Itp530

VAPOR COMPRESSION REFRIGERATION SYSTEMS

Purwiyatno Hariyadi

Phariyadi.staff.ipb.ac.id

REFRIGERATION:

Important Dates in Refrigeration History

- 1834 : Jacob Perkins patented refrigeration by vapour compression which was based on the reverse Rankine cycle
- *Use of Natural Refrigerants:*
  1880's : NH_3, SO_2, CO_2, HC's
- Toxic and flammable refrigerants led to fatal accidents
- *Use of Synthetic Refrigerants: (Stability, Non-toxicity and efficiency)*
  1930 : R11, R12
  1936 : R22
  1961 : R507

Purwiyatno Hariyadi
Email: hariyadi@seafast.org
Web: phariyadi.staff.ipb.ac.id

REFRIGERATION

- Provides cool storage of foods
- T ·····> 60°F (16°C) to 28°F (-2°C)
- Water in the food is not frozen
  - the shelf life of perishable products is extended only for days or a few weeks
- Growth of nearly all pathogenic m.o. is prevented
  - some spoilage microorganisms (psychrophiles) may thrive

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EFFECTS OF REFRIGERATION ON FOODS

DESIRABLE EFFECTS

a. Microbial growth rates decrease

b. Chemical and biochemical reaction rates decrease

c. Shelf life increases (2-5 fold for every 10°C decrease in temperature)

UNDESIRABLE EFFECTS

a. Textural deterioration

b. Chilling injury

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Purwiyatno Hariyadi
Email: hariyadi@seafast.org
Web: phariyadi.staff.ipb.ac.id

ENERGY REMOVAL DURING REFRIGERATION

Removal of heat (Q) :

$Q = mC_p\Delta T$

m = mass/weight of food

C_p = specific heat of food above freezing

ΔT = temperature difference

VAPOR COMPRESSION REFRIGERATION SYSTEMS

- A refrigeration system allows transfer of heat from a cooling chamber to a location where the heat can be easily discarded.
- The transfer of heat is accomplished by using a refrigerant, which can change its state from liquid to gas.
- However, unlike water the refrigerant has a much lower boiling point.

Purwiyatno Hariyadi
Email: hariyadi@seafast.org
Web: phariyadi.staff.ipb.ac.id

REFRIGERANT

- **A fluid which, through phase changes from liquid to gas and back to liquid, facilitates heat transfer in a refrigeration system.**
- **Refrigerants have much lower boiling points than water and their boiling points can be varied by changing the pressure of the system.**
- **A good example of a common refrigerant is ammonia (NH_3).**

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VAPOR COMPRESSION REFRIGERATION SYSTEMS

- Ammonia boils at -33.3C, compared to 100^{o}C for water at atmospheric pressure.
- Similar to water, ammonia needs latent heat of vaporization to change from liquid to vapor, and it discharges latent heat of condensation to change from vapor to liquid.
- The boiling point of a refrigerant can be varied by changing the pressure.
- Thus, to increase boiling point of ammonia to 0^{o}C, its pressure must be raised to 428.5 kPa (62.1 psia)

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Purwiyatno Hariyadi
Email: hariyadi@seafast.org
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SELECTION OF A REFRIGERANT

The following characteristics are important in the selection of a refrigerant:

1. A high latent heat of vaporization is preferred.
2. Excessively high condensing pressures should be avoided
3. The freezing temperature of the refrigerant should be below the evaporating temperature.
4. The refrigerant should have a sufficiently high critical temperature.
5. The refrigerant must non-toxic, non-corrosive, and chemically stable.
6. It should be easy to detect leaks.
7. Low cost refrigerant is preferred in industrial applications

SELECTION OF A REFRIGERANT

- **Ammonia offers exceptionally high latent heat of vaporization among all other refrigerants.**
- **Other commonly used refrigerants include, Freon 12 and Freon 22.**
- **Due to the adverse effects of Freon 12 on the ozone layer, the use of this refrigerant is now being seriously curtailed.**

Purwiyatno Hariyadi
Email: hariyadi@seafast.org
Web: phariyadi.staff.ipb.ac.id

Table. Properties of refrigerants used in warehouse refrigeration at -15°C evaporator temperature and 30°C condenser pressure

Refrigerant	Ammonia	Freon 12
Evaporator pressure, kPa	236.5	182.7
Condenser pressure, kPa	1166.5	744.6
Latent heat of vaporization @ -15 C, kj/kg	1314.2	161.7
Liquid refrigeration circulated per ton of refrigeration, kg/s	31×10^{-2}	2.8×10^{-2}
Stability (Toxic products)	no	yes
Flammability	yes	no
Odor	acrid	ethereal
Evaporator temperature range	-68 to -7	-73 to 10

SELECTION OF A REFRIGERANT

Current Issure: Environmental Effects of Refrigerants

- Depletion of the ozone layer in the stratosphere

- Global warming :

  Refrigerants directly contributing to global warming when released to the atmosphere

  Indirect contribution based on the energy consumption of among others the compressors (CO_2 produced by power stations)

Purwiyatno Hariyadi
Email: hariyadi@seafast.org
Web: phariyadi.staff.ipb.ac.id

SELECTION OF A REFRIGERANT:

Type of refrigerants

1. HaloCarbons
2. Azeotropic Refrigerants
3. Zeotropic Refrigerants
4. Inorganic Refrigerants
5. Hydrocarbon Refrigerants

SELECTION OF A REFRIGERANT:

Halocarbon refriegerant

- Halocarbon Refrigerant are all synthetically produced and were developed as the Freon family of refrigerants.

Examples :
- CFC's : R11, R12, R113, R114, R115
- HCFC's : R22, R123
- HFC's : R134a, R404a, R407C, R410a

Purwiyatno Hariyadi
Email: hariyadi@seafast.org
Web: phariyadi.staff.ipb.ac.id

SELECTION OF A REFRIGERANT:

Inorganic Refrigerants

- Carbon Dioxide
- Water
- Ammonia
- Air
- Sulphur dioxide

SELECTION OF A REFRIGERANT:

Azeotropic Refrigerants

- A stable mixture of two or several refrigerants whose vapour and liquid phases retain identical compositions over a wide range of temperatures.
- Examples : R-500 : 73.8% R12 and 26.2% R152
  R-502 : 8.8% R22 and 51.2% R115
  R-503 : 40.1% R23 and 59.9% R13

Purwiyatno Hariyadi
Email: hariyadi@seafast.org
Web: phariyadi.staff.ipb.ac.id

SELECTION OF A REFRIGERANT:

Zeotropic Refrigerants

- A zeotropic mixture is one whose composition in liquid phase differs to that in vapour phase. Zeotropic refrigerants therefore do not boil at constant temperatures unlike azeotropic refrigerants.
- Examples :R404a : R125/143a/134a (44%,52%,4%)
  R407c : R32/125/134a (23%, 25%, 52%)
  R410a : R32/125 (50%, 50%)
  R413a : R600a/218/134a (3%, 9%, 88%)

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SELECTION OF A REFRIGERANT:

Hydrocarbon Refrigerants

- Many hydrocarbon gases have successfully been used as refrigerants in industrial, commercial and domestic applications.
- Examples: R170, Ethane, C_2H_6
  R290 , Propane C_3H_3
  R600, Butane, C_4H_{10}
  R600a, Isobutane, C_4H_{10}
  Blends of the above Gases

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Purwiyatno Hariyadi
Email: hariyadi@seafast.org
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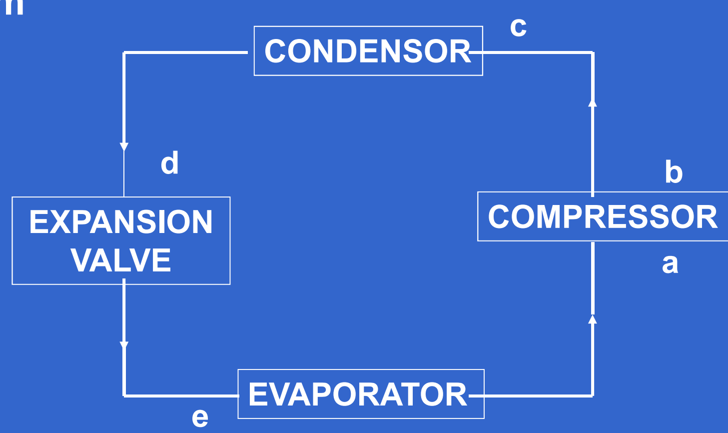
COMPONENT OF A REFRIGERATION SYSTEM

Major component of a vapor-compression refrigeration system are shown in the following diagram



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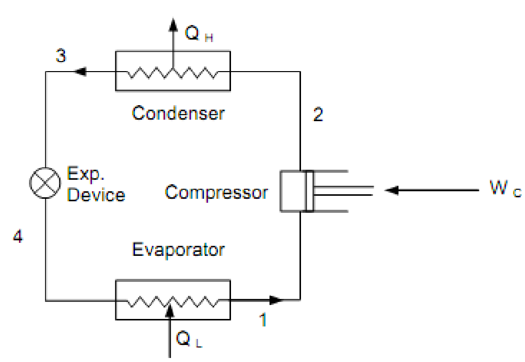

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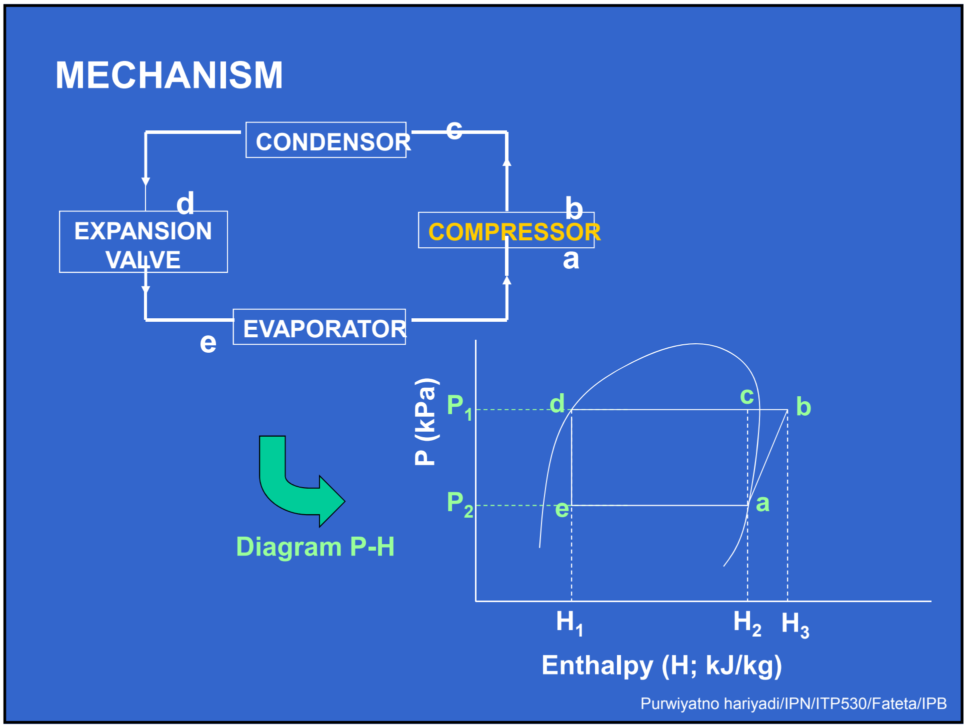

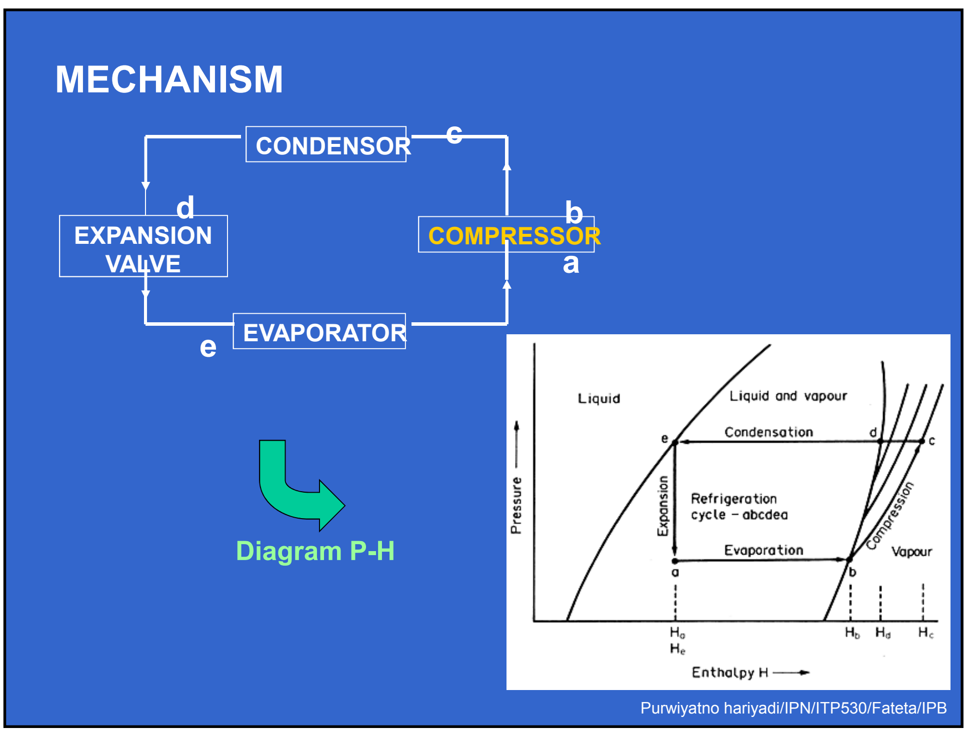

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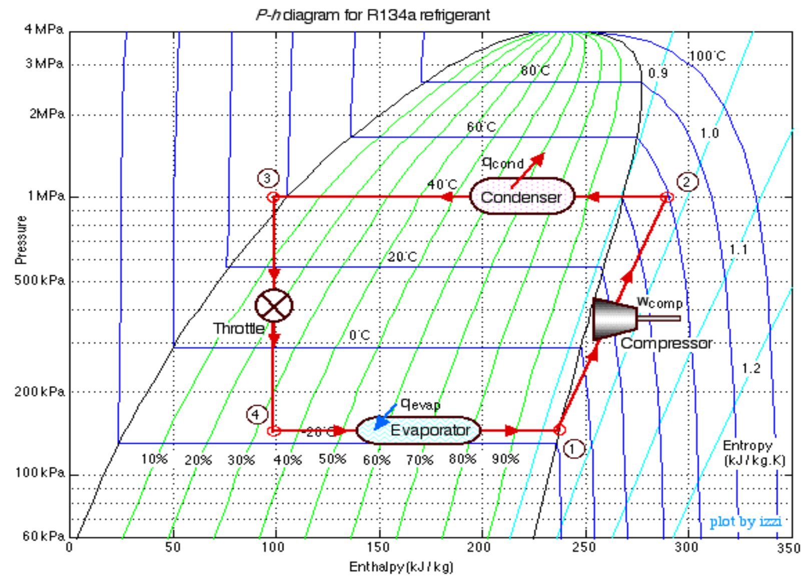
MECHANISM



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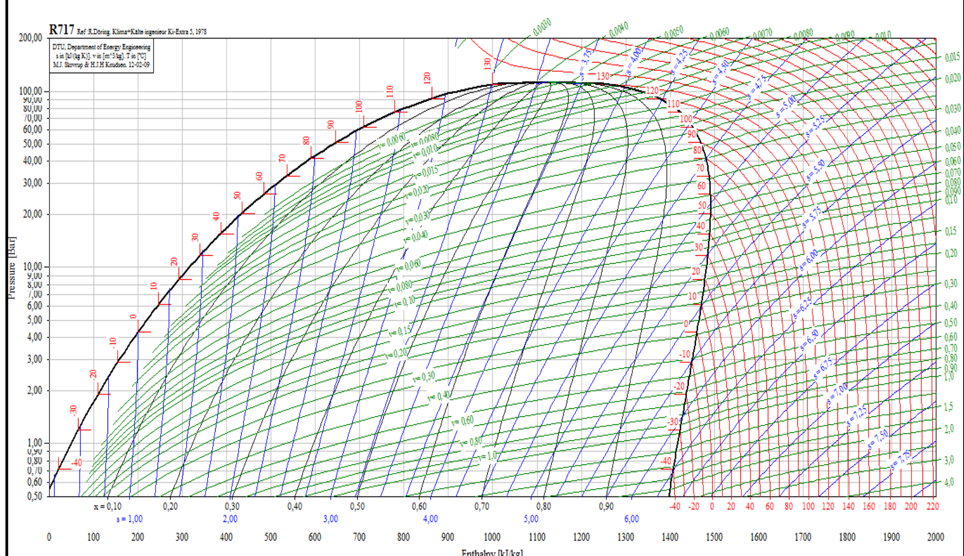
MECHANISM



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Purwiyatno Hariyadi
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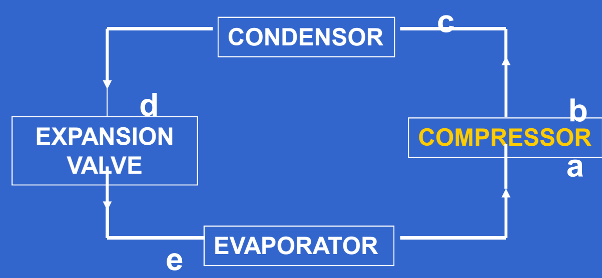
Web: phariyadi.staff.ipb.ac.id

COMPONENT OF A REFRIGERATION SYSTEM



Function as heat pumps and contain four essential mechanical components

A. Evaporator
- (1) Where the liquid refrigerant vaporizes into a gas
- (2) When this happens, heat from the stored food is "extracted"

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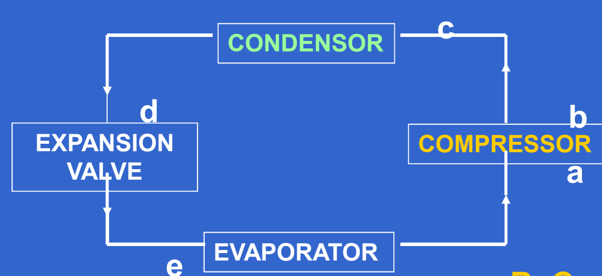
COMPONENT OF A REFRIGERATION SYSTEM



B. Compressor
- (1) Where the T and P of the refrigerant vapor is increased
- (2) When this happens, the heat in the refrigerant is released

C. Condenser
- (1) Where the heat is transferred from the refrigerant to another medium (air or water)
- (2) When this happens, the refrigerant decreases in T and condenses

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Purwiyatno Hariyadi
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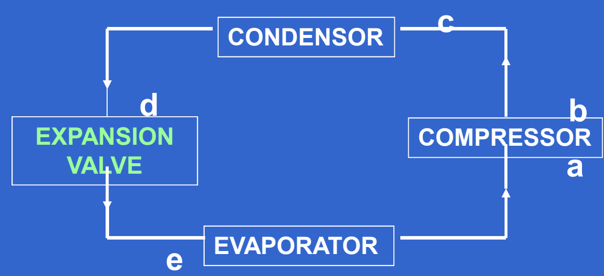
COMPONENT OF A REFRIGERATION SYSTEM

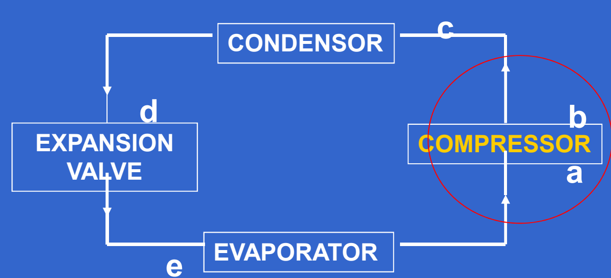


D. Expansion valve

(1) Where the flow of liquid refrigerant is controlled

(2) When this happens, the evaporator receives a constant supply of refrigerant

MECHANISM



Location a : - refrigerant gas enters compressor and compressed to a high pressure

Location b : - superheated compressed gas exits the compressor

Purwiyatno Hariyadi
Email: hariyadi@seafast.org
Web: phariyadi.staff.ipb.ac.id

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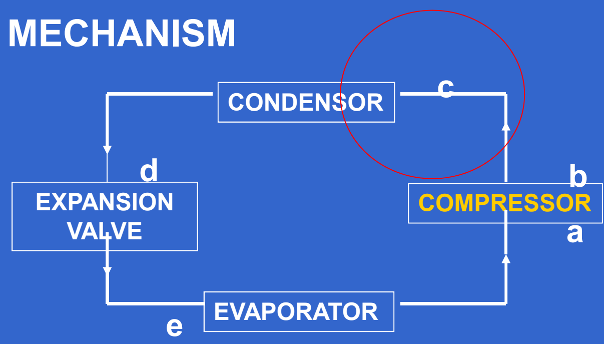
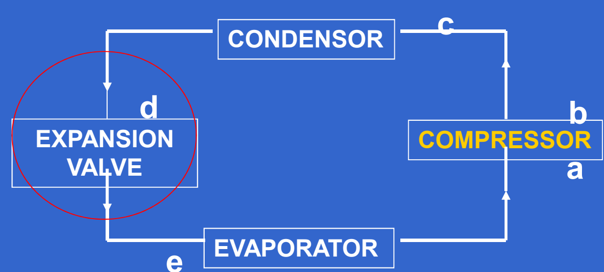


Location c :

- compressed gas enters the condenser
- the condensing temperature must be higher than that of an easily available heat sink, e.g., ambient air, water, etc.
- the refrigerant gas discharges latent heat of condensation the heat sink and changes phase to liquid

MECHANISM



Location d :

- refrigerant in a saturated liquid state
- expansion valve separates high as refrigerant passes through the expansion valve the sudden decrease in pressure causes some of the refrigerant to change into gas

Purwiyatno Hariyadi
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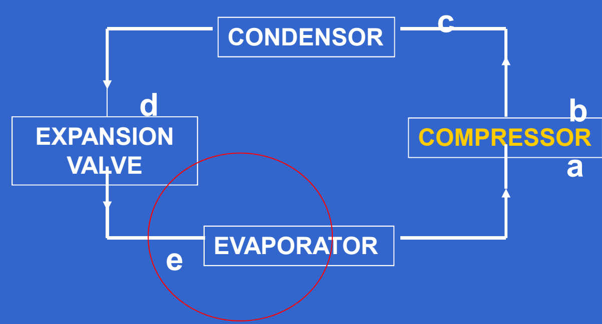

Location e : - the refrigerant absorbs heat, equivalent to its latent heat of vaporization, and completely converts into gas

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MATHEMATICAL EXPRESSIONS USEFUL IN THE ANALYSIS OF VAPOR-COMPRESSION REFRIGERATION

COOLING LOAD:

- The cooling load is total heat energy that must be removed from a given space in order to lower the temperature to a desired level.
- A common unit of cooling load is “ton of refrigeration”

1 ton of refrigeration = 288,000 Btu/24 hr
= 303,852 kJ/24 hr

Purwiyatno hariyadi/IPN/ITP530/Fateta/IPB

Purwiyatno Hariyadi
Email: hariyadi@seafast.org
Web: phariyadi.staff.ipb.ac.id

MATHEMATICAL EXPRESSIONS USEFUL IN THE ANALYSIS OF VAPOR-COMPRESSION REFRIGERATION

REFRIGERANT FLOW RATE

- The refrigerant flow rate depends upon the total cooling load on the system and the amount of heat that refrigerant can absorb

Refrigerant flow rate

$$= (\text{Cooling Load}) / (H_2 - H_1)$$

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MATHEMATICAL EXPRESSIONS USEFUL IN THE ANALYSIS OF VAPOR-COMPRESSION REFRIGERATION

COMPRESSOR

- The work done on the refrigerant during the compression step is the product on the enthalpy increase of the refrigerant inside the compressor and the refrigerant flow rate

rate of work done on the compressor

$$= (\text{refrigerant flow rate})\ (H_3 - H_2)$$

Purwiyatno hariyadi/IPN/ITP530/Fateta/IPB

Purwiyatno Hariyadi
Email: hariyadi@seafast.org
Web: phariyadi.staff.ipb.ac.id

MATHEMATICAL EXPRESSIONS USEFUL IN THE ANALYSIS OF VAPOR-COMPRESSION REFRIGERATION

CONDENSER

- The heat rejected to the environment in the condenser depends upon the refrigerant flow rate and the latent heat of condensation of the refrigerant

heat rejected in the condenser
= (refrigerant flow rate) (H_3 - H_1)

MATHEMATICAL EXPRESSIONS USEFUL IN THE ANALYSIS OF VAPOR-COMPRESSION REFRIGERATION

EVAPORATOR

- The heat absorbed by the evaporator depends upon the refrigerant flow rate and the latent heat of evaporation of the refrigerant.

heat absorbed by the evaporator
= (refrigerant flow rate) (H_2 - H_1)

Purwiyatno Hariyadi
Email: hariyadi@seafast.org
Web: phariyadi.staff.ipb.ac.id

MATHEMATICAL EXPRESSIONS USEFUL IN THE ANALYSIS OF VAPOR-COMPRESSION REFRIGERATION

COEFFICIENT PERFORMANCE

- The coefficient performance is a ratio between the heat absorbed by the refrigerant as it flows through the evaporator to the heat equivalent of the energy supplied to the compressor.

$$COP = (H_2 - H_1) / (H_3 - H_2)$$

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TERIMAKASIH

Pembekuan

PANGAN

Purwiyatno hariyadi/IPN/ITP530/Fateta/IPB

Purwiyatno Hariyadi
Email: hariyadi@seafast.org
Web: phariyadi.staff.ipb.ac.id