

When the fan operates at its higher speed, it delivers its greatest volume of air across the fins and coils for a rapid evaporation. As the area is cooled down, it soon reaches a temperature, where little or no extra cooling results, if the fan continues at its high-volume flow. A reduction in the fan speed will decrease the airflow volume but the lower volume rate will allow the air to remain in contact with the fins and coils for a longer period of time and give up its heat to the refrigerant.

Typical evaporator fan in an air-conditioning system:



Figure 1-8

**Note:** For the coldest air temperature from the evaporator, operate the fan at its Lowest speed possible, to allow a greater heat absorption by the refrigerant from the air.

#### 6.7. The receiver-drier:

Air-conditioning systems normally do not operate continuously, but are off or on according to the needs for air conditioning in the passenger compartment. Over the time, the system's seals dry and allow moisture penetration from the environment.

Moisture accumulates in the evaporator and turns into ice at low operating temperatures. Ice restricts the refrigerant flow and decreases the cooling action.

The air-conditioning system is sealed but moisture may enter on filling refrigerant or at service process.



Figure 1-9

In addition, the cooling output demand is not constant and varies depending upon the thermal load and the environment temperature. Surplus refrigerant that does not take part in the cooling process must be stored in order to prevent over-floating the system.

To compensate for those variables, the system is equipped with a small receiver tank. Here an additional amount of refrigerant (about 0.5 liter) is stored until needed by the system.

To prevent moisture absorbance, the receiver/drier tank is equipped with a desiccant or drying agent, which is sealed in during its manufacturing process. In addition, the receiver/drier is equipped with a sight glass which enables checking the refrigerant condition.

### 6.8. The refrigerant:

The term refrigerant refers to the liquid used in a cooling system to produce "cold" by removing heat from the air. The refrigerant that was used for the automobile industry until **1994** was the **R12** refrigerant.

This sort of refrigerant was chosen because it was the safest liquid available that remains stable at both high and low temperatures and still gives off or absorbs great quantities of heat. It is not toxic, not flammable and does not harm plastic or metal components.

Over the years, it was found out that the **R12** refrigerant is very harmful for the environment and in particular for the Ozone layer. For that reason the **R12** refrigerant was prohibited by law and the air-conditioning systems were converted to operate with an environmentally friendly refrigerant, the **R134a**.

As such, **the MAIN PLATFORM UNIT "Air-conditioning & Refrigeration System"** too operates with **R134a** refrigerant and should **NEVER** be refilled with **R12** refrigerant or the like.

## 7. Discussion: Basic thermodynamic principles and terms

**Note:** The content of this chapter serves only as a reference to and as a supplement for the given subject. Detailed information about thermodynamic principles and terms should be taken from a proper text-book about this subject.

**Work:** Work may be described as force applied to overcome a certain resistance along a certain distance. The invested work is calculated by multiplying the applied force (Kg) and the distance (m).

**Energy:** Energy may be described as the ability of a body to perform work. The main feature of Energy is its ability to change forms such as:

- Heat Energy
- Light Energy
- Mechanical Energy
- Electric Energy
- Chemical Energy
- Nuclear Energy

For the air-conditioning system we are interested in the following Energy forms:

**Heat Energy**, which deals with the thermal processes that occur in the cooling circuit and in the air-conditioned area. Heat energy is usually measured with Kcal units (1 Kcal = heat energy needed to rise the temperature of 1 Kg water in 1°C).

**Mechanical Energy**, which deals with the pressures, that occurs in the cooling circuit and with the power needed to operate the A/C compressor. Mechanical energy is usually measured with kW or HP units (1 HP=746 W=0.746KW).

**Electric Energy**, which deals with electric and electronic systems in a vehicle. Electrical energy is usually measured with kW units.

**Pressure:** Pressure is one form of Mechanical Energy which develops when a Fluid or a Gas applies force within a pipe or against a reservoir wall. The units usually used to measure pressure are (bars) 1 bar = 0.987 Atmosphere (a force of 1 Kg applied on an area of 1 cm<sup>2</sup>).

**Temperature:** Temperature may be defined as the heat energy of a certain body. Two reference points are determined for temperature measurements:

- The heat energy in water at its freezing point.
- The heat energy in water at its boiling point.

For temperature measurements, two systems are employed:

1. The Anglo-Saxon system which measures on the Fahrenheit scale (oF).
2. The Metric system which measures on the Celsius scale (oC).

**Note:** For the calculations in this chapter we will solely use the metric system. **Water freezing point = 0°C, water boiling point = 100°C.**

**Latent Heat:** Causes changes in the accumulation state of a certain substance, without changing the given substance temperature. Every substance can change its accumulation state from a Solid state into a liquid state or from a liquid state into a Gas state and vice versa.

These procedures are performed without any changes in the substance temperature, but are accompanied with the emission or absorption of Latent Heat.

The absorption of heat during evaporation and emission of heat during condensation maintains a steady temperature because Latent Heat enables the cooling cycle.

**Enthalpy:** Enthalpy is a figure, which indicates the energy quantity preserved in a given substance (potential internal energy in the form of heat + potential internal energy in the form of pressure).

The Enthalpy figure is determinate by the temperature and the pressure at which the substance exist.

**Specific Enthalpy:** Is a figure which indicates the energy quantity preserved in a weight unit of a given substance?

The specific Enthalpy is determined in the following way:

$$H = C_p(T - T_r)$$

When:

- H – Enthalpy
- C<sub>p</sub> – Specific heat
- T – Substance temperature (absolute)
- T<sub>r</sub> – Related temperature (absolute)

**Entropy:** The entropy is the energy quantity preserved in the substance at a certain state of form, for a given absolute pressure T (measured with Kelvin degrees).

The Entropy is determinate as the following:

$$S = \frac{h}{T}$$

When:

- S – Entropy
- h – Enthalpy
- t – Substance temperature (absolute)

**Thermal load:** The Thermal load of an Air-conditioning system is the Heat quantity that the system has to remove from the air-conditioned area. This is one of the main parameters that are taken in consideration while designing an air-conditioning system and its components.

### 8. Discussion: Coefficient Of Performance (COP)

Coefficient of performance of a cooling system is described as the relation between the discharged cooling output and the power needed to drive the compressor at the compression process (or the power input).

The mathematical relations look like:

$$COP = \frac{\text{Discharges cooling output [kW]}}{\text{Power input [kW]}}$$

## 9. Discussion: p-h diagram

A p-h diagram gives the refrigerant pressure as a function of its Enthalpy.

The diagram gives additional parameters as well, such as: refrigerant temperature, its Entropy and its form of state.

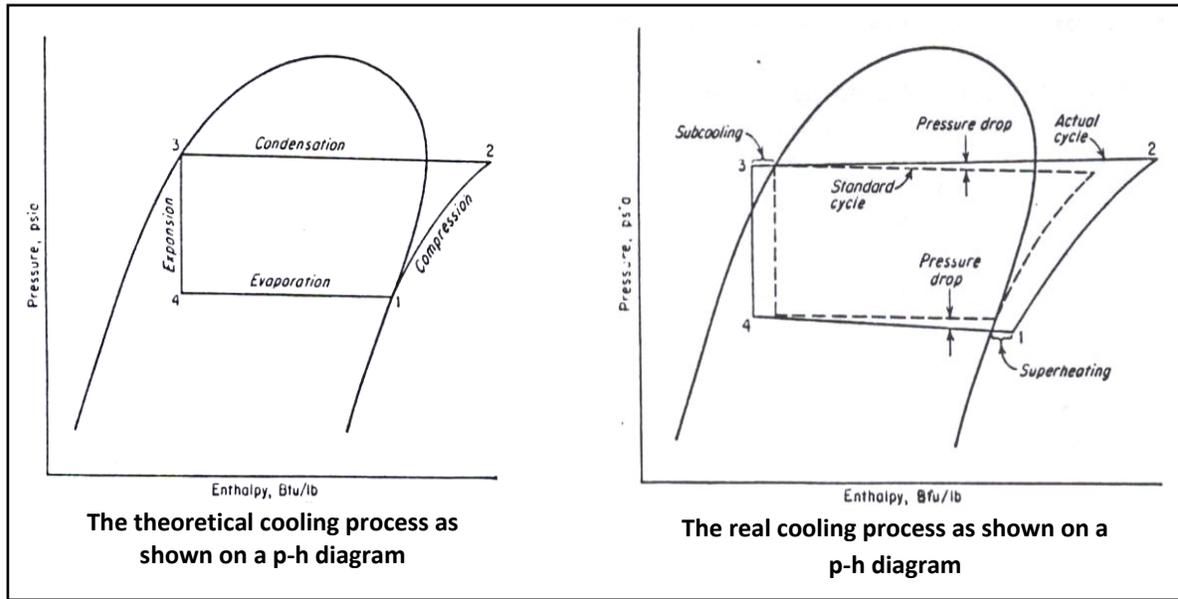


Figure 1-10

A real process of a cooling cycle is described on the right fig. as it appears on a p-h diagram. There are pressures lost at the condenser and at the evaporator, which causes a certain temperature drop of the refrigerant while flowing through them, although the heat transfer is performed without changing the refrigerant temperature. In addition, an over cooling process occurs at the condenser at the end of the condensing cycle and an overheating process occurs at the evaporator at the end of the evaporation cycle.

## 10. Discussion: Structure and operation of the system

As explained above and as seen in the basic cooling system, all air-conditioning systems must have four basic elements:

1. A compressor.
2. A condenser with a fan.
3. A throttling element as Thermostatic Expansion Valve (TEV) or capillary tube.
4. An evaporator with a fan.

These components determine the temperature, pressure and refrigerant output at each part of the circuit.

Identify these components in the following drawing of the basic air-conditioning system including MAIN PLATFORM UNIT and PROFESSIONAL AIR CONDITIONING PANEL.

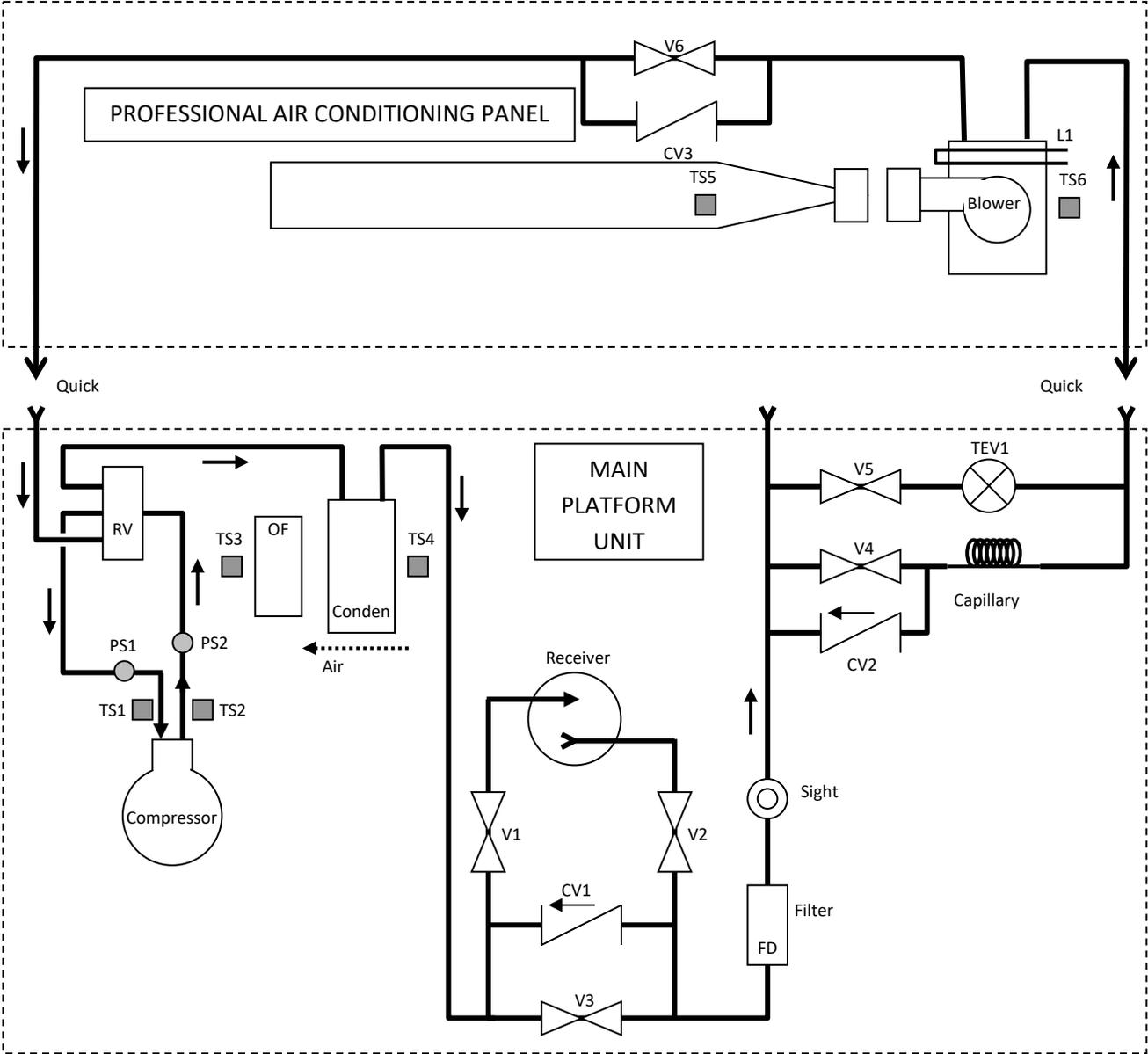


Figure 1-11

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

- **Receiver-Drier** – A container equipped with desiccant to remove moisture and is utilized 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 whether the cooling liquid level is satisfactory. Bubbles usually signal lack of cooling liquid in the system.
- **Receiver** – A container for storing gas.

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 chosen air-conditioning circuit. The valves are operated by the system monitor.

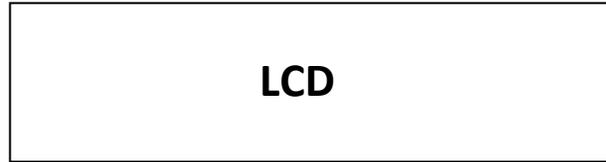
The basic air-conditioning system is composed of the MAIN PLATFORM UNIT (general air-conditioning and refrigeration system) and the PROFESSIONAL AIR-CONDITIONING PANEL.

The MAIN PLATFORM UNIT includes a 4-way valve (the RV). This valve enables changing the system from a cooling system to a heating system.

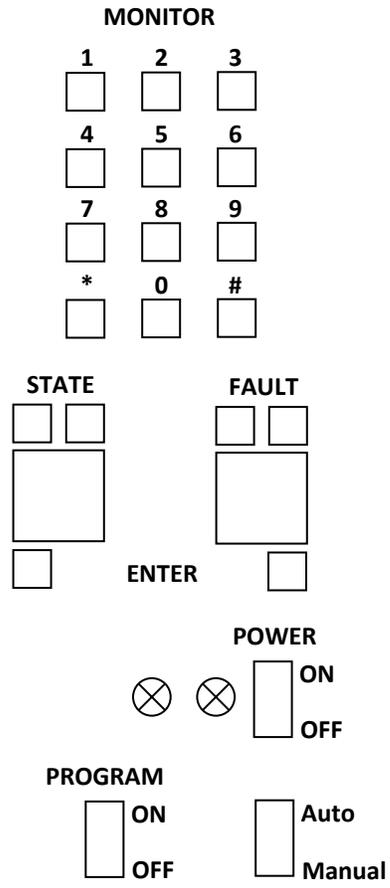
The system also includes Temperature Sensors (TS1-TS6), and Pressure Sensors (PS1 and PS2).

The evaporator includes a heater which acts as a thermal load or as a defrost device.

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



<b>Fault</b>	<input type="radio"/> Suction pressure too low <input type="radio"/> Room temperature is high <input type="radio"/> Discharge pressure too high <input type="radio"/> Ice on the evaporator <input type="radio"/> Suction & discharge pressure are equal <input type="radio"/> Room temperature is not cold enough <input type="radio"/> System is not working <input type="radio"/> Air-conditioning cools instead of heating
<b>Description</b>	



**11. 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's preface.
- Step 2: Check that the MAIN PLATFORM UNIT MONITOR and PROGRAM switches are at OFF position.  
  
A ground leakage relay, a semi-automatic switch, and a main power switch are installed in a main power box located on the rear panel.
- Step 3: Connect the MAIN PLATFORM UNIT power supply cable to the Mains.
- Step 4: Check that the high voltage ground leakage relay and the semi-automatic switch are ON.
- 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 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 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 and restrict the liquid refrigerant's flow entering the evaporator, to a rate equivalent to the amount of refrigerant being evaporated in the evaporator. The valve causes 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 onto itself.

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

Operating this program, the air-conditioning system is set to 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 11-16.

**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 relax device for safe 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.

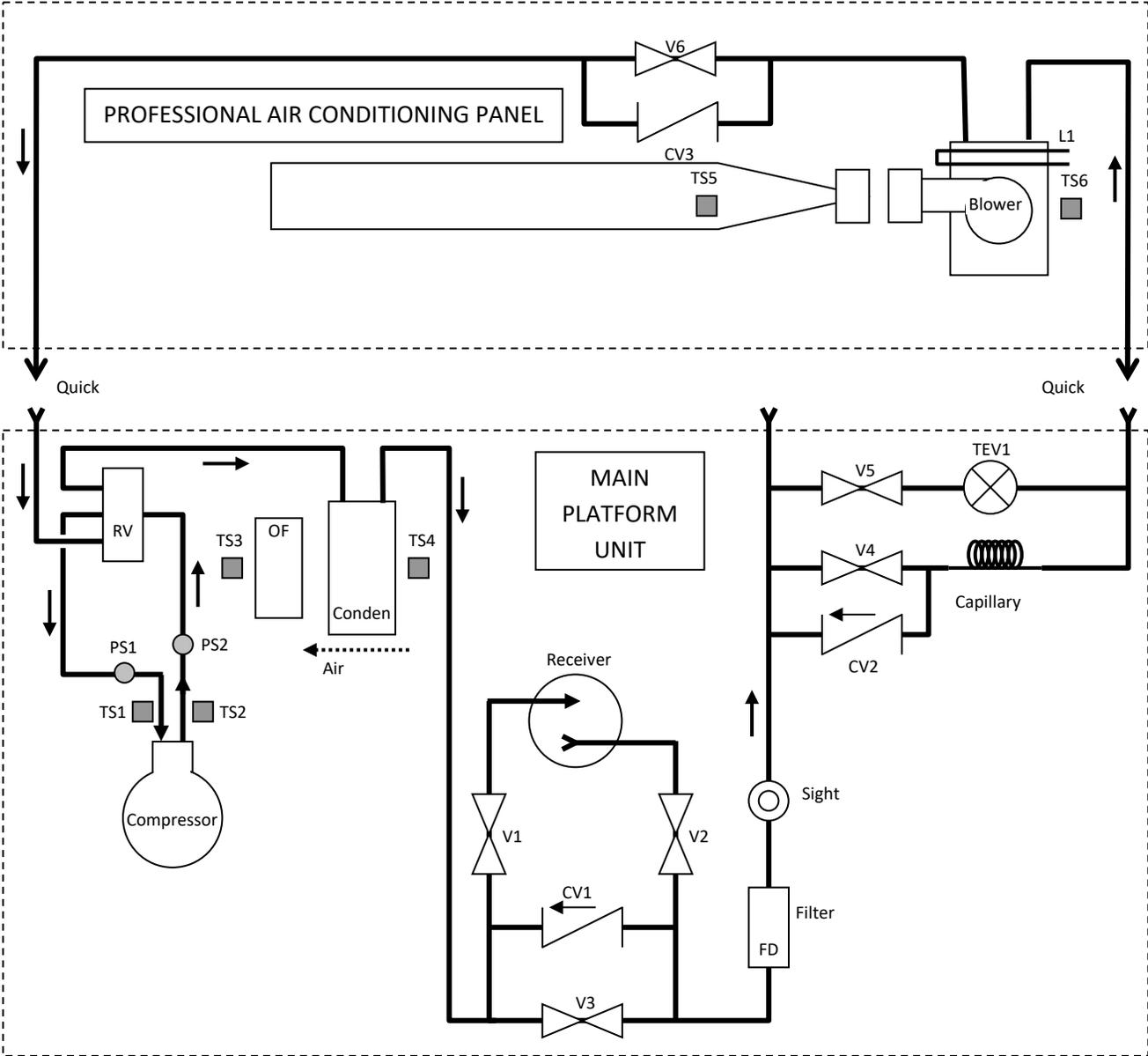
State 16 – TEV operation with graphic display and thermal load.

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

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



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)
- T7 – Not relevant to this panel
- T8 – Not relevant to this panel

The values are displayed in a table as follows:

LP	HP	T1	T2	T3	T4	T5	T6	T7	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.

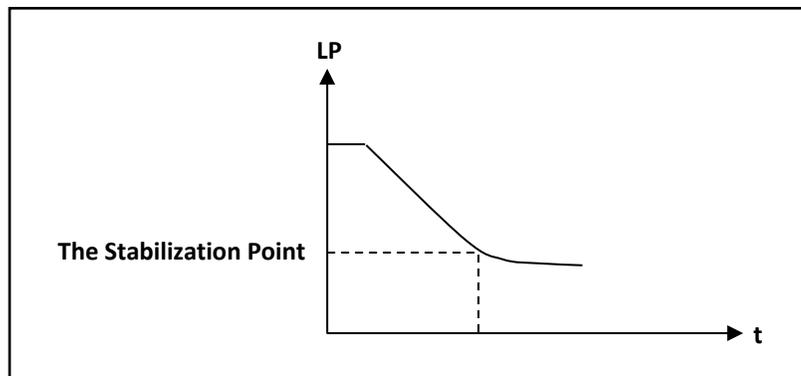
The compressor turns ON when the cooling chamber temperature is above  $S1 + D1$ .  $D1$  is determined in order to avoid the system oscillating.

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

The TEV mode is controlled by temperature.

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

Step 17: Immediately after operating the air-conditioning, the suction pressure should be high and go 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 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") enabling 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 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 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 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 stabilized point.

Step 29: Change the E1 speed to high and record the new stabilized 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 ST 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.

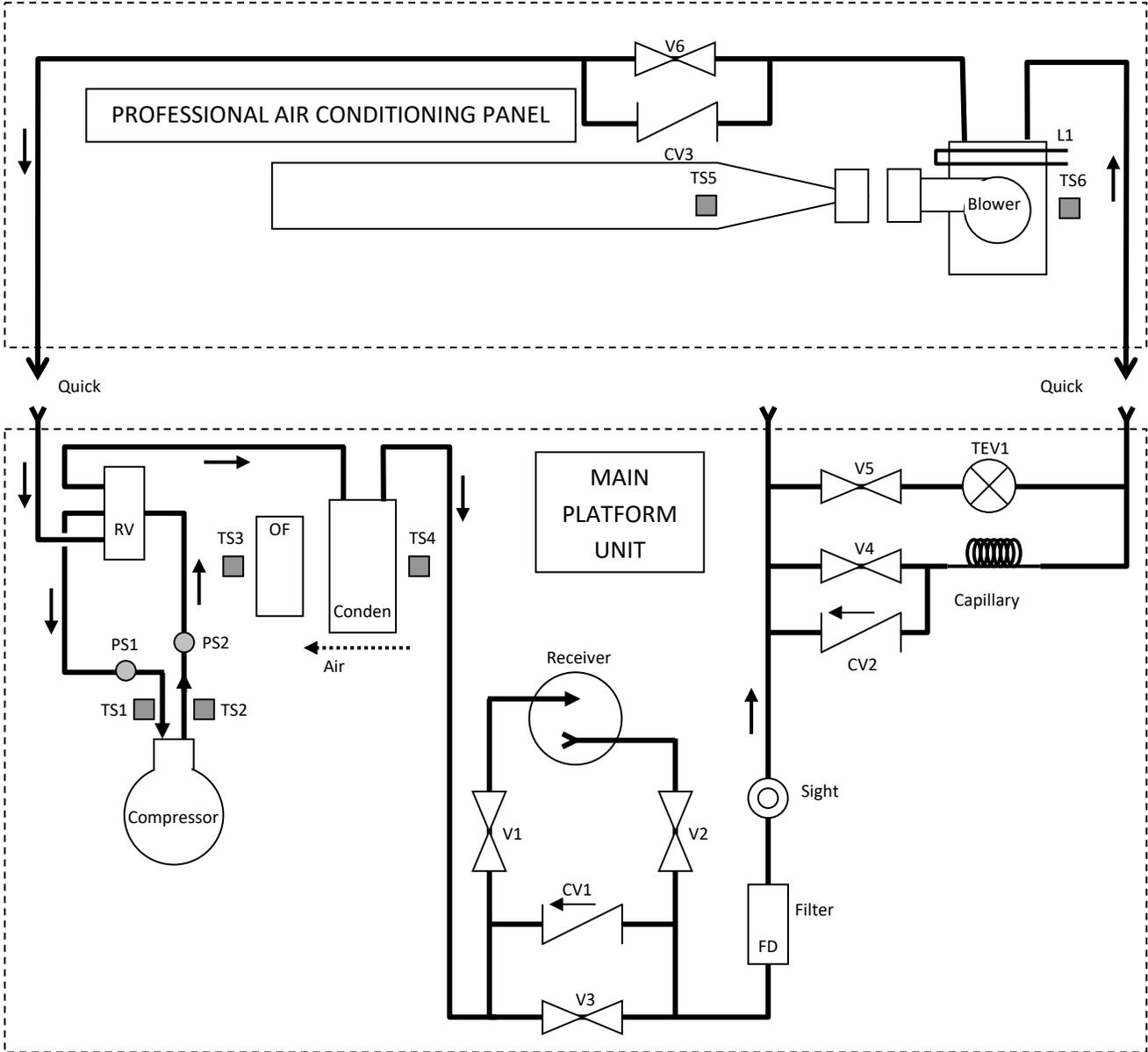
State 26 – capillary operation with graphic display.

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	T7	T8

Step 50: The control table is a little different. At 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 51: 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 52: Observe the temperature and pressure values and wait for the system to stabilize.

Step 53: When LP is at a stable point, record the temperature and pressure values at the stabilization point in the table at step 72.

The cooling chamber temperature should continue to go down.

Step 54: 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 55: 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 56: Change the E1 speed (by keying '\*') to high and record the new stabilization point values.

Step 57: Change the E1 speed back to low.

- Step 58: Wait until the system is stable.  
Identify the new stabilization point.
- Step 59: Change the STATE no. to 24 (°C) and press ENTER.  
Record the stabilization values.
- Step 60: Change the E1 speed to high and record the new stabilization point values.
- Step 61: Change the E1 speed back to low.
- Step 62: Change the STATE no. to 25 (°F) and press ENTER.  
Record the stabilization values.
- Step 63: The system at 21-26 states allows you to change the SP value in a certain range.
- Step 64: Key in the number 20 and key '#'.  
Record the stabilization values.
- Step 65: Change the state no. to 21 or 22.
- Step 66: Wait until the compressor stops working.
- Step 67: Record the pressures and temperatures.
- Step 68: Open the cooling chamber window.
- Step 69: Wait until the compressor turns ON.
- Step 70: Record the pressures and temperatures.
- Step 71: Change the STATE no. to 00 and press ENTER.  
Lower the PROGRAM switch and raise it.  
All the devices should shut OFF.

Step 72: 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								