Refrigeration & Air Conditioning

MEP451

Introduction

March 2009

1

Introduction

Definitions

Importance of Refrigeration and Air conditioning

Basic dimensions and SI units

Derived SI units

Basic English units

Derived English units

First Law of thermodynamics

Second law of thermodynamics

T-s, P-v and P-h diagrams

Carnot heat engine and Carnot refrigerator

Main parts of central AC system

Basic on-off control

2

Definitions

Air conditioning:

The science of conditioning the air. It may involves heating, cooling, humidification, dehumidification, and filtering

Refrigeration

Any method by which one can reduce the temperature of a body or a surface lower than the ambient temperature

HVAC: Heating, Ventilating on and Air Conditioning

ASHRAE=American Society of Heating, Refrigeration and Air conditioning Engineers (www.ashrae.org)

CIBSE=The Chartered Institution of Building Services Engineers (www.cibse.org)

3

Importance & Applications of Refrigeration and Air Conditioning

Air Conditioning

Human comfort in housing, at work and while traveling

Air condition in hospitals

Conditioning the air for certain industrial applications (i.e. food drying)

Air conditioning of the two holy mosques

Air conditioning in campuses (Ex. 4 units at KAU each of capacity 6000 tons)

District cooling (Dubai)

Refrigeration

Reservation of food (banana, apple, meat, etc)

Frozen meat and chicken (poultry)

Frozen of meat during Hajj season in Mena

Air conditioning

4

Basic SI Dimensions and Units

No	Parameter	Dimension	Units
1	Mass	M	Kg
2	Length	L	m
3	Time	T	s
4	Temperature	θ	°C or K

5

Derived SI units

No	Parameter	SI unit
1	F=Force	Newton, N
2	P=Pressure	Pascal, P
3	W=Work or Energy	Joule, J
4	$\dot{W}$ =Power	Watt, W

1 ton of refrigeration=12,000 Btu/hr=3.52 kW

Amount of heat removed from an English ton of liquid water at 32°F and transfer it into ice.

6

Basic English Units

No	Parameter	Dimension	SI unit
1	Mass	M	lbm (pound mass)
2	Length	L	ft
3	Time	T	s
4	Temperature	θ	°F and R

7

Derived English Units

No	Parameter	English unit
1	F=Force	lbf
2	P=Pressure	psi
3	W=Work or Energy	Btu, lbf-ft
4	Power	HP, Btu/hr, lbf-ft/s

8

Some conversion factors

1 kg=2.2 lbm
1 m=3.28 ft
°C=(°F-32)/1.8
1 Δ °C=1.8 Δ °F
1 N =0.224 lbf
1 kPa=0.1451 psi
1 Btu=1.055 kJ
1 Btu/lbm=2.33 kJ/kg
1 HP≈0.75 kW
1 Btu=778 lbf.ft
1 Ton of refrigeration =12,000 Btu/hr=3.52 kW
1 HP=550 lbf.ft/s=550 (lbf.ft/s) (3600 s/hr)* (Btu./(778 lbf.ft))=2545 Btu/hr
1 HP= 2545 Btu/hr
1 W=3.41 Btu/hr

9

First Law of Thermodynamics

For an infinitesimal process

$$\delta Q - \delta W = d\,E$$

For finite process

$$Q_{12} - W_{12} = \Delta E = E_2 - E_1$$

For a cycle

$$\oint Q - \oint W = 0$$

$$\sum Q = \sum W$$

10

First Law of Thermodynamics

For open system: Control Volume

$$\dot{Q} - \dot{W} = \sum_o \dot{m}_o \left(h_o + \frac{1}{2}V_o^2 + g z_o \right) - \sum_i \dot{m}_i \left(h_i + \frac{1}{2}V_i^2 + g z_o \right)$$

Unit of each term = Watt

11

Second Law of Thermodynamics

For a system

$$\Delta S \geq \int \frac{\delta Q}{T}$$

For a control volume

$$\frac{dS}{dt} + \sum \dot{m}_e s_e - \sum \dot{m}_i s_i \geq \int \frac{\delta \dot{Q}}{T}$$

12

Ideal Equation of state

SI units

$$PV = mRT$$

R=Ru/M
Ru=8.314 kJ/(kmole.K)
The molecular weight of air is around 29 kg/kmole
Then the air gas constant is
R=8.314/29=0.287 kJ/kg.K

English units

Ru=1544 ft.lbf/kmoleR
for air
R=Ru/M=1544/29=53.35 ft.lbf/(lbm.R)

13

Idea of unit conversion

V=Car speed 100 km/hr

$$100\frac{km}{hr} * \frac{1000\,m}{\text{km}} * \frac{hr}{3600\,\text{s}} = 100\frac{1}{3.6}\,m/s$$

14

Example on unit conversion

Specific heat of liquid water

C_p=4.2 kJ/kg.K

$$4.2\frac{kJ}{kg.K} * \frac{1Btu}{1.055kJ} * \frac{kg}{2.2lbm} * \frac{1K}{1.8F} = \frac{4.2}{1.055*2.2*1.8} = 1Btu/(lbm.F)$$

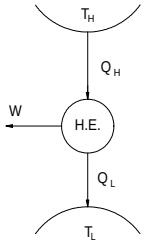
15

Carnot Heat Engine

$$\eta = \frac{W_{net}}{Q_H} = \frac{w_{net}}{q_H}$$

$$\eta_{carnot} = \eta_{th,rev} = \frac{T_H - T_L}{T_H}$$

$$\eta_{th,rev} = 1 - \frac{T_L}{T_H}$$

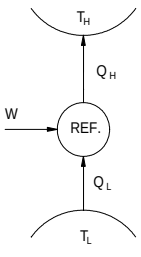


16

Carnot Refrigerator

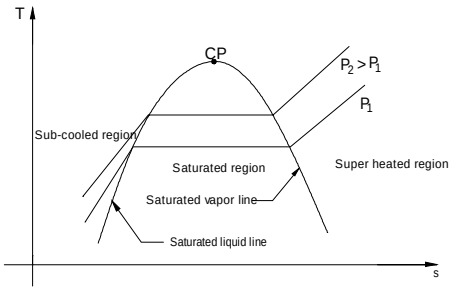
$$C.O.P. = \frac{Q_L}{W} = \frac{q_L}{w}$$

$$(C.O.P)_{rev,R} = \frac{Q_L}{Q_H - Q_L} = \frac{T_L}{T_H - T_L} = \frac{1}{T_H/T_L - 1}$$



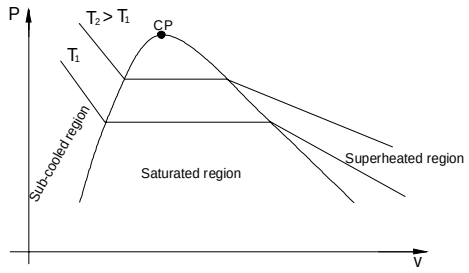
17

T-s Diagram



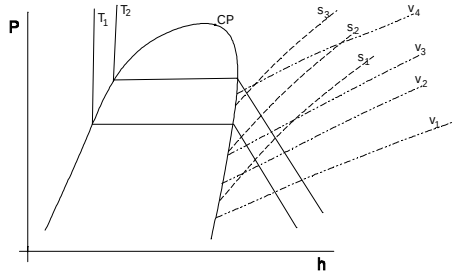
18

P-v Diagram



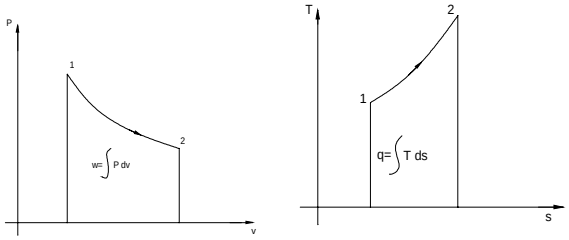
19

P-h Diagram



20

Area Under reversible process on T-s and P-v diagrams



21

Basic components of AC system

Cooling coil (sensible and latent cooling)

Heating Coil

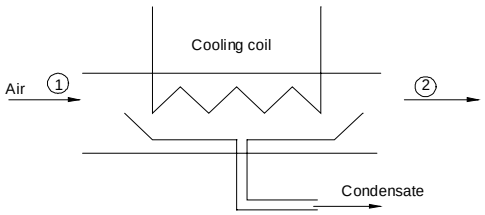
Humidifier

Filter

Fan

22

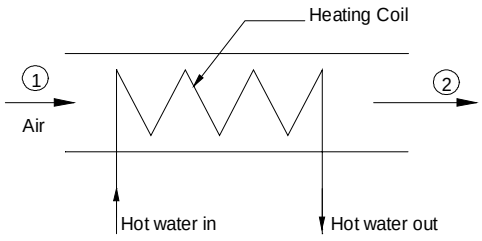
Cooling Coil or C.C.



Cooling coils can be A DX (direct expansion) coil or a chilled water type

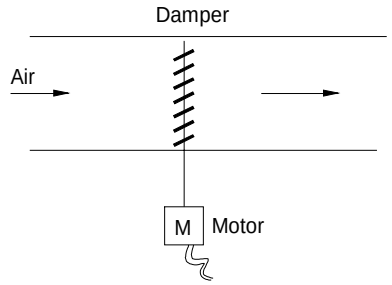
23

Heating Coil or H.C.



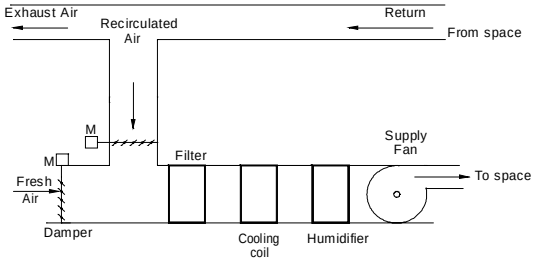
24

Air Damper



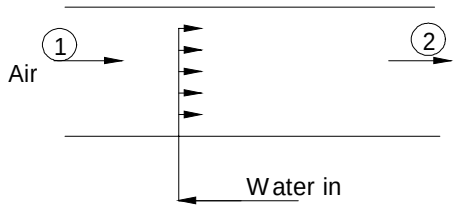
25

Air Hander Unit AHU



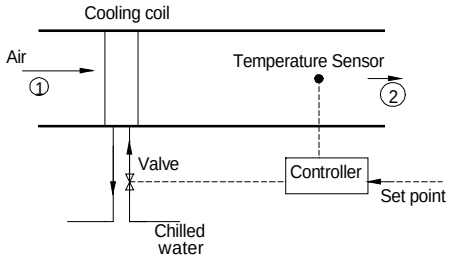
26

Humidifier



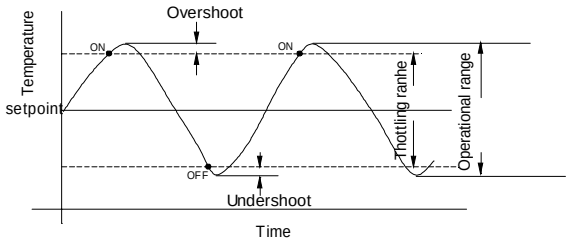
27

Basic On-OFF Control



28

Basic On-OFF Control



29