MEP 451

Refrigeration & Air Conditioning

Experiment Title: Analysis of Air Conditioning Processes

A: Cooling, De-humidifying & Reheat
B: Humidifying and heating

June 2009.

1. Introduction

Moist air is a mixture of dry air (gases such as O_2, N_2, CO_2, etc) and water vapor. A useful tool for studying and analyzing thermodynamics properties of moist air is the psychrometric chart. To provide thermal comfort conditioning in occupied spaces, air must be conditioned. Depending on the climate conditioning and the indoor requirement, air conditioning processes could be sensible heating or cooling, de-humidifying, humidifying etc. The purpose of this experiment is to practically show some of the uses of the psychrometric chart, and thermodynamically analyze some of the air conditioning processes.

2. Apparatus

Air conditioning Laboratory Unit A660 manufactured by P.A. Hilton Company. Figure (1) shows the layout of the unit. Numbered components list is shown on Fig. (2).

3. Objective

To be able to use the psychrometric chart. To draw the processes on the psychrometric chart and analyze them thermodynamically.

4. Process description

One of the basic air conditioning processes that is applied frequently in humid hot areas is cooling and dehumidifying process. To achieve this process cooling coil is used. Cooling coil can be either direct expansion (DX) type or chilled water type. When moist air is to be cooled and dehumidified, it passes over a cooling coil whose surface temperature is equal or lower than the dew point temperature of the incoming air. Figure (3) shows a sketch of this process, and Figure (4) shows how the process looks on a psychrometric chart. Air at state B is passed over a DX cooling coil. The air leaving the coil at state C passes over an electric heater, and exits at state D. Notice that the vapor which condensate over the coil is collected at the bottom and drained out.

In order to locate any of the states B, C or D, two properties must be known. For our experimental unit two thermometers are installed at each state to measured dry and wet bulb temperatures. This will facilitate locating the states on the chart. Since the air damper [see component 42 on Figure (1)] is closed, i.e. the air system is configured as a once through arrangement. The mass flow rate of air can be found from the inclined manometer measurement at state E. If the manometer reading is Z_E, and the specific volume of air at this state is ν_E, then the air mass flow rate is given by

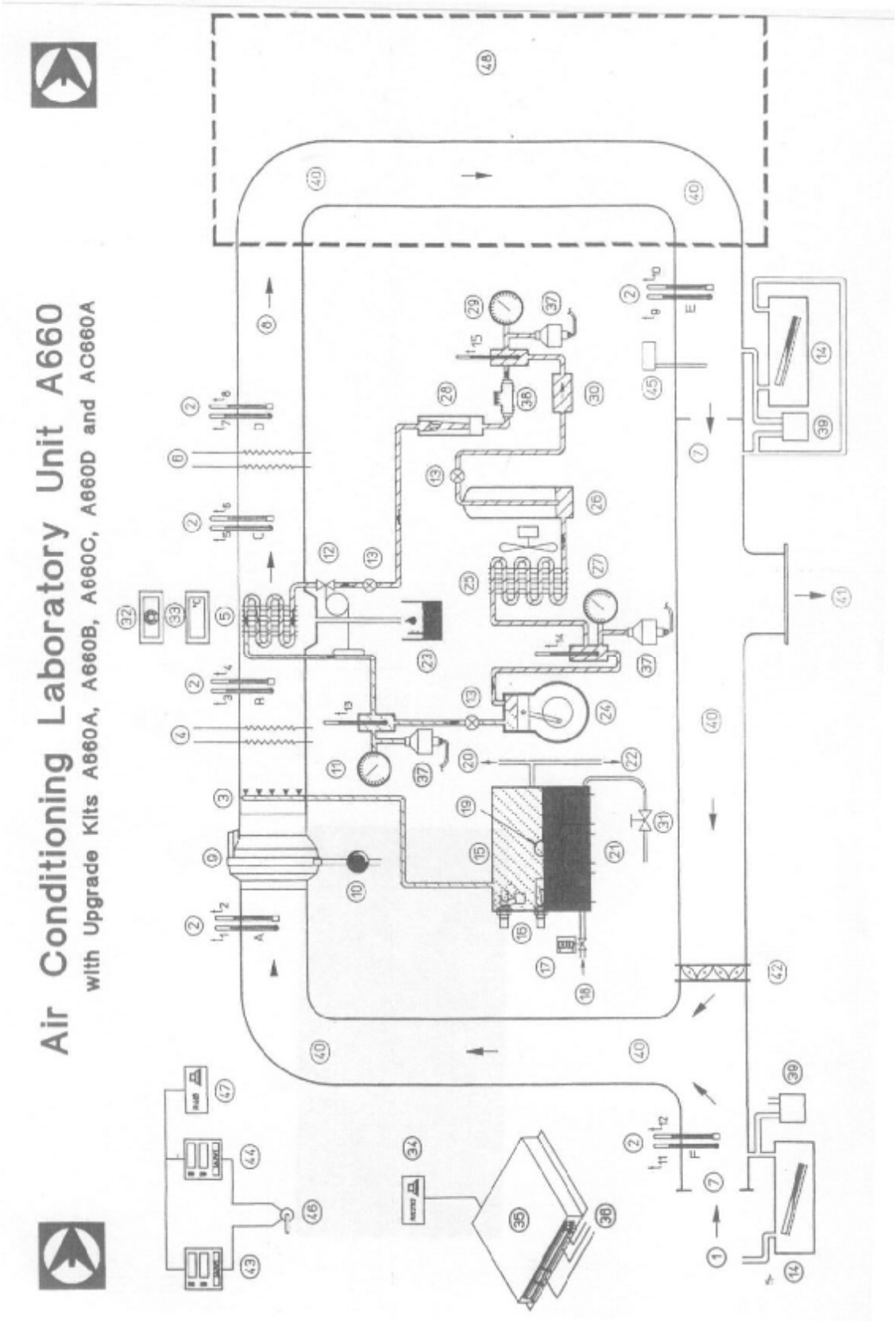
$$\dot{m}_a = 0.0517\sqrt{\frac{Z_E}{\nu_E}} \qquad (1)$$

where
Z_E is the inclined manometer reading at state E [mm H_2O], and
ν_E is the specific volume of air at state E (to be found from psychrometric chart) [m^3/kg]

The heat extracted from air when passing from B to C is given by

$$\dot{Q}_{BC} = \dot{m}_a(h_B - h_C) - \dot{m}_w h_w \qquad (2)$$

Where
$\dot{m}_m$ is the rate of mass liquid condensed
h_w is the enthalpy of the condensate water


Air Conditioning Laboratory Unit A660
with Upgrade Kits A660A, A660B, A660C, A660D and AC660A

Air Conditioning Laboratory Unit A660

1. Air Inlet
2. Wet and Dry Temperature Stations
3. Steam Injector
4. Pre-Heaters
5. Evaporator
6. Re-Heaters
7. Orifice
8. Treated Air
9. Fan
10. Fan Speed Control
11. Evaporator Pressure
12. Thermostatic Expansion Valve
13. Stop Valve
14. Inclined Manometer
15. Steam Generator Tank
16. Water Level Control
17. Solenoid Valve
18. Water Inlet
19. Sight Glass
20. Vent
21. Water Heaters
22. Overflow to Drain
23. Condensate Measurement
24. Compressor
25. Air Condenser
26. Liquid Receiver
27. Condenser Inlet Pressure
28. Refrigerant Flowmeter
29. Condenser Outlet Pressure
30. Filter/Drier
31. Steam Generator Tank Drain Valve

Optional Upgrades

Temperature Upgrade Kit A660A

32. *15 Way Selector Switch*
33. *Digital Temperature Indicator*

Computer Linked Upgrade Kit AC660A

34. *RS232 Serial link to PC*
35. *Datalogger*
36. *Transducer Inputs*
37. *Refrigerant Pressure Transducer*
38. *Refrigerant Flow Transducer*
39. *Differential Air Pressure Transducer*

Air Recirculating Duct Kit A660B

40. *Duct sections*
41. *Exhaust*
42. *Volume Control*

PID Control Upgrade Kit A660C

43. *PID Controller – Humidity %RH*
44. *PID Controller – Temperature °C*
45. *Combined %RH/Temperature Probe*
46. *Manual/PID Control Selector Switch*
47. *RS485 Serial link to PC*

Environmental Chamber A660D

48. *Environmental Chamber*

The second term in equation (2) above is the energy carried by the condensate, and since it is very small it can be neglected.

The amount of heat added to the air in the re-heater can be found using

$$\dot{Q}_{CD} = \dot{m}_a (h_D - h_C) \quad (3)$$

The heat extracted from air when passing from B to C is the same heat that is added into the evaporator of the vapor compression refrigeration cycle. This heat can be found once the refrigerant flow rate and the inlet and exit enthalpies are found. Figure (5) is a P-h diagram for R-134a that can be used to find the properties

$$Q_E = \dot{m}_{ref} (h_{13} - h_{15}) \quad (4)$$

Where
h_{13} is the enthalpy of refrigerant at the evaporator exit, and
h_{15} is the enthalpy at the evaporator inlet, which equals to the enthalpy at the condenser exit.

5. Procedure

1-Inspect the apparatus and its main components. You should locate the following parts:
a-Air intake b-Fan c-Pre-heater d-Humidifier
e-Cooling coil f-Re-heater g-Thermometers h-Inclined manometers
i- Temperature indicator k-Refrigeration cycle and its components
Check to see that pure water is provided to all wet bulb thermometers.
2-Make sure that the air circulation is once through system by shutting off the damper on the re-circulated duct.
3-Make sure that all heaters, the compressor are set off. Also set the system control to manual.
4-Turn the fan on, and set its speed to be intermediate position
5-Turn the compressor on
6-Turn on the 1 kW of the electric re-heater
7-Wait for steady state to provide by watching the variation of temperature at location 7 (i.e. t_7). Usually 10-20 minutes are enough to achieve steady state condition.
8) Record the data on table (1). You may need to take two set two data to make sure that steady state condition has be reached.
9) Locate state B, C, D, and E on the psychrometric chart, and fill table (2) below
10) Locate states 13 and 15 on R-134a P-h chart
11) Compare the values of Q_E with Q_{BC} and comment on the difference
12) Comment on you results

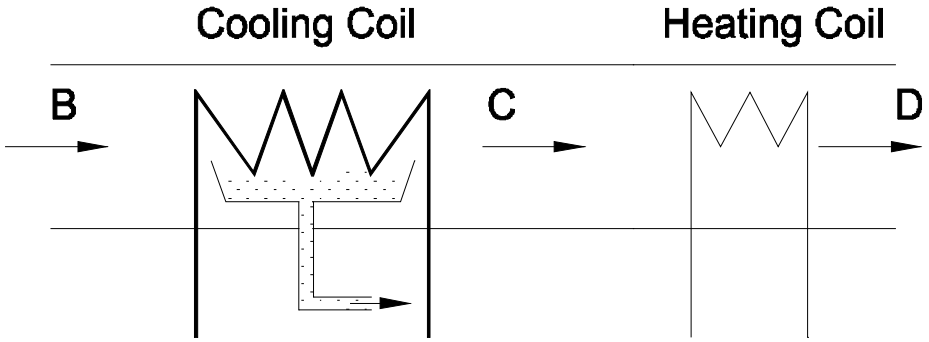


Figure 3 A schematic showing the cooling coil and the heating coil.

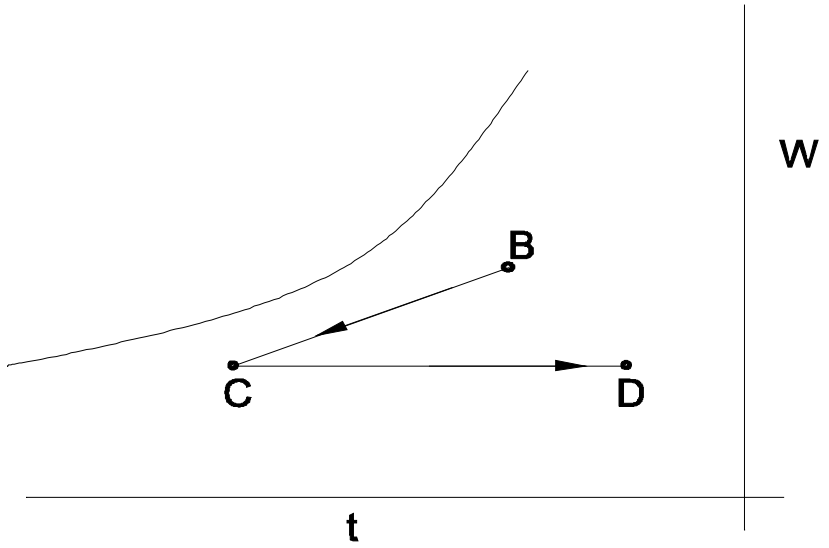


Figure (4) Representation of cooling and dehumidifying process [B→C], and sensible heating process [C→D] on the psychrometric chart.

Table (1) Observed data

Atmospheric pressure ( ) mm Hg
Heater input power ( ) kW

Test Reference				Units	1	2	Mean
A	Air at fan inlet	Dry	T_1	° C			
		Wet	T_2	° C			
B	After Pr-heater and Steam injector	Dry	T_3	° C			
		Wet	T_4	° C			
C	After Cooling/ Dehumidification	Dry	T_5	° C			
		Wet	T_6	° C			
D	After Re-heater	Dry	T_7	° C			
		Wet	T_8	° C			
E	Return	Dry	T_9	° C			
		Wet	T_{10}	° C			
F	Fresh Air Intake	Dry	T_{11}	° C			
		Wet	T_{12}	° C			
Evaporator Outlet			T_{13}	° C			
Condenser inlet			T_{14}	° C	`		
Condenser outlet			T_{15}	° C			
Supply voltage			V_L	Volts			
Evaporator outlet pressure			P_1	kPa (gage)			
Condenser inlet pressure			P_2	kPa gage)			
Condenser outlet pressure			P_3	kPa (gage)			
Fresh air intake Diff. manometer reading			Z_F	mm			
Duct Differential manometer reading			Z_E	mm			
Fan supply voltage			V_F	Volts			
Condensate Collected			m_w	grams			
Time interval to collect condensate			Δt	s			
Mass flow rate of condensate water			$m_w/(1000)\Delta t$	kg/s			
R-134a mass flow rate*			$\dot{m}_{ref}$	g/s			

*** Divide by 1000 to get the mass flow rate in kg/s**

Table (2) Air properties

State	t [°C]	t^* [°C]	h [kJ/kg]	W [kg/kg]	ν [m^3/kg]
B					
C					
D					
E					

Table (3) Summary of calculated parameters

Variable	Value	Units	Remarks
$\dot{m}_a$			
$\dot{Q}_{BC}$			
$\dot{Q}_{CD}$			
h_{13}			
h_{15}			
$\dot{Q}_E$			
$(Q_{BC} - Q_E)*100 / Q_E$			

Marks distribution for the report

No.	Item	Marks
1	Attend the lab. session and fill experimental data	1
2	Locate correctly state 13 & 15 on R-134a P-h chart	1
3	Locate correctly air states (A,B, C, D, & E) on psychrometric chart	2
4	Show details of your calculations and correct units	2
5	Calculate the percentage difference between Q_{BC} and Q_E	1
6	Discussion of results, remarks, conclusions and comments	2
7	Neatly and well presented report	1

6. Conclusions & Comments

{Each student should write at least one paragraph about conclusions and comments}