Introduction to Energy & Power Engineering Technology

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"Matter" is anything that can be recognized by the senses of taste, touch, smell, or sight and anything that has weight or volume. Air may not be recognized by any of these senses but because it has weight and volume, it is matter. *The law of conservation of matter and energy tells us that matter and energy cannot be created nor destroyed but, converted to some other state or substance where the sum remains constant*.

Matter is composed of very minute particles called molecules. A molecule is the smallest unit into which a substance can be subdivided and still retain the identity of the original substance. They are held together by chemical forces. Molecules make up all living and nonliving things. For most of scientific history, molecules were not visible by the strongest light magnification.

An electron microscope is a type of microscope that produces an electronically-magnified image of a specimen for detailed observation. The electron microscope (EM) uses a particle beam of electrons to illuminate the specimen and create a magnified image of it. The microscope has a greater resolving power than a light-powered optical microscope, because it uses electrons that have wavelengths about 100,000 times shorter than visible light (photons), and can achieve magnifications of up to 1,000,000x, whereas light microscopes are limited to 2000x magnification.

The electron microscope uses electrostatic and electromagnetic "lenses" to control the electron beam and focus it to form an image. These lens are analogous to, but different from the glass lenses of an optical microscope that form a magnified image by focusing light on or through the specimen. Electron microscopes are used to observe a wide range of biological and inorganic specimens including microorganisms, cells, large molecules, metals, and crystals.

Heat is a form of energy and exists in matter in the form of the molecules. The movement of molecules is directly and positively correlated to the amount of heat contained in the object, be it solid, liquid or gas. This wiggling and jiggling of molecules is where heat comes from. As a substance is heated up, the molecule movements get faster.

There are many perceptible examples of the relationship between movement and heat. Avoid touching a hot metal chip removed from a boring tool. Two pieces of ice may be melted by the heat generated when rubbing one piece against the other. The temperature of a body of water can be raised by stirring the water. A strip of iron can be pounded to a red heat.

The molecules of a solid do not alter their positions relative to each other but are in a state of vibration which is increased by the addition of heat. The molecules move in fixed paths, and these paths do not change so long as the body remains solid. If the solid is melted, the molecules suddenly vibrate more rapidly and may leave their fixed path cycles, being free to move in and about different paths. If a specific amount of heat is added to the liquid, the vibratory motion increases until the final attractive force that holds the body together is overcome and some of the molecules suddenly go off into space as a vapor or gas. The molecules of this gas have increased their motion beyond that than those of the liquid and have left their fixed paths of motion.

As all matter is composed of molecules which have weight and motion, each molecule contains a certain amount of energy of motion. The total energy of all the molecules which is due to their motion equals the heat energy of that body.

Heat, being a form of energy, cannot be created. All heat is obtained from either natural stores or produced by methods which depend upon natural stores of heat. The most obvious natural source of heat is the sun, and practically all of the earth's heat is a chemical reaction. The hammering of a strip of metal or heat caused by friction are examples of the mechanical source of heat. This is why we say the mechanics of heat.

Temperature

On touching in succession, two pieces of iron, one having been exposed to the sun's rays and the other piece shaded from them, it will be noticed that the first piece is the hotter of the two. However, our sense of hotness cannot be relied upon to measure which of two bodies is hotter. If pieces of iron and wood, both at the temperature of the room are touched in succession, the iron appears to be colder than the wood. Hence the necessity for employing an instrument to measure the temperature of bodies, one such instrument is a thermometer.

The temperature of an object is a measurement of the intensity of the heat in the object. It is not a measure of the quantity of heat the object possesses or how readily available the energy is. Temperature may be considered a measurement of the velocity of the molecules while the quantity of heat that object possesses is the total energy of motion of all the molecules composing the object.

The *exergy* of a system is the maximum useful work possible during a process that is moving the system into equilibrium with a heat reservoir. Equilibrium is struck when both the external and internal systems are equal in their total content. When the surroundings are the reservoir, exergy is the potential of a system to cause a change as it achieves equilibrium with its environment. Exergy is then the energy that is available to be used. After the system and surroundings reach equilibrium, the exergy at this point is zero. Determining exergy was the first goal of field of thermodynamics.

Ordinary temperature is measured by means of a thermometer. It consists of a glass tube, closed at both ends and having a bulb and lower end are filled with mercury which, on being heated or cooled, expands or contracts in direct proportion to the changes in temperature.

There are two types of temperature measures commonly used, the Fahrenheit and Centigrade scales, as shown in Figure 1. The former is used in engineering work in the English speaking countries, and the latter is used for scientific measurements in laboratories. Centigrade is more common throughout the world. Centigrade is abbreviated C and the Fahrenheit is abbreviated F.

There are two standard points on each of these measurements: the one being the temperature of melting or freezing water and the other being at the boiling point of water. On the Fahrenheit scale the boiling point of water is marked 212 degrees and the melting point of ice is marked 32 degrees. The space between these two points will be 212 minus 32 or 180, so that the scale will have 180 divisions between the melting point of ice and the boiling point of water, each part being called one degree. The Centigrade scale has a boiling point of water at 100, and a melting point of ice at 0 and there are 100 divisions or degrees between these two points on this scale (see figure 1 below).

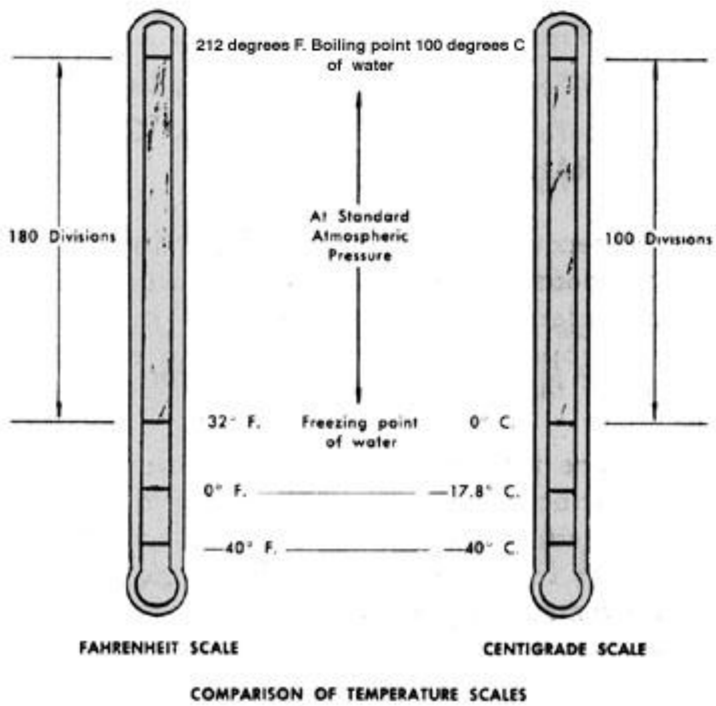

Figure A1. Boiling and freezing points on the centigrade and Fahrenheit scales are directly across from each other. Note that -40 is at the same location for both scales. Also note that this is precise when conditions are at atmospheric pressure. Test out the -40 calculation for yourself with the example formula below.

It is now evident that 180 degrees Fahrenheit are equal to 100 degrees Centigrade. Hence, 1 degree Fahrenheit is 100/180 which equals 5/9 of a Centigrade degree, and 1 degree Centigrade is 180/100 which equals 9/5 of a Fahrenheit degree. Therefore, in order to change from Fahrenheit to Centigrade temperature, we first find how many degrees Fahrenheit the given temperature is above the melting point of ice, and then take 5/9 of this result. This rule may also be written as follows:

$$C° = (F°-32°)\ 5/9$$

EXAMPLES:

The temperature of water in a boiler is 185 degrees Fahrenheit. What would this be on a Centigrade scale?

SOLUTION:

$$C = (F - 32°)\ 5/9$$

$$C = (185° - 32°)\ 5/9$$

$$= 153 \times 5/9 = 85° \text{ (answer)}$$

In order to change from Centigrade to Fahrenheit temperature, we simply reverse the rule we used above and obtain the following:

$$F° = (C° \times 9/5) + 32°$$

OR,

$$9/5\ C° + 32°$$

The temperature of a room is 20 degrees Centigrade. What is its Fahrenheit temperature?

SOLUTION:

$$F = 9/5\ C° + 32°$$

$$= (9/5 \times 20) + 32°$$

$$= 36° + 32° = 68°\ F \text{ (answer)}$$

Temperatures lower than -39 degrees Fahrenheit are usually measured with thermometers containing alcohol. The lowest temperature ever actually obtained is -457 degrees Fahrenheit.

Experiments have shown that -460 degrees Fahrenheit is absolute zero, at which point there is an entire absence of heat, or, the molecules cease to vibrate. All temperatures measured from this point are called “absolute” temperatures. However, there has been some considerable debate about the absence of heat concept. Nonetheless, like the Fahrenheit scale, the units of measures have been well established so we will continue to use them.

Expansion and contraction

Most substances expand when the temperature is raised and contract when cooled. For example, an iron tire of a little smaller diameter than a wooden wheel may be heated and slipped over the wheel; the wheel is then submerged in water; and the tire contracts and fits tightly. The expansion is due to the increased molecular activity, as described above. This expansion and contraction relating to the change in temperature is greatest in gases and least in solids. In engineering, it will cause considerable trouble with a design if no allowance is made for it. Great difficulty would be encountered if expansion joints were not installed in steam lines. Grate bars in furnaces must not fit tightly or upon being heated they will force the setting and crack it. If a heating supply pipe is installed where the elbows are butted tight against opposite walls of drywall, there will be a hole in one or two of the walls when the heat is turned on.

Material expands in all directions when heated, but most often we are concerned with the expansion in the direction of length or linear expansion. Depending on their composition, many substances expand more or less than others. The rate of expansion of most substances has been determined by experiment. Each substance has a specific *coefficient of linear expansion* and may be defined as the increase or decrease in length which a bar of unit length undergoes when its temperature is changed one degree. Some of the examples of coefficients of expansion and contraction are given in table 1 below.

(for one degree Fahrenheit)

Aluminum .0000114	Moeline Steel .0000065	Brass .00001	Mercury .0000334	Wrought Iron .0000065
Cast Iron .000006	Tin .00001410	Lead .000016	Zinc .0000163	Copper .000009

Table C1 Coefficients of expansion and contraction for 10 commonly used materials in engineering.

The method of finding the total expansion or contraction is as follows:

Multiply the coefficient of expansion by the length of the object, and by the change in temperature. The answer must be in the same unit as used in the solution. Thus, if length in feet is used the answer will be in feet, etc.

EXAMPLE:

What will be the expansion in a steam line 300 feet long when its temperature is raised from 80° F to 500° F?

SOLUTION:

Change in temperature = 500 – 80 = 420 degrees

Expansion then is .0000065 x 300 x 420 = 0.819 feet

Work power

Force is the action of any object pushing or pulling upon another object. Force tends to produce motion or a change in the shape of the body acted upon. Air pressure in a cylinder is a force and will produce motion of a piston unless an equal resisting force prevents its motion.

Work is the overcoming of resistance through space. When a force is exerted on a certain object it moves that object a certain distance against resistance, *work* is accomplished. Work equals force times distance. Although much force may be exerted on a body in an attempt to move it, unless actual displacement takes place, no work is done. When we lift an object, we do work against gravity which pulls the object to the earth i.e. resistance. In this case the amount of work depends on the weight of the object and the height we lifted it. This kind of work is usually expressed in foot-pounds. Thus, lifting 12 pounds a distance of 3 feet would result in 12 x 3 = 36 foot-pounds of work accomplished.

The following examples help make this point clear.

EXAMPLE:

How much work is required to lift a pipe weighing 500 pounds from a floor to its position 9 feet and 5 inches above the floor?

SOLUTION:

Work = Force x distance

= 500 lbs x 9.5/12 ft.

= 4708.3 ft. lbs. (answer)

PROBLEM:

How much work is done on the piston of a steam pump during a single stroke if its diameter is 10 inches, the length of the stroke is 12 inches, and the steam pressure is 115 pounds per square inch? The area of a piston formula is .7854 times diameter squared.

SOLUTION:

Area of piston = .7854 x d^2 x .7854 x 10^2 = 78.54 sq. in.

Then, total pressure on piston = 78.54 x 115 = 9032 lbs.

The distance through which this force is overcome is 12 in. = 1 ft.

Therefore, the work done in a single stroke of the piston is 9032 x 1 = 9032 foot-pounds. (answer)

Power is the rate at which work is done. It always includes the element of time. The common unit of power is the horsepower which is equal to 33,000 foot-pounds per minute. The horsepower output of any unit is obtained by finding the work done in foot pounds per minute and then dividing by 33,000 foot-pounds.

PROBLEM:

A steam engine does 330,000 foot-pounds of work in 30 seconds? What is its horsepower?

SOLUTION:

330,000 ft. lbs. x 60/30 = 660,000 ft. lbs. per minute

660,000/33,000 = 20 horsepower (answer)

PROBLEM:

An elevator weighing 5 tons must be raised 40 feet in two minutes. What horsepower is required to do this work? A ton is equal to 2000 pounds.

SOLUTION:

5 x 2000 lbs. x 40 ft./2 minutes = 200,000 ft. lbs. per minute

200,000/33,000 = 6.06 horsepower (answer)

Energy

Aside from living systems, energy is the single most important aspect of the economic world. This is because energy has the capacity to do *work*. That is, energy is the work which may be stored up in a substance in such a way that it may be used on demand. For example, when a 3-ton hammer is raised 8 feet, then 3 x 2000 x 8 = 48,000 foot-pounds of work is required to lift it. Now, if it is allowed to fall, it will do 48,000 foot-pounds of work. Hence, when the hammer was in the top position it had the capacity of doing this specific amount of work so we speak of it as containing a specific amount of energy.

In general there are two kinds of energy, one is due to position and the other due to motion. Energy due to position is called *potential* energy and an example of this was given with a hammer where the position of it when raised gave it a specific amount of energy. Energy due to motion is called *kinetic* energy and an example of this is the energy in a revolving flywheel or the energy in a sledgehammer when being swung. Any moving object contains kinetic energy, the amount of it being determined by the weight and velocity of the object.

There are various forms of energy. For instance, the examples mentioned above show that energy may be due to mechanical motion or to the position of objects. Such energy is called *mechanical* energy. Likewise, a substance charged with electricity contains electrical energy, and a chemical compound contains *chemical* energy. Heat also is a form of energy, and we speak of a substance containing heat as having heat energy. At the atomic level heat is also mechanical because of the motion of the molecules.

Energy of any one kind may be changed to energy of some other kind. For example, mechanical energy or the action of an engine may be used to generate electricity which is electrical energy.

Chemical energy may be changed to heat energy as is illustrated in electric irons or a space heater. Energy can be converted back and forth between chemical and mechanical again and again. However, each time conversion takes place, the amount of useful energy is reduced. This is due to losses during the conversion process. If you were to invent an economically viable process of energy conversion at 100% efficiency or greater, there would be no need for you to work again.

Since energy is the capacity of a body to do work, it is measured in foot-pounds. However, since heat is measured by temperature and change in temperature, it would be confusing to measure heat energy in foot-pounds when we are interested in heat content.

For the purpose of measuring heat energy a unit called the British thermal unit, is used. This is defined as being the amount of heat which will raise the temperature of one pound of water one degree Fahrenheit. This unit is generally abbreviated to B.T.U. One kilowatt (1000 watts) is equivalent to 3412 BTU.

The solution of a couple of simple problems will serve to operationalize the measurement of B.T.U.

PROBLEM:

How much heat is necessary to raise the temperature of 1 pound of water from 42 degrees Fahrenheit to 176 degrees Fahrenheit?

SOLUTION:

The rise in temperature equals 176° – 42° = 134°.

Hence, 134° x 1 lb. = 134 B.T.U.

PROBLEM:

If 25 pounds of water are heated from 35° F to 112° F, find the amount of heat taken up by the water.

SOLUTION:

Rise in temperature = 112° - 35° = 77°. The heat required equals 77° x 25 lbs. = 1925 B.T.U. (answer)

In case the water reduces temperature, it of course gives up heat and calculations are made in the same way, that is by multiplying the change in temperature in degrees Fahrenheit by the weight of the water in pounds. That is to say, the same calculations are made for cooling.

It has been shown by many experiments that 1 B.T.U. is equivalent to 778 foot-pounds of work. This means that when 778 foot pounds of work is performed, an amount of heat is produced equal to 1 B.T.U., and this amount of heat is sufficient to raise the temperature of 1 pound of water 1° Fahrenheit. This quantity, 778, is called the *mechanical equivalent* of one heat unit, since 1 B.T.U. is capable of doing 778 foot-pounds of work.

PROBLEM:

How many foot-pounds of energy are represented in 15,000 B.T.U.?

SOLUTION:

1 B.T.U. = 778 ft.lbs.

Therefore, 15,000 B.T.U. = 15,000 x 778 = 11,670,000 ft. lbs. (answer)

Note: a therm of natural gas is 1000 cubic feet of natural gas and this is the equivalent to 100,000 B.T.U. One watt is equal to 3.4 B.T.U and a pond of coal can have 8,000 to 15,000 B.T.U. or more depending on quality. One gallon of heating fuel oil has about 150,000 B.T.U. depending on quality. Convert all these fuel sources to B.T.U and their respective dollar value and you will see wide variances.

Specific heat – The amount of heat required to raise the temperature of 1 pound of specific substance 1 degree Fahrenheit is called the *specific* heat of the substance. For instance, it requires 0.214 B.T.U. to raise the temperature of 1 pound of aluminum 1 degree Fahrenheit. Therefore, the specific heat of aluminum is said to be 0.214. From the definition of B.T.U. previously given, it is easily seen that the specific heat of water is 1. Water is used as unity for many measures in science. The following table gives the specific heat of various solids and liquids:

SPECIFIC HEATS OF SOLIDS AND LIQUIDS

Substance	Specific Heat B.T.U	Substance	Specific Heat B.T.U.
Aluminum	0.214	Lead (melted)	0.040
Brass	0.092	Platinum	0.032
Cast Iron	0.123	Steel	0.117
Charcoal	0.241	Tin	0.054
Copper	0.095	Tin (melted)	0.062
Glass	0.196	Water	1.000
Ice	0.504	Wrought Iron	0.111
Lead	0.031	Zinc	0.094

Table A.2 The specific heat of 16 important solids or liquids where water is unity. The number of B.T.U. needed to raise the temperature of a substance is equal to the weight of the substance times the specific heat of the substance times the temperature differential. Once the substance starts to change its state (solid, liquid or gas), additional energy is needed to make the change in state.

The number of B.T.U. required in order to raise, or to be given up in order to lower the temperature of a substance through any number of degrees in its state, may be found by the following formula:

$$Q = W(S)(t_2 - t_1)$$

In which

Q = Quantity of heat in B.T.U. required

W = Weight of substance in pounds

S = Specific heat of substance

t_2 = Higher temperature, in degrees Fahrenheit

t_1 = Lower temperature, in degrees Fahrenheit

PROBLEM:

How much heat is required to raise the temperature of a block of ice weighing 175 pounds from -40° F to 32° F?

SOLUTION:

In this case, W = 175 lbs.

Since the material is ice, $_s$ = 0.504 as found from the table, also, t_s = 32° F and t_1 = -40° F.

Then substituting these known values in the formula, we have
Q = 175 x 0.504 x [32° - (-40°)]
= 175 x 0.504 x 72
= 175 x 36.288
= 3650.4 B.T.U.

Generation of heat

Combustion – Over the past two centuries, combustion has been and still is the primary source of usable energy. Domestic and commercial transportation systems depend upon internal combustion engines, rail systems depend upon direct combustion or power plants, power plants depend on combustion processes, airlines are combustion dependent, all commercial and industrial operations are dependent upon combustion. In fact, even today, every product or service on earth is in some way dependent upon combustion processes. Therefore, people who are educated and live on earth should have a fundamental understanding of combustion.

Combustion produces heat and heat can be produced in many ways. For ordinary industrial use it is caused by the burning of various fuels. Combustion is essentially the chemical union of oxygen in the air with carbon and hydrogen of a fuel producing light and heat. During the combustion process, light is waste.

Coal is the fuel most extensively used in power plant operations. Other fuels commonly used are coke, wood, oils and natural and other gases. These all contain free carbon or compounds of carbon and hydrogen and, in some cases, oxygen. However, the necessary oxygen is generally taken from the air to unite with carbon and hydrogen in the combustion of a fuel.

When carbon and oxygen combine while burning, they form carbon dioxide (abbreviated CO_2); when hydrogen and oxygen combine, they form water (abbreviated H_2O). These are called the *products of combustion.* This is an essential part of every educational field, be it business, engineering or health care.

When the air supplied to burning carbon and it is insufficient to form CO_2, another resulting product, carbon monoxide (abbreviated CO) is formed. If this happens, the combustion is then said to be *incomplete*. If at all possible, more air is needed immediately in order to get enough oxygen to change the CO to CO_2. This addition of more oxygen is necessary since carbon burned to CO_2 will produce much more heat per pound of fuel than when CO is produced. *Energy efficiency starts here.* Experiments have shown that when 1 pound of carbon is burned to CO_2, 14,600 – 4,000 = 10,200 B.T.U. are lost absolutely and which could have been used if sufficient oxygen had been secured from the air to combine with the other products and thus form CO_2.

Heating value of fuel

The amount of heat expressed in B.T.U. produced by the complete combustion of 1 pound of any fuel is called the *heating value* of that fuel. It is also sometimes called the *heat of combustion.* For instance, 1 pound of hydrogen burned to water will liberate 62,000 B.T.U. Therefore, the *heating value* of hydrogen is 62,000 B.T.U. If we know the percentage by weight of the elements composing a fuel, we can calculate approximately the heating value of that fuel by the following formula:

$$\text{B.T.U.} = 14{,}600\ C + 62{,}000\ (H - O/8)$$

In which, C = amount of carbon in 1 pound of fuel, H = amount of hydrogen in 1 pound of fuel, O = amount of oxygen in 1 pound of fuel.

The term O/8 is subtracted because oxygen contained in hydrogen compounds has no heating value and since it is already combined with a portion of the hydrogen of these compounds, it reduces the heating value of the fuel somewhat. The factor 8 is used because oxygen combines with hydrogen in the ratio of 1:8.

PROBLEM:

A coal contains 76.5% carbon, 6.4% oxygen, 8.6% hydrogen, 2.27% nitrogen, and 6.23% ash. What is the heating value per pound? (Note: The nitrogen and ash do not add to the heating value so will not be used in calculating the heating value of the fuel.)

SOLUTION:

If we substitute the known values in the formula given above, we have

$$\text{B.T.U.} = 14{,}600 \times 0.765 + 62{,}000\ (0.860 - 0.064/8)$$

= 11,169 + 4,836

= 16,005 B.T.U. (answer)

Air required for proper combustion: It has already been stated that most of the oxygen necessary for the complete combustion of a fuel is taken from the air. The amount of air which must be furnished varies for substances made up of different compounds and elements. For instance, any fuel having a large percentage of hydrogen in its composition will require more air for combustion than a fuel with a small percentage of hydrogen, because the hydrogen requires more air than any other element in the fuel.

When it is desired to find the weight of air necessary to furnish oxygen for one pound of a fuel, the following formula may be used:

$$A = 34.56\ (C/3 + H - O/8)$$

In which, A = weight of air required per pound of fuel, C = weight of Carbon in one pound of fuel, H = weight of Hydrogen in one pound of fuel, O = weight of Oxygen in one pound of fuel.

PROBLEM:

If we substitute known values, in the given formula, we have

$$A = 34.56\ (0.765/3 + 0.086 - 0.008)$$

$$= 34.56\ (0.255 + 0.086 - 0.008)$$

$$= 34.56 \times 0.333$$

$$= 11.52 \text{ lbs.}$$

Keep in mind that in all probability some of the oxygen will not come in contact with the carbon and hydrogen, so in practice from 1-1/4 to 2 times the amount of air found by the above formula is given per pound of any solid fuel in order attain *complete combustion*. The amount of air per pound of fuel in the given example would then be from 14 pounds to 23 pounds in depending on other design factors.

Transfer of heat

When heat is transferred from one point to another, it may be done in three ways: by conduction, by convention, or by radiation. Any or all three may be acting at the same time to transfer heat.

Conduction – If one end of a steel rod is held in the hand and the other end is placed in a fire, the end in the hand will become too warm for comfort and it will have to be dropped. Heat has a tendency to flow from a point of high temperature to a point of lower temperature and flows from the hotter end of the rod to the cooler end. This process of heat through the molecule of a substance is called *heat conductance*.

Heat is known to be a vibratory movement of the molecules; and when heat is applied at one end of the rod, the molecules in that end vibrate more rapidly. This causes these molecules to strike more violently against the molecules in the cooler section of the rod immediately adjacent. The rapidity of these molecules is thereby also increased – or this section also becomes heated. This process continues until the other end of the rod becomes heated. A glass rod could be held for a longer time than a steel rod of the same length in the same fire, which shows some substances are better conductors of heat than others. Generally, solids are the best conductors, then liquids and the poorest are the gases. The amount of heat that is transferred by conduction depends on the temperature difference, the physical dimensions of the substance, and, of course, the nature of the material.

Convection – The process of transferring heat by circulation taking place within the body of a liquid or a gas is called convection. The circulation is due to the variations of density, through the fluid body. An illustration of convection is found in placing a glass bowl of water over a flame. After a while the water will be observed to flow upward over the point where the flame is applied. This takes place because the heat from the flame passes from one side of the bottom of the bowl to the other side by conduction and raises the temperature of the water nearest to the flame. This increase in temperature of these particles of water causes the particles to expand – thus becoming lighter and rising to the top, carrying the heat along, while the heavier water comes into the sides to take its place.

Radiation -- When heat is carried across space from one point to another without the aid of any material substance, it is said to be transferred by radiation. For example, the heat from the sun reaches the earth by radiation since it is transferred through distance separating the two bodies without any other assistance. Heat is always transferred by radiation in a straight line, while conducted and convected heat may follow any curved path. Also, radiated heat may pass through an object without heating it. For instance, the rays of the sun will warm a person through a window glass, without heating the glass.

While heat cannot be conducted or convected through a vacuum, it may be radiated through it. The heat energy of the sun passes through it. The heat energy of the sun passes through millions of miles of vacuum before it reaches the atmosphere of the earth. Heat waves may be visible or invisible, depending on the temperature of the body radiating the heat. A red hot piece of iron gives off visible rays of heat, yet we all know rays of heat are still given off when the iron is say 400° Fahrenheit although the rays are invisible.

Radiant heat may be absorbed, reflected, or it may pass through a body on its path—depending on the nature of the substance of this body. A non-reflecting opaque body would absorb all the radiant heat that strikes it while a perfectly transparent body would absorb none of the radiant heat. Many forms of heat take on more than one of these transfer characteristics.

Change of state

Fusion – The fusion, or melting of a solid body, whether it is ice, steel, or any other solid capable of being melted, is due to the fact that, when a certain temperature is reached, the rapid vibration of the molecules overcomes that force of attraction of the molecules for one another by which the body was enabled to retain its solid state. If a piece of ice is placed in a suitable vessel and heat is applied, the ice will gradually melt; but the temperature of the water surrounding it will not rise above 32° Fahrenheit until the ice is fully melted. The ice has received heat constantly, but the heat has been utilized in changing the body from a solid to a liquid state. The heat that is added to a body to change its state, without changing its temperature, is called latent heat. If the state is changed from a solid to a liquid, the heat required to accomplish it is call the latent heat of fusion. It is customary to use 1 pound of a substance as the basis for comparing latent heats of fusion. A pound of ice at 32° Fahrenheit requires 144 British Thermal Units to convert it into water at 32° Fahrenheit. Hence, the latent heat of ice is said to be 144. Every substance capable of being liquefied has its own latent heat of fusion, which is the number of heat units required to convert 1 pound of it from the solid to the liquid state without a change in temperature. It is simply the additional energy required to do change state.

Vaporization – If a quantity of water is boiled in the open air and its temperature is noted, it will be found that the temperature remains at 212° Fahrenheit until the water entirely disappears. The water has absorbed a large quantity of heat while being converted into vapor without a change in temperature. The amount of heat expended in converting a pound of water at the boiling point into steam at the same temperature is called the latent heat of vaporization. The latent heat of steam at 212° Fahrenheit is 970.2 BTU that is, it requires about 970.2 British thermal units to convert 1 pound of water at 212° Fahrenheit to steam at the same temperature, under atmospheric pressure into one pound of steam. The latent heat of vaporization of other liquids is the amount of heat required to change 1 pound of that substance from liquid to a vapor state without a change in temperature.

Steam

Producing steam – In order to understand the operation of traditional power plants it is necessary to study steam. The boiling point of water is 212 degrees F. at atmospheric pressure. Steam is produced in a boiler as vapor and often contains a certain amount of water in suspension, as does the atmosphere in foggy weather. Let us suppose that we have a boiler partly filled with cold water and that heat is applied to the external shell of the boiler. As the water in the boiler is heated its temperature slowly rises. This increase of temperature continues from the initial temperature of the water until the temperature of the boiling point is reached. Actual boiling is dependent upon the temperature and the pressure in the boiler. When the boiling point is reached, small particles of water are changed into steam. They rise through the mass of water and escape to the surface. The water is then said "to boil". When the steam produced from the boiling water is at the same temperature as the water the steam is said to be saturated. If we keep applying heat to the water in the boiler, with pressure remaining the same, the temperature will remain constant until all the water is evaporated. Remember it takes an additional amount of energy (970.2 BTU per pound) to change state. If more heat is added after all the water is converted into steam while holding the pressure constant, the temperature will rise. Steam under this condition is said to be *superheated.*

In the formation of steam we divide the heat used into three different parts:

(1) The heat which goes to raising the temperature of the water from its original temperature to the temperature of the boiling point, called “Heat of the Liquid”.

(2) The heat which goes to changing the water at the temperature of the boiling point into steam at the temperature of the boiling point, called “Latent Heat”.

(3) The heat which goes to changing the saturated steam at the temperature of the boiling point into steam at a higher temperature but at the same pressure, called “Heat of Superheat”

Fuel Type	**Unit of Measure**	**BTUs Per Unit**	**Gallon Equivalent**
Gasoline, regular unleaded, (typical)	gallon	114,100	1.00 gallon
Gasoline, RFG, (10% MBTE)	gallon	112,000	1.02 gallons
Diesel, (typical)	gallon	129,800	0.88 gallons
Liquid natural gas (LNG), (typical)	gallon	75,000	1.52 gallons
Compressed natural gas (CNG), (typical)	cubic foot	900	126.67 cu. ft.

Liquefied petroleum gas (LPG or propane)	gallon	84,300	1.35 gallons
Methanol (M-100)	gallon	56,800	2.01 gallons
Methanol (M-85)	gallon	65,400	1.74 gallons
Ethanol (M-100)	gallon	76,100	1.50 gallons
Ethanol (E-85)	gallon	81,800	1.40 gallons
Bio Diesel (B-20)	gallon	129,500	0.88 gallons

Table A3. BTU value of 12 fossil fuels

One million BTU is about 90 pounds of coal, 125 pounds of dried wood, 8 gallons of motor oil, 10 therms of natural gas, one day of energy use per person in the USA and approximately 100 kWh of electricity produced in a power plant.

Renewable energy

Renewable energy is energy that comes from natural resources such as sunlight, wind, rain, tides, and geothermal heat, which are renewable (naturally replenished within a reasonable timescale). In 2008, about 19% of global final energy consumption came from renewables, which explicitly implies that 81% did not. The sun has abundant lumens that can be converted to useful energy. Sunlight is free. From a financial point of view, if we do a better job capturing the usable energy from the sun, we will have a limitless source of energy without negative externalities. The same point can be made for wind, the tides and geothermal sources.

Geothermal

Geothermal energy is energy obtained by tapping the heat of the earth. Drilling deep into the Earth in some areas will yield substantial heat. Most places on earth are acceptable for the installation of a geothermal heat pump. Water source heat pumps are also feasible under certain conditions. In this case, the water is heated by the sun.

Wind

Wind turbines are run by airflows. The turbine works in the same way a turbine in a traditional power plant operates, without steam pressure and without a boiler. Wind turbines can be quite powerful with a range of about 600 kW to 5 MW of rated power, although turbines with rated output of 1.5–3 MW have become the most common for commercial use. Power output of a turbine is a function of the cube of the wind speed, so as wind speed increases, power output increases dramatically.

Solar

Solar technologies are broadly characterized depending on the way they capture, convert and distribute solar energy. Active solar techniques include the use of photovoltaic panels to generate electricity. Passive systems can harness energy as well. Passive solar techniques include orienting a building to the sun, selecting materials with maximum advantage and making use of outdoor lighting with light dispersing materials with specific properties. In addition, designing systems circulate air naturally is another use of the sun. Of course solar thermal systems heat liquid to heat spaces or domestic systems.

Biofuels

Bioethanol is basically alcohol made from the sugar components of plant materials and it is made mostly from sugar and starch crops. With advanced technology being developed, cellulosic biomass, such as trees and grasses, are also used as feedstock for ethanol production. Ethanol can be used as a fuel for vehicles in its pure form, but it is usually used as a petro additive to increase octane and improve vehicle emissions. Much debate surrounds the use of food stocks for energy when over 2 billion people on earth are undernourished. This is why there has been a movement to trees and grasses.

Hydropower

Energy in water current can be harnessed and used. Water is about 800 times as dense as air, slow moving water can produce large amounts of energy. The most well known source of hydropower is the damn. However, there are other uses of moving water to generate power such as placing blades below the surface where currents are predictably powerful.