intelitek

Chapter 1 – Basic Cooling and Air Conditioning Systems

EXPERIMENT 1.5 – EVAPORATION & CONDENSING TECHNIQUES

Name	Class/Period	Date

1. Objectives:

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

- Explain what an evaporator is.
- Explain the evaporator.
- Explain what an evaporator with natural convection is.
- Explain what an evaporator with forced convection is.
- Explain what a condenser is.
- Explain the condenser types.
- Explain what a condenser with natural convection is.
- Explain what a condenser with forced convection is.
- Explain the blower control and its function.

2. Equipment Required:

- Main Platform Unit
- Professional Air Conditioning Panel

3. Discussion: **Evaporators**

The evaporator is a device, to exchange the heat where the cooling material evaporates.

In order for the cooling material to evaporate there is a need for heat precipitation. This heat is taken from the air or the water existing outside the evaporator pipes wrapping. In this way, the air or the water is cooled.

The evaporators are divided into two types:

1. Air evaporators which operate on the direct evaporation principle of the material.
2. Water evaporators which operate on the indirect cooling principle of the cooling material through an agent – the water.

3.1. Air Evaporators:

Air evaporators are divided into two types:

1. Evaporators with natural convection.
2. Evaporators with forced convection.

1. Evaporator with natural convection:

An evaporator with natural convection is usually a surface evaporator. The freezer compartment of the old home refrigerators (with no automatic ice defrosting) is an example for this kind of evaporator.

The natural convection evaporator is built of two aluminum tins glued and welded together. During the production, a depression in the shape of a half pipe is impressed in the inner tin, so when the tins are connected a flow path for the cooling material is made.

The freezer compartment evaporator is designed as an accommodation compartment for produce that should be frozen.

The cooling material flows inside the pipe impressed in the tin and, evaporates. While it evaporates, it receives heat from the air located near the side panel.

2. Evaporator with forced convection:

Evaporators with forced convection are evaporators where air flows through them by the use of a blower. The main application of this kind of evaporator is in cooling and air-conditioning facilities, and in home refrigerators/freezers (the NO FROST kind). The evaporator is built from pipes strung through perforated aluminum fins attached to each other. The gap between the fins allows air to flow between them. This gap is very important.

3.2. Water Evaporators:

The water evaporator is a heat exchanger where the cooling material during evaporation, cools water.

Usually the cooling material flows in the pipe and the water is located outside the pipe. The water has a better heat transfer characteristics than air and so the water evaporator's heat coefficient is better that the air evaporator's heat coefficient.

Water evaporators are usually applied to big air-conditioning systems designed for a great number of rooms spread over a number of floors.

Water evaporators are divided into the following types:

1. Soaked coil evaporator.
2. Battery evaporator.
3. Pod and pipes evaporator.

1. Soaked coil evaporator:

This evaporator is built from a copper pipe wrapped as a coil soaked in water or another liquid that should be cooled. The cooling material flows in the pipe and the water flows between the external wrap of the pipe and the tank.

A pump transfers the cooled water to the various consumers and the water returns hot after absorbing heat.

2. Battery evaporator:

The battery evaporator is similar in build to the soaked evaporator and is mainly used for cooling liquid in a bath, which is the only consumer, so there is no need to transfer the cooled liquid to another place.

3. Pod and pipes evaporator:

The pod and pipes evaporator is the most common and popular heat exchanger in large air-conditioning facilities today.

It is built from a thick pipe with two plates engraved at the edges. Inside these plates, the copper pipes are installed.

The cooling material flows inside the pipes and the water flows between the pipes external wrap and the pod.

The water cycle is a closed cycle, not like in the condenser, therefore there is no water loss.

It is possible to build a water evaporator where the water flows either inside the pipes or outside the pipes.

4. Discussion: **Condensers**

The condenser's function is to discharge the heat absorbed in the evaporator and dispersed by the compressor to the surroundings.

The condenser is a heat exchanger. The cooling material is condensed in it while exchanging heat and the surroundings absorbs the heat while heating the air.

The cooling material enters the condenser as a warm gas state and discharges noticeably heated air to the surroundings while it is cooling.

As soon as the cooling material reaches a saturated vapor state, it starts to condense at a fixed temperature and discharge latent heat to the surroundings. The cooling material condenses completely and finishes its course as a saturated liquid state in the condenser.

The condensers can be divided into two types:

1. Air-cooled condensers.
2. Water-cooled condensers.

4.1. Water Evaporators:

These condensers are divided according to their heat transfer characteristic:

a) Condensers with natural convection.
b) Condensers with forced convection.

a) Condensers with natural convection:

In condensers with natural convection, the heat discharges from the cooling material to the surrounding air through the pipe's side to its surrounding air without any external factor. The air warms up due to heat absorption, rises, and clear off space for cooler surrounding air. This process is natural, caused by the air differences in temperature. The air rises up and is mixed with the surrounding air. In its place cooler air reaches the condenser pipe's environment and it absorbs more heat.

Surface condenser:

The surface condenser is geared to small devices, mainly for domestic refrigerators. The simplest surface condenser is build from a copper pipe, bent and strengthened with iron wires. The main function of the iron wires in this type of condenser is to distribute the heat from the pipe to the air.

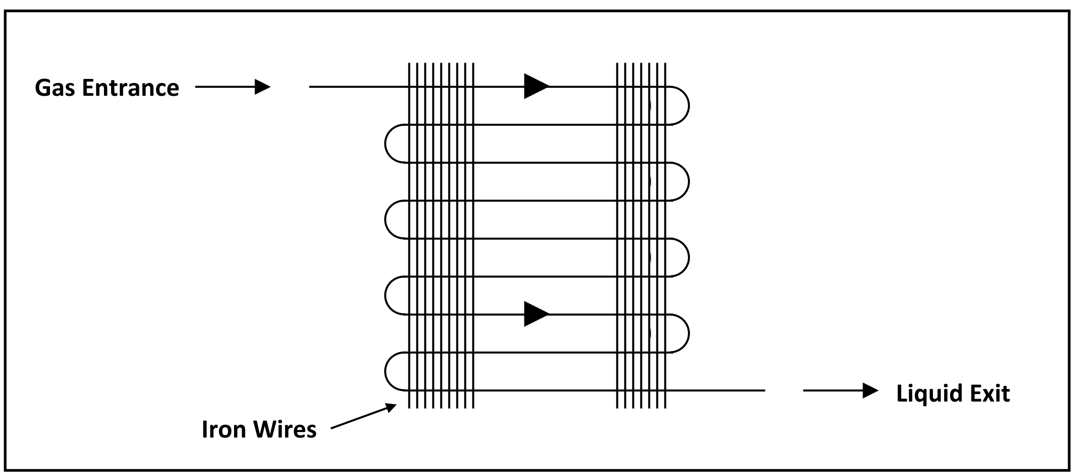


Figure 1-22

Another type of surface condenser is one made of an iron surface, which includes the pipe where the cooling material is flowing. The iron surface is used to improve heat transfer by enlarging the condenser's surface, thus the number of pipes needed for one condenser can be reduced.
This condenser is also aimed for domestic refrigerators. In these refrigerators, the surface condenser is sometimes latent from sight, but always situated in free air.

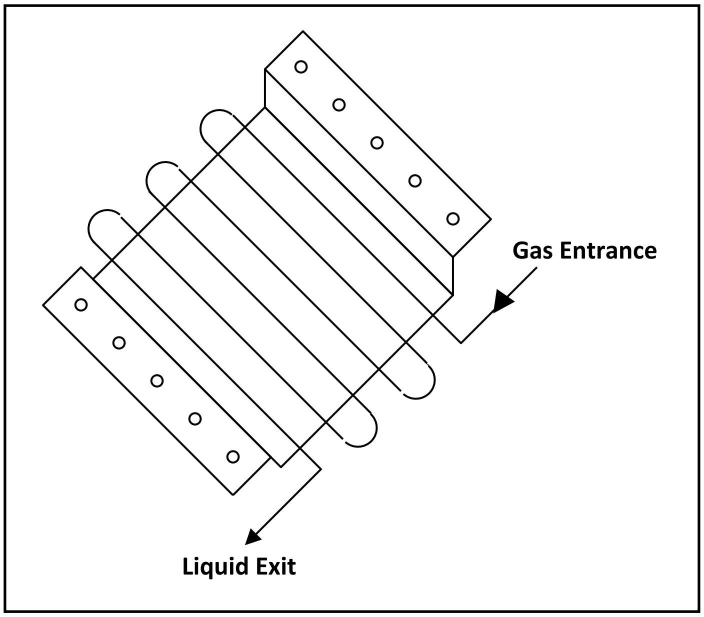


Figure 1-23

In many cases, the cooling material is used to cool down the compressor's oil. It moves through the compressor's pipe leaving the compressor, enters the condenser, cools down, and returns to the oil in order to cool it down.

Another way of cooling the oil crankcase is by connecting the pipe (in the oil crankcase) to the condenser itself.

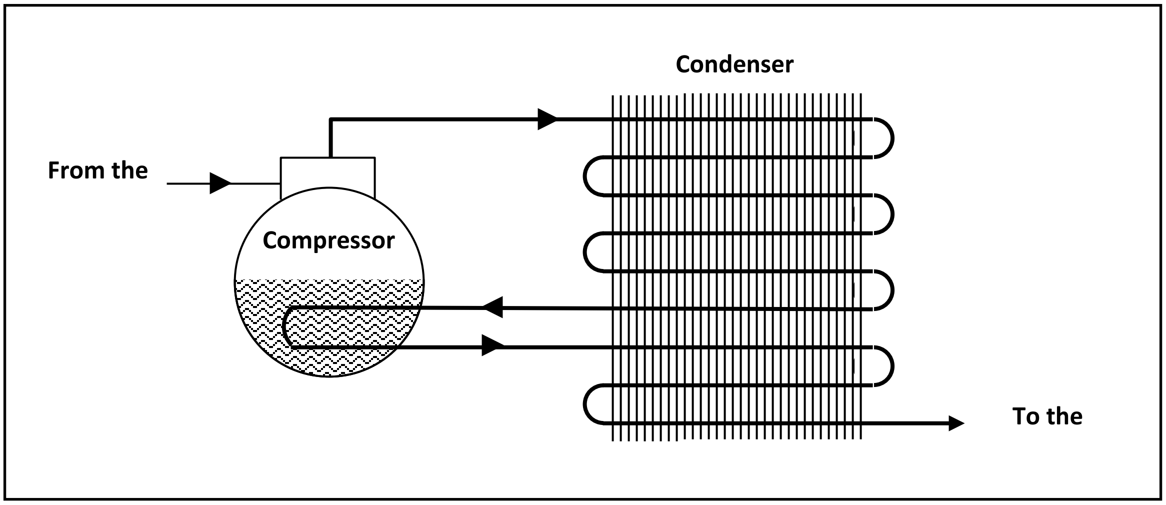


Figure 1-24

b) Condensers with forced convection:

A condenser with Forced Convection includes copper piping and aluminum sides. The sides' function is to enlarge the condenser's surface area so that the quantities of heat that can pass through it are larger, as described in the following figure:

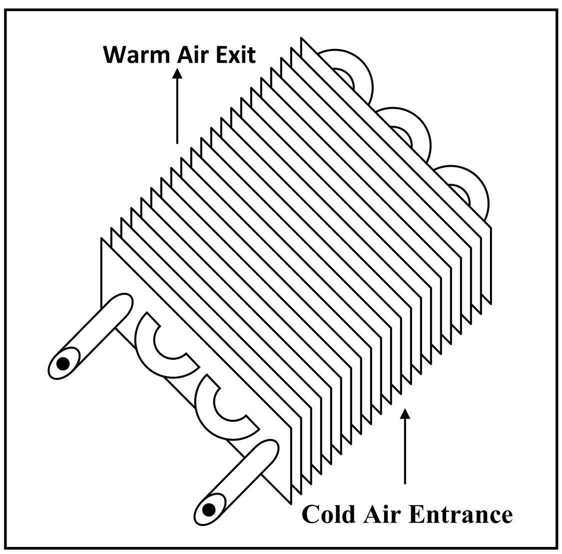


Figure 1-25

The forced convection condenser includes a polygonal condenser and a blower, which causes the air to flow through the polygonal condenser. The blower can be axial or centrifugal, but in most cases, it is axial.

The blower forces the air to pass through the condenser's battery and to absorb the heat coming from the condenser.

<u>For example, the circular condenser:</u>

This condenser is designed in a circular way for certain air-condition devices. The air enters from the sides and the axial blower pushes it up. Because of its special design, the circular condenser is more expensive than the regular condenser.

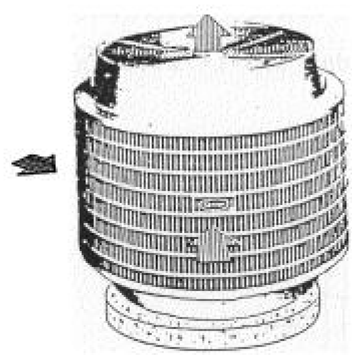
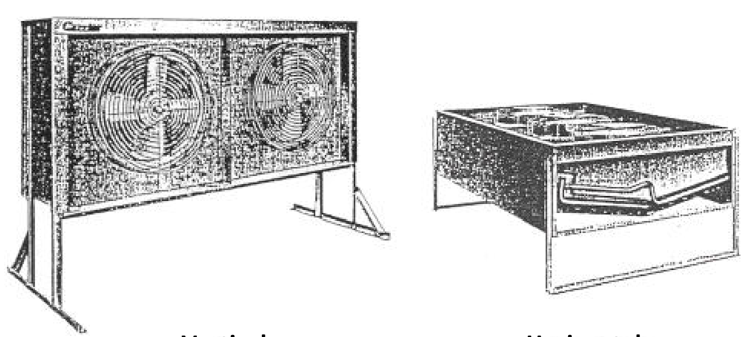


Figure 1-26 Axial Condenser

The Air-cooled condenser of large cooling and air-conditioning systems is a single unit which includes: condensing battery, air blower, and a motor which operates the blower by direct ignition when the blower is installed on the motor's axle, or by flywheel using straps.

Vertical condensers occupy less floor space, but they stick out. The air flows through them horizontally.

Horizontal condensers occupy more floor space, but do not stick out. The air flows through them vertically.



Vertical **Horizontal**

Figure 1-27

5. Discussion: The Fan

As in air-conditioning, the principle is cooling gas while it spreads inside the evaporator. It is compressed by the compressor inside the condenser, transported as a fluid to evaporator and there it spreads. The evaporator and condenser are constructed from curved pipes. Air flows around them. The air, which flows around the condenser, cools the condenser and the fluid inside it and the transferred air heats and discharges outside the air-conditioning system.

The air transferred through the evaporator cools down, flows to the air-conditioning area and cools it. Without air transfer there would not be an air-conditioning process. An immense heat would have been created in the condenser and an immense cold in the evaporator until ice was created in its pipes.

The fan's function is to push air through the condenser and the evaporator.

6. Discussion: Thermal load

The thermal load of an air-conditioning system is the heat quantity that the system has to remove from the cooling material in the cooling area. This is one of the central parameters taken into consideration when designing an air-conditioning system and its components [BTU/Hr].

6.1. Cooling capacity:

The cooling capacity of an air-conditioning system is the measure of the ability of an air-conditioning system to remove heat from the cooling area.

The cooling capacity of an air-conditioning system should always be larger than the cooling load.

When the cooling capacity is equal to the thermal load, the system is balanced. This balance occurs in a temperature where all the cooling capacity equals the thermal load.

6.2. Thermal loads and external temperature change:

The Professional Air Conditioning Panel cooling system has a heating body installed in the evaporator. Its function is to resemble the cooling space heated condition during the experiments. The heat produced by this device can be adjusted.

Beside the evaporator unit a fan is installed which can be operated at different speeds. The cooling chamber of the system is built from an insulated material. Some heat leakage exists and is accounted for.

The heat load can be evaluated by measuring the differences in temperature between the air temperature at the evaporator's inlet and the temperature at its outlet.

The system capacity can be evaluated by the experiment where the compressor works together with the heating unit. The system's temperature changes from the beginning of the experiment until it reaches working stability. This point is called Steady State.

The measurements of the various temperatures and pressures existing in the system are measured at this point.

When designing a cooling system, additional heat loads such as: lighting, heat discharging devices, roofs, windows etc. are taken into account.

7. Discussion: Calculating heat convection in evaporators and contenders

The Professional Air Conditioning Panel Cooling System is equipped with fan, which operate under the forced heat convection principle.

In order to simplify the calculation it is common to assume that the refrigerant temperature stays constant along its way through the evaporator and condenser. When it moves through the coil, the air temperature changes.

The data required for calculating the heat convection in the evaporator or the condenser is: the air temperature in the inlet and outlet, the cooling material temperature in the inlet and outlet, and the gas flow rate.

The air's convection surface through the condenser's fins is an important factor for calculating heat convection, as such the evaporators and condensers are marked with length, width, the pipe's diameter, and the fins number per inch values.

The temperature differences between the refrigerant and the air are actually the cause for heat convection occurring between the evaporator and/or the condenser and the surrounding air. The following equation is used in order to calculate the average logarithmic temperature:

$$\Delta T_m = \frac{(\Delta T_{max} - \Delta T_{min})}{\ln\left(\frac{\Delta T_{max}}{\Delta T_{min}}\right)}$$

ΔT_m = The average logarithmic temperature.

ΔT_{max} = The temperatures difference between the cooling material at the heat exchanger inlet (evaporator or condenser) and the air at the outlet.

ΔT_{min} = The temperatures difference between the cooling material at the heat exchanger outlet and the air at the inlet.

A calculation example according to figure 1-28:

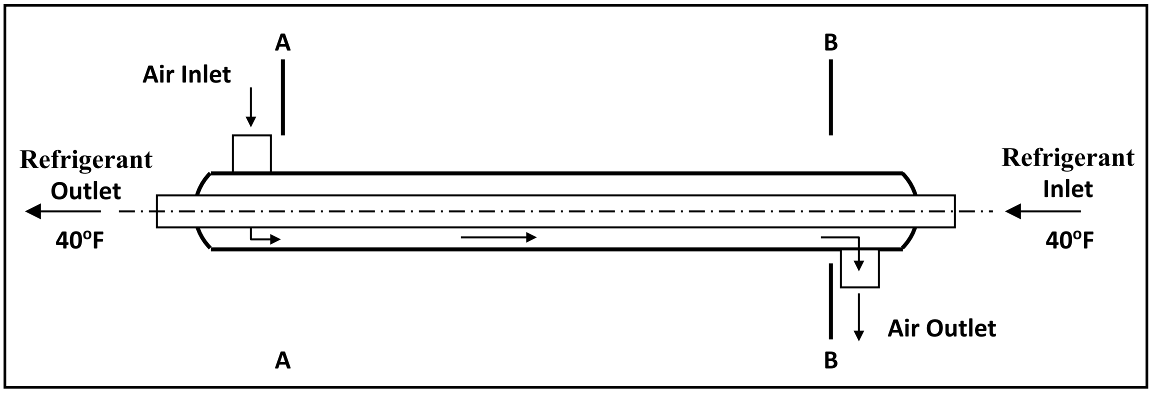


Figure 1-28

$$\Delta T_{max} = 80 - 40 = 40^{o}F \qquad \Delta T_{max} = 26.5 - 4.5 = 22^{o}C$$

$$\Delta T_{min} = 80 - 40 = 40^{o}F \qquad \Delta T_{min} = 13.3 - 4.5 = 8.8^{o}C$$

$$\Delta T_{m} = \frac{40 - 16}{\ln\left(\frac{40}{16}\right)} = \frac{24}{\ln 2.5} = \frac{24}{0.9163} = 26.19^{o}F \qquad \Delta T_{m} = \frac{22 - 8.8}{\ln\left(\frac{22}{8.8}\right)} = \frac{13.2}{\ln 2.5} = \frac{13.2}{0.9163} = 14.4^{o}C$$

7.1. The heat convection process:

The heat convection described for the condenser is an integrated process which includes 3 stages:

1. Transferring the heat from the refrigerant to the partition.
2. Heat convection through the partition side (the pipe side).
3. Transferring the heat to the surrounding air.

The amount of convection heat in each of the states can be calculated with the appropriate equation:

1. The amount of heat transferred by the refrigerant – $Q_1 = m \cdot \Delta T$
   m = the mass of the refrigerant in pounds (or kg).

2. The amount of heat which passes through the partition side – $Q_2 = A \cdot U \cdot \Delta T_m$
3. The amount of heat the air receives – $Q_3 = cfm \cdot 1.08 \cdot \Delta T$
   cfm = Air flow in ft^3 /min (air volume supply in units)

   1.08 = Specific heat air constant

   ΔT = Temperature difference between the condenser input and output air in °F.

Rule: In an integrated heat convection process, the amount of convection heat in each of the stages must be equal to the amount of convection heat in the other stages.

The above rule can be written mathematically:

$$Q_1 = Q_2 = Q_2$$

7.2. Heat convection through the partition:

Calculating the amount of heat convection through the partition is an important part of designing the heat exchanger. This design establishes the heat exchanger size and its ability to function properly in the system.

The amount of heat convection through the pipes sides is calculated according to the following equation:

$$Q = A \cdot U \cdot \Delta T_m$$

Q = Heat amount in $\frac{Kcal}{h}$ or $\frac{BTU}{h}$ units.

A = All the pipes surround surface area in $\mathbf{m^2}$ or $\mathbf{ft^2}$ units.

U = The comprehensive heat convection factor between the air and the refrigerant in $\frac{Kcal}{m^2 °Ch}$ or $\frac{Kcal}{ft^2 °Fh}$ units.

$\mathbf{\Delta T_m}$ = Logarithmic temperature difference.

7.3. The pipes surround surface (the partition):

In the heat exchanger, the pipes surround surface is the partition surface.

The surround surface of a single pipe is calculated according to the following equation:

$$A = \pi D l$$

π = the number 3.14

D = the pipe's diameter in **m** or **ft** units.

l = the pipe's length in **m** or **ft** units.

When the number of pipes in the heat exchanger is n units, the equation should be multiplied by n:

$$A = n \cdot \pi \cdot D \cdot l$$

intelitek

8. Procedure:

Step 1: Check that the PROFESSIONAL AIR CONDITIONING PANEL 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).

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

V1	V2	V3	V4	V5	V6	V7	RV	CM	OF

In this experiment we shall measure the temperature difference of the evaporator and the condenser and we shall calculate their heat transfer in BTUs.

We will check it in two speeds of the evaporator fan and with and without thermal load.

TEV mode:

Step 11: Change the STATE number to 11 (for °C) or 12 (for °F) and press ENTER.

Step 12: Lower the PROGRAM switch and raise it.

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

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

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

LP	HP	T1	T2	T3	T4	T5	T6	T7	T8

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.

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.

Observe this sight glass and check that there are no bubbles and the LP value reached the stabilization point.

Step 14: The cooling chamber temperature should continue to go down even after the LP is stable.

Observe that.

Step 15: The chamber temperature T6 goes down as long as the system is cooling (the compressor works).

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), the default value of D1 is 5°C (9°F).

Check that.

Step 16: See what happens when the cooling chamber temperature reaches the S1 point.

Step 17: Record the pressures and temperatures.

Step 18: Wait until the compressor turns ON.

Step 19: Record the pressures and temperatures.

Step 20: Wait until the compressor turns OFF.

Step 21: Record the pressures and temperatures.

Step 22: Press the '*' key and check that the evaporator fan (E1) changes to HI.

Step 23: Wait until the compressor turns ON.

Step 24: Record the pressures and temperatures.

Step 25: Wait until the compressor turns OFF.

Step 26: Record the pressures and temperatures.

Step 27: Press the '*' key again and check that E1 is changed into 'LO'.

Step 28: Fill in the following table with the stabilization point's values of the two setup points.

No.	Comp.	E1	Time	S1	D1	LP	HP	T1	T2	T3	T4	T5	T6
1.	ON	LO											
2.	OFF	LO											
3.	ON	HI											
4.	OFF	HI											

Step 29: The air supply of the evaporator fan is 100 M^3/h (900 ft^2/h) at low speed and 200 M^3/h (1800 ft^3/h) at high speed. The condenser air supply is 430 M^3/h (3870 ft^3/h) and it has only one speed.

Calculate the heat transfer of the evaporator and condenser.

Q = cfm · 1.08ΔT (see paragraph 7.1).

Step 30: Change the STATE number to 14 (for ^oC) or 15 (for ^oF) and press ENTER

This will operate the thermal load.

Step 31: Wait until the compressor stops working.

Step 32: Record the pressures and temperatures.

Step 33: Wait until the compressor turns ON.

Step 34: Record the pressures and temperatures.

Step 35: Change the fan speed to High.

Step 36: Wait until the compressor turns OFF.

Step 37: Record the pressures and temperatures.

Step 38: Wait until the compressor turns ON.

Step 39: Record the pressures and temperatures.

Step 40: Fill in the following table with the stabilization point's values of the two setup points.

No.	Comp.	E1	Time	S1	D1	LP	HP	T1	T2	T3	T4	T5	T6
1.	ON	LO											
2.	OFF	LO											
3.	ON	HI											
4.	OFF	HI											

Step 41: Calculate the heat transfer of the evaporator and condenser.

Step 42: Change the STATE no. to 00 and press ENTER.

Lower the PROGRAM switch and raise it.

All the devices should shut OFF.