SBS5225 HVACR I

http://ibse.hk/SBS5225/

Experiment 1: Analysis of Air Conditioning Processes

Introduction

Moist air is a mixture of dry air (gases such as O_2, N_2, CO_2, etc) and water vapour. 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 the uses of the psychrometric chart, and thermodynamically analyze some of the air conditioning processes.

Objectives

- To study the components of air conditioning systems.
- To carry out performance test on typical air conditioning processes.

Theory and Principles

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 1 shows a sketch of this process, and Figure 2 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 vapour which condensate over the coil is collected at the bottom and drained out.

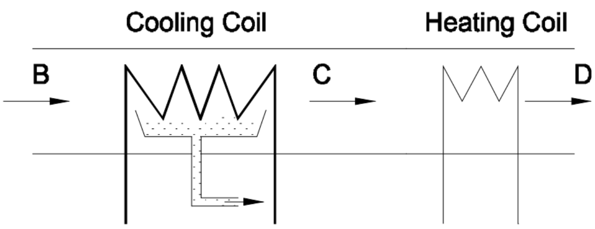


Figure 1. Air flow through a cooling coil and a heating coil

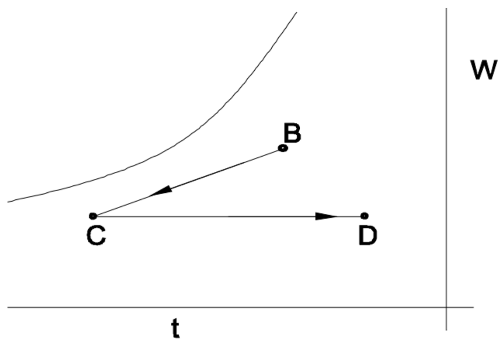


Figure 2. Cooling and dehumidifying process (B → C], and sensible heating process (C → D) on the psychrometric chart

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 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, and the specific volume of air at this state is v_D, then the air mass flow rate ($\dot{m}_a$) is given by:

$$\dot{m}_a = 0.0517\sqrt{\frac{z}{v_D}} \text{ kg s}^{-1} \quad (1)$$

where z = Orifice differential (mm H_2O)
v_D = Specific volume of air at Station E in $m^3\ kg^{-1}$ (from psychrometric chart)

The heat extracted from air when passing from B to C (in kW) is given by:

$$Q_{BC} = \dot{m}_a(h_B - h_C) - \dot{m}_w h_w \quad (2)$$

where $\dot{m}_w$ is the rate of mass liquid condensed (kg s^{-1})
h_w is the enthalpy of the condensate water (kJ kg^{-1})

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 (in kW) can be found using:

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

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

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

where h_{13} is the enthalpy of refrigerant at the evaporator exit (kJ kg^{-1}), and
h_{15} is the enthalpy at the evaporator inlet (kJ kg^{-1}), which equals to the enthalpy at the condenser exit.

Equipment and Instruments

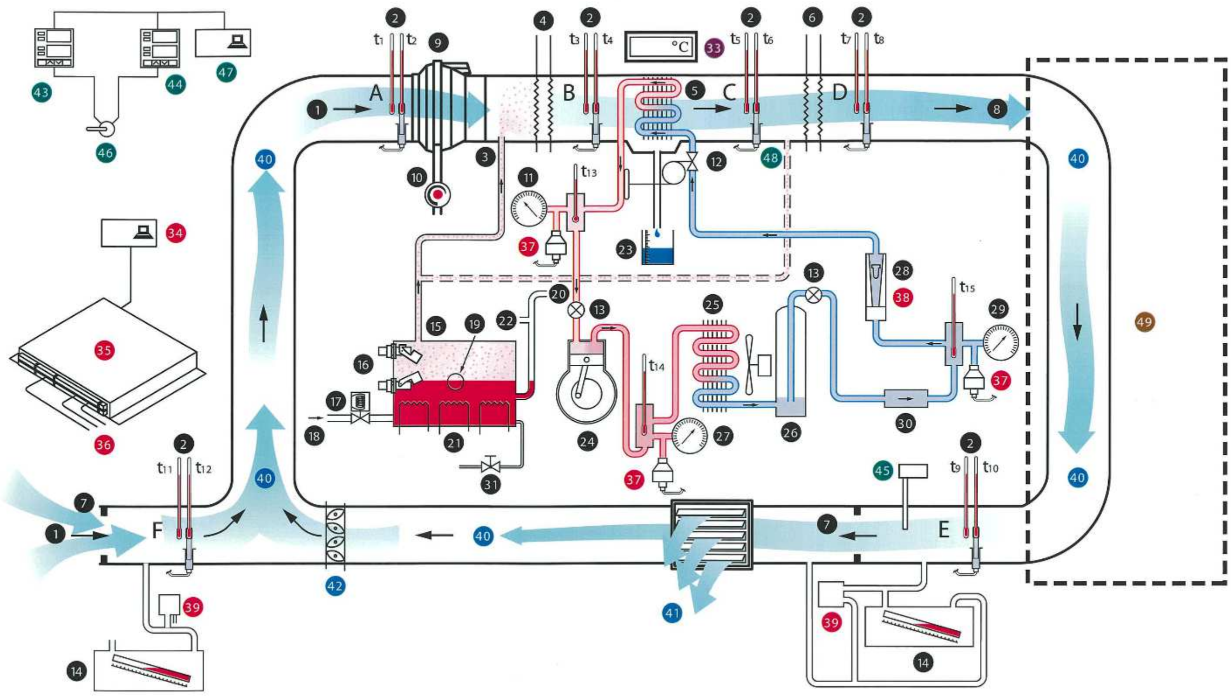
- A660 Air Conditioning Laboratory Unit, with A661B Recirculating Duct Upgrade Kit
- Sling psychrometer

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 flow is set to a low rate with moderate recirculation by controlling 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. Use the sling psychrometer to check the room air conditions.
9) Locate state B, C, D, and E on the psychrometric chart, and fill Table 2.
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.

Air Conditioning Laboratory Unit A660

with Upgrade Kits A661A, A661B, A660C A660D and AC661A



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
16. Water Level Control
17. Solenoid Valve
18. Water Inlet
19. Sight Glass
20. Vent
21. Water Heaters
22. Overflow 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 A661A

32. *15 Way Selector Switch (If Fitted)*
33. *Digital Temperature Indicator*

Computer Linked Upgrade AC661A

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

Air Reciirculating Upgrade A661B

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

PID Control Upgrade A660C

43. *PID Controller - Humidity %RH*
44. *PID Controller - Temperature ºC*
45. *Combined %RH/Temperature Probe*
46. *Manual/PID Control Selector Switch*
47. *Link to PC*
48. *PID Steam Injector*

Environmental Chamber A660D

49. *Environmental Chamber*

Results

The tables provided in the Appendix are for recording the measurement data and calculated parameters. After the experiment, the following information should be established to report the findings.

- Clear presentation of the measurement data
- Determination of the state properties of air and refrigerant from tables or charts
- Calculations to determine the flow rates and draw up energy and mass balances

Discussions

The following issues shall be evaluated and discussed.

- The percentage difference between Q_{BC} and Q_E
- Factors affecting the accuracy of the measurements
- Understanding of various air conditioning processes and use of psychrometric chart

Laboratory Report

Each student should prepare their own report based on the data and information obtained during the experiment. While the results from the observations and measurements can be shared among the members in the same student group, each student shall generate information to show his/her own understanding and ideas. Students making direct copy of the information in other's report (plagiarism), if found, will be disqualified.

The laboratory report in PDF format shall be submitted to the Moodle before the deadline. Late submission will receive reduction in marks.

References

ASHRAE, 2017. *ASHRAE Handbook Fundamentals 2017*, SI edition, Chp. 1: Psychrometrics, American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Atlanta, GA.

Gatley, D. P., 2005. *Understanding Psychrometrics*, 2nd ed., American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Atlanta, GA.

Web Links

Free Online Psychrometric Chart http://www.flycarpet.net/en/PsyOnline
The basic psychrometric processes (Oct 2009) http://www.cibsejournal.com/cpd/2009-10/

/SH/1710/

Appendix

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 Pre-heat and Steam Injection	Dry	t_3	° C			
		Wet	t_4	° C			
C	After Cooling/ Dehumidification	Dry	t_5	° C			
		Wet	t_6	° C			
D	After Re-heating	Dry	t_7	° C			
		Wet	t_8	° C			
E	Return Air	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 AC			
Evaporator Outlet Pressure			P_1	kPa (gauge)			
Condenser Inlet Pressure			P_2	kPa (gauge)			
Condenser Outlet Pressure			P_3	kPa (gauge)			
Fresh Air Intake Differential Pressure			Z_F	mm H_2O			
Duct Differential Pressure			Z_E	mm H_2O			
Fan Supply Voltage			V_F	Volts AC			
Condensate Collected			m_c	grams			
Time interval to collect condensate			Δt	s			
Mass flow rate of condensate water			$m_c/(1000)\Delta t$	kg/s			
R-134a mass flow rate*			m_{ref}	g/s			

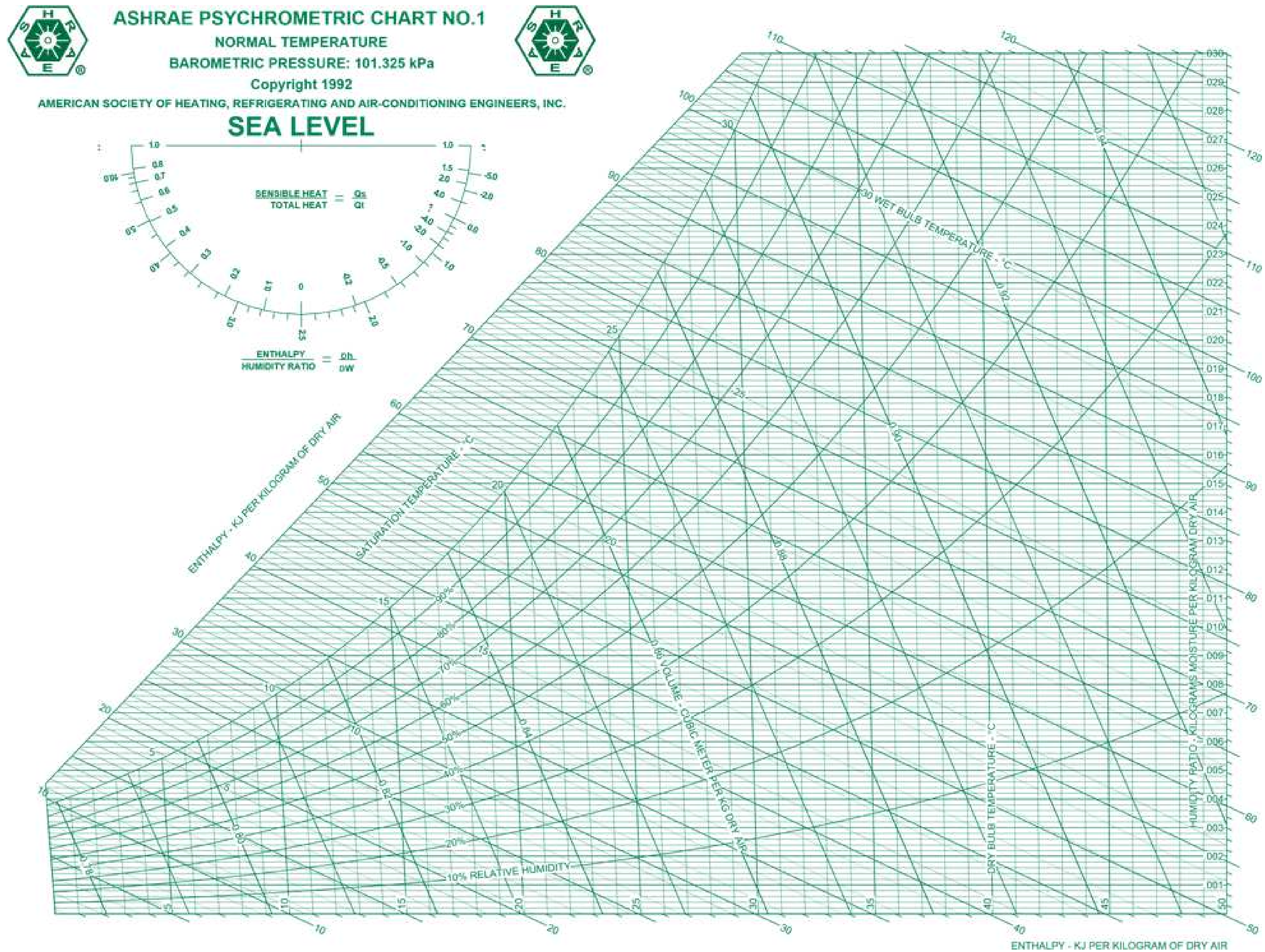
*** Divided by 1000 to get the mass flow rate in kg/s**

Table 2. Air properties

State	DBT [°C]	WBT [°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
$\dot{m}_a$			
Q_{BC}			
Q_{CD}			
h_{13}			
h_{15}			
Q_E			
$(Q_{BC} - Q_E)$*100/ Q_E			


ASHRAE PSYCHROMETRIC CHART NO.1
NORMAL TEMPERATURE
BAROMETRIC PRESSURE: 101.325 kPa
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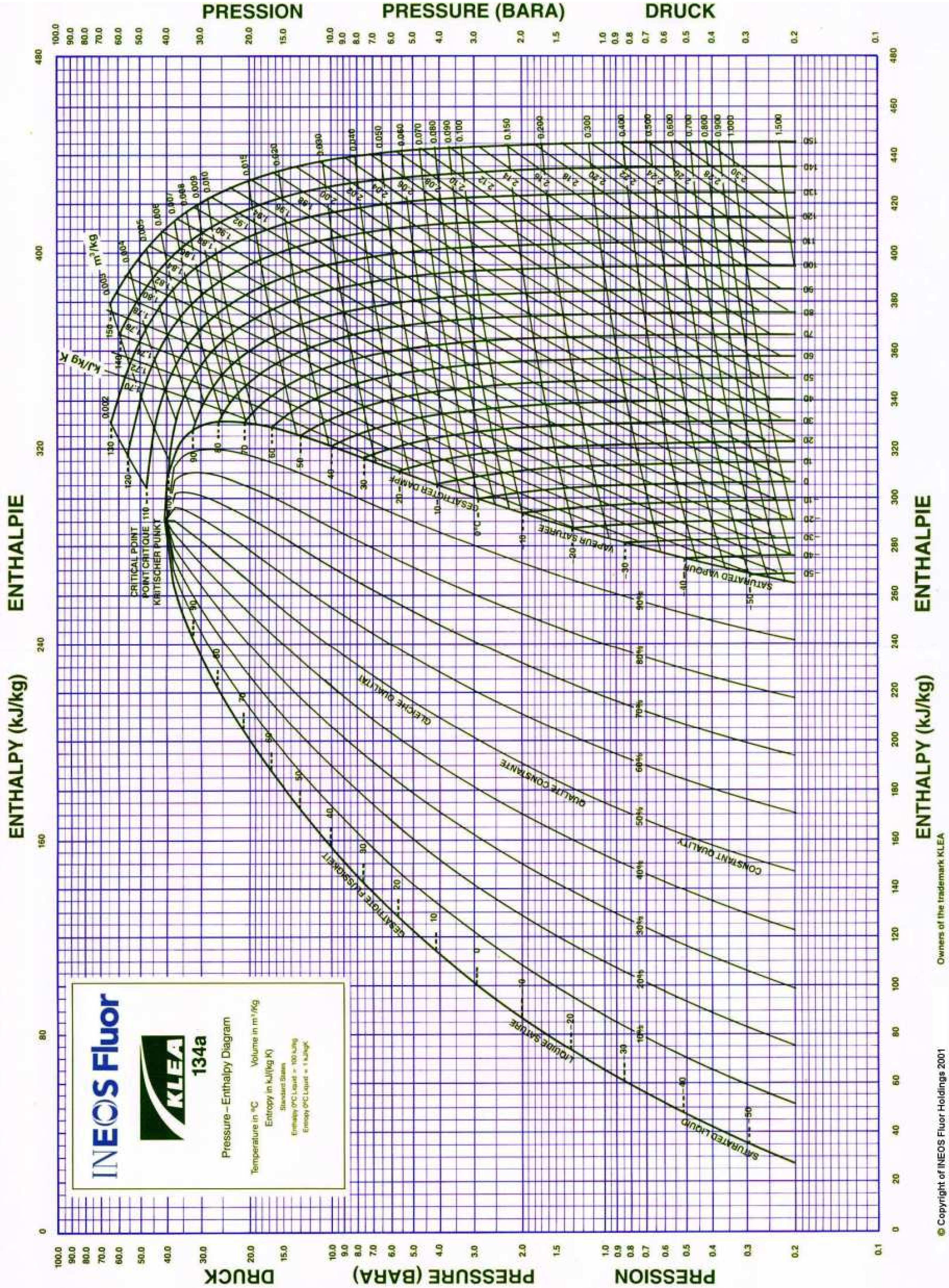
AMERICAN SOCIETY OF HEATING, REFRIGERATING AND AIR-CONDITIONING ENGINEERS, INC.
SEA LEVEL
SENSIBLE HEAT / TOTAL HEAT = Qs / Qt
ENTHALPY / HUMIDITY RATIO = Δh / ΔW
ENTHALPY - KJ PER KILOGRAM OF DRY AIR
SATURATION TEMPERATURE - °C
WET BULB TEMPERATURE - °C
VOLUME - CUBIC METER PER KG DRY AIR
10% RELATIVE HUMIDITY
DRY BULB TEMPERATURE - °C
HUMIDITY RATIO - KILOGRAMS MOISTURE PER KILOGRAM DRY AIR
ENTHALPY - KJ PER KILOGRAM OF DRY AIR


PRESSION
PRESSURE (BARA)
DRUCK
ENTHALPY (kJ/kg)
ENTHALPIE
INEOS Fluor
KLEA
134a
Pressure – Enthalpy Diagram
Temperature in °C
Volume in m³/Kg
Entropy in kJ/(kg K)
CRITICAL POINT
POINT CRITIQUE
KRITISCHER PUNKT
SATURATED LIQUID
LIQUIDE SATURE
SATURATED VAPOUR
VAPEUR SATUREE
GESATTIGTER DAMPF
CONSTANT QUALITY
QUALITE CONSTANTE
GLEICHE QUALITAT
kJ/kg K
m³/kg
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