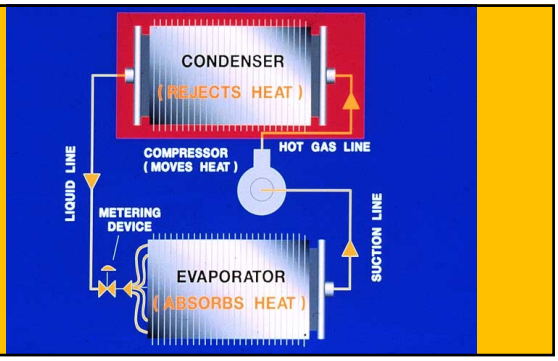
Condensers, Chillers
By
Ramesh Paranjpey
Fellow Life member ASHRAE
Cell No.+91-9822398220
Mail: Ramesh.paranjpey@gmail.com
Web:http://Ramesh-paranjpey.com

1

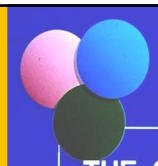
BASIC COMPONENTS OF A REFRIGERATION SYSTEM

- EVAPORATOR
- CONDENSER
- COMPRESSOR
- LIQUID METERING DEVICE

2

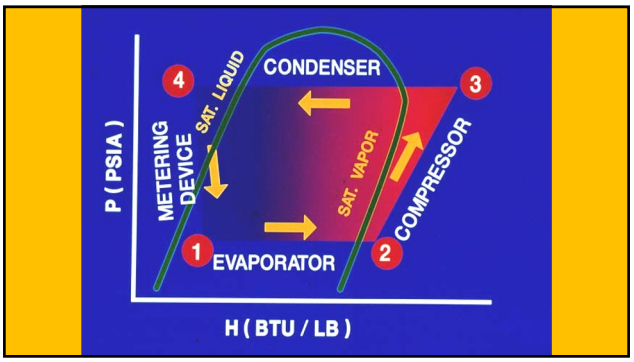


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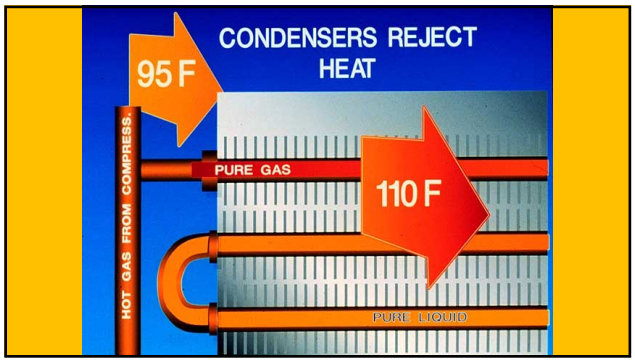


THE CONDENSER IS A DEVICE FOR REMOVING HEAT FROM THE REFRIGERATION SYSTEM

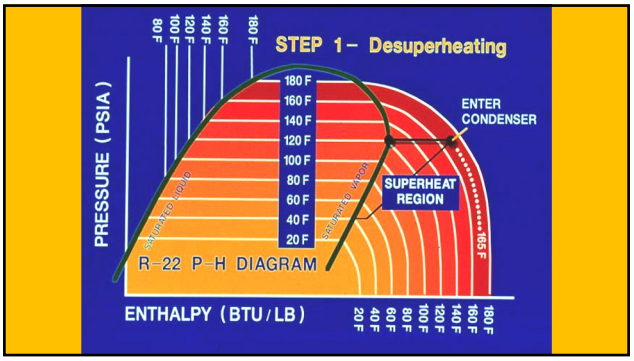
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P (PSIA)
METERING DEVICE
SAT. LIQUID
CONDENSER
SAT. VAPOR
COMPRESSOR
EVAPORATOR
H (BTU / LB)

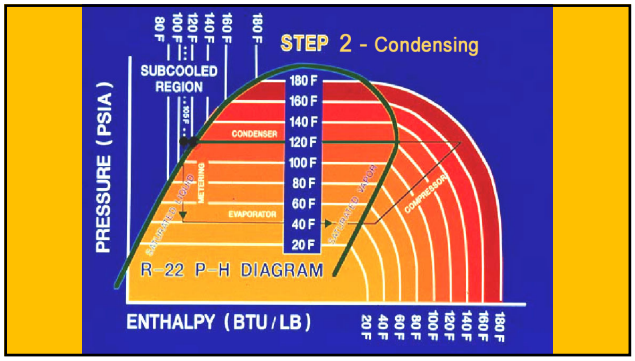
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CONDENSERS REJECT HEAT
95 F
HOT GAS FROM COMPRESS.
PURE GAS
110 F
PURE LIQUID

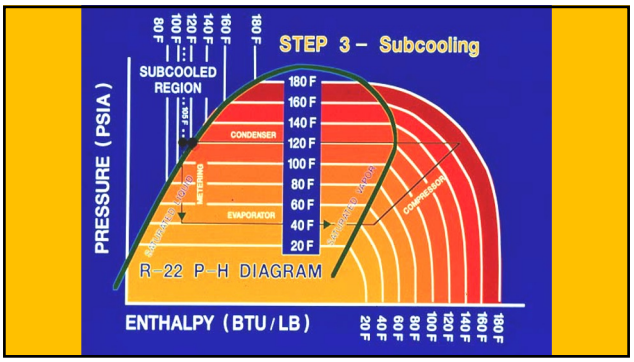
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STEP 1 – Desuperheating
PRESSURE (PSIA)
ENTER CONDENSER
SUPERHEAT REGION
R-22 P-H DIAGRAM
ENTHALPY (BTU / LB)

7

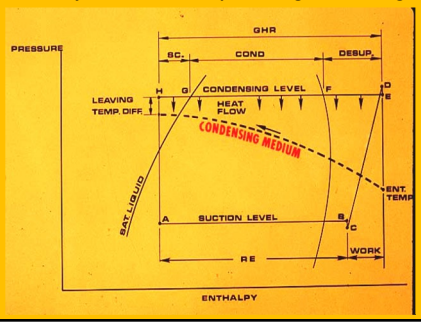

STEP 2 - Condensing
PRESSURE (PSIA)
SUBCOOLED REGION
CONDENSER
EVAPORATOR
R-22 P-H DIAGRAM
ENTHALPY (BTU / LB)

8



9

Condenser Heat Rejection-GHR=De-superheating+ Condensing+ Subcooling



10

1. CONDENSER HEAT REJECTION FACTOR : $\frac{\text{CONDENSER HEAT REJECTION}}{\text{REFRIGERATION EFFECT}}$

THEN: CHR = RE X HRF

2. CONDENSER HEAT REJECTION: R.E. + BHP X 2545

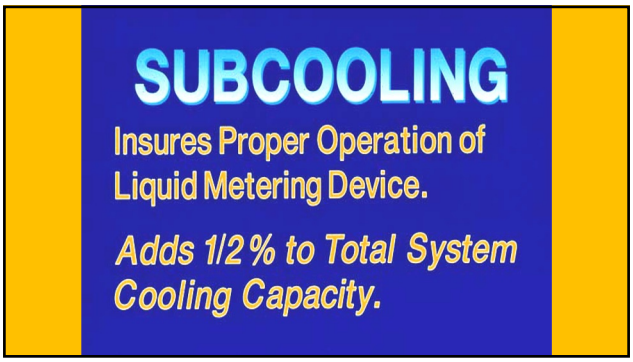
3. CONDENSER HEAT REJECTION = R.E. + KW X 3414

11

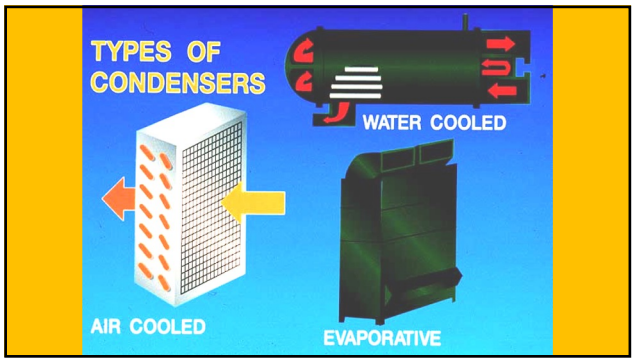
CONDENSER HEAT REJECTION IS EQUAL TO

Compressor Capacity in kW +Power consumed by motor in kW=Condenser Capacity in kW

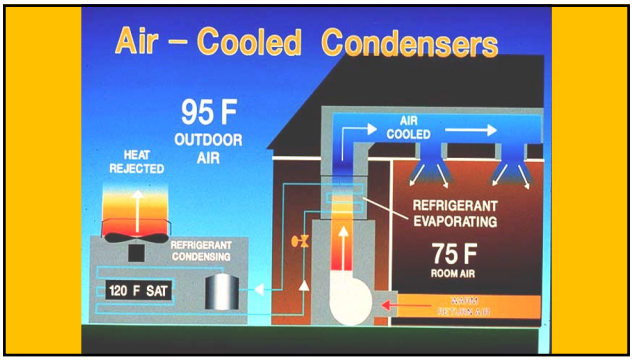
12


SUBCOOLING
Insures Proper Operation of Liquid Metering Device.
Adds 1/2% to Total System Cooling Capacity.

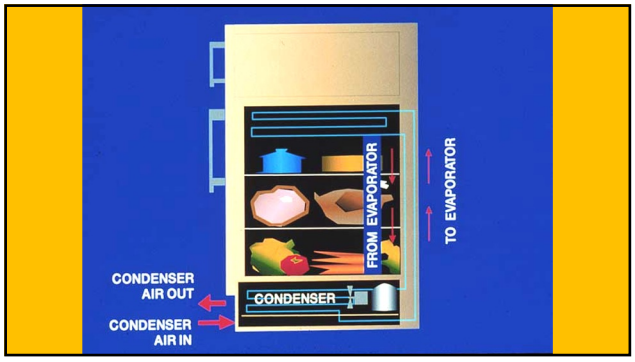
13


TYPES OF CONDENSERS
WATER COOLED
AIR COOLED
EVAPORATIVE

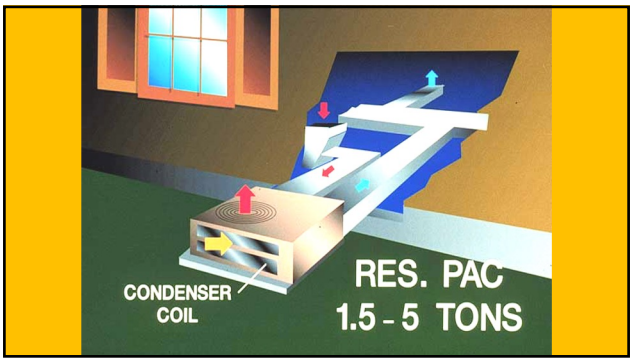
14


Air – Cooled Condensers
95 F
OUTDOOR AIR
HEAT REJECTED
AIR COOLED
REFRIGERANT EVAPORATING
75 F
ROOM AIR
REFRIGERANT CONDENSING
120 F SAT

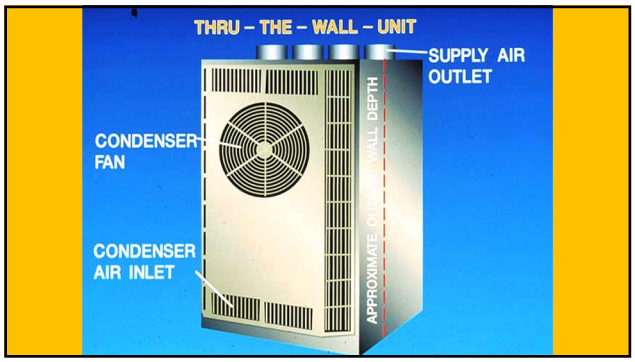
15


FROM EVAPORATOR
TO EVAPORATOR
CONDENSER
CONDENSER AIR OUT
CONDENSER AIR IN

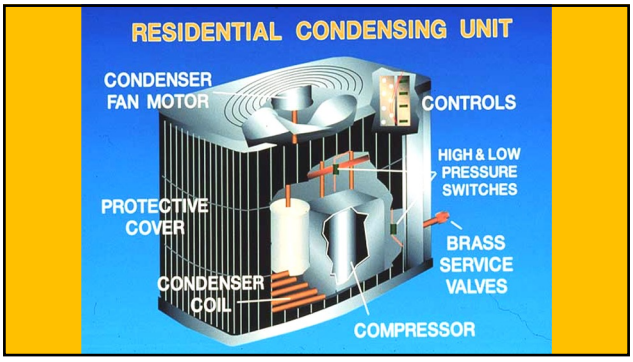
16


CONDENSER
COIL
RES. PAC
1.5 - 5 TONS

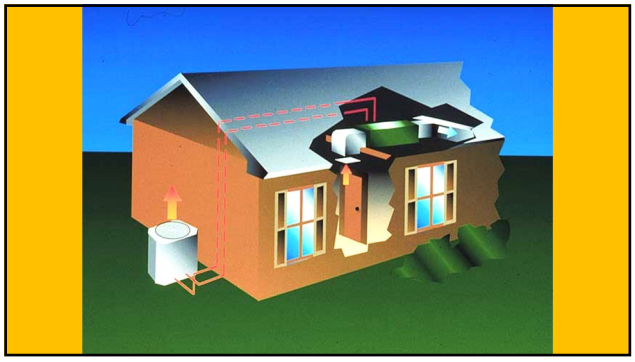
17


THRU – THE – WALL – UNIT
SUPPLY AIR
OUTLET
CONDENSER
FAN
CONDENSER
AIR INLET
APPROXIMATE OUTSIDE WALL DEPTH

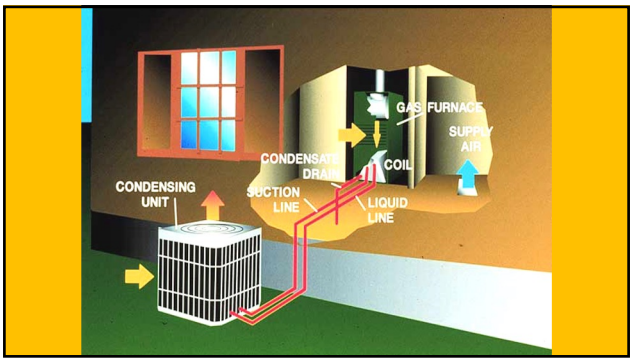
18


RESIDENTIAL CONDENSING UNIT
CONDENSER
FAN MOTOR
CONTROLS
HIGH & LOW
PRESSURE
SWITCHES
PROTECTIVE
COVER
BRASS
SERVICE
VALVES
CONDENSER
COIL
COMPRESSOR

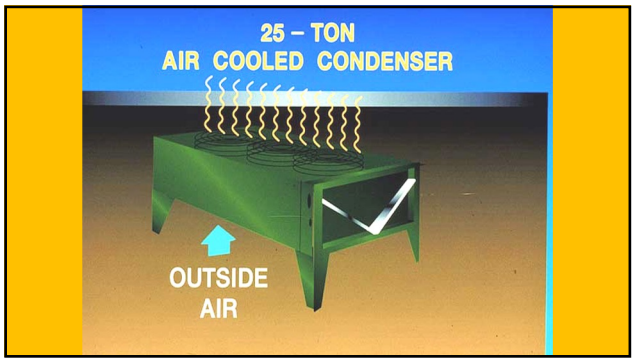
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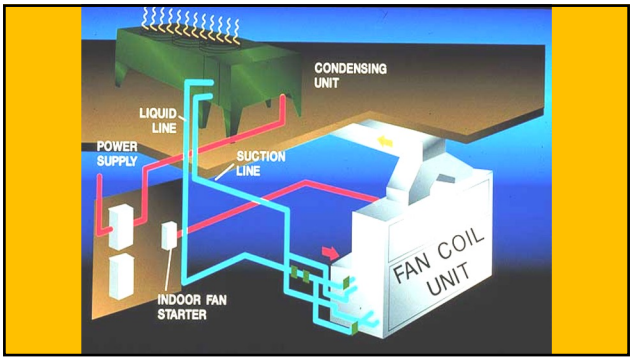
20


GAS FURNACE
SUPPLY AIR
COIL
CONDENSATE DRAIN
CONDENSING UNIT
SUCTION LINE
LIQUID LINE

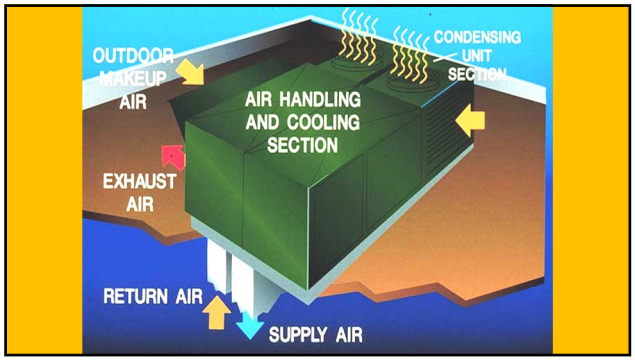
21


25 – TON
AIR COOLED CONDENSER
OUTSIDE AIR

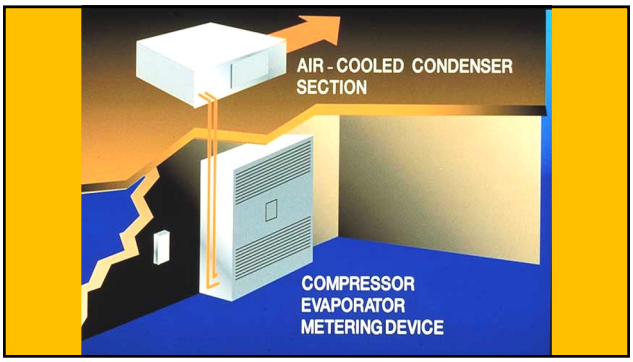
22


CONDENSING UNIT
LIQUID LINE
POWER SUPPLY
SUCTION LINE
FAN COIL UNIT
INDOOR FAN STARTER

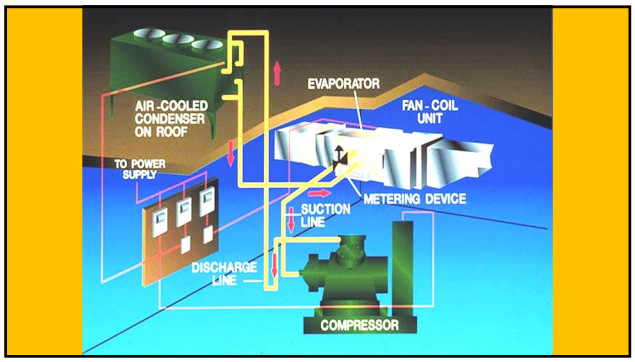
23


OUTDOOR MAKEUP AIR
CONDENSING UNIT SECTION
AIR HANDLING AND COOLING SECTION
EXHAUST AIR
RETURN AIR
SUPPLY AIR

24


AIR - COOLED CONDENSER SECTION
COMPRESSOR
EVAPORATOR
METERING DEVICE

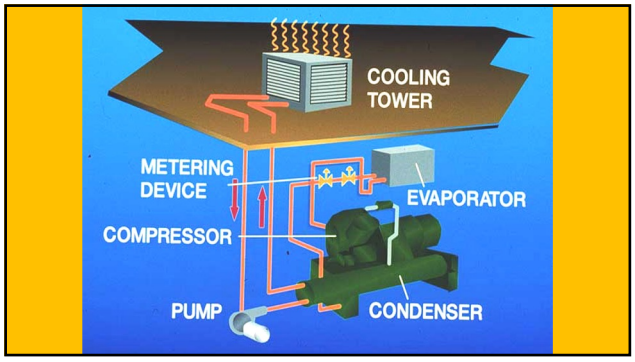
25


EVAPORATOR
AIR - COOLED CONDENSER ON ROOF
FAN - COIL UNIT
TO POWER SUPPLY
METERING DEVICE
SUCTION LINE
DISCHARGE LINE
COMPRESSOR

26

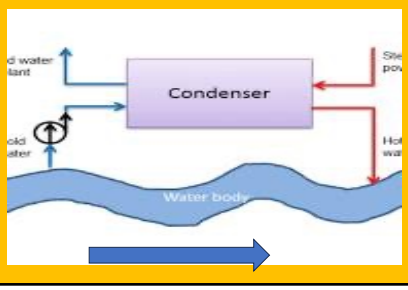

AIR COOLED CONDENSING UNIT FOR DUCTED, INSIDE LOCATION
CENTRIFUGAL FAN
AIR DISCHARGE
AIR INTAKE

27


COOLING TOWER
METERING DEVICE
EVAPORATOR
COMPRESSOR
PUMP
CONDENSER

28

ONCE THROUGH SHELL & TUBE CONDENSER



29

Once Through Shell & Tube Condenser

CONDENSING TEMPERATURE	105° F.
LEAVING DIFFERENCE	10°
LEAVING WATER TEMP.	95°
ENTERING WATER TEMP.	75°
WATER RISE	20° F.

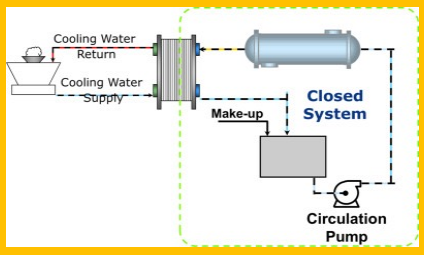
$$\text{GPM/TON RE} = \frac{15{,}000 \text{ BTUH}}{20 \times 8.33 \times 60}$$

$$= \frac{15{,}000}{20 \times 500}$$

$$= 1.5$$

30

RECIRCULATED Water-SHELL & TUBE CONDENSER



31

Recirculated Water-Shell & Tube Condenser

CONDENSING TEMPERATURE	105° F.
LEAVING DIFFERENCE	10°
LEAVING WATER TO TOWER	95°
ENTERING WATER FROM TOWER	85°
WATER RISE	10° F.

$$\text{GPM/TON RE} = \frac{15{,}000 \text{ BTUH}}{10 \times 8.33 \times 60}$$

$$= \frac{15{,}000}{10 \times 500}$$

$$= 3.0$$

32

Evaporative Condenser/Cooling Tower

*EVAPORATION

$$\frac{15{,}000}{1{,}000} = 15 \text{ LB./HR./TON}$$

*BLEED-OFF

EQUAL TO EVAPORATION = 15 LB./HR./TON

TOTAL = 30

$$\text{GPM} = \frac{30}{8.33 \times 60} = .06 \text{ GPM/TON}$$

*WINDAGE LOSS

.2 % x 3 GPM/TON = .006 GPM/TON

TOTAL MAKE-UP = .066 GPM/TON

33

Water Saving With Use of Cooling Tower

WATER CONSUMPTION

ONCE-THRU CONDENSER 1.5 GPM/TON

COOLING TOWER .066 GPM/TON

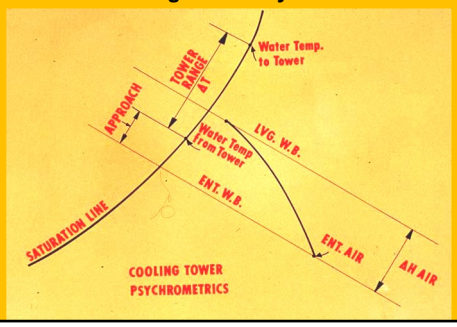
$$\%\text{ TOWER USAGE } \frac{.066}{1.5} \times 100 = 4.4\%$$

SAY 5 %

% WATER SAVING = 100 − 5 = 95 %

34

Cooling Tower Psychrometric



35

Air Cooled CFC/HFC Condenser



36

AIR COOLED AMMONIA CONDENSER



37

ADVANTAGE OF AIR COOLED CONDENSER:-

1 Easy and economical installation
2. Water piping , pumps, cooling tower eliminated
3. Mainly used for HFC/HCFC Refrigerants
4. Applications-Window, Split air conditioners, Car Air conditioners, Truck Refrigeration, Railways, Package Air Conditioners small capacity cold rooms, and many more

Disadvantages:-

1. Consumes more power compared to Water-Cooled condensers

38

In India air cooled condensers for ammonia application are seldom used due to high ambient temperatures experienced in summer. Use of wet pads to cool incoming air on the air-cooled condensers is one of the methods to overcome high ambient temperatures and thus keep discharge temperatures and pressures within limit, this has been tried in few places.

However by and large air-cooled condensers are not used and recommended for ammonia applications in India as water is available in most of the industrial areas.

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ECO MESH AMMONIA AIR COOLED CONDENSER



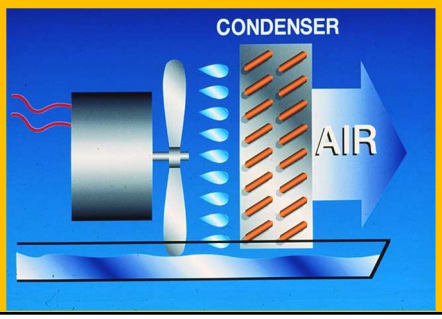
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ADIBATIC WET PAD

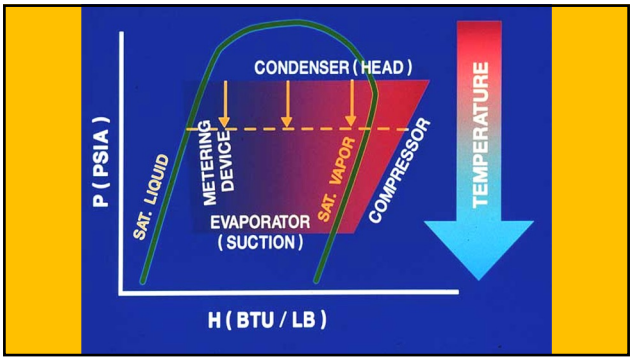


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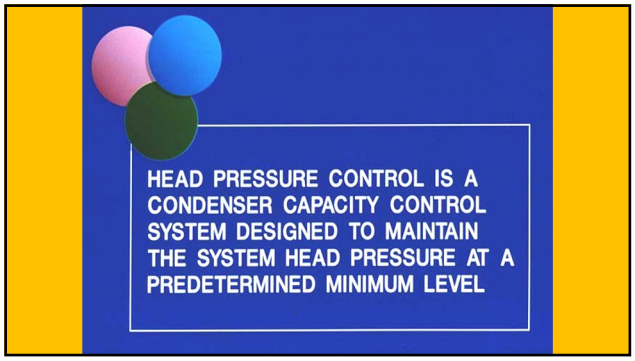
Air Cooled Condenser



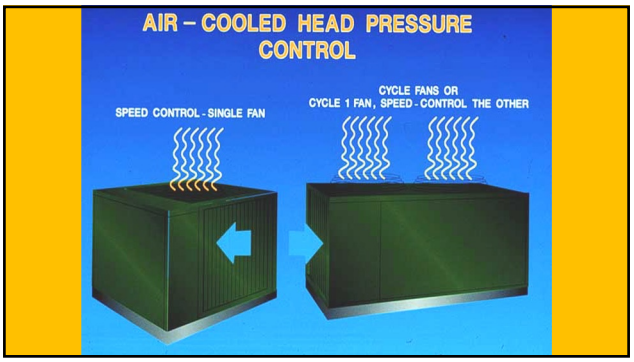
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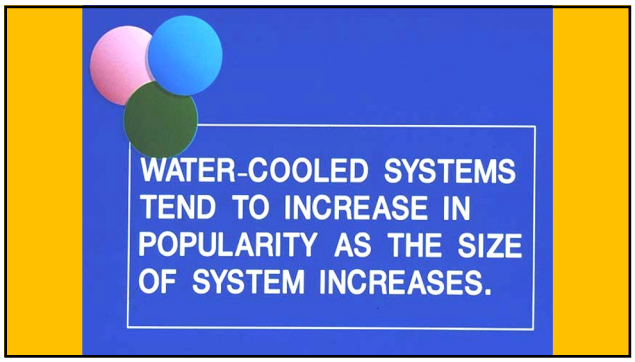
43



44



45



46

WATER COOLED ATMOSPHERIC CONDENSER



47

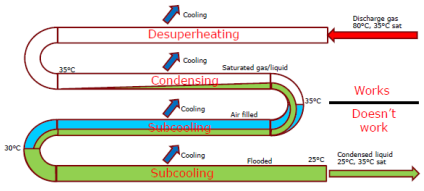
ATMOSPHERIC CONDENER



48

ATMOSPHERIC CONDENSER

Air contamination deteriorate condenser performance



Note: Subcooling is not always a good thing…

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ADVANTAGES:

1. Efficient operation due to low discharge pressures. With 28^{0}C wet bulb temperatures, it is possible to achieve and maintain 37 to 38^{0}C condensing temperatures and thus lower discharge pressures and thereby lower power consumption.
2. The efficiency is better since both sensible and latent heat transfer takes place when water comes in contact with hot tubes carrying ammonia gas.(Heat and Mass Transfer)
3. These condensers are generally site fabricated and thus reduces other incidental costs.
4. Can be attended /repaired while the plant is in operation by isolating particular bank.
5. Additional banks can be added when more capacity is required.
6. Coil surface visible, hence external cleaning can be done in case fouling is observed
7. Requires low pressure/head, water circulation pump
8. Do not require additional fan power, as these do not use fans and depend only on natural air movement.

50

DISADVANTAGES:

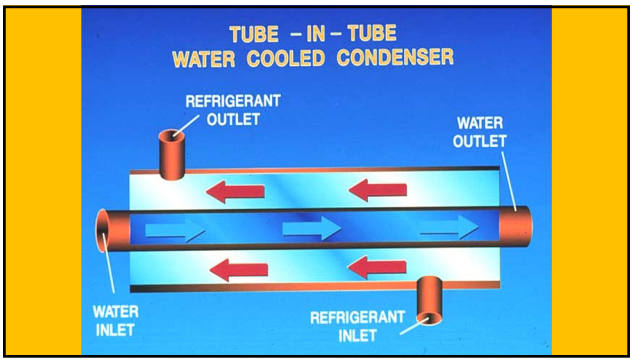
1. Occupies large floor space area. However, this drawback is generally overcome by installing the condenser banks on the roof slab of the machine room.
2. Needs to be kept nearer to machine room to ensure shorter high-pressure ammonia gas pipelines.
3. Spray water losses are high due to wind velocities as water is carried by winds.
4. Due to constantly varying wind velocities and direction, it is always not possible that all spray water will wet the tube surface and hence capacity of condenser may not remain at 100% all the times and fluctuates.
5. Higher pressure drops on discharge side due to longer length of discharge pipe.

51

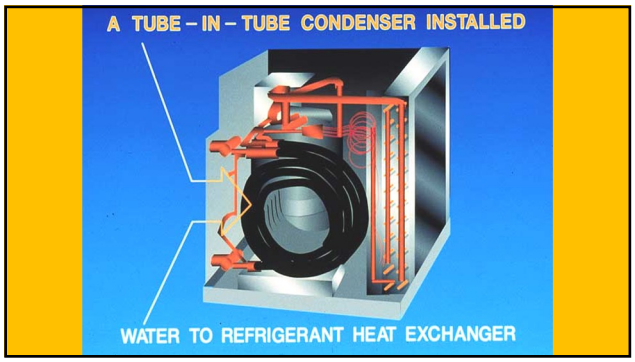
WATER COOLED CONDENSER

1. Tube - in - Tube
2. Shell - and - Coil
3. Shell - and - Tube

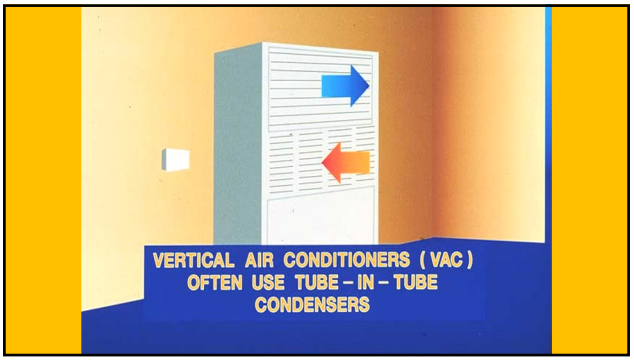
52


TUBE – IN – TUBE
WATER COOLED CONDENSER
REFRIGERANT OUTLET
WATER OUTLET
WATER INLET
REFRIGERANT INLET

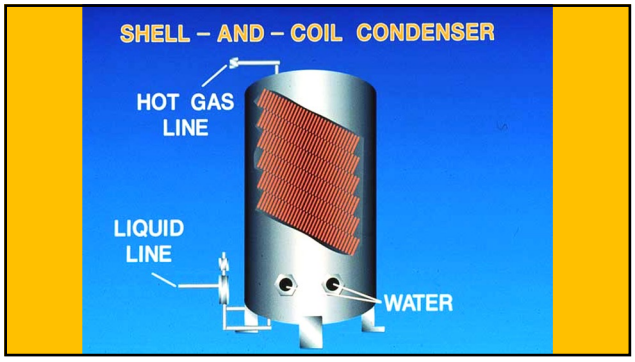
53


A TUBE – IN – TUBE CONDENSER INSTALLED
WATER TO REFRIGERANT HEAT EXCHANGER

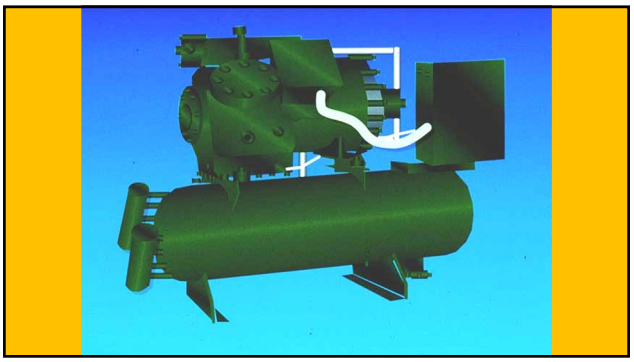
54


VERTICAL AIR CONDITIONERS (VAC)
OFTEN USE TUBE – IN – TUBE
CONDENSERS

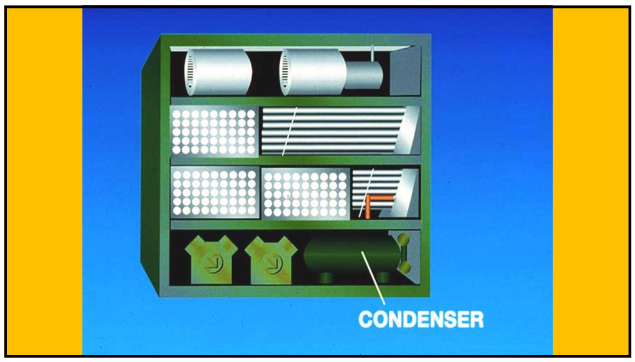
55


SHELL – AND – COIL CONDENSER
HOT GAS LINE
LIQUID LINE
WATER

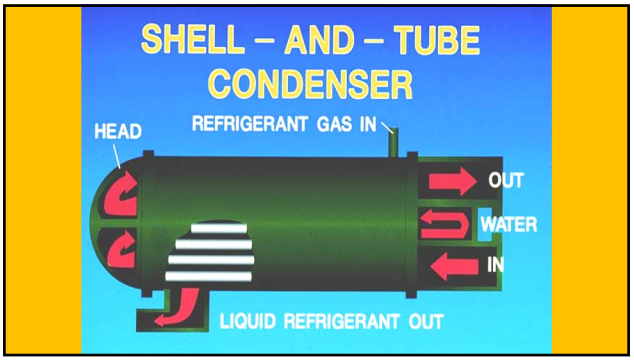
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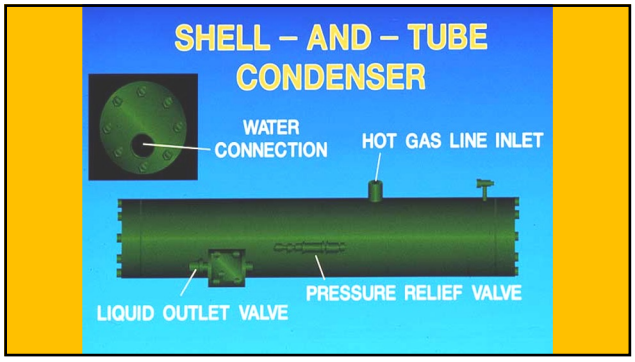
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CONDENSER

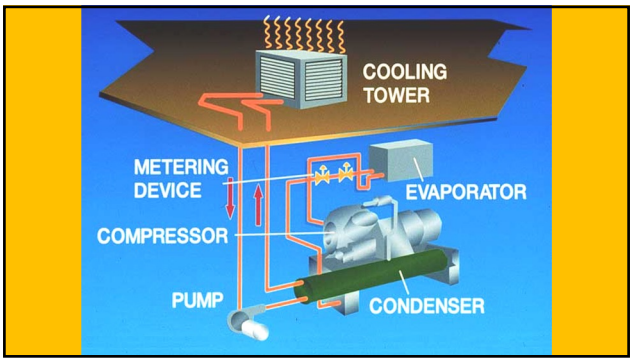
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SHELL – AND – TUBE CONDENSER
HEAD
REFRIGERANT GAS IN
OUT
WATER
IN
LIQUID REFRIGERANT OUT

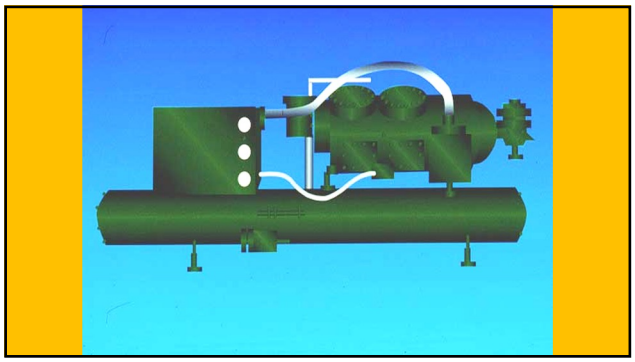
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SHELL – AND – TUBE CONDENSER
WATER CONNECTION
HOT GAS LINE INLET
PRESSURE RELIEF VALVE
LIQUID OUTLET VALVE

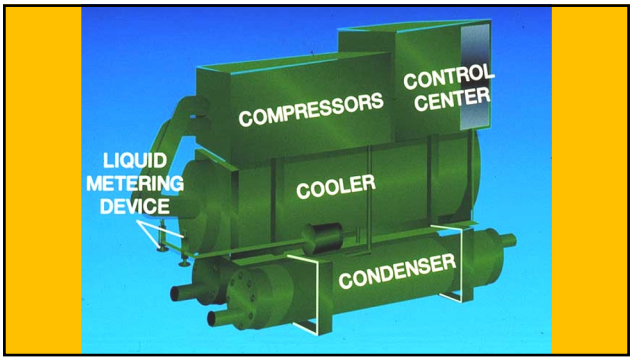
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62



63

Shell and Tube Water Cooled Condenser



64

ADVANTAGES:

1. Compact construction, can be used in skid mounted factory assembled condensing unit
2. The condenser is installed generally in the plant room
3. The discharge pipe line is small
4. Water consumption is less compared to Atmospheric condenser

65

DISADVANTAGES:

1. Requires additional cooling tower and water pump sets with its water piping, valves and controls
2. Cleaning of tubes requires stopping of compressors & dismantling water heads
3. Manufacturing in factory requires special skills and machinery for handling, rolling, welding, tube expansion, testing etc.
4. Cooling tower fans and water pump sets requires extra power.
5. Cleaning of tubes require long wire brushes or chemical cleaning facility
6. Additional space for tube cleaning equal to at least the length of tubes needs to be provided in the machine room.
7. With 28^0C-wet bulb, the water inlet temperature is around 32^0C, water out let temperature is 36^0C and condensing temperature is around 40^0C, which is higher than evaporative or atmospheric condensers.

66

EVAPORATIVE CONDENSERS



67

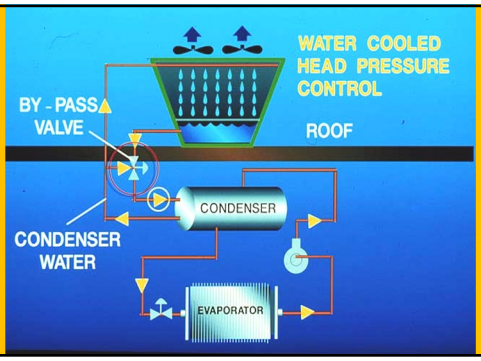


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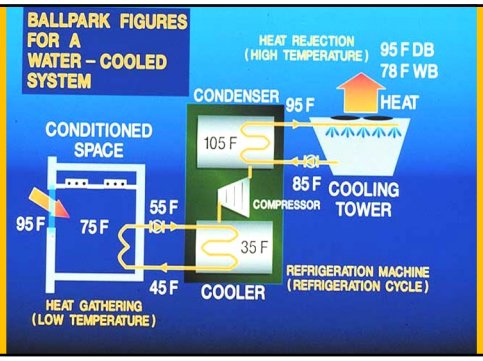


EVAPORATIVE CONDENSERS

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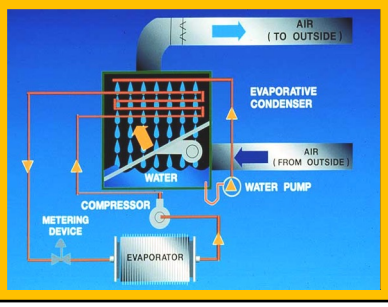


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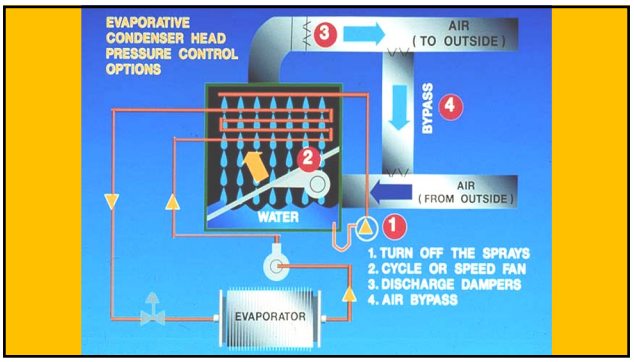


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EVAPORATIVE CONDENSER IN MACHINE ROOM WITH DUCTING

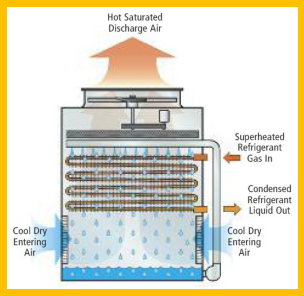


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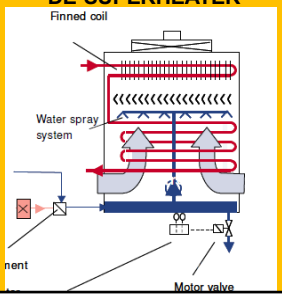
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Draw Through Evaporative Condensers



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HYBRID EVAPORATIVE CONDENSER WITH DE-SUPERHEATER



75

Evaporative Condenser



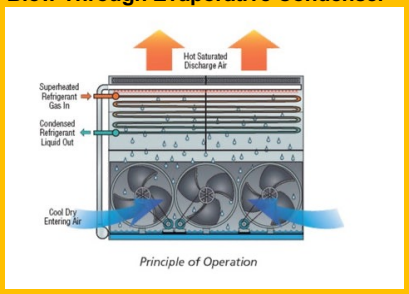
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Evaporative Condensers

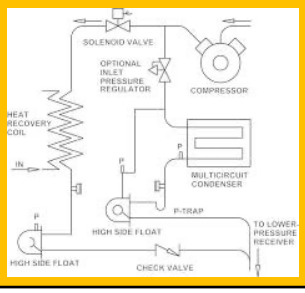
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Blow Through Evaporative Condenser



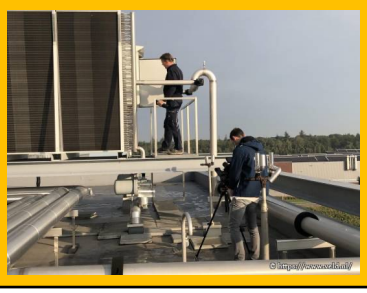
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EVAPORATIVE CONDENSER WITH HIGH SIDE FLOAT AT THE OUTLET



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WITT HIGH SIDE FLOAT CONNECTED TO EVAPORATIVE CONDENSER OUTLET



80

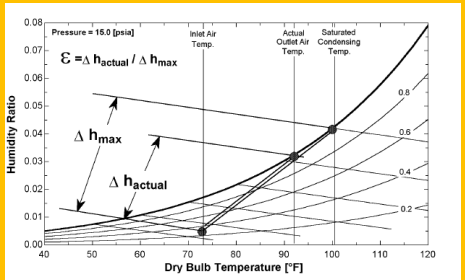


Figure 2.9 Evaporative Condenser Psychrometrics

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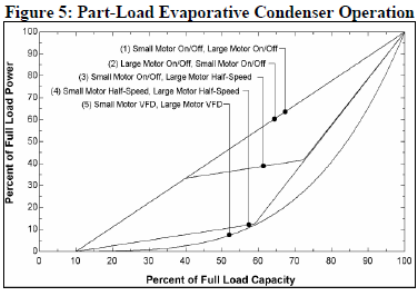
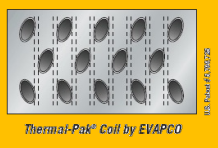


Figure 5: Part-Load Evaporative Condenser Operation

82

Evaporative condenser Tube Arrangement



Thermal-Pak® Coil by EVAPCO



Round Tube Coil by Others

83

Evaporative condenser operation

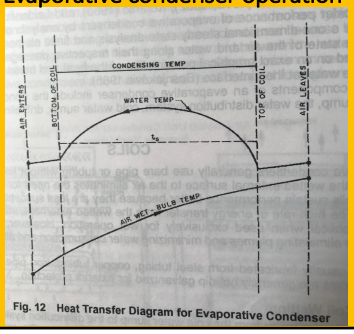


Fig. 12 Heat Transfer Diagram for Evaporative Condenser

84

Type	Evaporative condenser	Shell & Tube condenser
Dry Bulb Temeprature-ºC	40	40
Wet bulb Temperature -ºC	28	28
Water Tank Temperature-ºC	32	32
Water spray Temperature-ºC	32	36
Condensing Temperature-ºC	38	40
Compressor capacity kW(TR)	201.1(57.17)	198.4 (56.39)
Power consumption-kW	45.14	46.88
Power consumption –kW/TR	0.7896	0.831
C.O.P.	4.45	4.23

85

Advantages-

1. Most widely used& popular in Ammonia Refrigeration installations
2. Low Condensing Temperatures-Saving in Power
3. Low Water consumption
4. Low Pump power
5. Low Fan Power
6. Can be kept anywhere, preferably near the machine room

Disadvantage-

1. Required RO or water with lower hardness and impurities
2. Tube Cleaning Difficult as inner tubes are not approachable by hand
3. Requires chemical cleaning
4. Required maintaining water quality in the tanks same as incoming outside source.

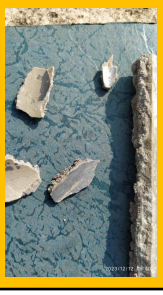
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SCALE FORMING ON TUBES

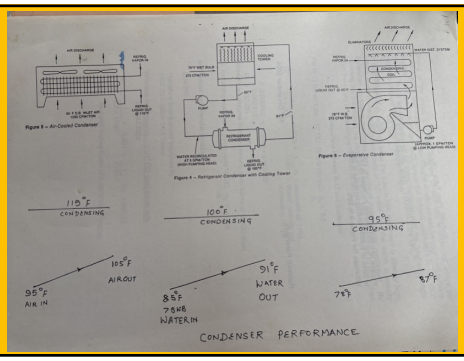


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SCALE FORMING



88



89

PHE SEMI WELDED CONDENSER FOR AMMONIA



90

ADVANTAGES:

1. Extremely compact, enabling factory produced condensing units,
2. High heat transfer coefficients on water as well as ammonia side due to turbulent flow and higher velocities.
3. Capacity can be increased/decreased easily by adding/removing plates
4. Reduces total ammonia charge in the system
5. Reliable product since plates manufactured on automatic machines
6. Longer life due to S.S. construction of plates
7. Chances of ammonia leaking in to water do not exist. If ammonia leaks, it would be to atmosphere and not in the water. This is important since many times cooling towers are common for the entire utilities and other heat exchanger materials may not be compatible with ammonia.

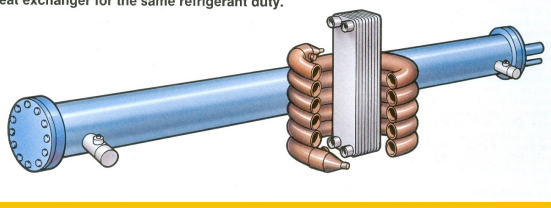
91

Disadvantages

1. Requires chemical cleaning equipment
2. Water quality needs to be monitored and treated water is preferred
3. Ammonia gas has high discharge temperatures and hence proper material for gaskets need to be selected. These may need frequent replacements and are expensive.
4. Higher pressure drops on water and ammonia side due to narrow passages
5. If condensing temperatures lower than 40^0C are required, it is possible with PHE, since PHE can work with very small temperature differences between water temperature and condensing temperature, however initial costs are of PHE are higher compared to other designs.
6. The software available does not recognize two phase conditions i.e. first removal of superheat, then latent heat for condensing and if required sub-cooling. The Refrigerant flow rates for the same capacity indicated are different in condenser than evaporator. The mass flow in system should remain constant, the PHE works out different mass flow rates for condenser and evaporator

92

Size comparison between shell-and-tube heat exchanger, coaxial heat exchanger and brazed heat exchanger for the same refrigerant duty.

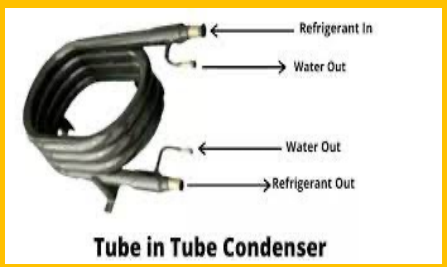


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TUBE IN TUBE CONDENSER



94

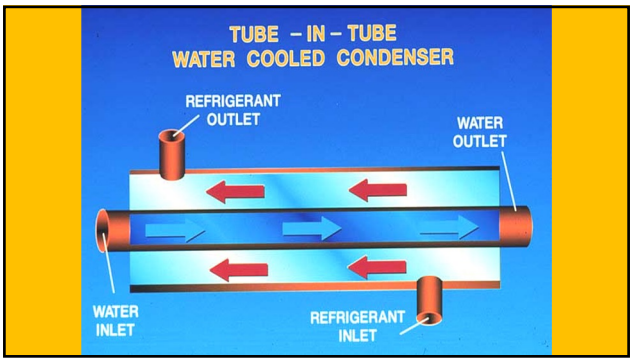


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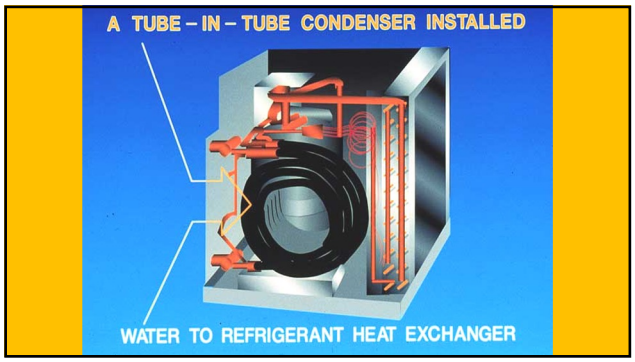
Package Unit Using Tube in Tube condenser



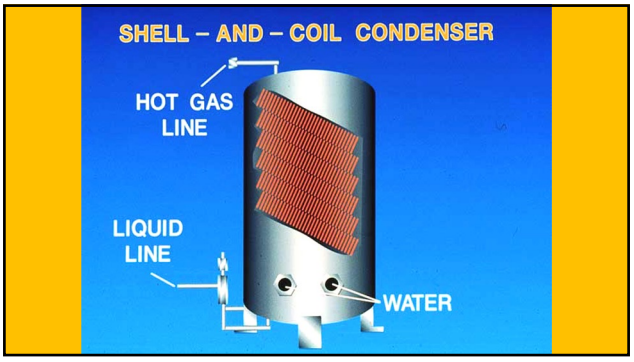
96


TUBE – IN – TUBE
WATER COOLED CONDENSER
REFRIGERANT OUTLET
WATER OUTLET
WATER INLET
REFRIGERANT INLET

97


A TUBE – IN – TUBE CONDENSER INSTALLED
WATER TO REFRIGERANT HEAT EXCHANGER

98


SHELL – AND – COIL CONDENSER
HOT GAS LINE
LIQUID LINE
WATER

99


UNIT USING MICRO CHANNEL CONDENSER

100

VERTICAL CONDENSER



101

WORKING PRINCIPLE

- Ammonia vapor flows over the tubes, while water runs through the tubes. The heat is transferred between the two fluids.
- **Materials**
- The tubes are typically made of steel, while the shell is made of seamless/ERW or rolled shell. Steel is used because ammonia can react with copper and its alloys, causing corrosion.
- **Water flow**
- The cooling water flows down the inner wall of the pipe spirally along gravity. A large amount of water is needed to obtain a large heat transfer coefficient.
- **Baffles**
- Baffles are used to direct the flow of the vapor through the shell. This prevents the vapor from taking a short cut through the shell, which would be ineffective.
- Use- When water is not clean

102

Advantages

1. Can be used with dirty water as water is falling in the tube in spiral manner and tubes are not completely filled with water
2. Can be cleaned when plant is in operation

Disadvantages

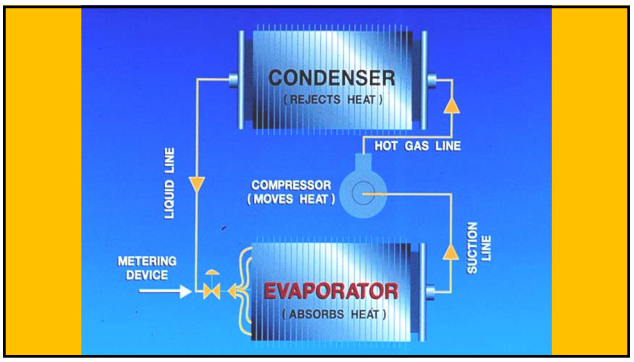
1. Heat transfer is low
2. Requires frequent cleaning
3. Requires more space compared to horizontal Shell & Tube, PHE condensers, very rarely used

103

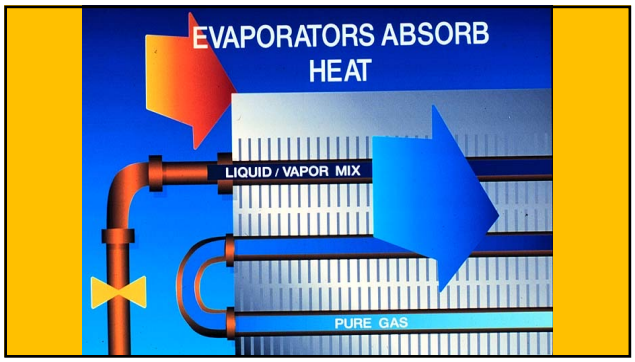
EVAPORATOS/CHILLERS

AIR COOLERS PRESENTATION -
REFER PART-6 FOR MORE DETAILS

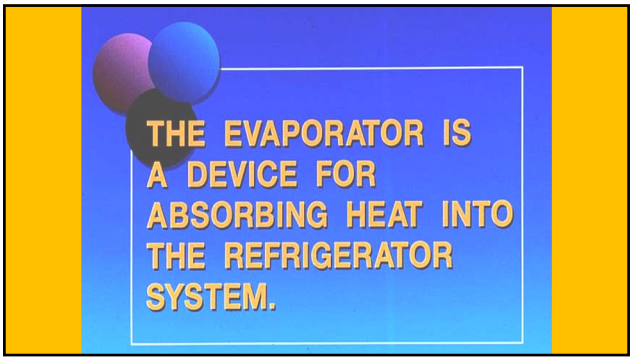
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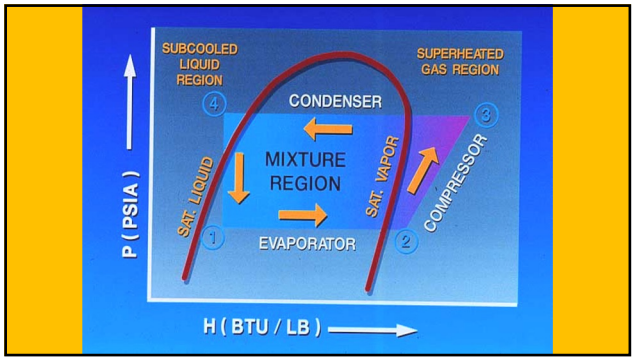
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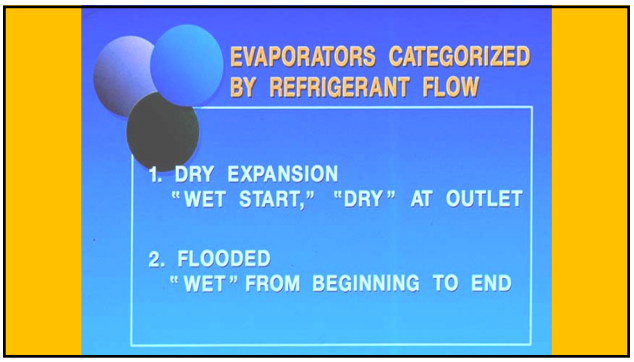
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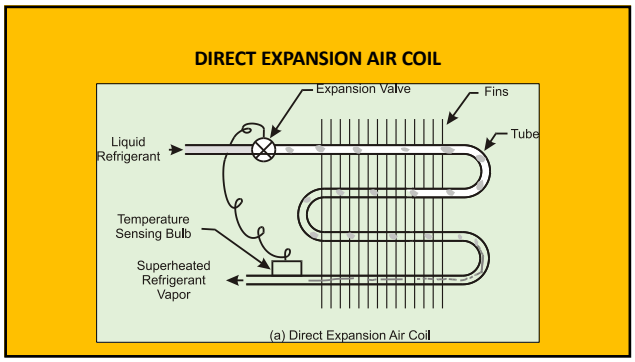
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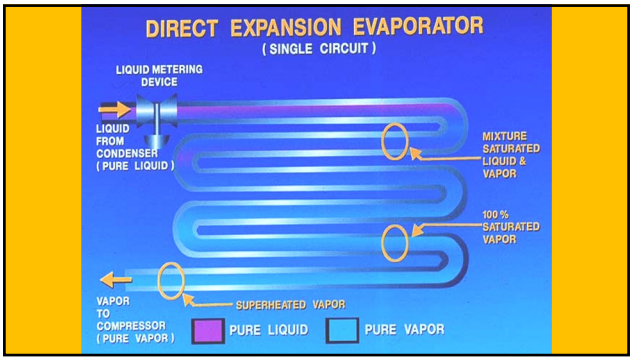
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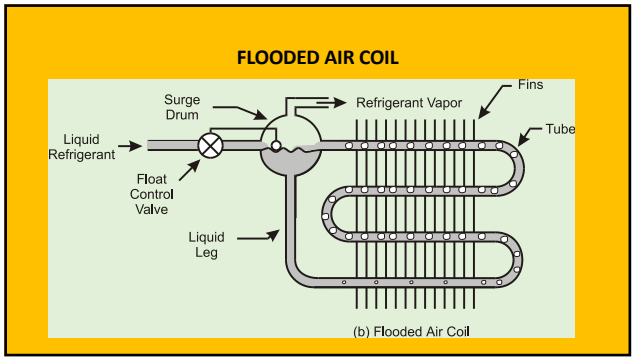
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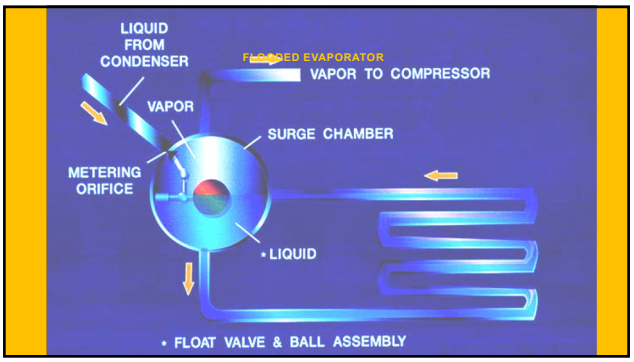
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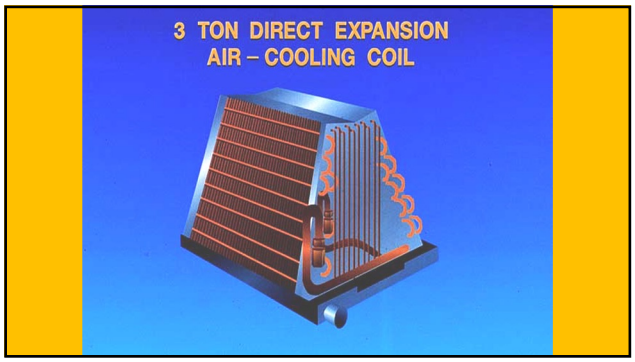
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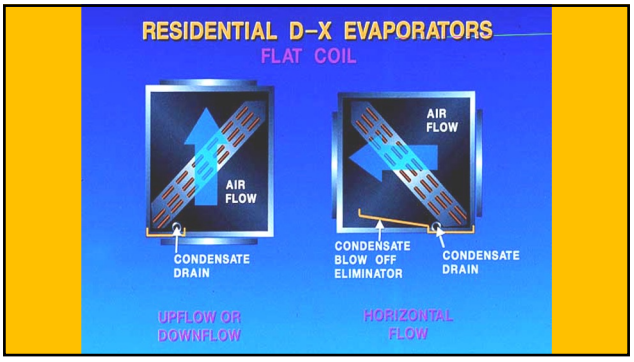
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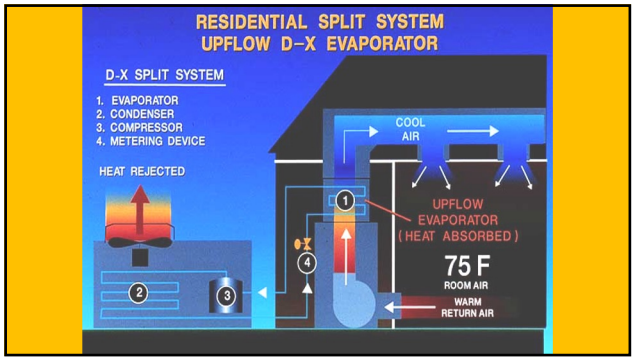
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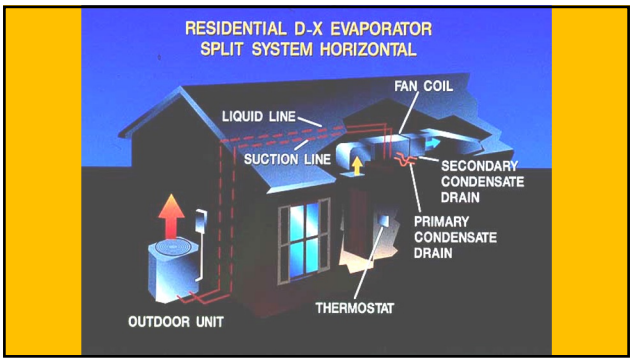
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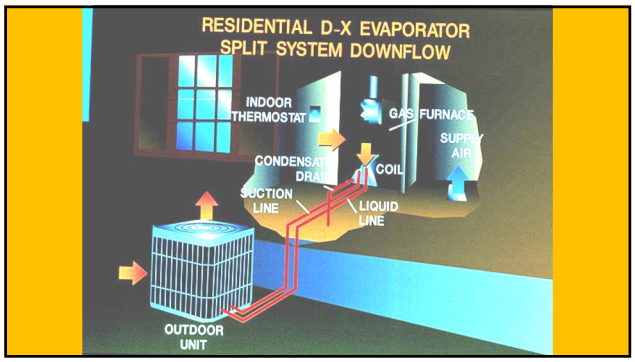
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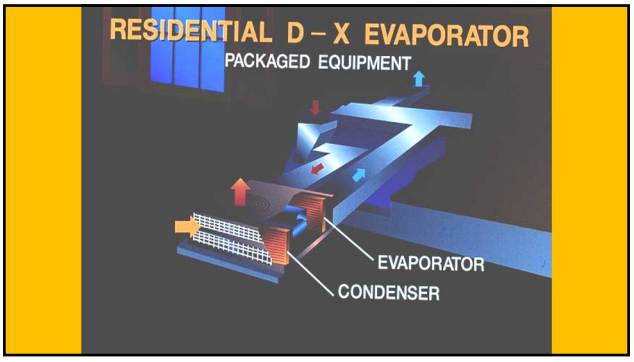
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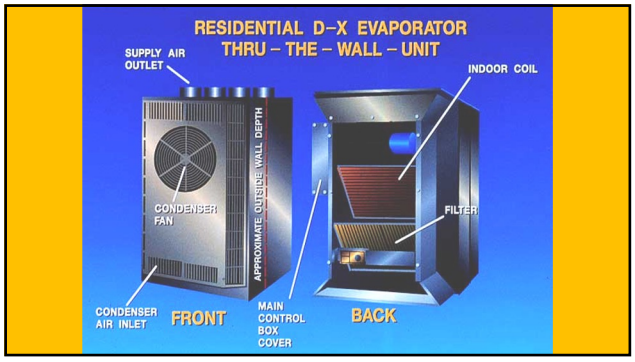
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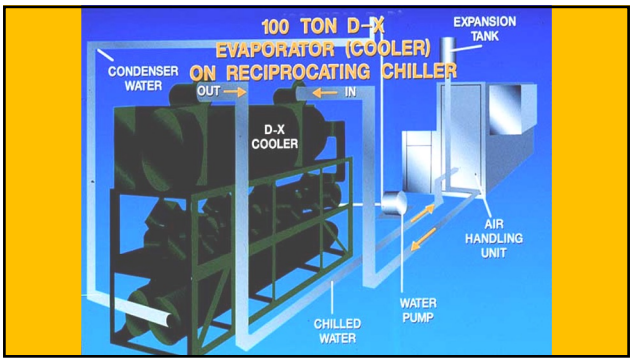
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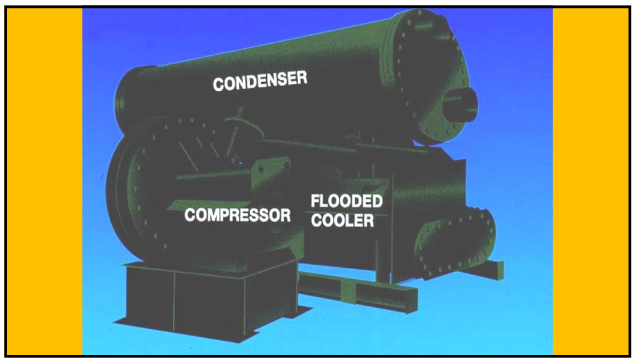
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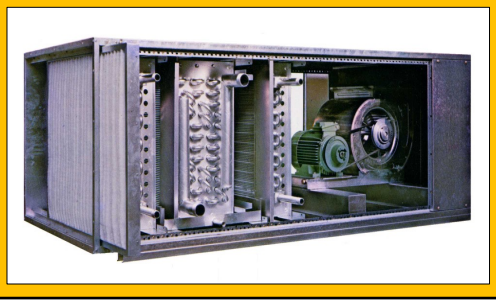


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122

AIR HADLING UNIT WTH CHILLED WATER COIL

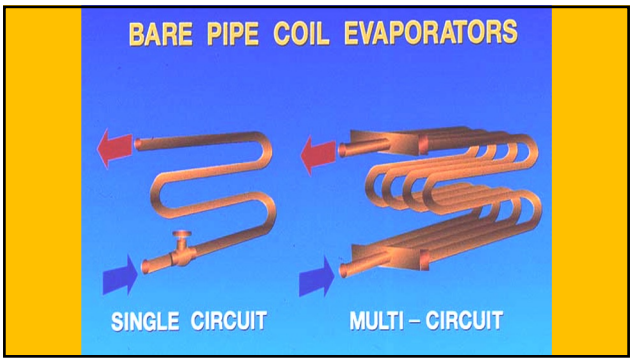


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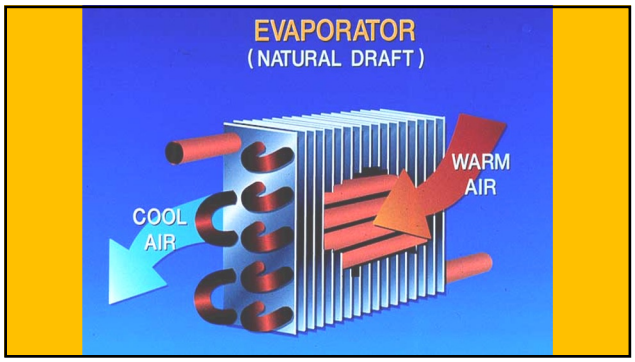
EVAPORATORS CATEGORIZED BY TYPE OF CONSTRUCTION

- BARE – TUBE
- FINNED – TUBE
- PLATE – SURFACE

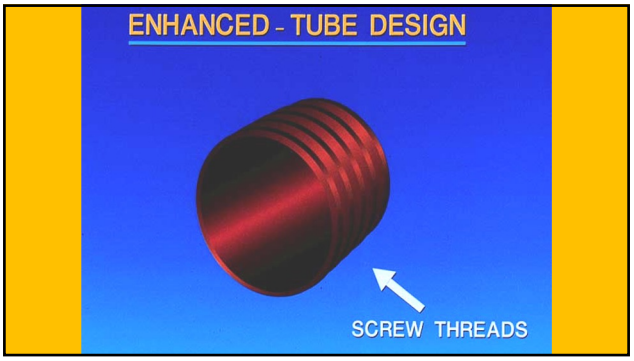
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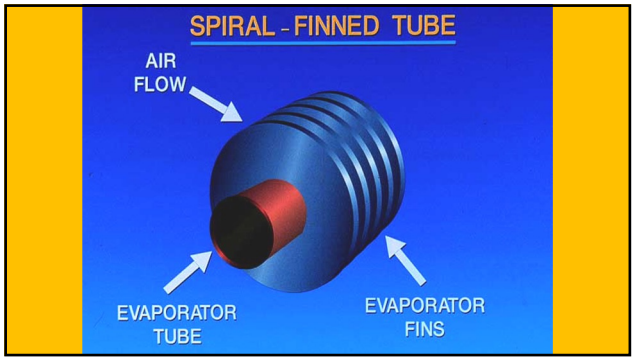
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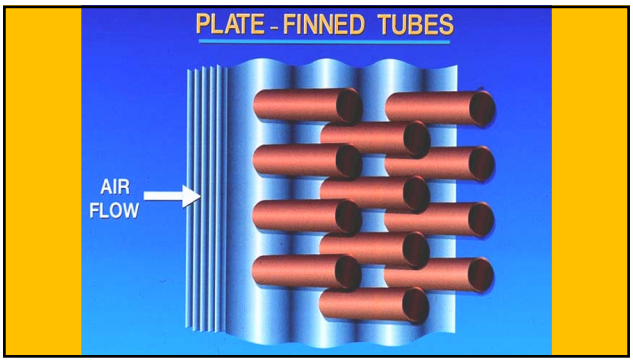
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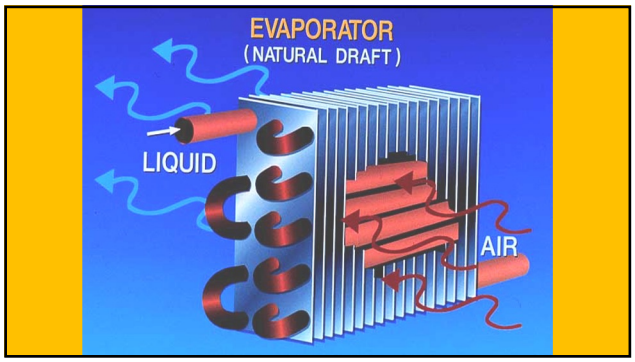
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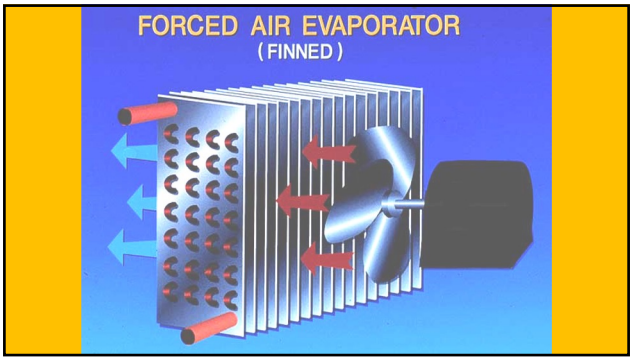
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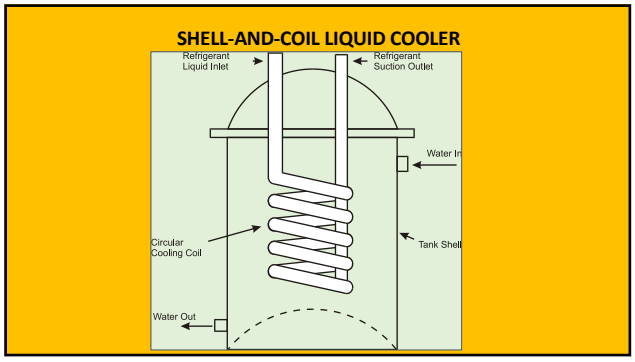
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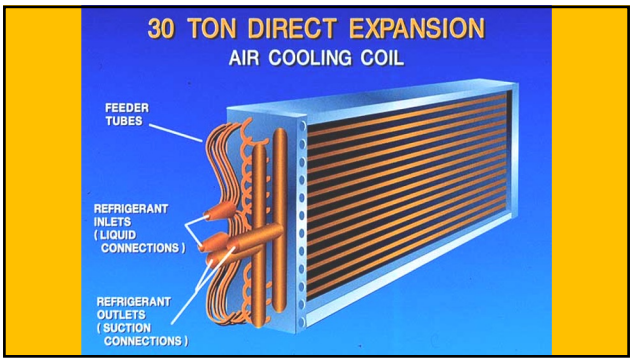
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131



132



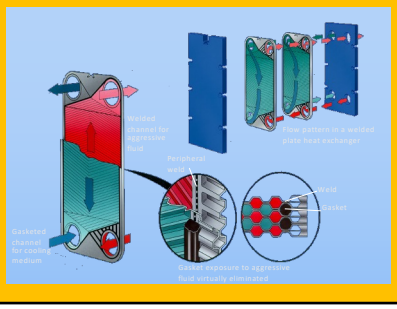
133

PLATE HEAT EXCHANGER-CHILLER



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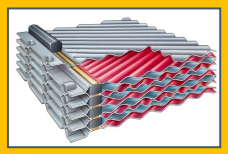
SEMI-WELDED PHE - FUNCTION



135

Semi-welded PHE - applications

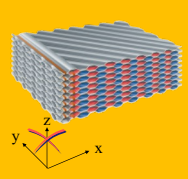
- Aggressive media on one side
  - Refrigeration
    - Condensers
    - Vaporisers

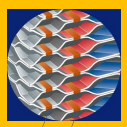


136

AlfaRex - modules

- 10 plates are laser-welded together forming a module
- The plates have two grooves to allow alternate welding of plates
- The modules is only welded in two dimension

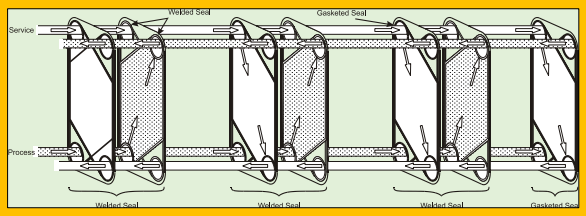




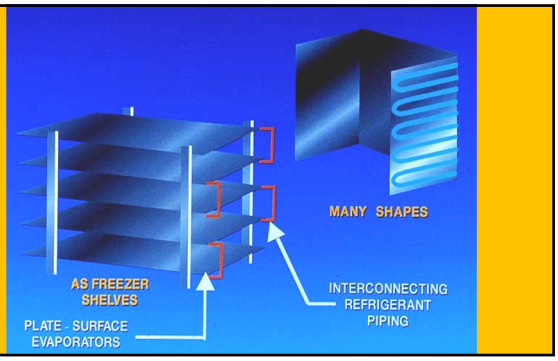
Alternate laser-welds

137

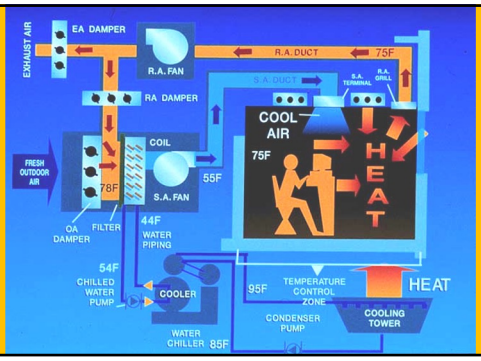
PLATE HEAT EXCHANGER



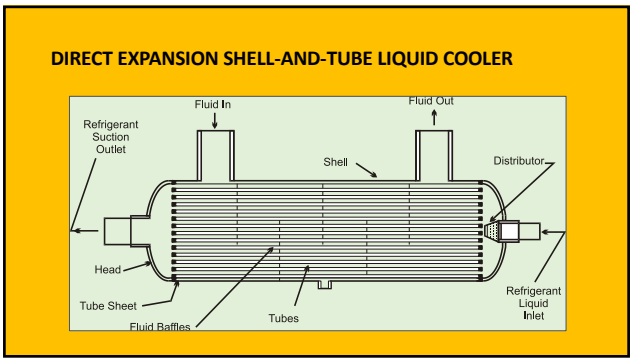
138



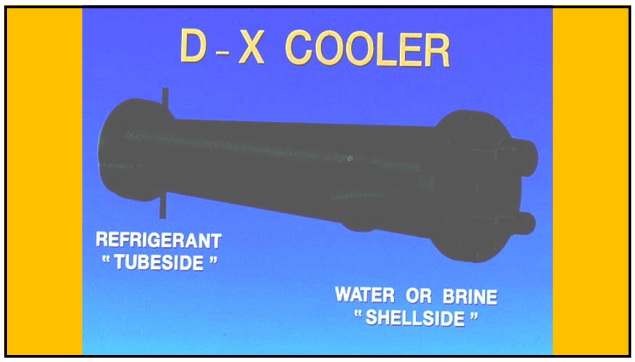
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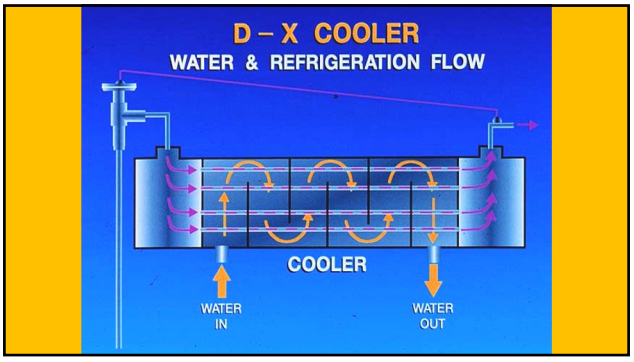
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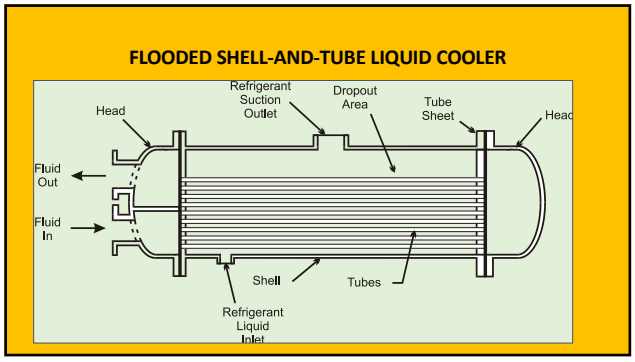
141



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SHELL & TUBE FLOODED COOLER

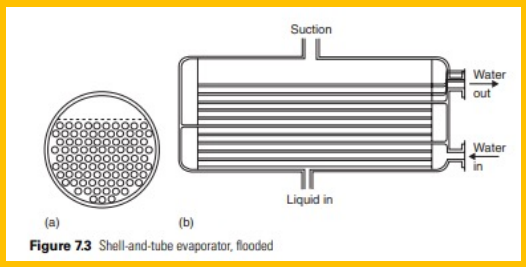
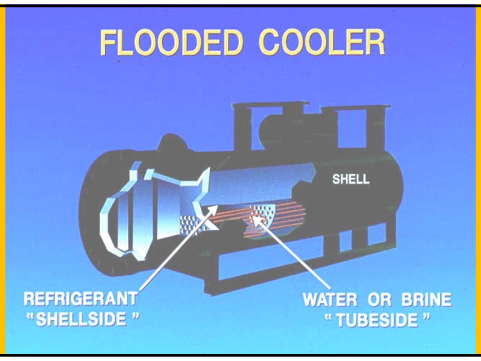


Figure 7.3 Shell-and-tube evaporator, flooded

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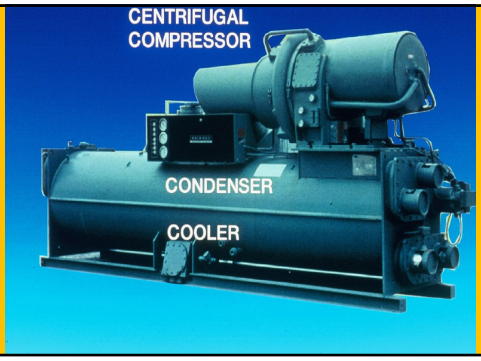


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HORIZONTAL PLATE FREEZER

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CENTRIFUGAL CHILLER EFFICIENCY PROGRESS
EFFICIENCY - kW/TON

YEAR	AVERAGE	GOOD
1979	0.80	0.72
1980	0.72	0.68
1990	0.65	0.62
1991	0.64	0.60
1993	0.63	0.55
1995	0.61	0.52
1997	0.60	0.50
1999	0.59	0.49
2000	0.58	0.48
2002/2006	0.56	0.45
2012-2013	0.45	0.32 IPLV

0.1 kW/TON = 9.9 billion kg of CO_2+ 6.3 grams SO_2,
+ 3.5 billion gms NOx OR = 3 MILLION CARS OFF ROAD
OR = PLANTING 600 MIL. TREES

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TERBOCOR CHILLER



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Johnson Controls YZ Centrifugal Chiller with magnetic bearings & R1233Zd Refrigerant-Winner AHR EXPO Award 2018



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PACKAGE CHILLER
PHE –CHILLER/CONDENSER L.P. PACKAGE



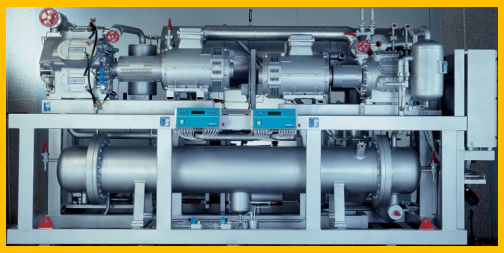
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TEKO AMMONIA SCREW CHILLERS



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CO2 AMMONIA CASCADE CHILLER



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PROPANE CO2 CASCADE CHILLER WITH MULTIPLE COMPRESSORS



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SHELL & PLATE CONDENSER & CHILLER



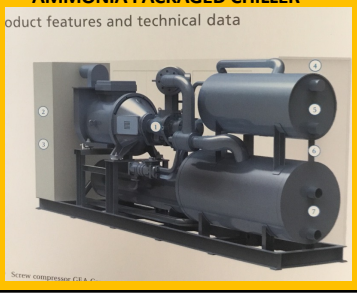
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PLATE PACK FULLY WELDED ON OUTSIDE



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SHELL & PLATE CONDENSER/CHILLER-SABROE AMMONIA PACKAGED CHILLER



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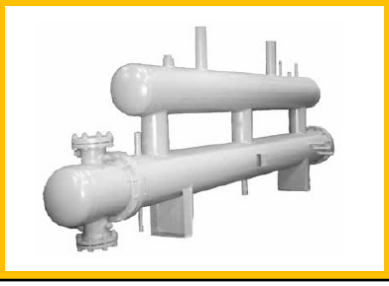
SHELL & TUBE FLOODED CHILLERS





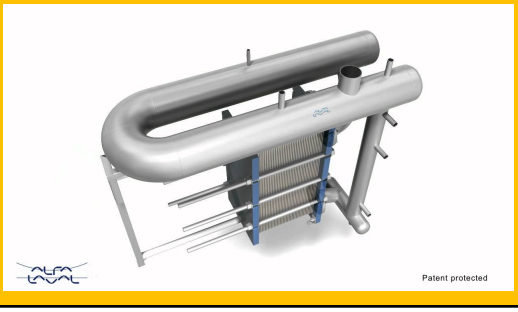
159

SURGE DRUM ON CHILLER



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ALFA LAVAL PHE WITH "U" TURN ACCUMULATOR



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PLATE FREEZER



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FALLING FILM COOLER



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FALLING FILM CHILLER



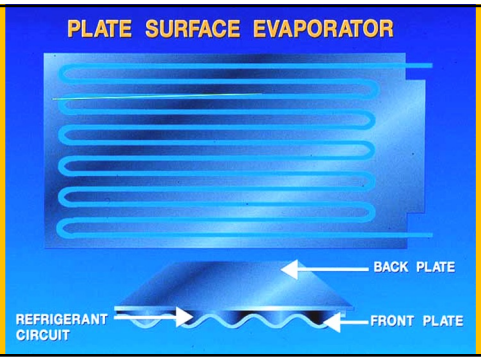
164

FALLING FILM CHILLER PLATES



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PLATE SURFACE EVAPORATOR



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SHELL & PLATE HEAT EXCHANGER



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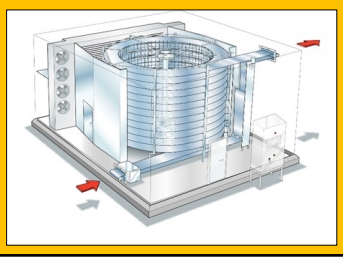
SPIRAL HEAT EXCHANGERS



- A fully welded heat exchanger for tough process duties

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SPIRAL FREEZER



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SPIRAL FREEZER



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IQF-IN LINE FREEZING



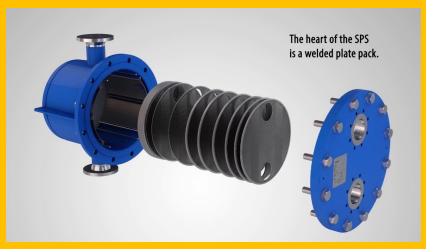
171

IQF-IN LINE FREEZING



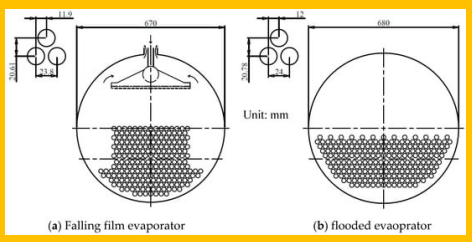
172

SHELL & PLATE EVAPORATORS



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SPRAY EVAPORATOT V/S FLOODED EVAPORATOR



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PACKAGE AMMONIA WATER CHILLER USING SEMI HERMATIC –ENCAPSULATED MOTOR



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AMMONIA SPRAY CHILLER



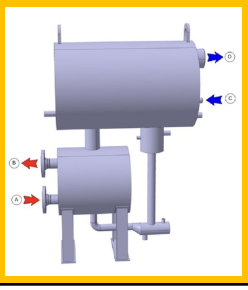
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Comparison of spray Ammonia chiller with same capacity flooded chiller

Characteristics	Spray Chiller newly installed	Earlier flooded chiller removed
Shell diameter-inch	48	60
Tube length-ft	17	24
Tube OD-inch	0.75	1.25
No. of passes	2	8
Pressure drop-psi	7.5	11
Ammonia Charge-lb/TR	0.5	10

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SHELL & PLATE CONDENSER/EVAPORATOR



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ANY QUESTIONS?

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