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| **CMGT 235 – Electrical and Mechanical Systems** | | |
| **Discussion No. 01** | **Unit 1 - Mechanical Systems** | **Fall 2022** |

**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)**

* Refers to the air quality within and around buildings and structures, especially as it relates to the health and comfort of building occupants.
* Directly affects occupant health, comfort, and productivity.

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

ASHRAE Standard 62.1 Ventilation for Acceptable Indoor Air Quality

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Other ASHRAE Standards Commonly Used for HVAC Design

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| ASHRAE Standard 62.2  Ventilation for Acceptable Indoor Air Quality in Low-Rise Residential Buildings | ASHRAE Standard 52.2  Method of Testing General Ventilation Air-Cleaning Devices for Removal Efficiency by Particle Size | ASHRAE Standard 55  Thermal Environmental Conditions for Human Occupancy |

**Design**

HVAC systems generally share a few basic design elements:

* Outside air intake
* Air handling unit—a system of fans, heating and cooling coils, air-flow control dampers, air filters, etc.
* Air distribution system
* Air exhaust system

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ACiiigAooooAKKKKACiiigAooooAKKKKACiiigAooooAKKKKACiiigAooooAKKKKACiiigAooooAKKKKACiiigAooooAKKKKACiiigAooooAKKKKACiiigAooooAKKKKACiiigAooooAKKKKACiiigAooooAKKKKACiiigAooooAKKKKACiiigAooooAKKKKACiiigAooooAKKKKACiiigAooooAKKKKACiiigAooooAKKKKACiiigAooooAKKKKACiiigAooooAKKKKACiiigAooooAKKKKACiiigAooooAKKKKACiiigAooooAKKKKACiiigAooooAKKKKACiiigAooooAKKKKACiiigAooooAKKKKACiiigAooooAKKKKACiiigAooooAKKKKACiiigAooooAKKKKACiiigAooooAKKKKACiiigAooooAKKKKACiiigAooooAKKKKACiiigAooooAKKKKACiiigAooooAKKKKACiiigAooooAKKKKACiiigAooooAKKKKACiiigAooooAKKKKACiiigAooooAKKKKACiiigAooooAKKKKACiiigAooooAKKKKACiiigAooooA//2Q==)

**Function**

Outside Air Intake

Outside Air (OA) is brought into the Air Handling Unit (AHU) by the Supply Fan

Air Handling Unit (AHU)

OA also referred to as Supply Air is filtered to remove particulates

Supply Air is conditioned – cooled or heated, by either the Cooling Coil or the Heating Coil

Supply Air Moisture Content – Humidifying (add moisture) or Dehumidifying (remove moisture)

Air Distribution System

Ductwork distributes the conditioned (heated or cooled) air throughout the building before returning it to the AHU

Air Exhaust System

Exhaust/Return Air is forced out of the system by the Exhaust/Return Fan

Exhaust Air – portion of the Return Air pushed outside the building

Return Air – portion sent back to the system to be recirculated

Mixed Air – includes a percentage of Return Air mixed with new Outside Air

100% new Outside Air – all Return Air is exhausted, no recirculated air

**Building Pressurization**

A building’s interior air pressure will be either negative or positive, depending on the airtightness of the building and other forces such as wind, exhaust loads, and amount of make-up air.

**Negative indoor air pressure**: This occurs when the inside pressure is less than the pressure outside causing air to leak into the building. This is called infiltration.

**Positive indoor air pressure**: This result’s when the inside pressure is greater than the outside pressure. In this case air pushes from inside the building to the outside. This is called exfiltration.

Proper pressurization of buildings and indoor spaces is a crucial component required for the management of:

* Indoor air quality
* Maximizing energy efficiency
* Maintaining occupant health and comfort

Lack of control regarding building pressurization can lead to a host of problems including:

* The infiltration of moisture
* Cold winter or hot summer drafts
* Doors that are difficult to open or slam shut

Which is better?

* In general, a building benefits from having slight positive indoor pressure.
* This is especially true during the heating season because it is expensive to heat the cold air that infiltrates from outside when interior pressure is negative.

A close up of a map

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**HVAC Components**

Heating

The overall heat loss in buildings occurs from heat loss due to:

(1) transmission through walls, windows, doors, ceilings, floors, etc.

(2) heat loss caused by ventilation, and

(3) heat loss caused by infiltration.

* If the heat loss is significant enough to create an uncomfortable environment for the occupants, the building HVAC system must provide warm air to replace the heat loss.
* Heat loss is measured in Btu per hour (Btu/h or BTUH).
* BTU – British Thermal Unit; the amount of energy required to raise one pound of water one-degree Fahrenheit.

**Boilers**

|  |  |  |
| --- | --- | --- |
| Types of Boilers  — Fire Tube  — Water Tube | Boiler Classifications  — high-pressure (operate at >15 psig)  — low-pressure  — steam-boiler  — hot water-boiler | Boiler Fuels  — Natural Gas  — Oil  — Coal  — Electricity |

**Furnaces**

A “forced air” furnace works by blowing heated air through ducts that deliver the warm air to rooms throughout the building via air registers or grills.

Furnace Fuels

— Natural Gas

— Oil

— Coal

— LPG (Liquid Petroleum Gas)

— Electricity

**Heating Coils**

Water is the most widely used heat transfer medium because it’s readily available and low in cost. Water can be used as a heat transfer medium if the temperature range is between 15 degrees Fahrenheit (when mixed with glycol) when cooling and a high of 210 degrees Fahrenheit when heating.

A picture containing indoor

Description automatically generatedTypes of Heat Exchanger Coils:

Condenser Coils

DX or Evaporator Coils

Cold Water Coils

Hot Water Coils

Steam Coils

Booster Coils

Electric Coils

Ventilation

**Indoor Air Quality (IAQ)**

* IAQ refers to the air quality within and around buildings and structures, especially as it relates to the health and comfort of building occupants.
* Understanding and controlling common pollutants indoors can help reduce your risk of indoor health concerns.

EPA - IAQ

<https://www.epa.gov/indoor-air-quality-iaq>

**Ventilation Rates**

Cubic Feet per minute per person (CFM/person)  
Air Changes per Hour (ACH)

**The Standards for Ventilation and Indoor Air Quality**

ANSI/ASHRAE Standards 62.1 Ventilation for Acceptable Indoor Air Quality for commercial buildings

ANSI/ASHRAE Standards 62.2 Ventilation and Acceptable Indoor Air Quality in Low-Rise Residential Buildings for residential buildings

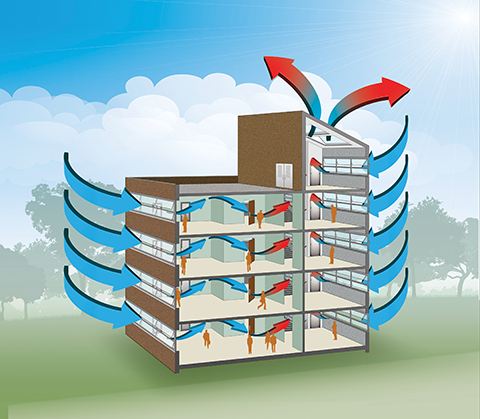
* Consensus standards and represent the standard of practice for the building industry with respect to ventilation and indoor air quality.
* Provisions of these standards most often form the basis for ventilation requirements in building codes.

Mechanical Ventilation (Active Ventilation)

A picture containing indoor

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Natural Ventilation (Passive Ventilation)

 A picture containing sky, grass, outdoor

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

Air Conditioning

Air Conditioning means comfort cooling with either chilled water systems or refrigerant systems.

These systems include cooling coils to remove heat from the air.

A screenshot of a cell phone

Description automatically generated

**AC (Air Conditioning) also means conditioning the air in the following ways:**

Temperature (tempering the air)

— Cooling (removing heat)

A close up of a logo

Description automatically generated— Heating (adding heat)

Humidity control

— Dehumidifying (removing moisture)

— Humidifying (adding moisture)

Volume of airﬂow

— cfm (cubic feet per minute)

Velocity (speed) of airﬂow

— fpm (feet per minute)

Cleaning

— Filtering

Pattern of airﬂow

— Direction

• horizontal

• vertical

**Six Factors of Human Comfort**

**Basics of Energy**

* Energy is the ability to do work.
* Energy is a quantity, such as **Heat**.

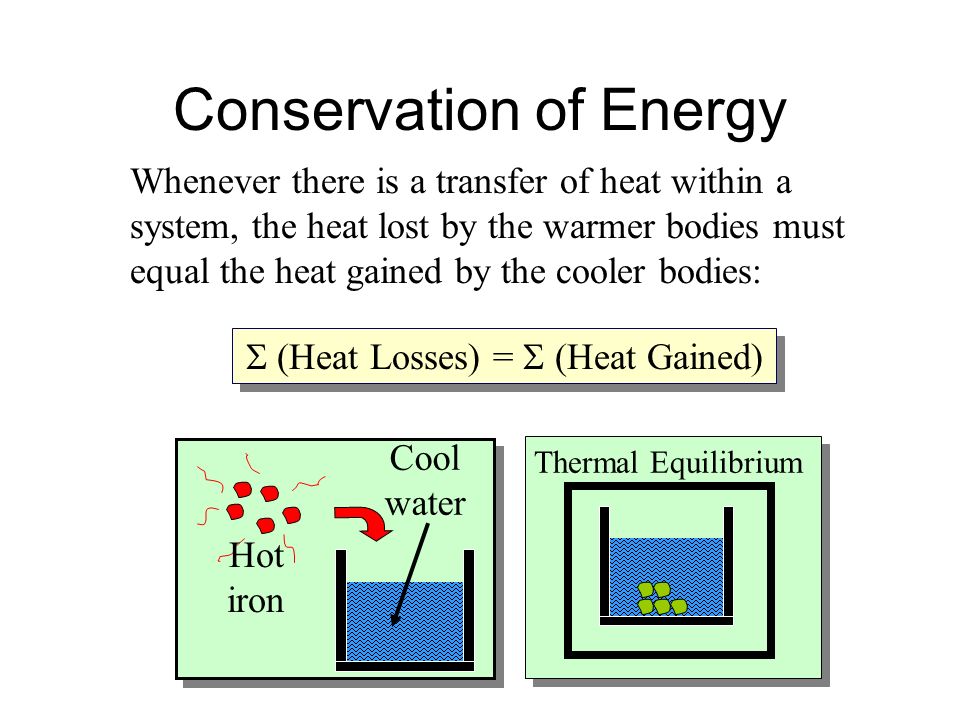
All forms of energy fall under two categories:

A screenshot of a cell phone

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**Thermal (Heat) Energy**

* Thermal Energy, called heat, is the 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.



**Units of Heat**

Calorie (cal)

One calorie (1 cal) is the quantity of heat required to raise the temperature of 1 g of water 1 ⁰C

10 calories of heat with raise the temperature of 10 g of water by 10 ⁰C

One kilocalorie (1 kcal) is the quantity of heat required to raise the temperature of 1 kg of water 1 ⁰C

British Thermal Unit (Btu)

One British Thermal Unit (1 Btu) is the quantity of heat required to raise the temperature of 1 lb of water 1 ⁰F

10 Btu will raise the temperature of 10 lb of water by 10 ⁰F

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.

SI Unit of Heat

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.

Comparison of Heat Units:

1 cal = 4.186 J 1 Btu = 778 ft lb

1 kcal = 4186 J 1 Btu = 252 cal

1 Btu = 1055 J

**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 x C x ΔT

Where

Q = heat absorbed (or released) (Btu)

M = mass (lb)

C = heat capacity (often called “specific heat”) (Btu/lb ⁰F)

ΔT = temperature increase or decrease, ⁰F

Example 1.

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

Solution.

**Heat Capacity**

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

Substance with a low specific heat capacity warm quickly because they need less heat energy for a given change in temperature. They also give up their heat quickly.

Substances with a high specific heat capacity take a long time to warm up and they retain their heat for a long time.

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

Material Density (lb/ft3) Heat Capacity (Btu/lb°F)

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-ft2 concrete wall 8-in thick if it is warmed from 55ºF to 85ºF by exposure to sunlight?

Solution.

Converting Between U.S. and S.I.

|  |  |  |
| --- | --- | --- |
| **Quantity** | **U.S.** | **S.I.** |
| Q (heat supplied or released) | Btu | kJ (kilo Joule) |
| M (unit mass) | lb | kg |
| C (specific heat) | Btu/lb ºF | kJ/kg ºC , kJ/kg ºK |
|  |  |  |
| ΔT (temperature increase or decrease) | ºF | ºK, ºC |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| 1 Btu | = | 4,186.8 J | = | 1 kcal |
| lb ºF | Kg ºK | kg ºC |

Example 3 – Heat Aluminum

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

Q = M x C x ΔT

How many Btu’s?

Example 4 – Heating Water

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:

Q = M x C x ΔT

How many Btu’s?

Convert from SI to US

Using US Units

1 litre = ? lb? Can’t compare!

A litre is a unit of volume

A pound is a unit of weight

1 litre weighs 1 kg

There are 2.2 lb/kg

 2.2 lb water

Q = M x C x ΔT

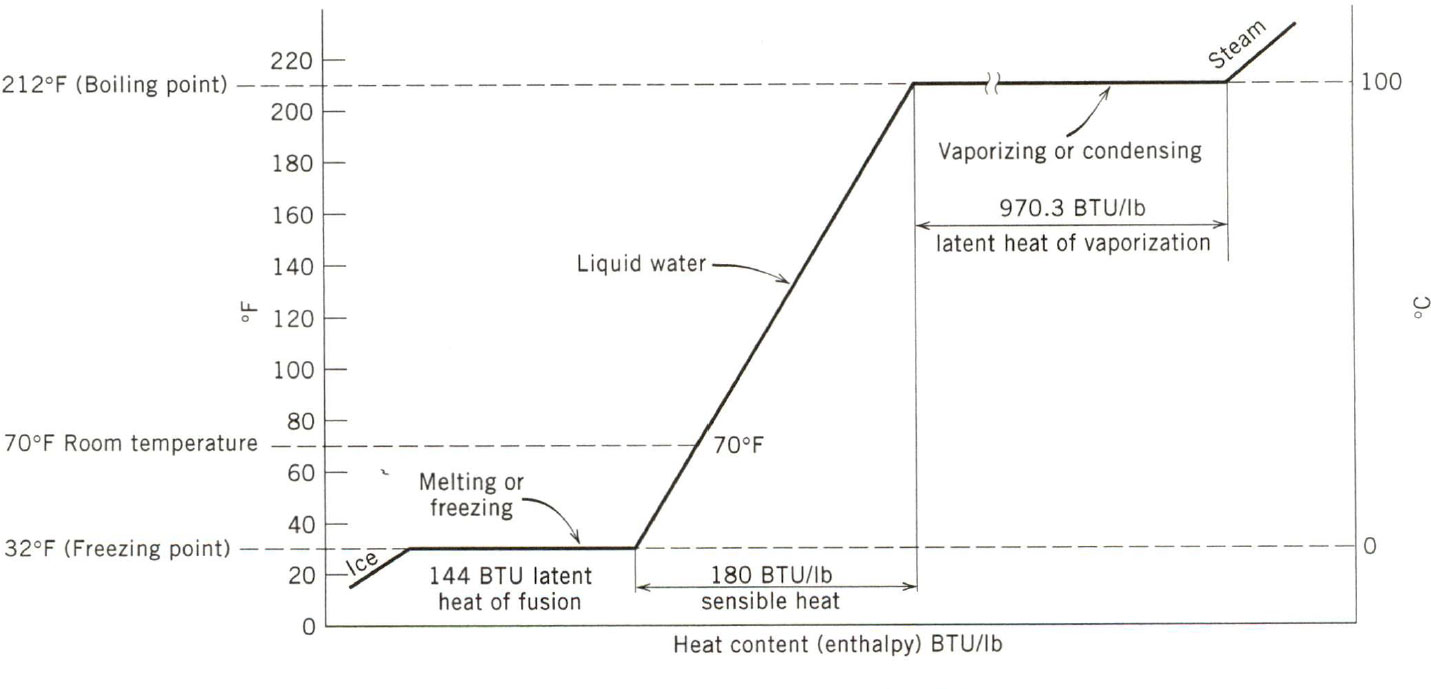
**Sensible and Latent Heat**

**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.



**Heat content (enthalpy) chart of water in Btu per pound.**

At the 32°F (0°C) lower change-of-state point, freezing water loses 144 Btu/lb and melting ice gains

144 Btu/lb of latent heat.

At the 212°F (100°C) upper change-of-state point, vaporizing water absorbs (gains) 970 Btu/lb and condensing steam releases (loses) 970 Btu/lb of latent heat.

In the liquid state between 32°F and 212°F, water gains or loses 1 Btu of sensible heat per pound, for each 1°F of temperature change, that is, 180 Btu/lb for the 180 °F temperature change between 32°F and 212°F.

Example 5.

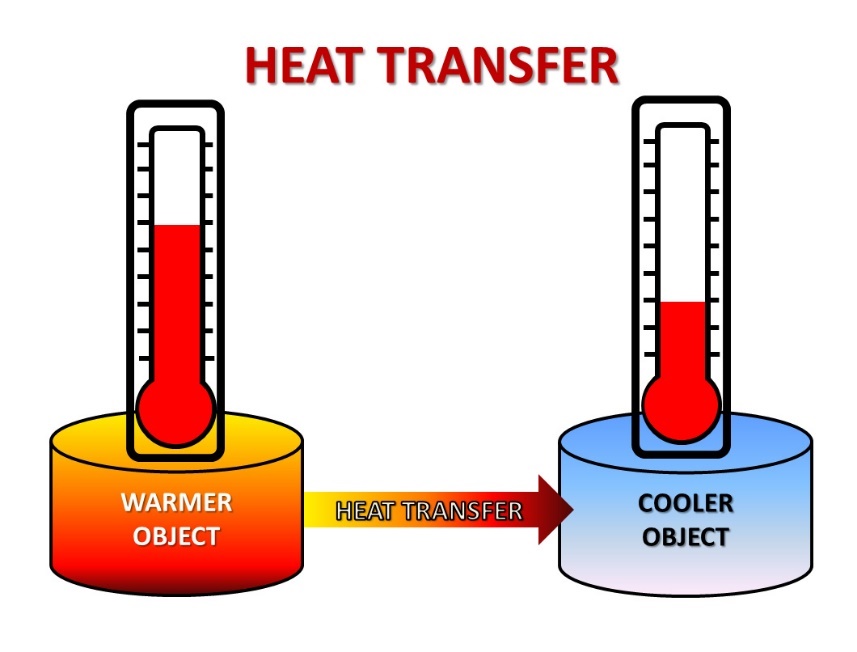
How much heat must be added to a 1 lb of water at room temperature (70⁰F) to bring it to the boiling point?

Example 6.

A block of ice, 1 ft3 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?

**Heat Transfer: Conduction, Convection, Radiation**



1. Conduction
2. Convection
3. 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.

**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

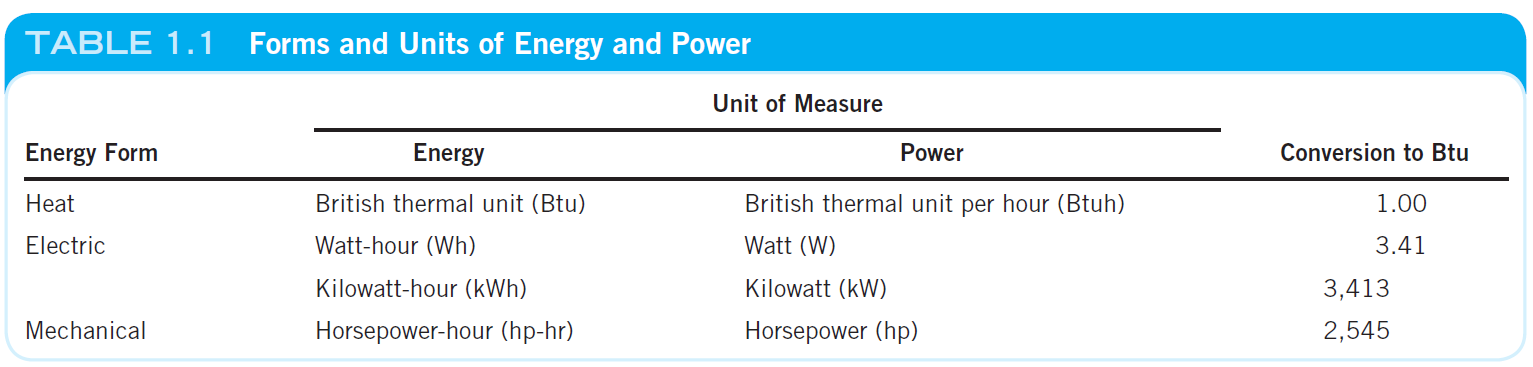
*Mean radiant temperature* (MRT) is a measure of the average temperature of the surfaces that surround a point, with which it will exchange thermal radiation.

**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.



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

Power = Energy /time

or

Energy = Power X time

Example 7.

A 50 ft2 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?