Generating Steam in the Power Plant

Table of Contents

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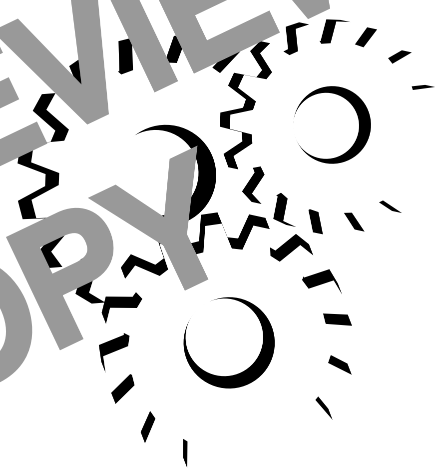
GENERATING STEAM IN THE POWER PLANT

Lesson One

Transforming Energy Into Work



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TPC Training Systems

11201

Lesson 1 Transforming Energy Into Work

TOPICS

Energy and Matter
Fuels
Combustion
Temperature Measurement
Pressure Measurement
Quantity of Heat
Heat Transfer
Conduction
Radiation
Convection
Sensible and Latent Heat
Vaporization
Boiling Point
Enthalpy
Heat and Work
Basic Steam Generation

OBJECTIVES

After studying this Lesson, you should be able to…

- Define energy and describe the main forms of energy encountered in a power plant.
- Explain the process of combustion and list the three elements necessary for combustion to occur.
- Explain the principles of temperature and pressure measurement and describe the four scales on which temperature is measured.
- Describe the methods of heat transfer and the effects heat transfer can have on a material.
- Summarize the interrelationship of temperature, volume, and pressure in a gas.

KEY TECHNICAL TERMS

Energy 1.01 capacity to do work
Matter 1.02 any physical substance that can be perceived by sight, hearing, taste, or smell
Molecule 1.02 smallest particle of any substance that can exist by itself and still have all the properties of the substance
Atom 1.03 smallest known unit of an element
Combustion 1.16 reaction that combines oxygen and fuel to release the chemical energy (heat) stored in the fuel
Absolute zero 1.25 point at which all molecules stop moving
Conduction 1.35 heat transfer by direct physical contact
Radiation 1.37 heat transfer directly through space
Convection 1.38 movement of a volume of hot liquid, gas, or vapor from one area to another
Vaporization 1.43 process by which a liquid changes to a vapor
Enthalpy 1.47 sum of the internal energy of a system plus the systems volume multiplied by the pressure exerted on the system
Condensation 1.52 return of vapor molecules to liquid molecules

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The utility plant—often called the power plant—converts the chemical energy stored in fuels into heat energy, which changes water into steam. The steam drives a turbine which converts the heat energy of the steam into mechanical energy. The turbine's mechanical energy drives a generator which converts mechanical energy into electrical energy, or electricity.

This Lesson explains the basic principles and concepts that govern each step of the energy conversion process. It identifies the forms of energy and the energy transformations that occur in a steam plant. This lesson also describes fuel formation, fuel combustion, the effects of heat on water, and the fundamentals of steam generation.

Energy and Matter

1.01 *Energy* is the capacity to do work. *Work* is done when a force acts on matter and moves it. Heat, light, electricity, and sound are forms of energy. So are chemical energy, mechanical energy, thermal energy, and nuclear energy.

1.02 *Matter* is any physical substance that can be perceived by the senses of sight, hearing, taste, or smell. Matter exists in one of three states: as a solid, as a liquid, or as a gas. All matter is made up of *molecules*. Molecules are the smallest particles of any substance that can exist by themselves, and still have all the properties of the substance. Molecules are shaped like spheres. In a given substance, they are all the same size, and are constantly in motion. They continually collide with each other, and with the walls of the container that holds them.

1.03 Molecules are made up of atoms. *Atoms* are the smallest known unit of an element (see Figure. 1-1). Atoms, in turn are made up of positive and negative charges of electricity. The negative charges, called electrons, circle the nucleus of the atom in an orbit as shown in Fig. 1-1. The nucleus contains positive charges called protons, plus neutrons which have no electrical charge.

1.04 All energy exists as either stored energy or energy in transition. *Kinetic energy* is the stored energy that a substance or a body possesses because of the motion of its molecules or component parts *potential energy*, in contrast to kinetic energy, is the stored energy that a substance or a body has due to the relative position or shape of its component parts. Electrical, magnetic, chemical, and nuclear systems have potential energy. Energy in transition is energy in the process of moving from one condition of stored energy to another. All energy in transition begins and ends as stored energy.

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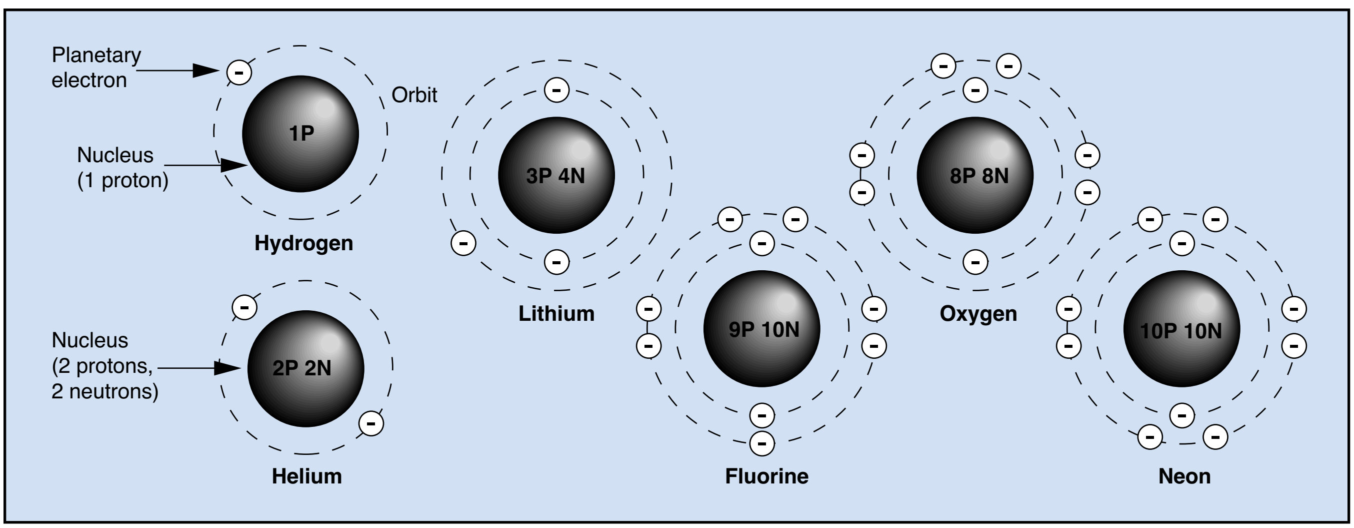
Fig. 1-1. Atomic structure of various elements



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1.05 Therefore, to understand any form of energy, you need to know whether it is stored energy, or energy in transition. You also need to know the relative sizes of the bodies or particles in the energy system. The main forms of energy you will encounter in the power plant are mechanical, thermal, chemical, and electrical.

1.06 Mechanical energy is either stored or in transition (manifested by work done). It is associated with relatively large bodies. Mechanical potential energy exists due to the relative position of two or more bodies, and a distance that separates them. For example, a rock resting on the edge of a cliff in such a position that it will fall freely if pushed has mechanical potential energy. Water behind a dam gate has mechanical potential energy. A sled poised at the top of a hill has mechanical potential energy.

1.07 Mechanical kinetic energy exists because of the relative velocities of two or more objects. If you push the rock, open the dam gate, or start the sled downhill, something will move at a certain velocity. The rock will fall, the water will flow over the dam, and the sled will slide down the hill. In each case the mechanical potential energy was changed to mechanical kinetic energy by an outside force or external source of energy.

1.08 All power plant machines and processes require this kind of startup from an energy source outside of the system. For example, the tremendous amount of chemical energy stored in coal or fuel oil will not raise steam in the boiler until energy has been expended (through combustion) to start the fuel burning. Chemical energy is energy stored within a substance due to the forces that bind the atoms together in a molecule.

1.09 Thermal energy (not to be confused with nuclear energy) is energy also associated primarily with molecules. It exists as stored energy (in which case it is called internal energy) or as energy in transition (in which case it is called heat). The total internal energy of a substance equals the sum of its internal potential energy and its internal kinetic energy.

1.10 Internal potential energy is the energy associated with the forces of attraction that exist between molecules. How much internal potential energy there is depends on the mass of the molecules and the average distance between them. The force of attraction between molecules is greatest in solids, less in liquids and soft substances, and least in gases and vapors. Internal kinetic energy is associated primarily with the activities of molecules. The temperature of a substance arises from, and is proportional to, the same molecular activity.

1.11 Heat is thermal energy in transition, or the flow of thermal energy. It can flow between two objects or regions only when they are at different temperatures (see paragraph 1.34). Heat is the sum total of the energy associated with the random molecular motion of a substance or body. Adding heat to the substance or body increases the thermal activity of its molecules.

1.12 Electrical energy is energy associated with the flow of electrons. Electrons, or negative charges of electricity (see paragraph 1.03) in the outer orbits of certain elements, represent electrical potential energy. They are easily separated from the positively-charged nuclei in their parent atoms, and caused to flow in metals, vacuums, or in tubes containing gas. When an orbiting electron is removed from an atom it is called a free electron. It is these free electrons that make up the flow of an electric current in electrical conductors.

Fuels

1.13 Natural fuels derived from prehistoric fossils are the main source of heat energy for steam generation. The three major natural fuels are coal, oil, and natural gas. Coal is a solid fuel, oil is a liquid fuel, and natural gas is a gaseous fuel. These fuels formed thousands of years ago from decayed plants under pressure from the earth's crust.

1.14 Natural fuels contain stored energy that comes from a chemical process that occurs during a plant's life. Plants absorb carbon dioxide from the air, water from the soil, and sunlight to produce complex chemical compounds such as starch and sugar. The molecules of these compounds store the energy from the sun as chemical energy.

1.15 Energy can be exchanged among various bodies, or it can be converted from one form to another. In producing electric energy in the steam power plant, many energy conversion steps take place between the raw energy of the fuel used to heat the boiler and the

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electricity delivered from the plant. For instance, chemical energy of fuel to heat energy of combustion to heat energy of steam to kinetic energy of steam jets, to kinetic energy of turbine rotor, to electric energy at the generator terminals.

Combustion

1.16 *Combustion* releases the chemical energy in fuels. Combustion is a chemical reaction or series of chemical reactions in which a substance rapidly combines with oxygen to produce heat. Three conditions are necessary for combustion to begin (see Fig. 1-2): a supply of oxygen, fuel (combustible substance), and enough heat to start and maintain the chemical reactions.

1.17 **Oxygen.** Air is usually the source of the oxygen supply needed for combustion. Air consists of several gases: about 21 percent of air by volume is oxygen, and about 78 percent is nitrogen. The remaining one percent is a mixture of argon, carbon dioxide, and small amounts of other gases. Only oxygen aids combustion. The other gases carry away heat energy.

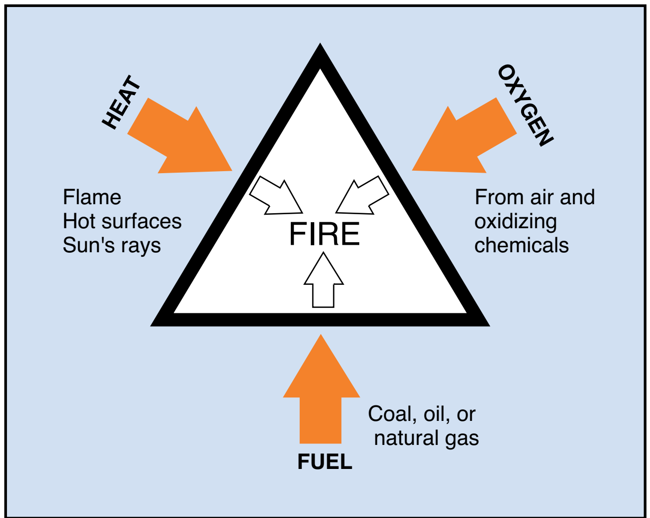
1.18 **Fuel.** How easily a substance burns depends on how readily it turns into a gas. No substance can burn until it releases combustible vapors. The most important combustible vapors are hydrocarbons, which are compounds of carbon and hydrogen. Natural gas burns more readily than coal or oil because it is always in the gaseous state. Solid and liquid fuels burn only when they partially transform into gases.

1.19 **Heat.** Heat causes fuel to release combustible vapors. An external heat source must heat the fuel until its vapors reach ignition temperature. Ignition temperature is the lowest temperature at which an air-fuel mixture begins to burn. At this point, the chemical reaction produces heat faster than it is lost to its surroundings, and the combustion process can sustain itself.

Temperature Measurement

1.20 Temperature expresses the "hotness" or "coldness" of a substance. The temperature of a substance also indicates the internal kinetic energy of its molecules. And, when compared to environmental temperature, it indicates the substance's ability to accept or release heat. A temperature change represents a change in the amount of heat energy contained in the substance. Adding heat energy may cause an increase in temperature. Removing heat energy may cause a decrease in temperature.

Fig. 1-2. The three requirements for combustion



1.21 Temperature is measured in relation to two fixed values. The first is the ice point of water or the temperature at which water freezes. The second is the steam point of water or the temperature at which water boils. The two temperature scales in common use are the Fahrenheit and Celsius (formerly called Centigrade) scales (see Fig. 1-3).

Fig. 1-3. Comparison of Celsius and Fahrenheit scales

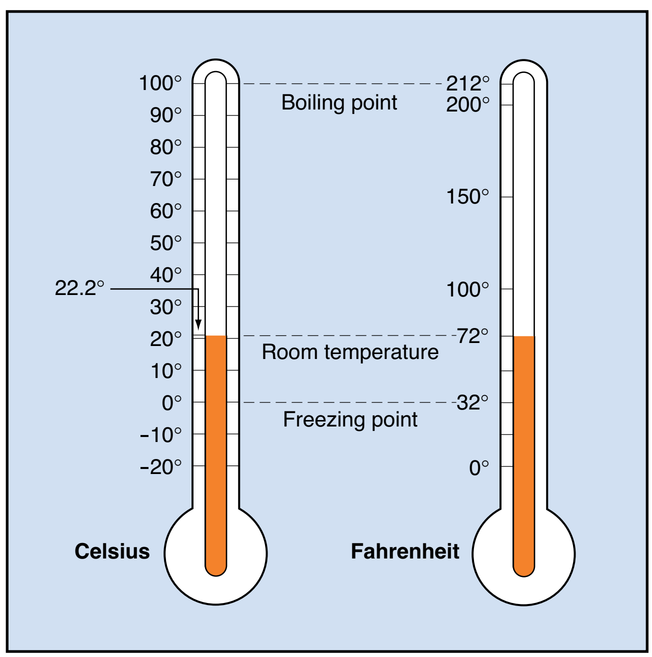


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Fig. 1-4. Comparison of absolute and ordinary temperature scales

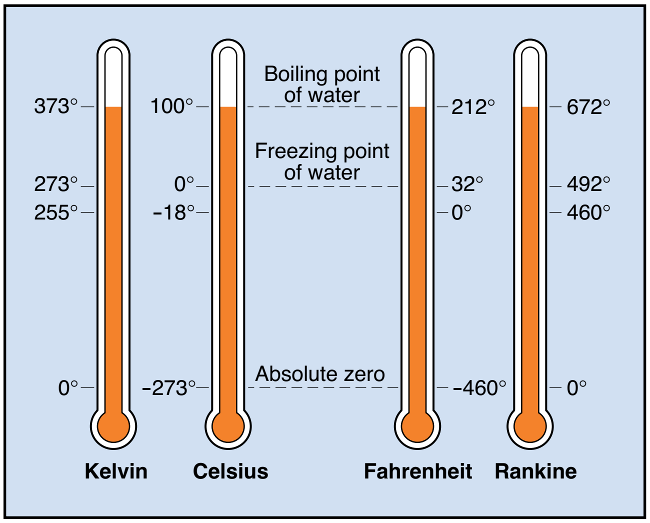

Table 1-1. Temperature conversion formulas

To convert	Use formula
F to C	C = 5/9 (F - 32)
C to F	F = 9/5 C + 32
C to K	K = C + 273
K to C	C = K - 273
F to R	R = F + 460
R to F	F = R - 460
K to R	R = 9/5K
R to K	K = 5/9R

1.22 On the Fahrenheit (F) scale, you see that the freezing point is 32°F and the boiling point is 212°F at one atmosphere (1 atm) pressure. The scale between the freezing point and boiling point is divided into 180 equal degrees. Temperatures lower than 0°F have negative values, expressed by a minus (-) sign.

1.23 On the Celsius (C) scale, the ice point is 0°C and the steam point is 100°C at 1 atm. The scale between the freezing point and boiling point is divided into 100 equal degrees. As on the Fahrenheit scale, temperatures lower than 0°C have negative (-) values.

1.24 You can convert temperature values easily from one temperature scale to another if you remember two facts. The first is that the freezing points on the two scales differ by 32°. The second is that the ratio of the divisions on the Fahrenheit scale to those on the Celsius scale is 9 to 5. To convert a Fahrenheit value to a Celsius value, subtract 32 from the Fahrenheit reading and then multiply the result by 5/9. To convert a Celsius value to a Fahrenheit value, multiply the Celsius reading by 9/5 and then add 32.

1.25 You can also measure temperature on the Kelvin and Rankine scales (see Fig. 1-4). These scales are convenient because all values are positive. The zero mark is set at *absolute zero*, the point at which all molecules stop moving. Absolute zero is theoretically the lowest possible temperature that can be reached. Absolute zero equals approximately -273°C or -460°F.

1.26 The Kelvin scale has the same divisions as the Celsius scale. To obtain a Kelvin value, add 273° to the Celsius reading. The Rankine scale corresponds to the Fahrenheit scale. To obtain a Rankine value, add 460° to the Fahrenheit reading. Conversion formulas for Kelvin and Celsius temperatures are listed in Table 1-1.

The Programmed Exercises on the next page will tell you how well you understand the material you have just read. Before starting the exercises, remove the REVEAL KEY from the back of your Book. Read the instructions printed on the Reveal Key. Follow these instructions as you work through the Programmed Exercises.

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1-1. Energy is the capacity to do ________.	1-1. WORK Ref: 1.01
1-2. The stored energy that a substance possesses because of the motion of its molecules is ________ energy.	1-2. KINETIC Ref: 1.04
1-3. Thermal energy in transition is called ________ energy.	1-3. HEAT Ref: 1.09
1-4. A substance's temperature depends on the activity of its ________.	1-4. MOLECULES Ref: 1.10
1-5. The three elements needed for combustion are fuel, heat, and ________.	1-5. OXYGEN Ref: 1.16, Fig. 1-2
1-6. The lowest temperature at which a substance will burn is called its _______ temperature.	1-6. IGNITION Ref: 1.19
1-7. The steam point of water on the Celsius scale is ________° at 1 atm.	1-7. 100 Ref: 1.23
1-8. The two absolute temperature scales are the Rankine and ________ scales.	1-8. KELVIN Ref: 1.25, Fig. 1-4

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Pressure Measurement

1.27 In boiler operation, the heat produced by combustion applied to water generates steam. Because steam generation is related to pressure, you need a basic knowledge of pressure measurements to understand the process. Pressure is force exerted by or on a solid, liquid, or gas per unit area. It is generally measured in pounds per square inch (psi).

1.28 Pressure measurements are related to atmospheric pressure, which is the pressure that the atmosphere exerts on the earth. A column of air 1 in. square extending from the earth to the top of the atmosphere weighs 14.7 lb. Therefore, standard atmospheric pressure at sea level equals 14.7 psi or one atmosphere (1 atm). Absolute pressure (psia) is the total pressure above 0 psi or a perfect vacuum. Some older pressure gauges measure in terms of gauge pressure (psig). The zero reading for gauge pressure is set at 14.7 psi. Thus, a gauge reading of 10 psig equals 24.7 psia, as shown in Fig. 1-5.

Quantity of Heat

1.29 Heat quantities are measured in terms of the British thermal unit (Btu) and the calorie (cal). One Btu equals the amount of heat needed to raise the temperature of 1 lb of water 1°F (see Fig. 1-6). One Btu is roughly equivalent to the heat released by burning a large wooden kitchen match. The calorie, which is a metric unit, is the amount of heat required to raise the temperature of 1 gram (gm) of water 1°C. One Btu equals about 252 cal.

1.30 The quantity of heat needed to raise the temperature of a material 1 degree (usually at constant pressure or constant volume) is called the heat capacity of the material. The heat capacity of a material is measured in Btu per degree Fahrenheit (Btu/°F) or calories per degree Celsius (cal/°C). Materials having a high heat capacity absorb more heat per unit quantity for every degree rise in temperature than materials with a low heat capacity. And, materials with a high heat capacity release more heat per unit quantity for every degree loss in temperature than materials with a low heat capacity.

1.31 Before the abilities of two or more materials to absorb heat can be compared, you must measure the heat capacities of equal weights of the materials. The ratio of the heat capacity of a material to its weight is called the specific heat of the material. Thus, specific heat is the amount of heat absorbed per unit quantity of a material when its temperature increases one degree. The units of specific heat are Btu per pound per degree Fahrenheit (Btu/lb/°F) and calories per gram per degree Celsius (cal/gm/°C).

1.32 You can also determine a material's specific heat by comparing it to the specific heat of water. The specific heat of water is 1.0 in both the English and metric systems. One Btu is required to raise 1 lb of water 1°F, and 1 cal is needed to raise 1 g of water 1°C.

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Fig. 1-5. Measurement of gauge and absolute pressure

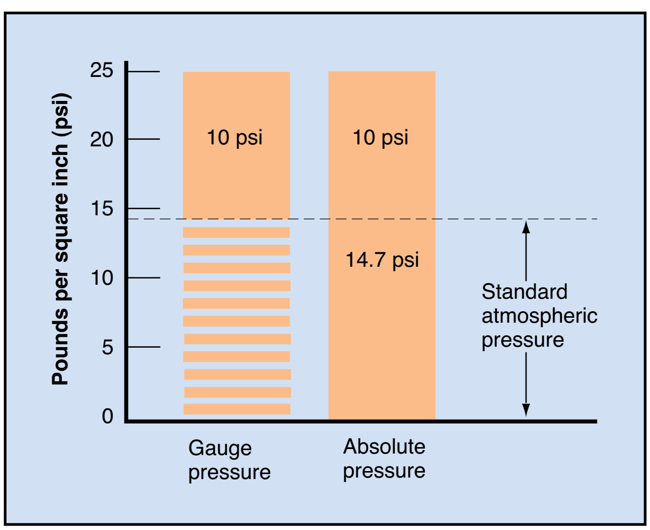
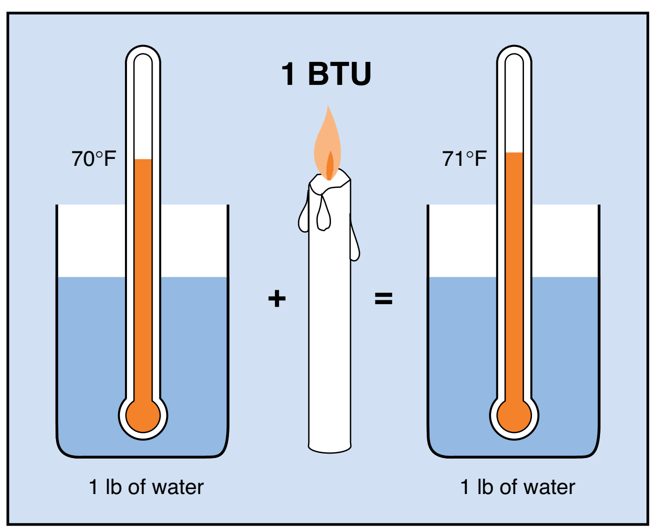


Fig. 1-6. The British thermal unit



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1.33 The specific heats of other materials also have the same numerical values in both systems of measurement. Thus, if 2 Btu are required to raise the temperature of 1 lb of a material 1°F, or if 2 cal are needed to raise the temperature 1°C, the specific heat of the material is 2.0. Twice the amount of heat is needed to raise the temperature of the material 1° than is needed to raise the temperature of the same amount of water. The specific heats of several common materials are listed in Table 1-2.

Table 1-2. Specific heat values

Material	Specific heat (Btu/lb)
Water	1.000
Ice	0.504
Glass	0.180
Iron	0.129
Copper	0.093
Air	0.240
Lead	0.031
Alcohol	0.615
Ammonia (liquid)	1.100
Ammonia (gas)	0.520

Heat Transfer

1.34 Heat can flow only from an object with a high temperature to an object with a lower temperature. Thus, heat will transfer from one object to another only when the two objects have different temperatures. The rate of heat transfer is greater when a large temperature difference exists, and smaller when a slight temperature difference exists. The two basic methods of heat transfer are conduction and radiation. A third method, convection, is often considered a means of heat transfer, but it is more accurately a process involving the movement of a fluid rather than the movement of heat. Fig. 1-7 illustrates conduction, radiation, and convection.

Conduction

1.35 *Conduction* is heat transfer by direct physical contact between a heat source and a cooler body, or by heat flow from one part of an object to another part of the same object. For example, if the end of a metal rod is placed in a fire, the entire rod becomes warmer as heat is conducted along it. The transfer of heat occurs from molecule to molecule making up the rod's metal. These molecules collide with neighboring molecules, causing an increase in their activity. This action continues along the length of the rod as long as the two ends have different temperatures.

1.36 The rate at which heat transfers between materials by conduction depends upon both how great the temperature difference between them is, and the conductivity or heat-carrying qualities of the materials through which the heat passes. Gases are the poorest conductors. Liquids, in general, are also poor conductors. Solids differ greatly in their abilities to conduct heat. Dry, fibrous materials are poor conductors, whereas metals are the best conductors.

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Fig. 1-7. Methods of heat transfer

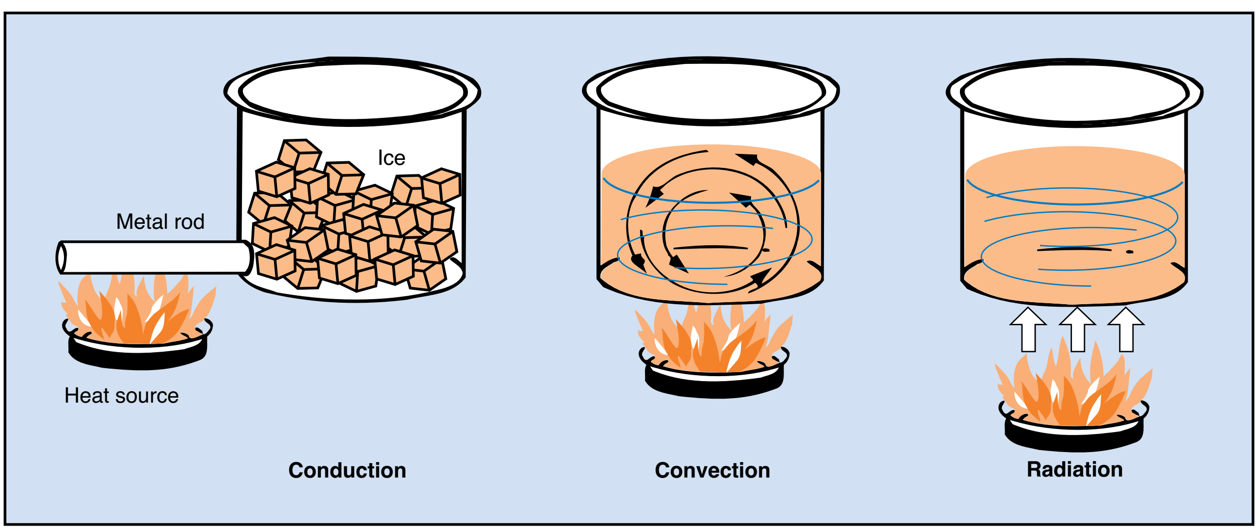

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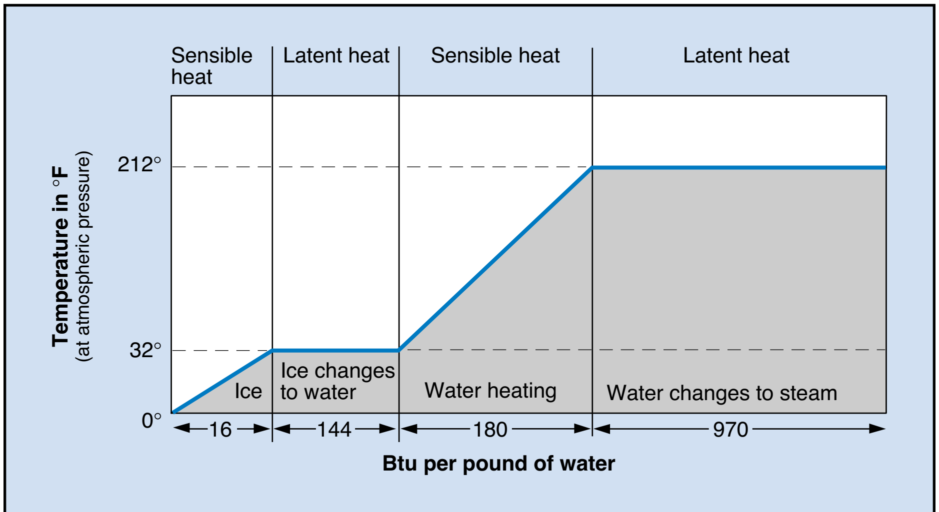
Fig. 1-8. Relationships for sensible and latent heat of water



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Radiation

1.37 *Radiation* is heat transfer directly through space from a hot body to a cooler one. It does not require any physical contact between the two bodies. For example, heat from a fire warms an object near it by radiation even though the air in between remains cold. The rate of heat absorption depends on the amount of temperature difference between the bodies, the distance between the bodies, the color of the body receiving the heat, and the amount of its exposed surface area. Heat absorption increases with an increase in the temperature difference, with less distance between the bodies, with darker colors, and with greater exposed areas.

Convection

1.38 *Convection* is the actual movement of a volume of hot fluid—liquid, gas, or vapor—from one area to another. In fact, convection contributes to the mixing of the various portions of a fluid. It hastens the rate at which heat is absorbed by the whole mass of the fluid.

1.39 Convection can be natural or forced. Natural convection occurs because a heated fluid tends to move as the result of different densities in different parts of the fluid. When a portion of a fluid is heated, it expands and rises. The cooler portions of the fluid then enter the space vacated by the warmer fluid. This causes a circulatory or mixing motion which carries heat from one part of the fluid to another. Forced convection is the movement of a heated fluid by a mechanical device such as a pump or fan.

Sensible and Latent Heat

1.40 Heat transfer has two different effects on a material. If adding or removing heat causes a change in the temperature of a material, the heat is called sensible heat. If adding or removing heat does not cause a temperature change, but does change the physical state of a material, the heat is called latent heat. The physical state of a material refers to whether it is solid, liquid, or gas.

1.41 An example of heat transfer effects is changing ice into steam. To heat a pound of ice at 0°F to 32°F, 16 Btu must be added. This added heat is sensible heat because its effect on the ice is reflected in a change in temperature. If, however, 144 Btu (the latent heat of fusion) are added to the pound of ice at 32°F, the ice will change to water, but the temperature will not increase. This additional heat is latent heat because it results in a change of state.

1.42 The heat added to water to raise its temperature from 32°F to its boiling point (212°F at one atmosphere pressure) is sensible heat. The heat added to change the water at 212°F to steam at 212°F is latent heat. Figure 1-8 shows the relationship between sensible and latent heat.

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Vaporization

1.43 *Vaporization* is the process by which a liquid changes to a vapor, either by evaporation or boiling. When water is in the liquid state, its molecules possess kinetic energy and randomly collide with each other. The collisions give some of the surface molecules sufficient energy to overcome the forces that hold them to the water. When a molecule escapes from the water, it enters the vapor state. This vaporization process from the surface of a liquid is called evaporation.

Boiling Point

1.44 When the vapor molecules move randomly in the space above the water surface, they exert a pressure on the container greater than that exerted by the air molecules. The pressure exerted by the vapor molecules is called vapor pressure. The vapor pressure increases until the number of molecules entering the vapor space equals the number of molecules leaving the surface of the water. When the vapor pressure equals the atmospheric pressure exerted on the water surface (see paragraph 1.45), the water reaches its boiling point. Water evaporates rapidly at the boiling point.

1.45 When water is in an open container, the atmosphere exerts external pressure on it. When the external pressure equals 1.0 atm, the temperature at which water boils is called the normal boiling point. But if the external pressure on the water surface is greater than 1.0 atm, water will boil only at a temperature higher than its normal boiling point. If the external pressure is less than 1.0 atm, water will boil at a temperature lower than its normal boiling point. The normal boiling points of several common substances are listed in Table 1-3.

1.46 The normal boiling point of water is 212°F (100°C). When 970 Btu are added to a pound of water at 212°F (100°C), it changes into steam. The latent heat required to change water from a liquid to a vapor is called the latent heat of vaporization.

Enthalpy

1.47 *Enthalpy* is an engineering term used to describe the total heat content of a system. Enthalpy is the sum of the internal energy of the system, plus the system's volume multiplied by the pressure exerted on the system by it's surroundings. This is expressed:

$$U + PV = H$$

Where U is the system's internal energy, P is the pressure of the surroundings on the system, V is the system's volume, and H is the enthalpy of the system. Because the sum of a system's internal energy is rarely known, enthalpy values are relative, and are measured above some arbitrary base reference. Usually changes in enthalpy, rather than absolute enthalpies, are of most interest in the power plant.

Heat and Work

1.48 As water changes into steam at 1.0 atm pressure, it expands about 1700 times. If the steam is confined in a boiler, its volume remains constant, but the temperature and pressure increase. When the steam reaches operating pressure and the steam stop valves are opened, the high-temperature, high-pressure steam is released from the boiler and flows to the steam turbine. The steam pressure thus provides the potential for doing work.

1.49 But the actual conversion of heat to work is done in the turbine. The change in the steam's internal energy (as indicated by changes in pressure and temperature) between the boiler and the condenser indicates the amount of heat that has been converted to work in the turbines. The formula for converting heat to work is: 1 Btu = 778 ft-lb, or the amount of energy required to raise the temperature of water 1°F equals the amount of energy required to lift a 1 lb weight 778 ft against the force of gravity.

Table 1-3. Normal boiling points

Substance	Temperature	
	°C	°F
Sulfur	444.6	832.3
Mercury	356.7	674.1
Water	100.0	212.0
Alcohol (ethyl)	78.3	172.9
Ether	34.6	94.3
Oxygen	−183.0	−297.4
Nitrogen	−195.8	−320.4
Hydrogen	−252.8	−423.0
Helium	−269.0	−452.2

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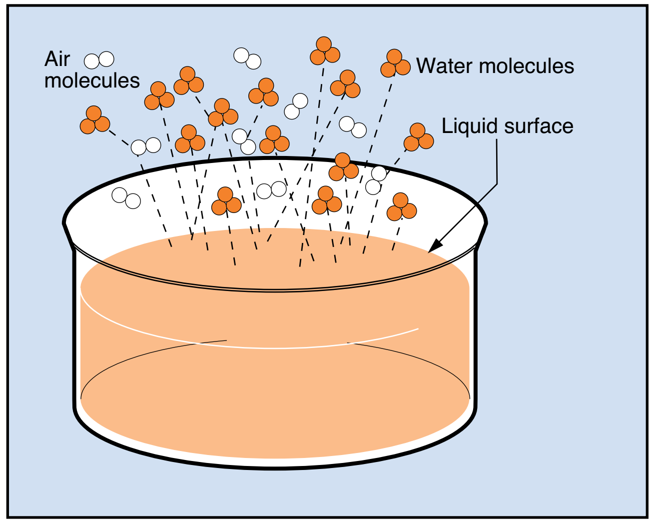
1.50 To understand how steam energy is converted to work by the turbine, you need to learn the relationships among temperature, volume, and pressure. (Volume describes the bulk or space occupied by a solid, liquid, or gas.) The interrelationship of temperature, volume, and pressure on gases such as steam can be summarized as follows:

- When the temperature of a gas remains constant but the pressure exerted on the gas is increased, its volume decreases proportionately. When the pressure is decreased, the volume increases proportionately.
- When the pressure of a gas remains constant but its absolute temperature is increased, its volume increases proportionately. When the absolute temperature is decreased, the volume decreases proportionately.
- When the volume of a gas remains constant but its absolute temperature is increased, its pressure increases proportionately. When the absolute temperature is increased, the pressure decreases proportionately.

Basic Steam Generation

1.51 A steam generating system uses combustion heat to change boiler water into steam. Steam is water in its gaseous state. Adding heat to water in an enclosed container such as a boiler increases the speed and kinetic energy of the water molecules. Some water molecules at the water surface gain enough speed to escape from the water (see Fig. 1-9)

Fig. 1-9. Water molecules escaping liquid surface



and enter the vapor space above the water, or evaporate. The water traps slow-moving vapor molecules and returns them (condenses them) to the liquid state.

1.52 The return of vapor molecules to liquid molecules is called *condensation*. Condensation occurs when pressure on a vapor is increased, or when heat is removed from the vapor. When the rate of evaporation equals the rate of condensation, a condition of equilibrium exists.

1.53 When the vapor pressure in the vapor space equals the atmospheric and water pressures on the water surface, the water boils and produces steam. The steam and the water remain at the same temperature as long as they are in direct contact. Steam and water in this condition are in equilibrium contact.

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1-9. Absolute pressure readings indicate the total pressure above a perfect ________.	1-10. VACUUM Ref: 1.28
1-10. The units of measurement for the quantity of heat are the British thermal unit and the ________.	1-11. CALORIE Ref: 1.29
1-11. Conduction, radiation, and convection are the three methods of ________.	1-11. HEAT TRANSFER Ref: 1.34, Fig. 1-7
1-12. Sensible heat added to a material causes a change of ________.	1-12. TEMPERATURE Ref: 1.40
1-13. Evaporation is vaporization from the surface of a(n) ________.	1-13. LIQUID Ref: 1.43
1-14. Enthalpy describes the total ________ of a system.	1-14. HEAT CONTENT Ref: 1.47
1-15. If the temperature of a gas remains constant but its pressure decreases, the volume ________ proportionately.	1-15. INCREASES Ref: 1.50
1-16. Vapor and liquid molecules are in a condition of equilibrium when the rate of evaporation equals the rate of ________.	1-16. CONDENSATION Ref: 1.52

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Answer the following questions by marking an "X" in the box next to the best answer.

1-1. The smallest particles of a substance that can exist by themselves and retain the properties of the substance are

- ☐ a. elements
- ☐ b. molecules
- ☐ c. neutrons
- ☐ d. protons

1-2. Thermal energy in transition produces what type of energy?

- ☐ a. Chemical
- ☐ b. Electrical
- ☐ c. Heat
- ☐ d. Mechanical

1-3. The energy stored in natural fuels came from a chemical process in a plant involving

- ☐ a. carbon dioxide, carbon monoxide, sunlight
- ☐ b. carbon dioxide, sunlight, water
- ☐ c. carbon monoxide, hydrogen, sunlight
- ☐ d. hydrogen, sunlight, water

1-4. Fuel, heat, and oxygen are the three requirements for ________ to take place.

- ☐ a. combustion
- ☐ b. conduction
- ☐ c. evaporation
- ☐ d. radiation

1-5. The ice (freezing) point of water is 0° on what temperature scale?

- ☐ a. Celsius
- ☐ b. Fahrenheit
- ☐ c. Kelvin
- ☐ d. Rankine

1-6. A gauge pressure reading of 14.7 psi is equal to an absolute pressure reading of ________psia.

- ☐ a. 0
- ☐ b. 14.7
- ☐ c. 24.7
- ☐ d. 29.4

1-7. The amount of heat absorbed per unit quantity of a material when its temperature is raised one degree is a measure of

- ☐ a. enthalpy
- ☐ b. heat capacity
- ☐ c. heat transfer
- ☐ d. specific heat

1-8. The method of heat transfer that involves the flow of heat directly through space is

- ☐ a. conduction
- ☐ b. forced convection
- ☐ c. natural convection
- ☐ d. radiation

1-9. The normal boiling point of water is

- ☐ a. 0°C
- ☐ b. 100°C
- ☐ c. 212°C
- ☐ d. 970°C

1-10. The conversion of vapor molecules to liquid molecules is called

- ☐ a. boiling
- ☐ b. condensation
- ☐ c. evaporation
- ☐ d. vaporization

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SUMMARY

Energy is the basis of the work done in a power plant. It exists in one of two forms—either stored or in transition. Energy can be stored in mechanical, thermal, chemical, or electrical form. Energy in transition is simply in the process of moving from one form to another.

The fuel used in a power plant contains stored chemical energy, which is released in the combustion process, a chemical reaction.

Temperature indicates kinetic energy of a substance. It is measured in relation to the freezing point and the boiling point of water. There are two common scales on which temperature can be measured: Fahrenheit and Celsius. Two less commonly used scales, Rankine and Kelvin, measure temperature based on absolute zero, or the point at which molecules stop moving. The effect of heat on water is to create steam—the essential product for power plant operation.

The transfer of heat itself occurs by conduction and radiation. A third process, convection, is the actual movement of fluid based on its temperature. The effect that heat has on water when it turns to steam is called latent heat. The temperature at which water boils and then evaporates is related to how much pressure is exerted on the water.

Steam is generated in a boiler system when the vapor pressure equals the atmospheric and water pressures, and the system is in equilibrium as long as the steam and the water remain in contact with each other.

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Answers to Self-Check Quiz

1-1. b. Molecules. Ref: 1.02

1-2. c. Heat. Ref: 1.09, 1.11

1-3. b. Carbon dioxide, sunlight, water. Ref: 1.14

1-4. a. Combustion. Ref: 1.16

1-5. a. Celsius. Ref: 1.23

1-6. d. 29.4. Ref: 1.28

1-7. d. Specific heat. Ref: 1.31

1-8. d. Radiation. Ref: 1.37

1-9. b. 100°C. Ref: 1.46

1-10. b. Condensation. Ref: 1.52

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