Energy and Environmental Engineering

Refrigeration and Air-conditioning

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2nd law of thermodynamics

- Kelvin Planck Statement: The Kelvin statement of the second law of thermodynamics: **It is impossible to convert the heat from a single source into work without any other effect**.
- Clausius Statement: The Clausius statement of the second law of thermodynamics states that "**it is impossible to construct a device that operates in a cycle and produces no effect other than the transfer of heat from a cooler body to a hotter body**."

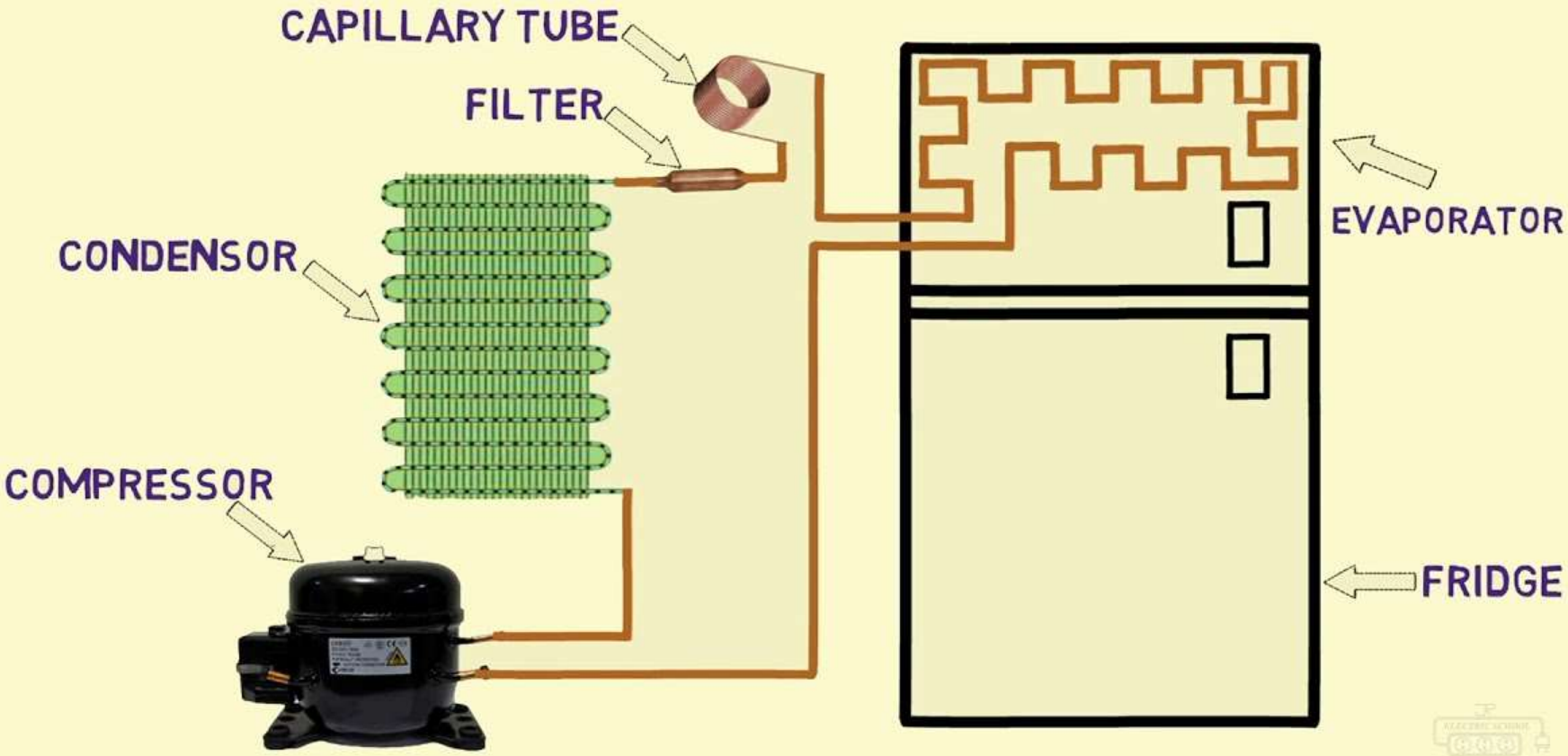
Introduction

Second law of thermodynamics

Domestic Refrigerator

Commercial Refrigerator

How Fridge Cooling System Work



Working animation

- https://www.youtube.com/watch?v=h5wQoA15OnQ

Vapour Compression Refrigeration System - Construction

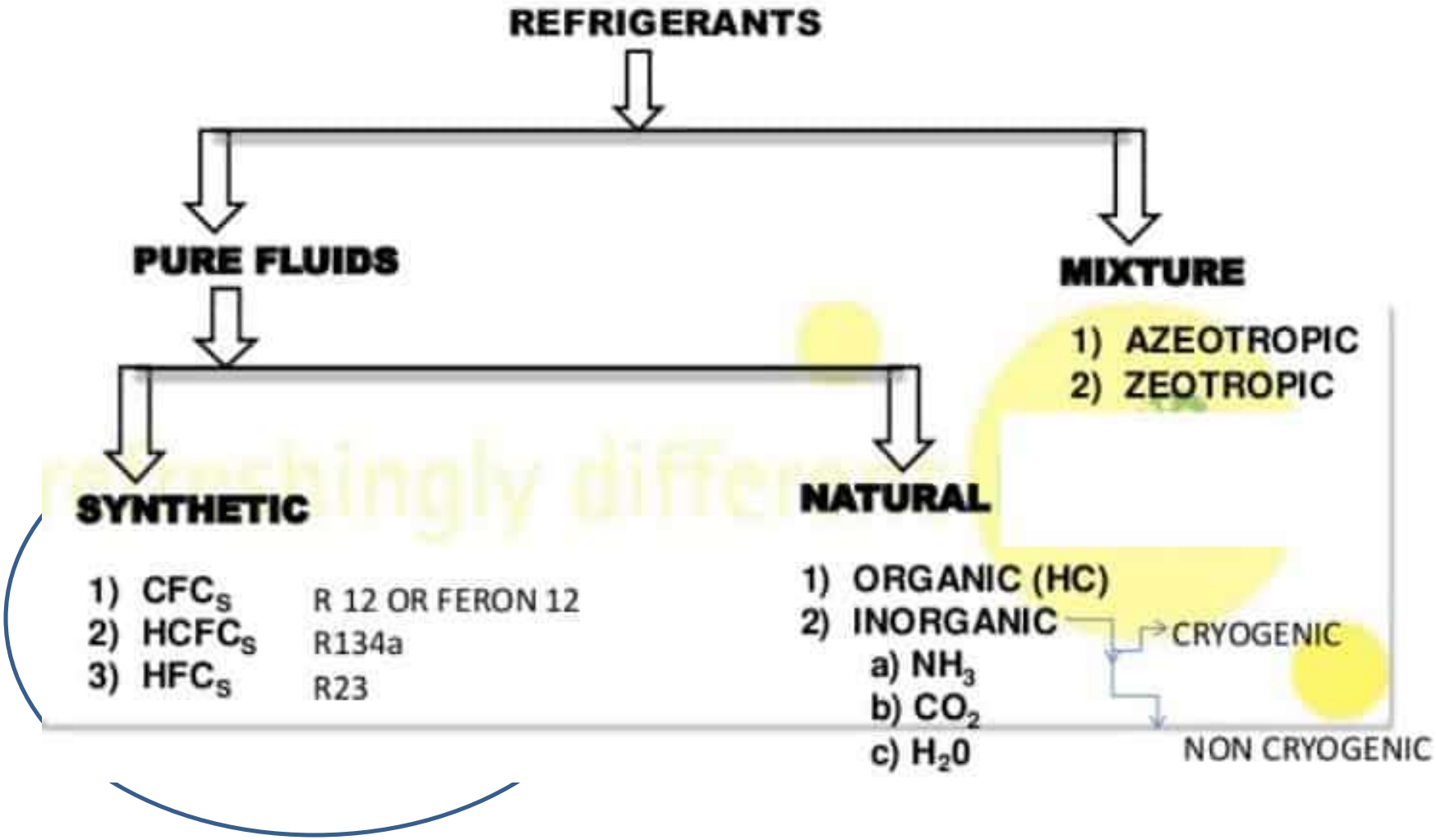
- **Condenser :** It is a coil of tubes made of copper.
- **Receiver tank:** It is the reservoir of liquid refrigerant.
- **Expansion Valve:** This is a throttle valve. High pressure refrigerant is made to flow at a controlled rate through this valve.
- **Evaporator :** It is the actual cooler and kept in the space to be cooled. The evaporator is a coil of tubes made of copper

Refrigeration

- The term **refrigeration** means cooling a space, substance or system to lower and/or maintain its temperature below the ambient one (while the removed heat is rejected at a higher temperature).
- In other words, refrigeration is artificial (human-made) cooling.
- Energy in the form of heat is removed from a low-temperature reservoir and transferred to a high-temperature reservoir.

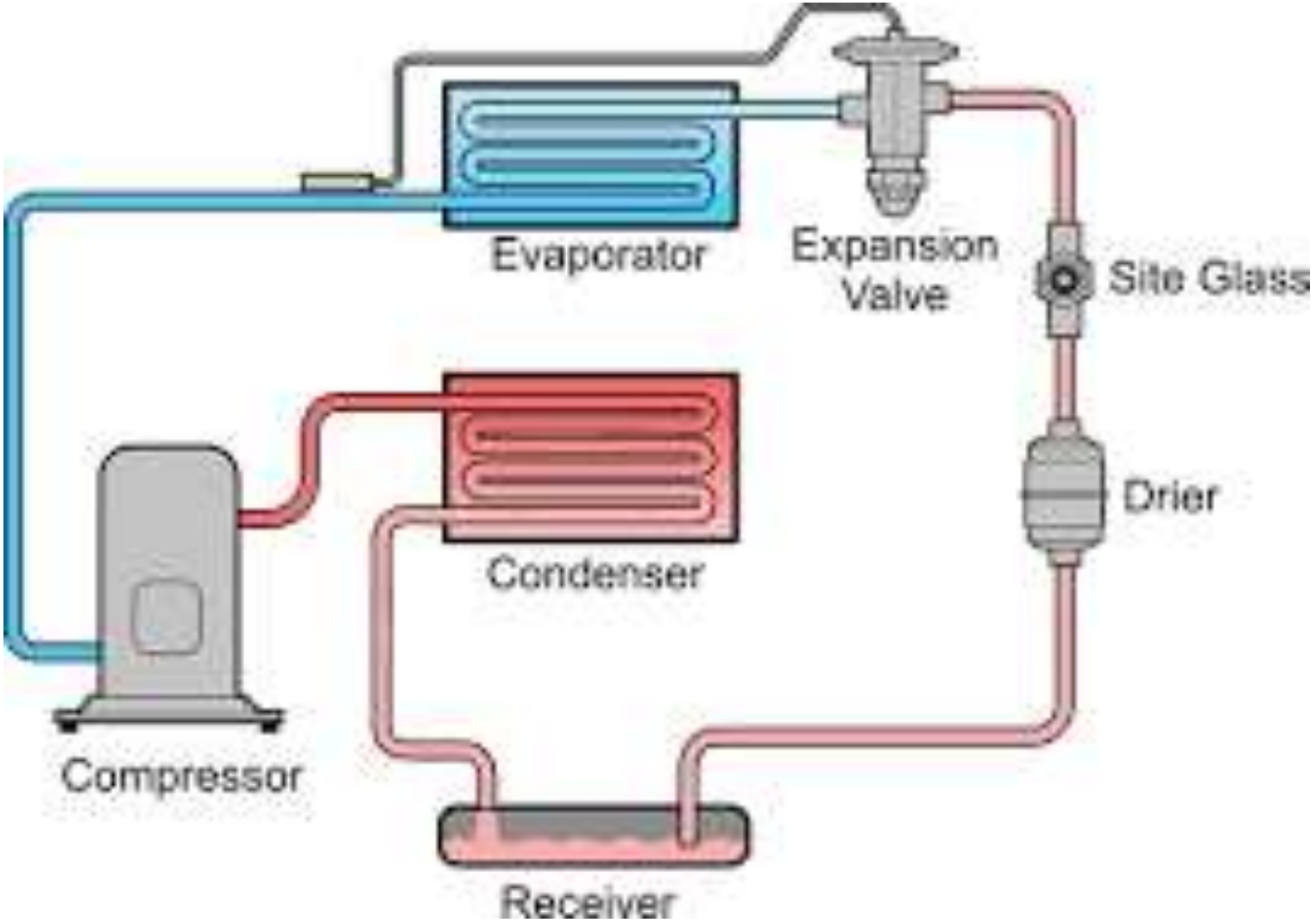
Refrigerant

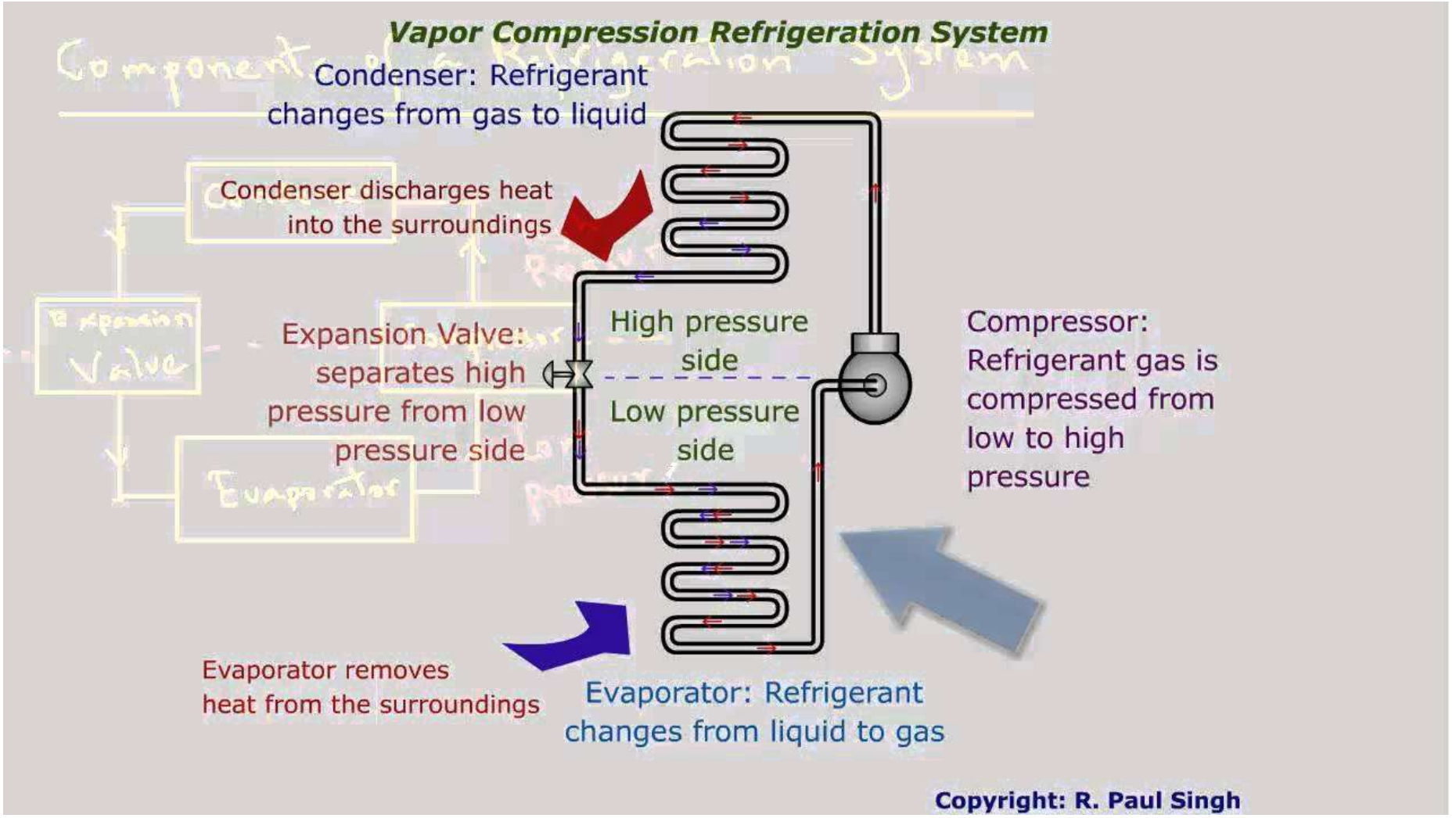
- A **refrigerant** is a working fluid used in the refrigeration cycle of air conditioning systems and heat pumps where in most cases they undergo a repeated phase transition from a liquid to a gas and back again.
- Classification of refrigerants:
  - Primary
  - Secondary

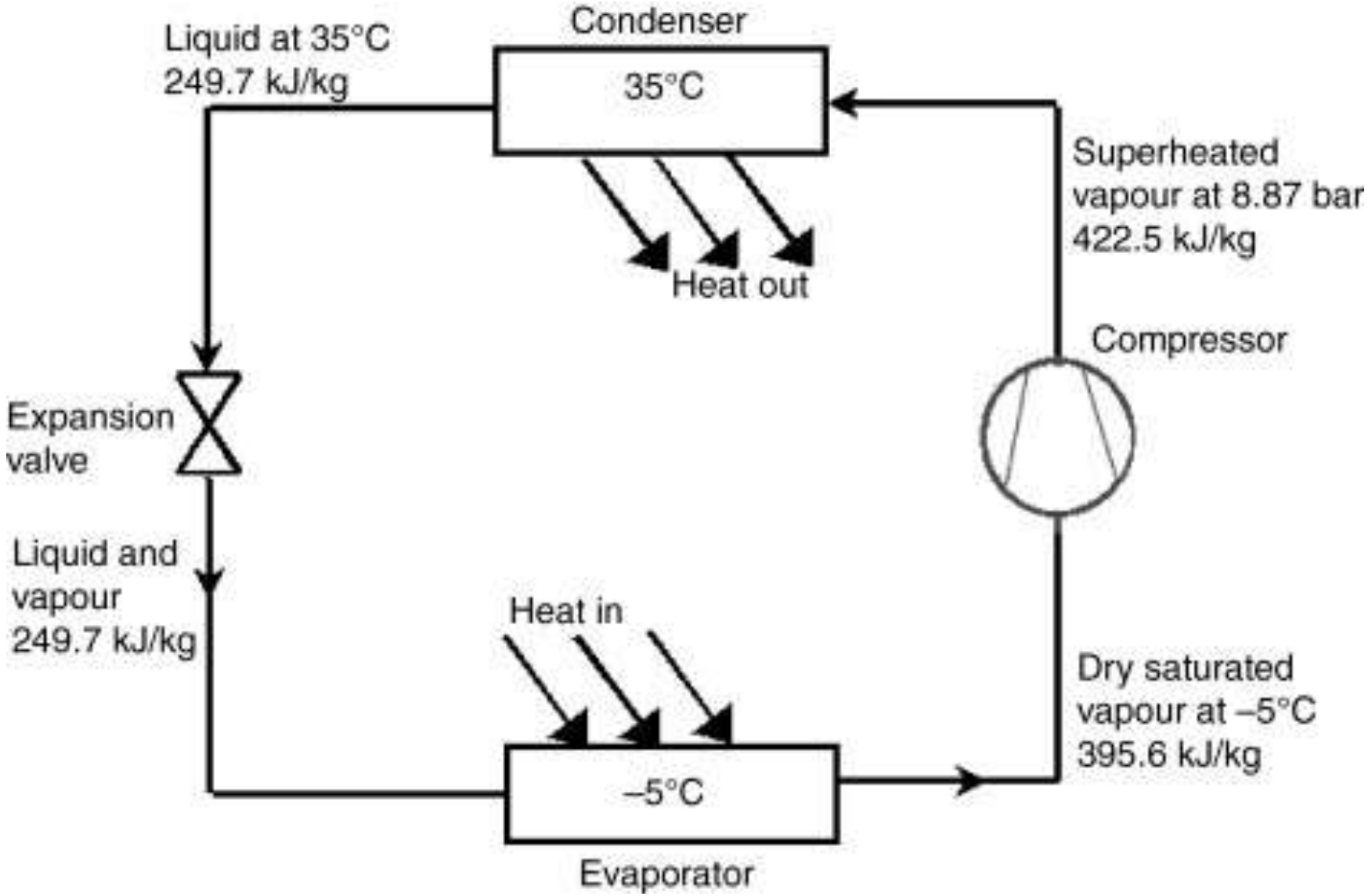


R134a has the formula CF_3CH_2F and a boiling point of −26.3 °C (−15.34 °F) at atmospheric pressure. R-134a cylinders are colored light blue.

Schematic diagram

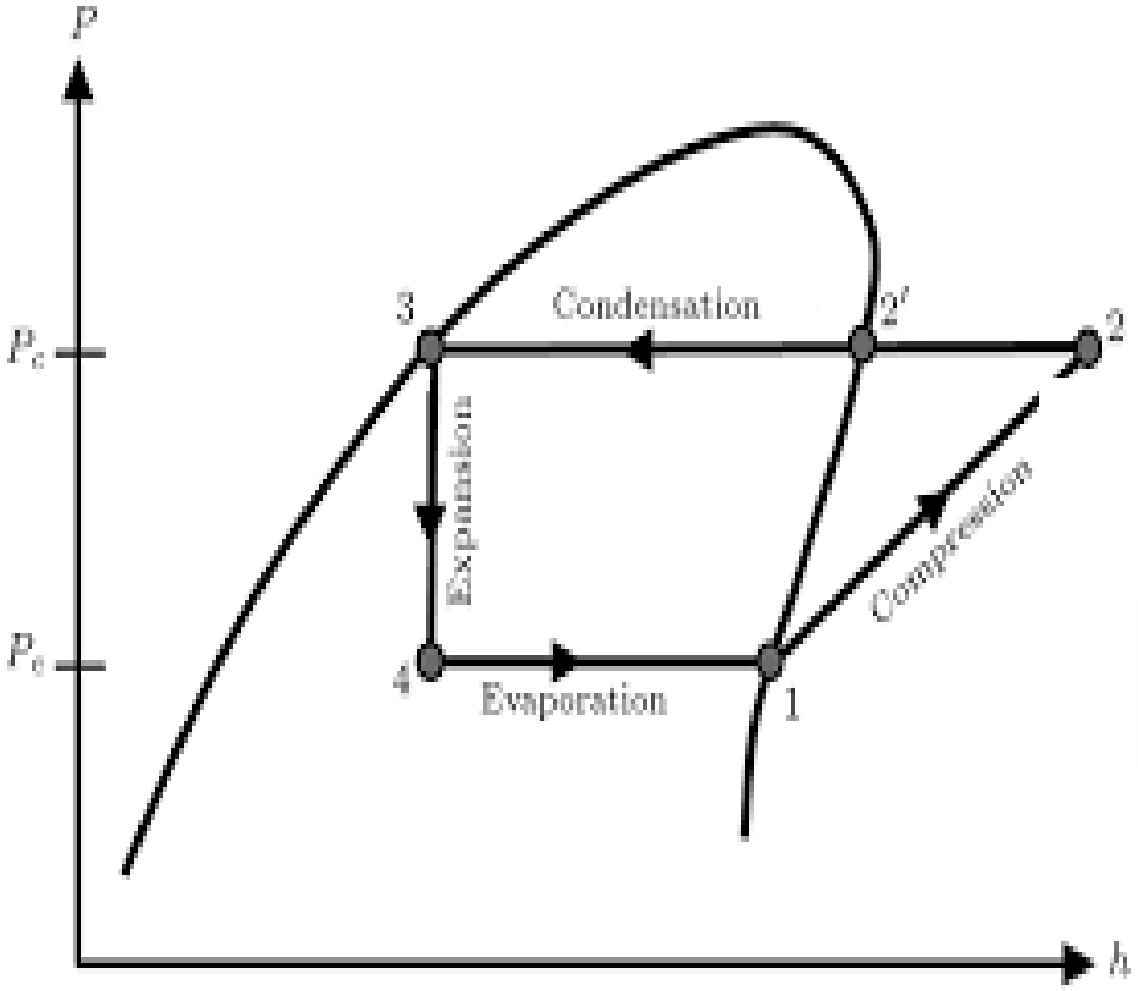



Vapor Compression Refrigeration System
Condenser: Refrigerant changes from gas to liquid
Condenser discharges heat into the surroundings
Expansion Valve: separates high pressure from low pressure side
High pressure side
Low pressure side
Compressor: Refrigerant gas is compressed from low to high pressure
Evaporator removes heat from the surroundings
Evaporator: Refrigerant changes from liquid to gas
Copyright: R. Paul Singh



Pressure in evaporator 1.3 Bar

Refrigeration cycle



COEFFICIENT OF PERFORMANCE

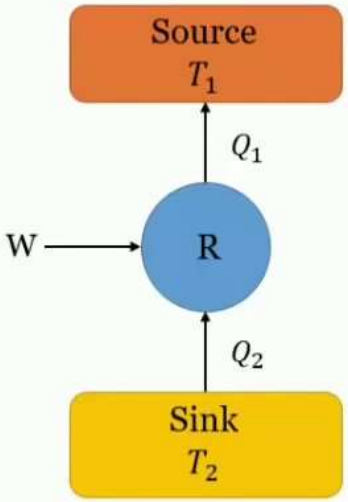
Instead of using thermal efficiency, we use coefficient of performance

$$COP_R = \frac{Q_L}{W_{IN}}$$

$$COP_{HP} = \frac{Q_H}{W_{IN}} \rightarrow (1.5 \rightarrow 4.0)$$

COP

Refrigerator



$T_2 < T_1$

Where

Q_2 = Quantity of heat removed from a low temperature region

Q_1 = Quantity of heat supplied to a high temperature region

$$Q_1 = Q_2 + W$$

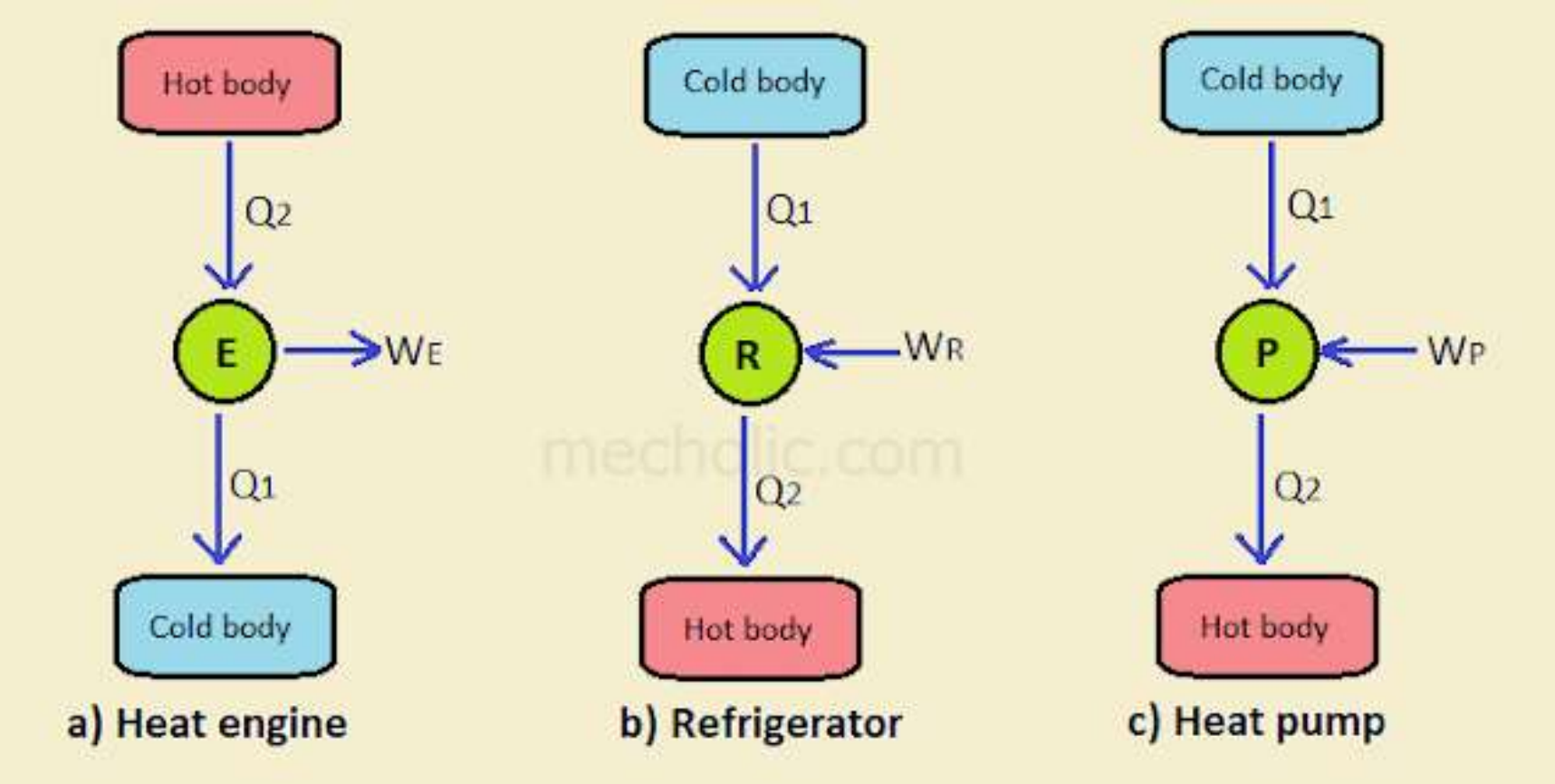
$$W = Q_1 - Q_2$$

$$(COP)_R = \frac{Net\ Refrigeration\ Effect}{Work\ Supplied}$$

$$(COP)_R = \frac{Q_2}{W} = \frac{Q_2}{Q_1 - Q_2} = \frac{T_2}{T_1 - T_2}$$

Difference between COP & Eff

Heat Engine, Refrigerator & Heat Pump



$$\eta_{Ref} = \frac{Q_c}{W} = \frac{Q_C}{Q_H - Q_H} = COP_{Ref}$$

$$\eta_{HP} = \frac{Q_H}{W} = \frac{Q_H}{Q_H - Q_C} = COP_{HP}$$

$$\text{COP}_{HP} \text{ or energy performance ratio} = \frac{Q_2}{W_p}$$

$$\text{COP}_{HP} = \frac{Q_2}{Q_2 - Q_1}$$

$$\text{COP}_{HP} = \frac{Q_1 + W_R}{Q_2 - Q_1} = \frac{Q_1}{Q_2 - Q_1} + \frac{W_R}{Q_2 - Q_1}$$

$$\text{COP}_{HP} = \frac{Q_1}{Q_2 - Q_1} + \frac{Q_2 - Q_1}{Q_2 - Q_1}$$

$$= \frac{Q_1}{Q_2 - Q_1} + 1$$

$$\text{COP}_{HP} = \text{COP}_R + 1$$

Unit of Refrigeration

- The unit of refrigeration is expressed in terms of **ton of refrigeration (TR)**.
- One ton of refrigeration is defined as the amount of refrigeration effect (heat transfer rate) produced during uniform melting of one ton (1000kg) of ice at 0°C to the water at the 0°C in 24 hours.

Application of Refrigeration

- Domestic
- Commercial
- Industrial
- Marine and transportation
- Comfort air conditioning
- Pharmaceutical industries

Type of Refrigeration

- VCR: Vapor Compression Refrigeration Cycle (mechanical energy)
- VAR: Vapor Absorption Refrigeration Cycle (use thermal energy)

No.	Properties	R134a
1	Boiling Point	-14.9°F or -26.1°C
2	Auto-Ignition Temperature	1418°F or 770°C
3	Ozone Depletion Level	0
4	Solubility In Water	0.11% by weight at 77°F or 25°C
5	Critical Temperature	252°F or 122°C
6	Cylinder Color Code	Light Blue
7	Global Warming Potential (GWP)	1200

Refrigerant properties

Substance	R-Num	BP(°C)	ODP	GWP
Carbon dioxide	R744	−78.5	0	1
Ammonia	R717	−33.3	0	0
1,1,1,2-Tetrafluoro ethane	R134a	−26.3	0	1300
Isobutane	R600a	−11.6	0	20
Dichloro di-fluoro methane	R12	−29.8	0.84	10,600
Difluoromonochloromethane	R22	−40.8	0.055	1700

Introduction

- Refrigeration- process of removing heat from a substance under controlled conditions
- -continued extraction of heat from a body whose temperature is already below to its surroundings
- Substance used to remove heat is called as refrigerant

AC

- Air conditioning- branch of engineering which deals with study of conditioning of air

- Conditioning of air means supplying and maintaining internal atmospheric conditions for human comfort, industrial application, food processing, storage of food and other material

COP

- COP=Q/W
- Relative COP=act. COP/ theoretical COP

- Q=amt. of heat extracted in refrigerator

- W=work done on refrigerant

IN USA

- EER=heat removed in BTU/ energy consumed in watts-hr
- Amt. of heat removed from space in BTU in a HVAC system per Watts-hr of electricity consumed
- EER= 3.412 X COP

- SEER= avg. performance of HVAC system
- SEER= seasonal energy efficiency ratio
- IPLV (integrated part load value)= RAC institute has fixed certain performance standards of chillers used in system. Rating of chillers is represented by term IPLV IN Kw/ton.
- Measures the efficiency under variable load and temperature for non-residential central air-conditioning plant

Unit

- tonne of refrigeration (TR)= amt. of refrigeration effect produced by the uniform melting of one tonne of ice from and at zero degree centigrade in 24 hrs

- 1 TR= 1000 kg x 335 kJ in 24 hrs
  = (1000 x 335)/(24 x 60x 60)
  = 3.87 kJ

1 tonne of refrigeration = 14000 kJ/h

Domestic refrigerator

- Primary function-provide food storage space maintained at low temperature for the preservation of food
- Secondary function-formation of ice cubes
- Storage temperature- 273 K - 277 K
- Freezers are provided at top portion (in some cases it may be in bottom position)
- May be single-door, double-door top freezer, double door bottom freezer and side by side door freezer

- Can work on VCRs or VARs
- VCRs is more compact and more efficient
- Power compression can be varied according to size (75 W, 92 W,125 W, 180 W, 370 W)
- Condenser is tube and wire type
- In between condenser and capillary tube ,receiver and drier is used
- Evaporators:-

  1] Bare tube evaporators

  2]Plate surface evaporators

  3] Finned evaporators

Properties of Refrigerant

- Low Freezing Point. Refrigerants should have low freezing point than the normal operating conditions.
- Low Condensing Pressure. ...
- High Evaporator Pressure. ...
- High Critical Pressure. ...
- High Vapor Density. ...
- High Dielectric strength. ...
- High Latent Heat of Vaporization. ...
- High Heat Transfer Coefficient.