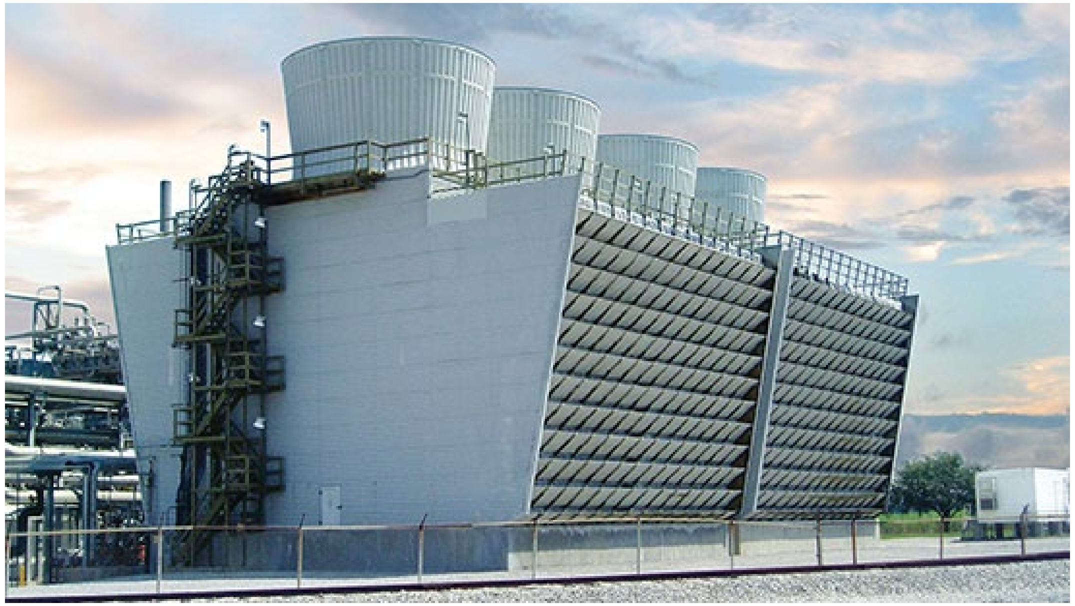
Mechanical Systems

HVAC Fundamentals

HVAC Systems
Purpose

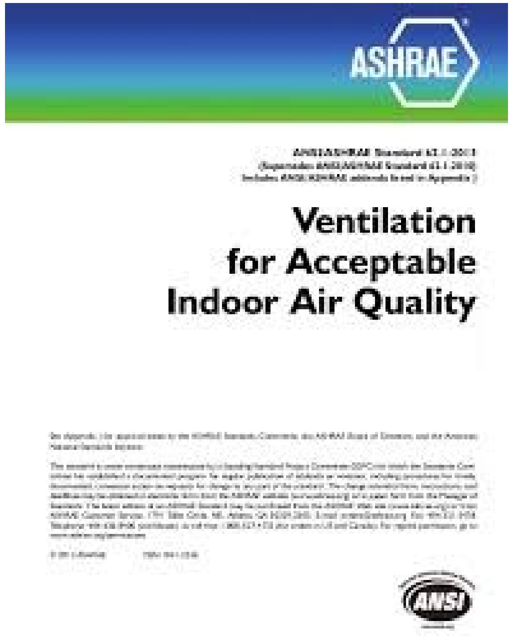
Heating, Ventilating, and Air Conditioning (HVAC) systems are designed to provide and control:

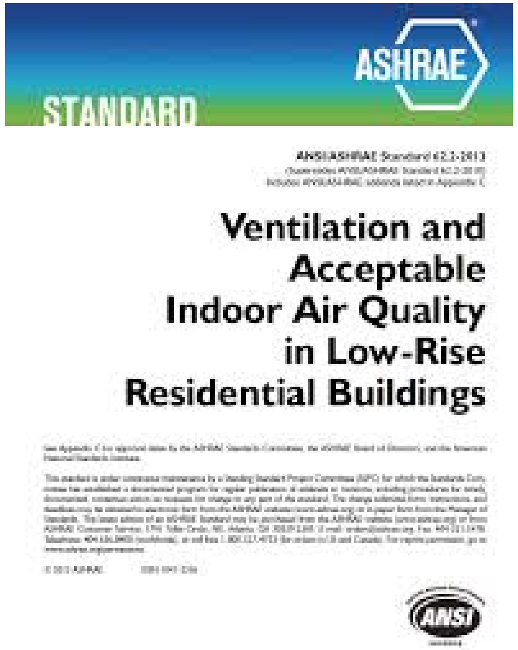
- ❑ Temperature (heat intensity)
- ❑ Enthalpy (heat quantity in the air)
- ❑ Humidity (relative, dew point)
- ❑ Pressure (atmospheric, building pressurization)
- ❑ Air Motion (mechanical, fans, diffusers)
- ❑ Ventilation (air freshness, oxygen content)
- ❑ Air Quality (pollution, contaminant, odors)



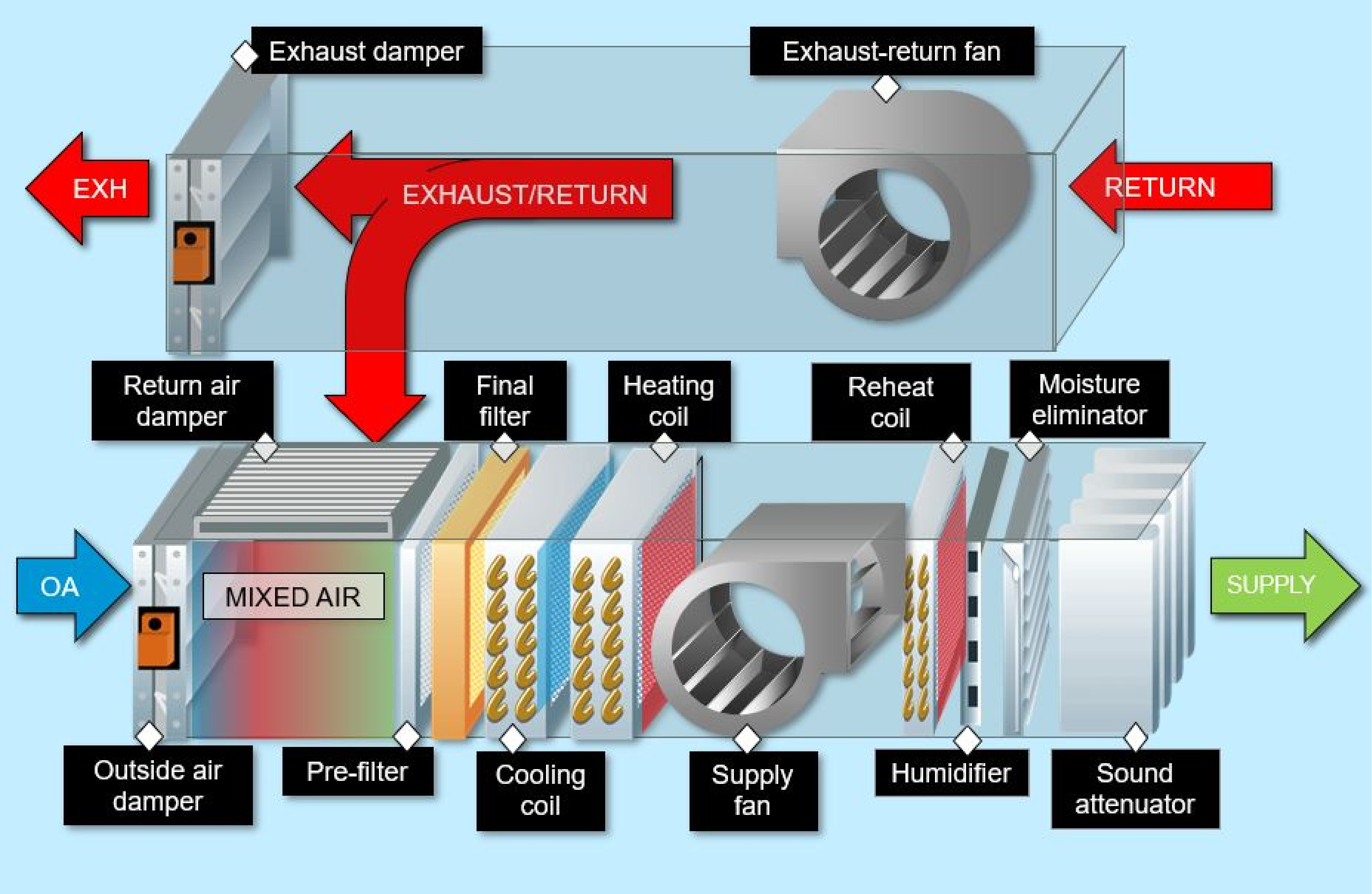
Indoor Air Quality (IAQ)

American Society of Heating, Refrigeration, and Air Conditioning Engineers (ASHRAE)





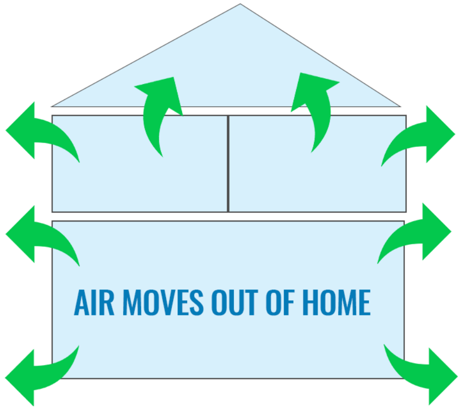
Design


Exhaust damper
Exhaust-return fan
EXH
EXHAUST/RETURN
RETURN
Return air damper
Final filter
Heating coil
Reheat coil
Moisture eliminator
OA
MIXED AIR
SUPPLY
Outside air damper
Pre-filter
Cooling coil
Supply fan
Humidifier
Sound attenuator

Building Pressurization

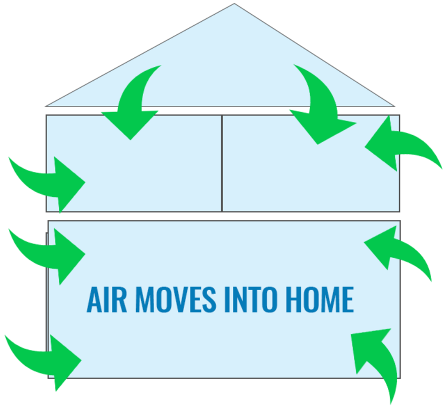
Positive Air Pressure

- Your air pressure inside is greater than pressure outside
- Air gets pushed into walls and insulation

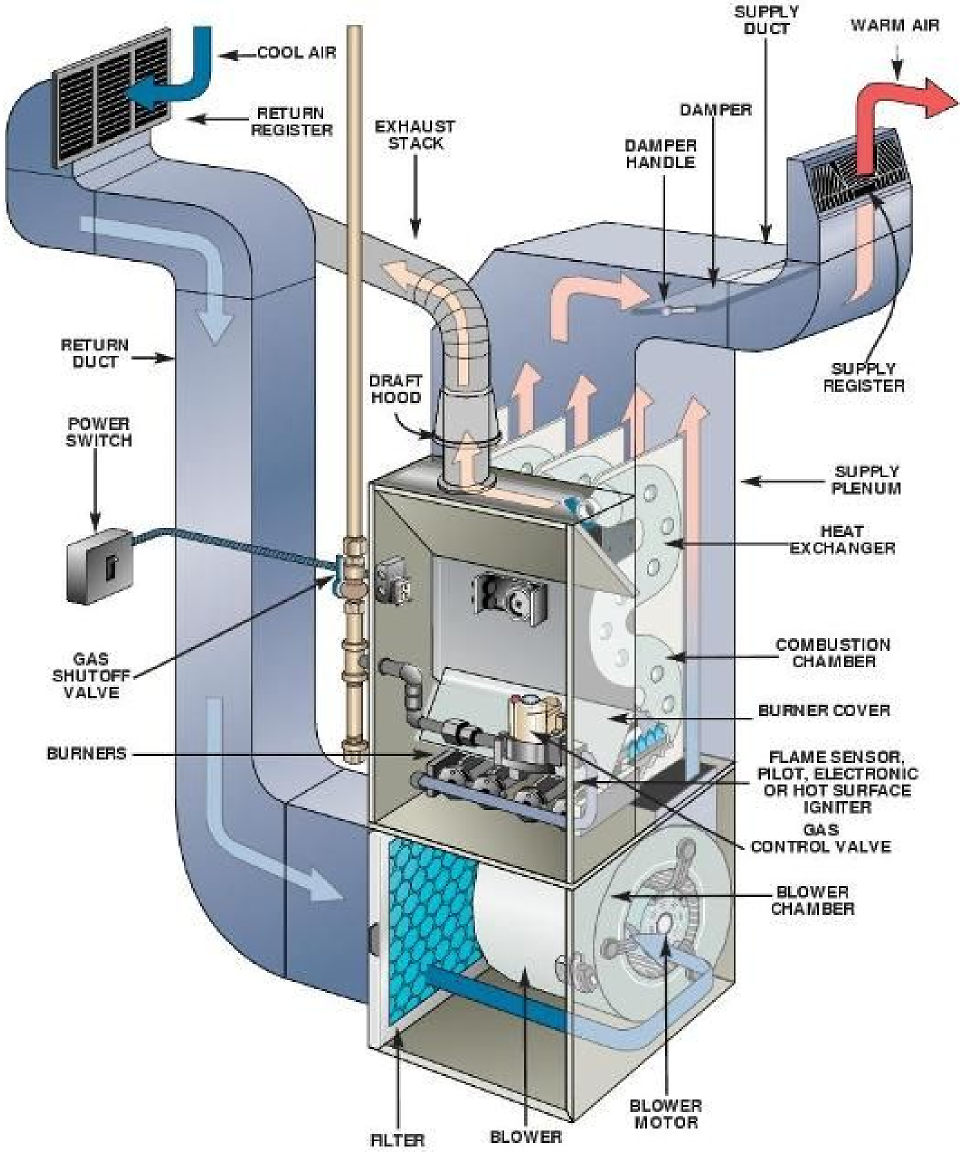


Negative Air Pressure

- When indoor air pressure is lower than pressure outside
- Outside air rushes in to try and balance out the pressure difference



HVAC Components
Heating



HVAC Components
Ventilation

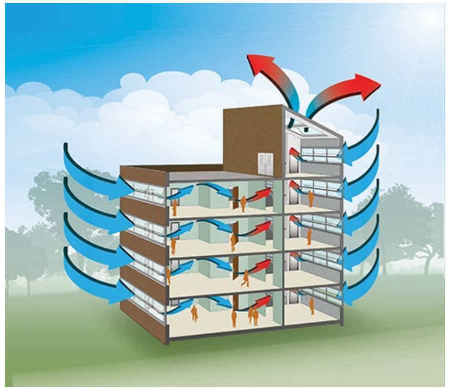
Natural Ventilation (Passive)

HVAC Components
Ventilation

Mechanical Ventilation (Active)

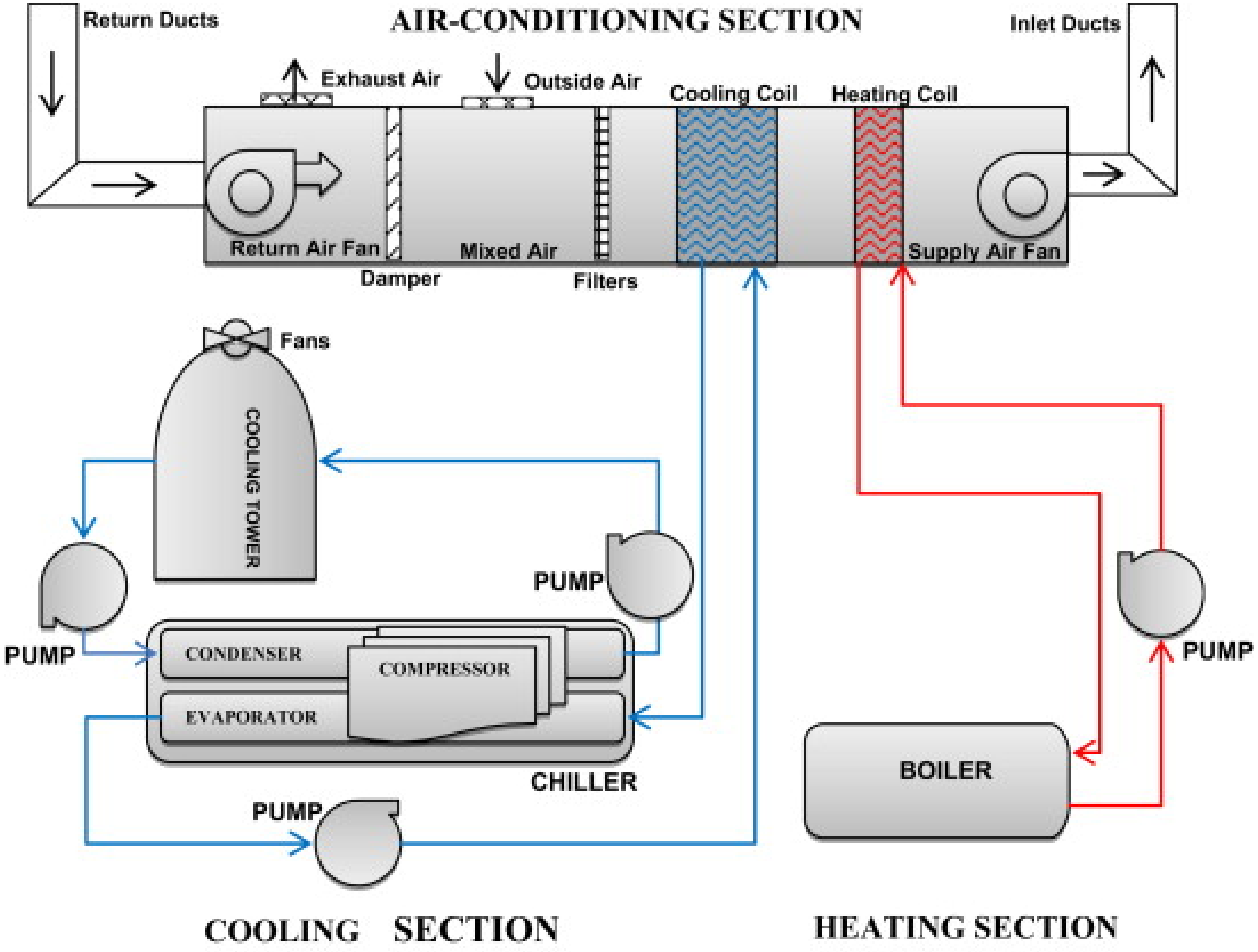
HVAC Components
Ventilation

EPA - IAQ
https://www.epa.gov/indoor-air-quality-iaq



https://www.calacademy.org/efficient-building-design

HVAC Components
Air Conditioning

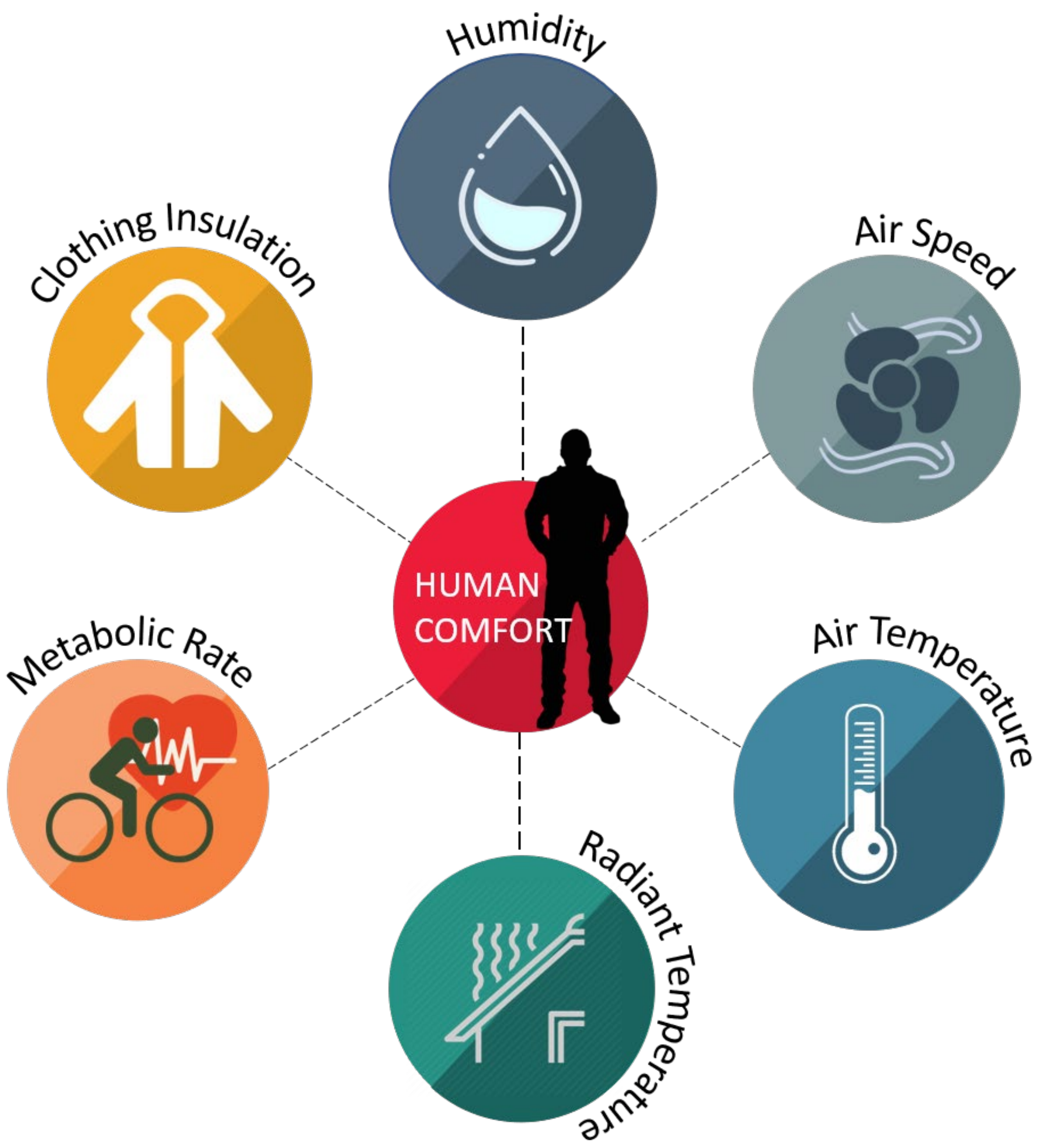


HVAC Components
Air Conditioning

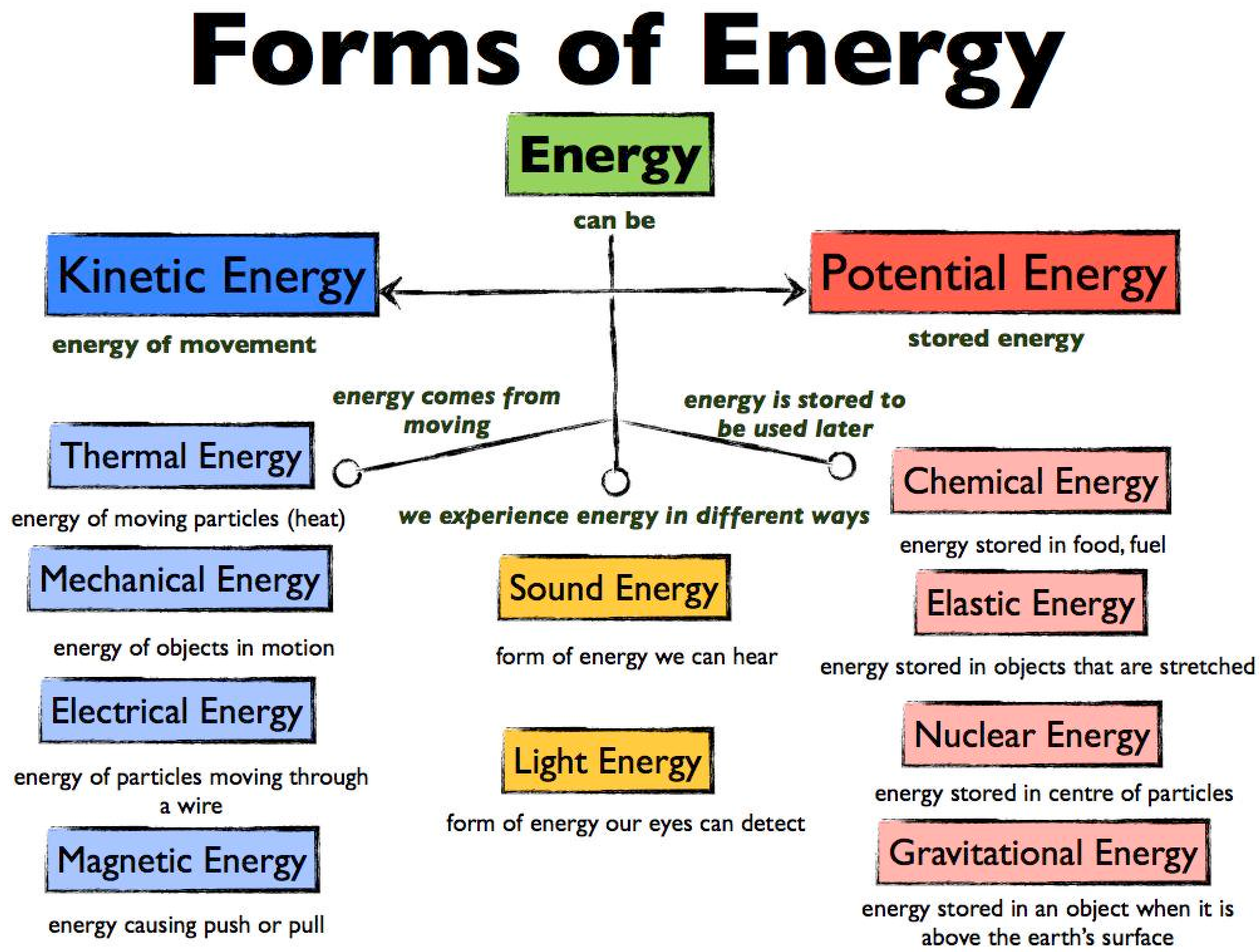
Air Cooled

Water Cooled

HVAC Components
Air Conditioning



Basics of Energy



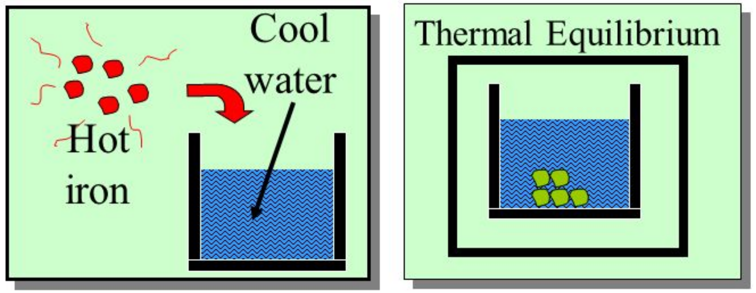
Thermal (Heat) Energy

- Energy of any object with a temperature above absolute zero, due to the kinetic energy of its molecules.
- For a given quantity of material, the higher its temperature, the more thermal energy it has.
- Heat is not something an object has, but rather the energy that it absorbs or gives up.

Conservation of Energy

Whenever there is a transfer of heat within a system, the heat lost by the warmer bodies must equal the heat gained by the cooler bodies:

$$\Sigma \text{ (Heat Losses)} = \Sigma \text{ (Heat Gained)}$$



Units of Heat

Calorie (cal)	British Thermal Unit (Btu)	SI Unit of Heat
• One calorie (1 cal) is the quantity of heat required to raise the temperature of 1 g of water 1 ^oC • 10 calories of heat with raise the temperature of 10 g of water by 10 ^oC • One kilocalorie (1 kcal) is the quantity of heat required to raise the temperature of 1 kg of water 1 ^oC	• One British Thermal Unit (1 Btu) is the quantity of heat required to raise the temperature of 1 lb of water 1 ^oF • 10 Btu will raise the temperature of 10 lb of water by 10 ^oF • The British Thermal Unit (Btu) is widely used in the HVAC industry. It is an outdated unit. • When working with the Btu, the pound unit is actually a unit of mass, not weight.	• Joule - the SI unit of work or energy, equal to the work done by a force of one newton when its point of application moves one meter in the direction of action of the force.

HVAC Fundamentals

Heat Formula

Heat flows from the point of higher temperature to one of lower temperature.

The heat content, Q, is given by the equation:

$$Q = M \times C \times \Delta T$$

Where

Q = heat absorbed (or released) (Btu)

M = mass (lb)

C = heat capacity (often called “specific heat”) (Btu/lb ^{o}F)

ΔT = temperature increase or decrease, ^{o}F

Example 1.

A 12 ft X 20 ft concrete patio is 6 in thick. If the slab is warmed by the sun to 90^{o}F during the day and cools to 45^{o}F overnight, how much heat is stored and released by the floor on a daily basis?

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Solution.

For Concrete, $C = 0.21$ Btu/lb°F (specific heat)
$\rho = 144$ lb/ft^3 (density)
$W = \rho\, v$ (M)

Heat Storage

$Q = M \times C \times \Delta T$

$Q = (12\text{ ft} \times 20\text{ ft} \times 6\text{ in} \times 1\text{ ft}/12\text{ in}) \times 144\text{ lb/ft}^3 \times 0.21\text{ Btu/lb°F} \times (90°F - 45°F)$

$Q = 120\text{ ft}^3 \times 144\text{ lb/ft}^3 \times 0.21\text{ Btu/lb°F} \times 45°F$

$Q = 163{,}296$ Btu

HVAC Fundamentals

Heat Capacity

The heat capacity of a substance is the heat required to raise the temperature a unit degree.

Density and Heat Capacity for many common materials are listed in the table below.

Material	Density (lb/ft^3) ρ	Heat Capacity (Btu/lb°F) C
Water	62.4	1.0
Wood	45	0.57
Foam Insulation	2.5	0.34
Air	0.075	0.24
Concrete	144	0.21
Steel	489	0.12
Aluminum	169	0.215

Example 2.

How much heat (Btus) will be stored in a 100-ft^2 concrete wall 8-in thick if it is warmed from 55^{o}F to 85^{o}F by exposure to sunlight?

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Heat Storage

$Q = M \times C \times \Delta T$

$Q = (100\ ft^2 \times 8\ in \times 1\ ft/12\ in) \times 144\ lb/ft^3 \times 0.21\ Btu/lb°F \times (85°F - 55°F)$

$Q = (67\ ft^3 \times 144\ lb/ft^3) \times 0.21\ Btu/lb°F \times 30°F$

$Q = 60{,}480\ Btu$

Example 3.

2 kg of Aluminum (AL) is heated from 20^{o}C to 100^{o}C. The specific heat of AL is 0.91 kJ/kg ^{o}C and the heat required can be calculated as:

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Solution.

$Q = M \times C \times \Delta T = 2\ \text{kg} \times 0.91\ \text{kJ/kg}\ ^{o}\text{C} \times (100^{o}\text{C} - 20^{o}\text{C}) = 145.6\ \text{kJ}$

How many Btu's? rapidtables.com 138 Btu

Example 4.

One litre of water is heated from 0ºC to boiling (100ºC). Specific heat of water is 4.19 kJ/kg ºC and the heat required can be calculated as:

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Solution.

$Q = M \times C \times \Delta T = (1 \text{ litre} \times 1 \text{ kg/litre}) \times (4.19 \text{ kJ/kg } ^oC) \times (100^oC - 0^oC) = 419 \text{ kJ}$

How many Btu's? rapidtables.com 397 Btu

Example 4.

Convert from SI to US

Q = 419 kJ = 419,000 J

1 J = 0.000948 Btu
1000 J = 1 kJ = 0.948 Btu

Q = 419 kJ x 0.948 Btu / kJ = 397 Btu

Example 4.

Using US Units

1 litre = ? lb   Can't Compare!

A litre is a unit of Volume

A lb is a unit of Weight

1 litre weighs 1 kg

There are 2.20462 lb /1 kg

$Q = M \times C \times \Delta T = 2.20462\ lb \times 1\ Btu/lb\ °F \times (212°F - 32°F) = 397\ Btu$

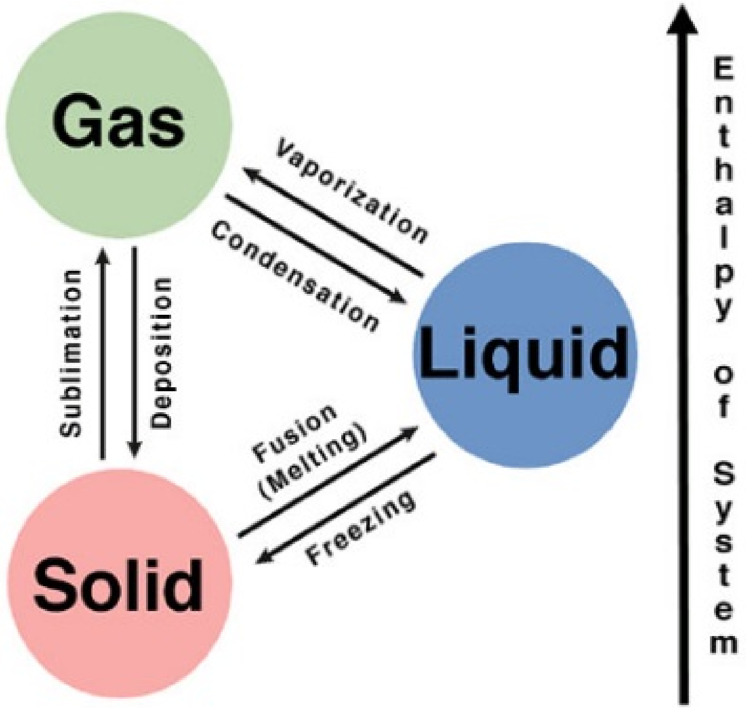
Sensible and Latent Heat

Sensible Heat

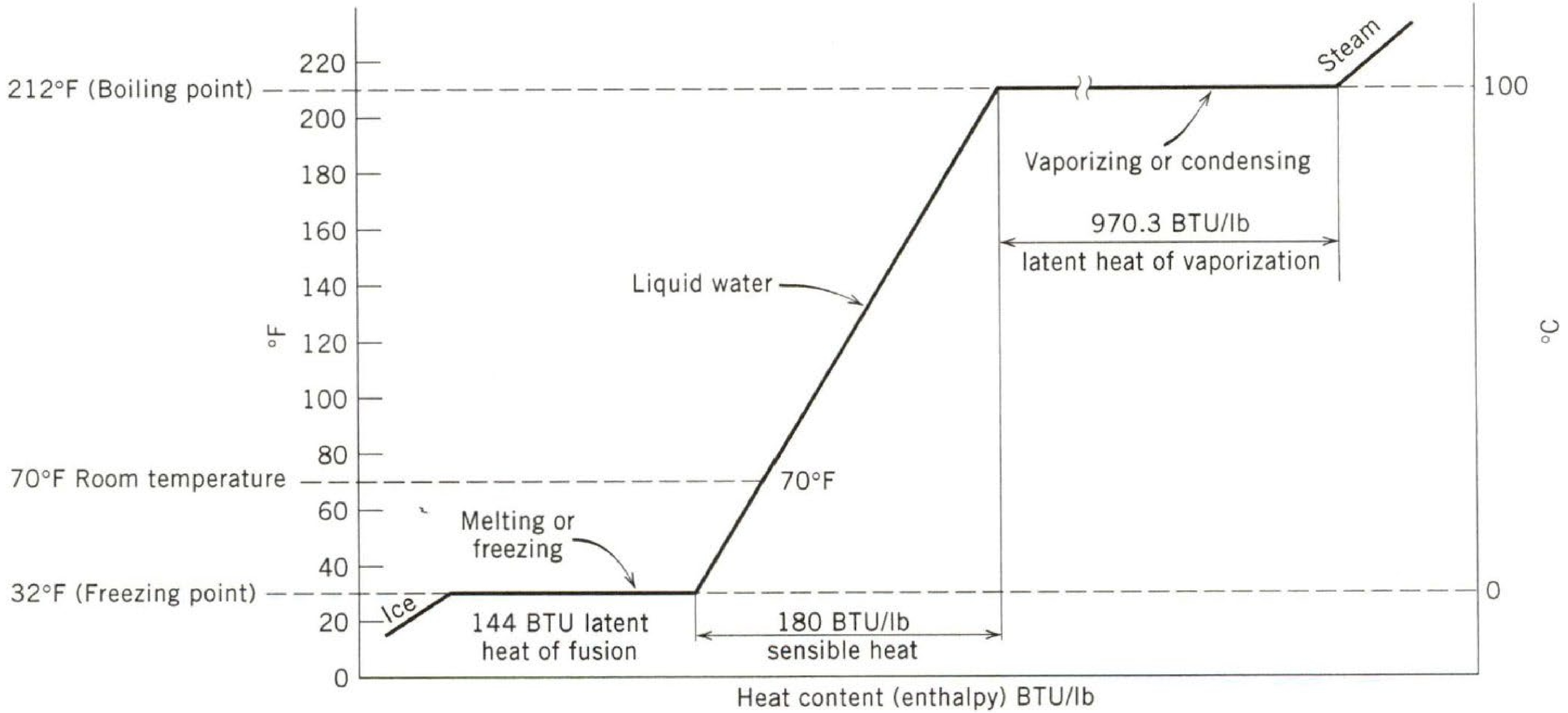
Causes a change in temperature of substance when heat is added or removed. Can be measured by a thermometer.

Latent Heat

Causes a change of state in the substance when heat is added or removed. Changing a solid to a liquid or a liquid to a gas while the temperature remains constant.



HVAC Fundamentals



Example 5.

How much heat must be added to a 1 lb of water at room temperature (70^{o}F) to bring it to the boiling point?

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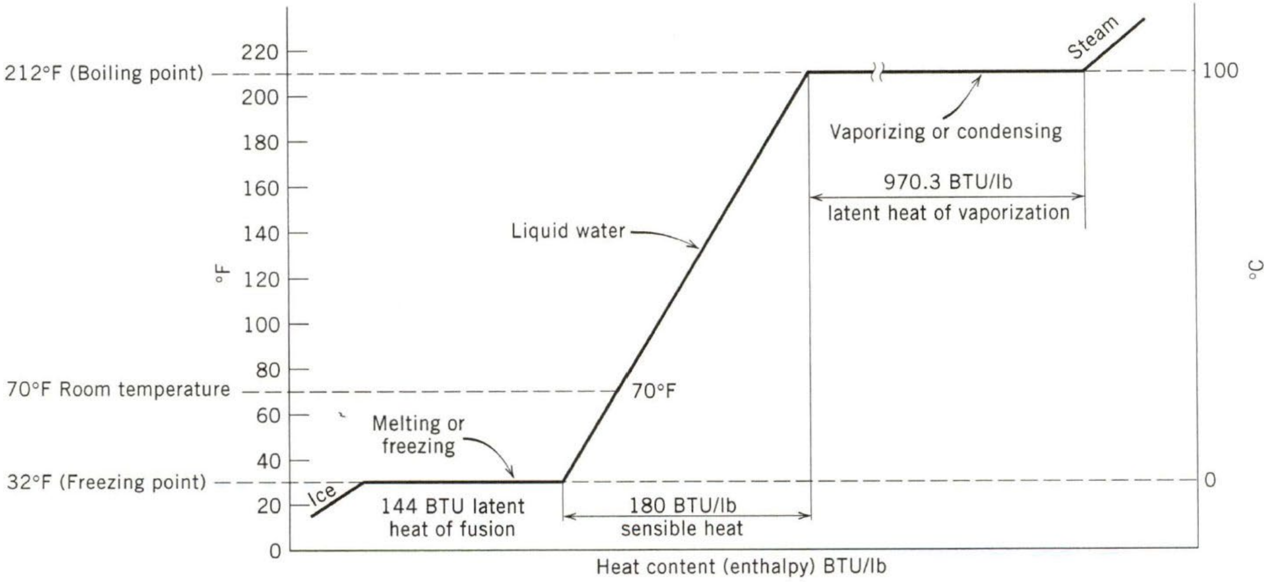
Solution.

$Q = M \times C \times \Delta T$

$Q = 1\ lb \times 1\ Btu/lb°F \times (212°F - 70°F) = 142\ Btu$



Example 6.

A block of ice, 1 ft^3 in volume, is taken from a freezer where it was stored at 20°F (-6.7 °C) .
How many BTU of heat will be required to convert the ice to water at 60°F?

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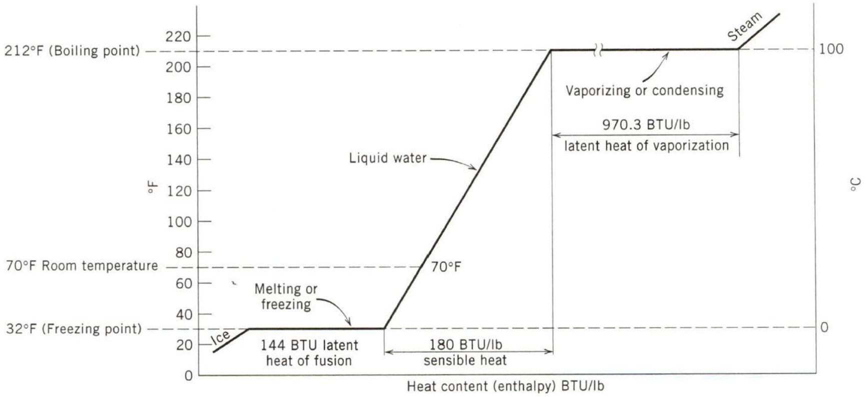


Weight of the ice: $M = 1\ ft^3 \times 62.41\ lb/ft^3 = 62.41\ lb$

Sensible Heat needed to raise the temperature from 20°F to 32°F

$Q = 62.41\ LB \times 1\ Btu/lb°F \times (32°F - 20°F) = 748.92\ Btu$

Latent Heat is involved since there is a phase change from solid (ice) to liquid (water)

$Q = 62.41\ lb \times 144\ Btu/lb = 8{,}987.04\ Btu$

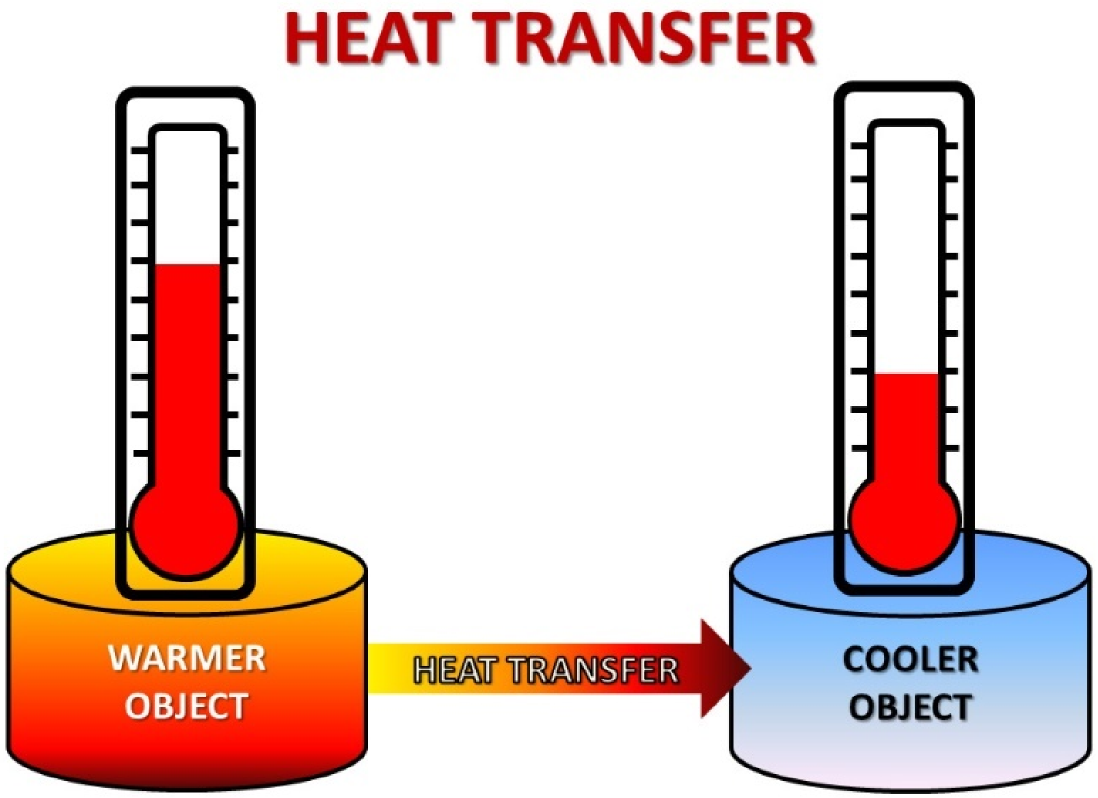
Sensible Heat is needed to raise the temperature from melted @32 °F to 60 °F

$Q = 62.41\ lb \times 1\ Btu/lb°F \times (60°F - 32°F) = 1{,}747.48\ Btu$

Total Heat (Enthalpy) = Latent Heat + Sensible Heat

= 748.92Btu + 8,987.04 Btu + 1,747.48 Btu = 11,483 Btu

Heat Transfer: Conduction, Convection, Radiation



Conduction
Transfer of heat between substances that are in direct contact with each other. The better the conductor, the more rapidly heat will be transferred.

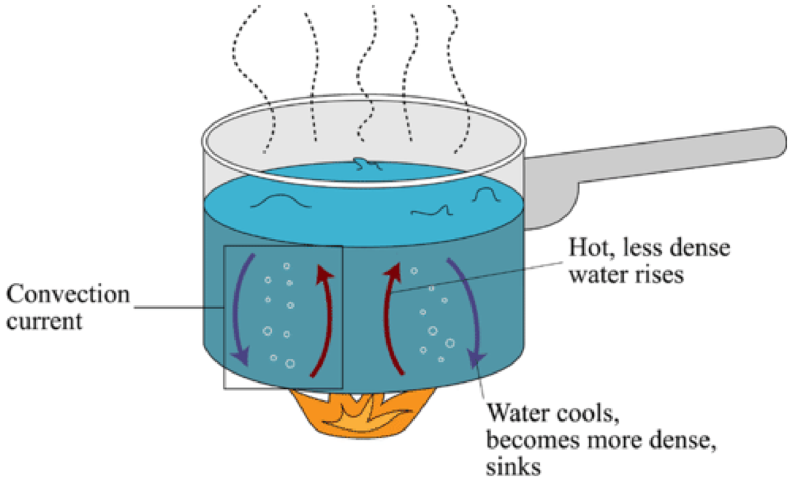
Examples:
A cold cast iron skillet is placed onto a stovetop. When the stove is turned on, the skillet becomes very hot due to the conduction of heat from the burner to the skillet.
A cube of ice placed in your hand.

Convection

Thermal energy is transferred from hot places to cold places by convection. Convection occurs when warmer areas of a liquid or gas rise to cooler areas in the liquid or gas. Cooler liquid or gas then takes the place of the warmer areas which have risen higher. This results in a continuous circulation pattern.

Example:

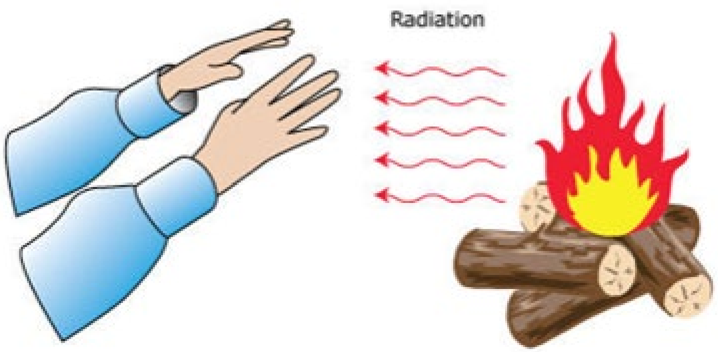
Boiling water - The heat passes from the burner into the pot, heating the water at the bottom. Then, this hot water rises and cooler water moves down to replace it, causing a circular motion.



HVAC Fundamentals

Radiation
Transfer of heat through space from a mass at a higher temperature to a mass at a lower temperature via electromagnetic waves.

Examples:
Sun warms your body
Heat from a fire



Mean radiant temperature (MRT) is a measure of the average temperature of the surfaces that surround a point, with which it will exchange thermal radiation.

Power

The rate of energy flow is "power".

The unit of power for thermal energy is in Btus per hour, abbreviated Btuh (BTUH)

This unit is used in quantifying the amount of heating gained or lost by a structure (load) and the amount of heating or cooling capacity required by equipment to offset the heat or load.

TABLE 1.1 Forms and Units of Energy and Power

	Unit of Measure		
Energy Form	Energy	Power	Conversion to Btu
Heat	British thermal unit (Btu)	British thermal unit per hour (Btuh)	1.00
Electric	Watt-hour (Wh)	Watt (W)	3.41
	Kilowatt-hour (kWh)	Kilowatt (kW)	3,413
Mechanical	Horsepower-hour (hp-hr)	Horsepower (hp)	2,545

Power

For all forms of energy, the following equation will apply, but units will depend on the energy

$$\text{Power} = \frac{\text{Energy}}{\text{Time}}$$

$$\text{Power} \times \text{Time} = \text{Energy}$$

Example 7.

A 50 ft^2 x 6 in. concrete slab is in full sun all day and absorbed 72,000 Btu of heat energy. If the absorbed heat is released during the night between 11:00 pm and 5:00 am, what is the average capacity of the slab over this period to assist in heating the building?

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Solution.

Power = Energy / Time
= 72,000 Btu / 6 hr
= 12,000 Btu/hr = 12,000 Btuh