# Chillers & Energy Efficiency Measures

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*Training on*
Energy Efficiency and Conservation
*conducted by*
Bangladesh Power Management Institute (BPMI)



## Overview



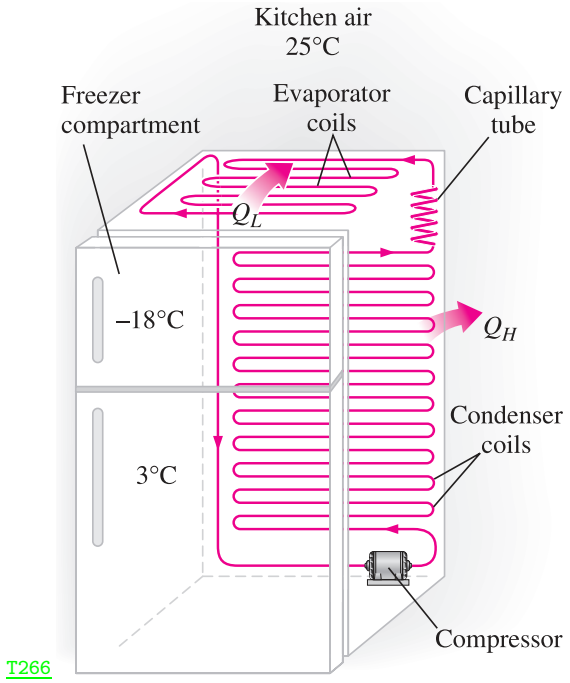
# Classification of Refrigeration Applications

1. Domestic refrigeration
2. Commercial refrigeration
3. Industrial refrigeration
4. Marine & transportation refrigeration
5. Comfort air-conditioning
6. Industrial air-conditioning

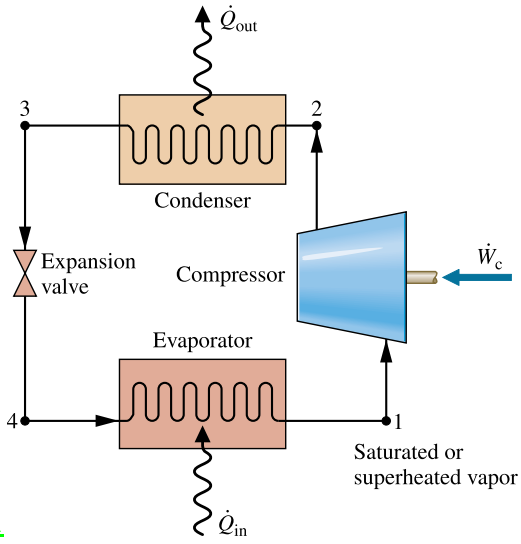




# Basic Vapour Compression Refrigeration System

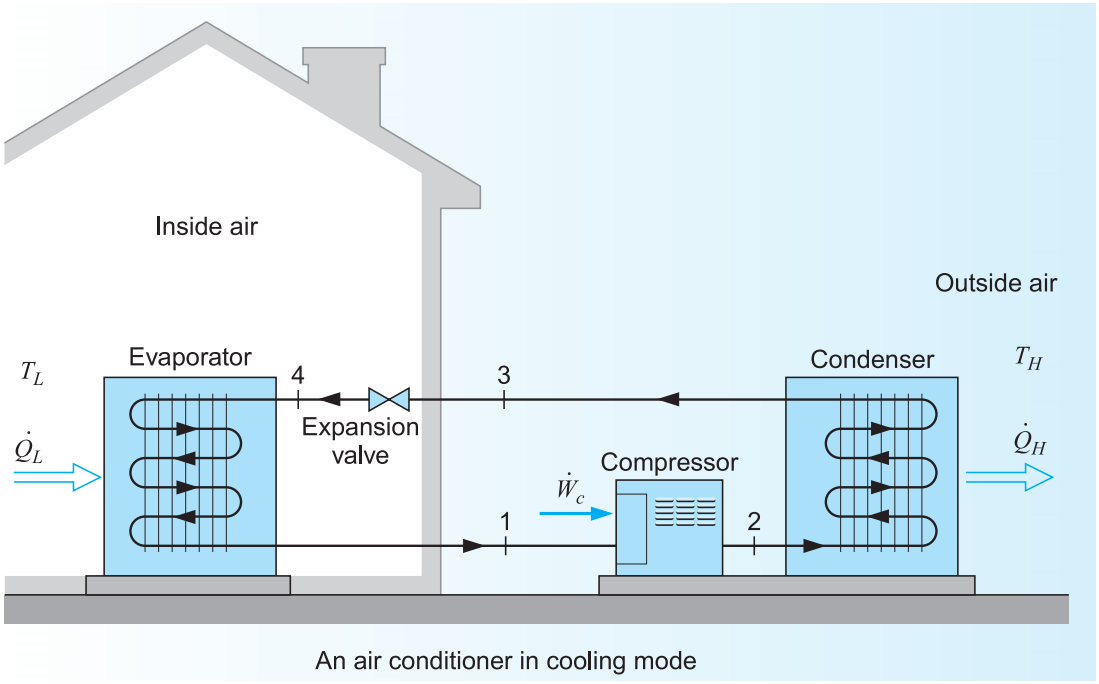



T266




T641

# Vapour-Compression Air-Conditioning (AC) System

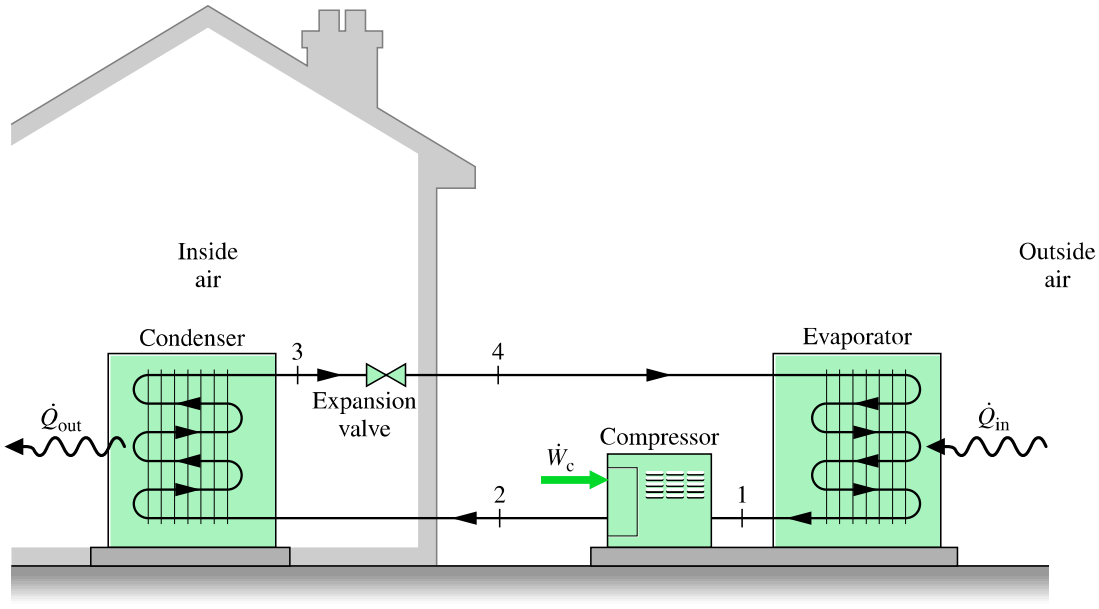



T144



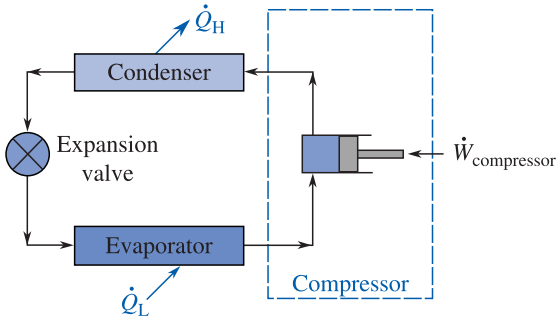


# Vapour-Compression Heat Pump (HP) System

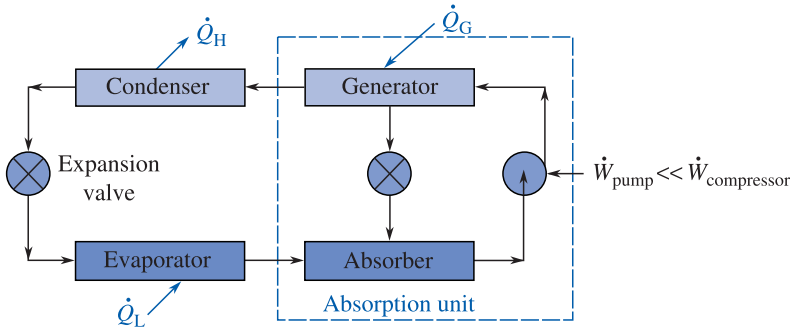



T268

# Vapour Absorption Refrigeration System




(a) Standard vapor-compression refrigeration.

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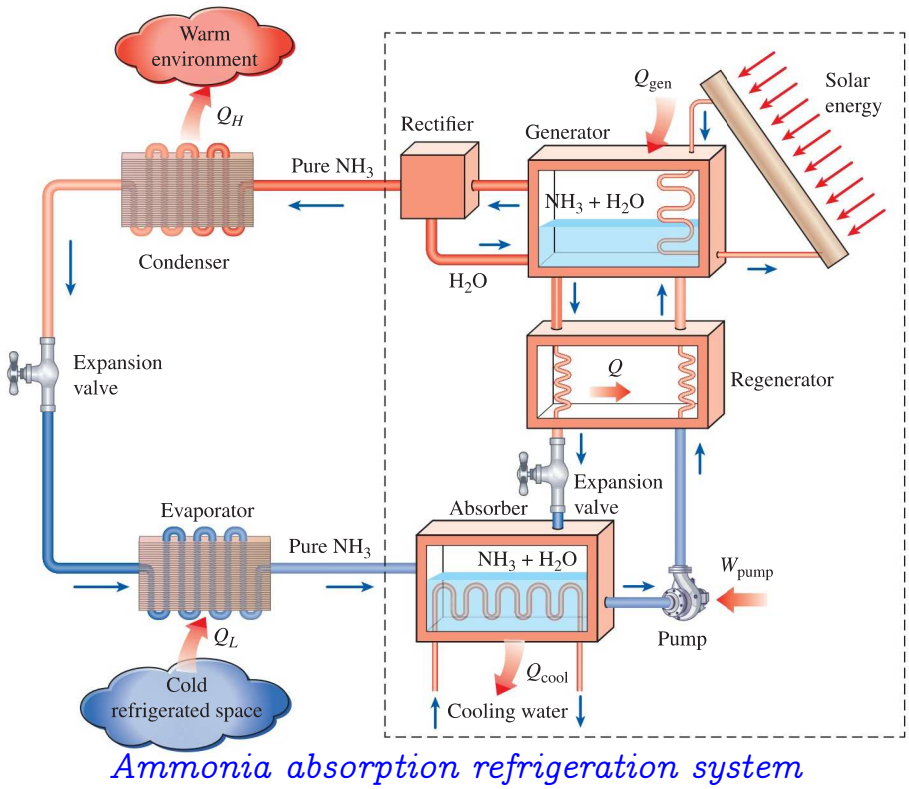
(b) Absorption vapor-compression refrigeration.





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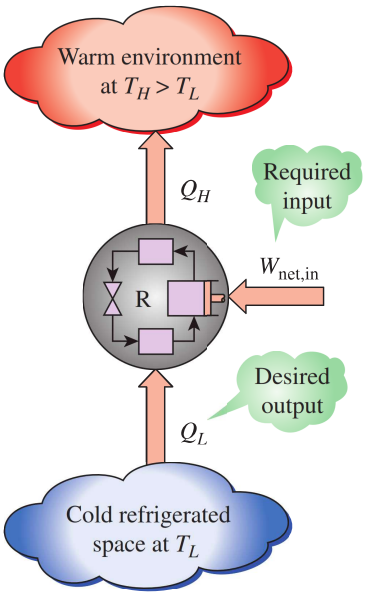
*Ammonia absorption refrigeration system*

# COP: Refrigeration /AC System

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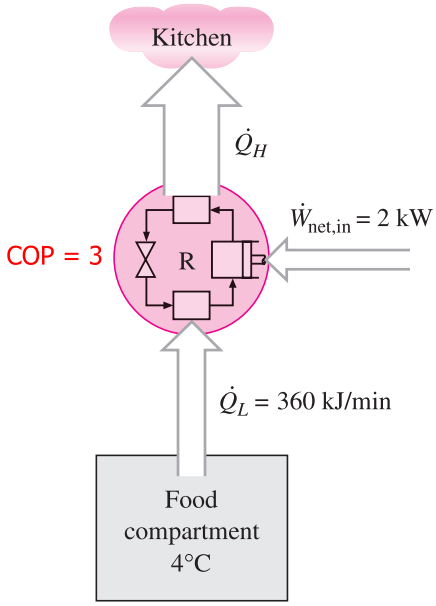


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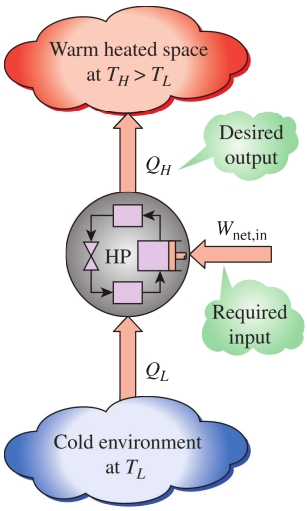
$$\text{Coefficient of Performance, } COP_R = \frac{\text{Desired Output}}{\text{Required Input}} = \frac{Q_L}{W_{net,in}}$$

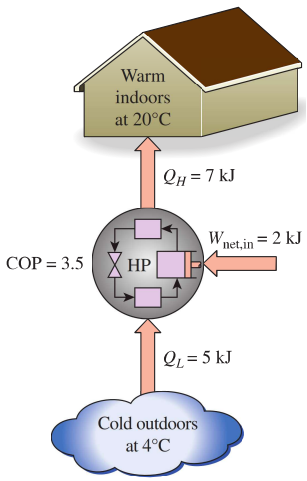




# COP: Heat Pump




T112




T137

$$\text{Coefficient of Performance, } COP_{HP} = \frac{\text{Desired Output}}{\text{Required Input}} = \frac{Q_H}{W_{net,in}}$$

$$COP_{HP} = \frac{Q_H}{W_{net,in}} = \frac{Q_L + W_{net,in}}{W_{net,in}} = COP_R + 1$$

## Refrigeration Capacity/Performance

- 1 ton refrigeration (TR): heat absorbed by 1 ton (2000 lb) of ice melting at $0^oC$ in 24 hours.
- 1 TR = 3.516 kW = 12000 BTU/hr = 200 BTU/min
- Coefficient of Performance, $COP = \frac{Refrigeration\ \ Effect}{Net\ \ Work\ \ Required}$
- Energy Efficiency Ratio, $EER = \frac{RE\ \ in\ \ BTU/hr}{Power\ \ required\ \ in\ \ W}$
- $kW/ton \Rightarrow$ power required per ton of refrigeration

$$kW/ton = \frac{3.516}{COP} \qquad EER * kW/ton = 12$$

| EER | COP | kW/ton |
|---|---|---|
| 6.0 | 1.758 | 2.0 |
| 12.0 | 3.516 | 1.0 |
| 24.0 | 7.032 | 0.5 |





## Integrated Part-Load Value (IPLV)

- COP or EER:

$$IPLV = 0.01A + 0.42B + 0.45C + 0.12D$$

- kW/ton:

$$IPLV = \frac{1}{\frac{0.01}{A} + \frac{0.42}{B} + \frac{0.45}{C} + \frac{0.12}{D}}$$

A $\equiv$ COP or EER or kW at 100% capacity
B $\equiv$ COP or EER or kW at 75% capacity
C $\equiv$ COP or EER or kW at 50% capacity
D $\equiv$ COP or EER or kW at 25% capacity

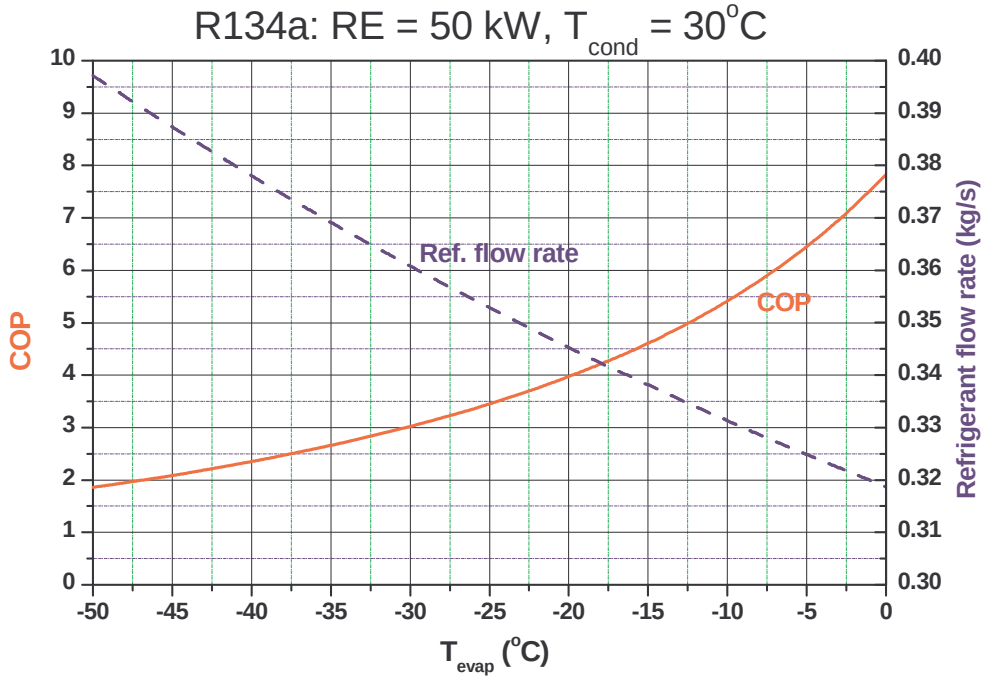
# Minimum Performance (ASHRAE 90.1)

| type | COP | IPLV |
|---|---|---|
| Vapour Compression System: | | |
| Air cooled, with condenser, capacity $<$ 150 ton | 2.7 | 2.8 |
| Air cooled, with condenser, capacity $>$ 150 ton | 2.5 | 2.5 |
| Air cooled, condenserless, all capacity | 3.1 | 3.2 |
| Water cooled, reciprocating, all capacity | 3.8 | 3.9 |
| Water cooled (screw & centrifugal) $<$ 150 ton | 3.8 | 3.9 |
| Water cooled (screw & centrifugal) 150$<$ $<$ 300 ton | 4.2 | 4.5 |
| Water cooled (screw & centrifugal) $>$ 300 ton | 5.2 | 5.3 |
| Vapour Absorption System: | | |
| Air-cooled, single-effect | 0.45 | - |
| Water-cooled, single effect | 0.60 | - |
| Double-effect | 0.95 | 1.0 |





# Effect of Evaporator Temperature

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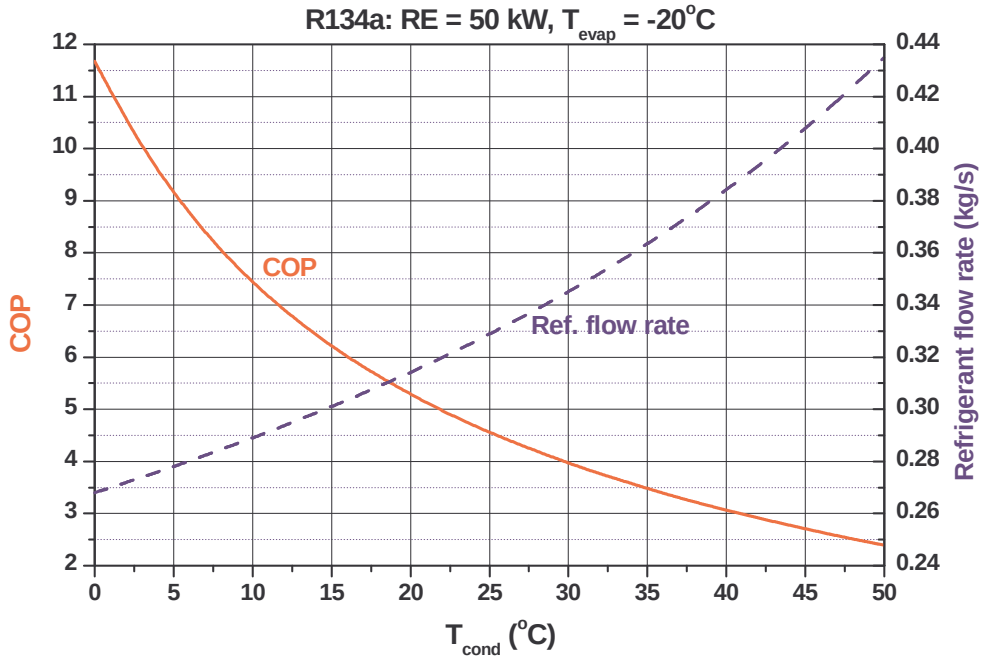
# Effect of Condenser Temperature

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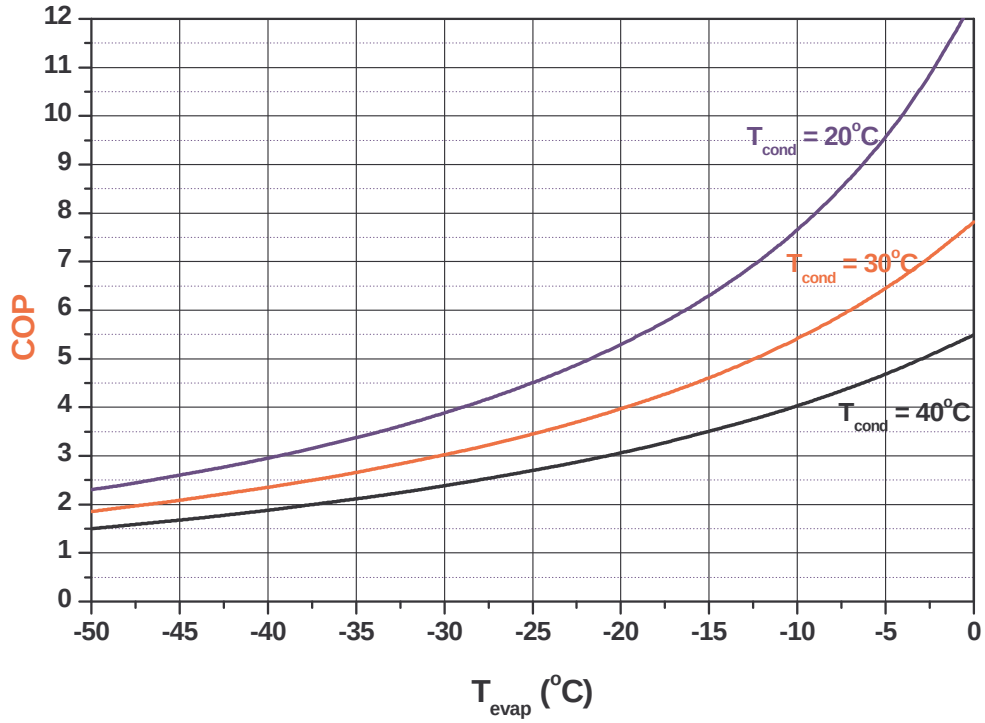
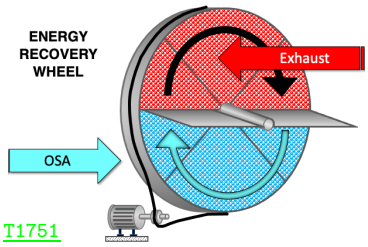
# Effect of Evaporator & Condenser Temperatures

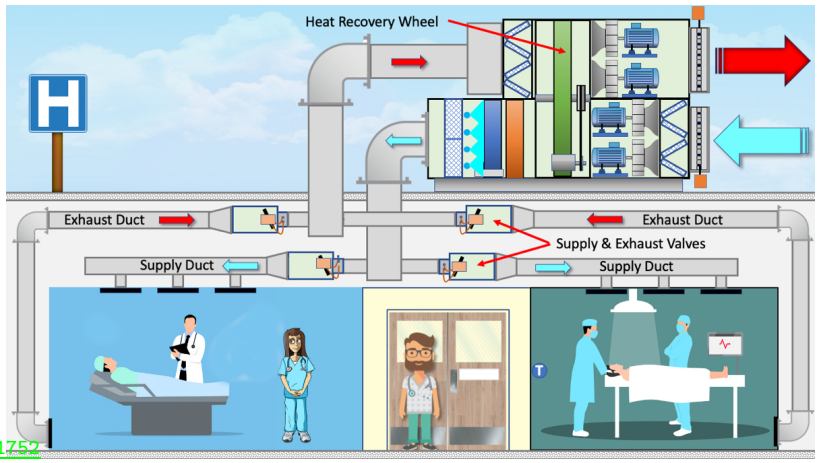



T260

# Energy Saving for Ventilating Air




T1751

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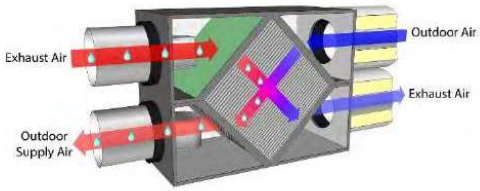
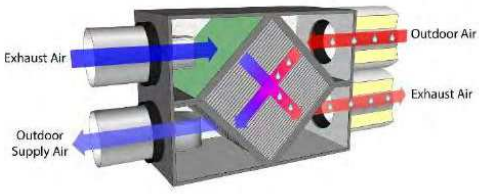



a) Winter




b) Summer

T1754





# Thanks a Lot