Chapter 19 – Conventional Energy

Key Terms

black lung disease
breeder reactor
chain reaction
control rod
energy
fossil fuel
fuel assembly
joule
methane hydrate
nuclear fission
nuclear fusion
oil shale
power
proven resource
tar sand
work
Yucca Mountain

Skills

1. Characterize current energy resources used in the United States.
2. Contrast U.S. use of energy versus energy use in other nations.
3. Classify the reserves of fossil fuels found in different nations.
4. Evaluate the costs, both economic and environmental, of using fossil fuels.
5. Evaluate the benefits, both economic and environmental, of using fossil fuels.
6. Appraise the costs and benefits of nuclear energy.
7. Diagram a light water reactor and know the functions of all components, including the water systems.
8. Evaluate proposed methods for nuclear waste disposal.

> **Take Note:** Nearly every AP exam contains an essay question about energy. These questions have included solar energy, coal, natural gas, biomass, and nuclear power, to name a few. It is expected that a student can carry out simple algebraic calculations on energy conversions, costs, and emissions values. You must be familiar with the recovery of the nonrenewable resource, the environmental damage from the recovery, the use of the resource, and the environmental damage that results from the use of the resource. Be sure that you know specifically which pollutant arises from which fossil fuel. You must also know ways to decrease the pollutants that arise from use of these fossil fuels. Energy questions will also be prevalent in the multiple-choice portion of the AP exam.

Energy

Energy is defined as the ability to do work. Work is force acting across a distance. Power is the rate at which work is done. Food energy is measured in calories. A calorie is the amount of energy that can raise the temperature of 1 gram of water 1°C. A kilocalorie, denoted calorie by most individuals, is 1000 calories. A newton is the force needed to accelerate 1 kg of mass 1 meter/second.

> **Take Note:** See table 19.1 for a list of energy units you should be familiar with using in calculations.

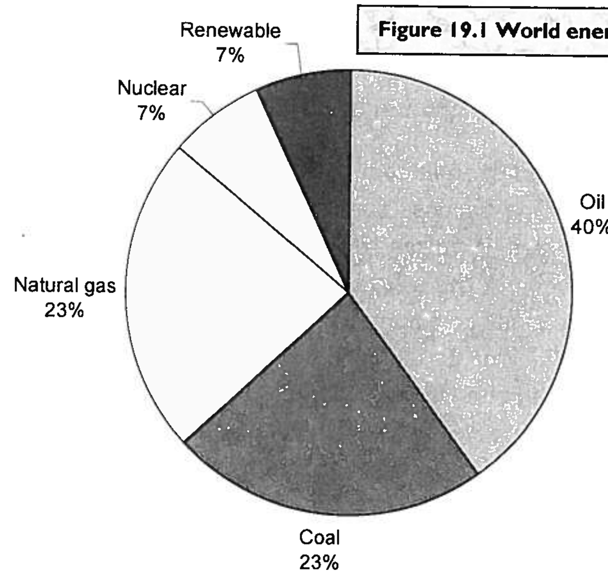
Table 19.1 Energy Units

1 joule (J) = the force exerted by a current of 1 amp per second flowing through a resistance of 1 ohm
1 watt (W) = 1 joule (J) per second
1 kilowatt-hour (kWh) = 1 thousand (10^3) watts exerted for 1 hour
1 megawatt (MW) = 1 million (10^6) watts
1 gigawatt (GW) = 1 billion (10^9) watts
1 petajoule (PJ) = 1 quadrillion (10^{15}) joules
1 PJ = 947 billion BTU, or 0.278 billion kWh
1 British thermal unit (BTU) = energy to heat 1 lb of water 1°F
1 standard barrel (bbl) of oil = 42 gal (160 l) or 5.8 million BTU
1 metric ton of standard coal = 27.8 million BTU or 4.8 bbl oil

Humans began using domesticated animals more than 10,000 years ago to assist us with our work. Wind and water were used to grind grain, cut timber, and provide other necessary energy. Steam engine development reduced available wood supplies and increased the use of coal. Coal fell into decline when it was discovered that petroleum could be used for many of the same applications. Eighty-six percent of the world's energy use is supplied by fossil fuels.

In the past, developed countries have used far more energy than developing countries. With the rapid industrialization and economic growth in China and India, developing countries will consume a greater proportion of energy than they have in the past.

Figure 19.1 World energy use



Political turmoil in the Middle East has impacted fuel prices in the past. The effects were far more dramatic in developing than developed countries. The two events in the 1970s that affected prices were the oil embargo by OPEC (Organization of Petroleum Exporting Countries) in 1973 and the Iranian Revolution in 1979. The mid-2000s increase in gasoline prices were linked to increased worldwide demand for petroleum; increased price of petroleum; and damage done to refineries, pipelines, and U.S. rigs in the Gulf of Mexico due to Hurricane Katrina.

American Energy Use

The United States consumes oil for 43 percent of our energy use. Due to the vast coal reserves in the United States, we use more coal than natural gas, even though coal combustion is far more polluting. Nuclear power accounts for 8 percent of all commercial power, and the renewable energy resources, primarily hydroelectric, is 6 percent. The United States is the world's largest oil importer, as we use foreign oil for 75 percent of our supply. Most of our imported oil comes from Canada followed by Saudi Arabia. The majority of the energy in the U.S. is used by industry.

Mining and smelting processes account for the majority of this energy use, followed by the chemical industry. Residential and commercial buildings use about 20 percent of the U.S. energy for heating, lighting, cooling, and water heating. Transport consumes 27 percent of the U.S. energy supplies in a year, with 98 percent of that energy supplied by petroleum.

Net energy production must be considered when evaluating energy resources. It takes tremendous amounts of energy to mine coal and transport the coal to a power plant. Seventy percent of the energy is lost in energy conversion at the power plant and 10 percent more during electrical transmission. Seventy-five percent of the energy lost as petroleum is converted into fuels, transported, and burned in vehicles. Natural gas has the greatest efficiency. It only loses about 10 percent of its original available energy and produces far less CO_2 per unit than coal or oil.

Take Note: One of the 2005 essay questions on the AP exam addressed coal mine restoration and the problems associated with acid mine drainage. The question also expected the student to address other environmental costs associated with using coal for energy.

Coal

Coal is the fossilized remains of ancient plant material. Most coal was fossilized during the Carboniferous period, and therefore coal is considered a nonrenewable resource because it takes so long to form.

The first step in coal formation is peat. Peat bogs still exist throughout the world, and peat is burned as biomass fuel in many places. Peat produces less heat than any of the coals. As peat fossilizes, it forms the sedimentary rock coals. The softest coal is called lignite and it is found primarily in the western states. It has a lot of moisture in it and a woody texture. Bituminous coal is the most common coal and typically has a lot of sulfur. It has greater heat producing capacity than lignite. It is found in the Appalachians, Mississippi Valley, Central Texas, and the Great Lakes region in the United States. The coal with the greatest heat capacity is anthracite, a metamorphic rock. Anthracite is 95 percent carbon and has little sulfur, making it the cleanest burning of the coals. In the United States, the greatest reserves of anthracite are in Pennsylvania.

Coal Reserves

Coal is the most abundant of the fossil fuels. Proven reserves are stores of coal that can be removed with current technology at an economically feasible price. Known reserves are not fully examined, and the economic feasibility of its removal has not been established. The proven reserves of coal in the world should last approximately 200 years at the current rate of use. Coal reserves are not equally distributed around the world. The nations with the greatest coal reserves (in order) are the United States, Russia, China, India, and Australia. Coal is uncommon in Africa, the Middle East, and Central and South America.

Coal Mining and Environmental Damage

The two major types of coal mining in the United States are subsurface and surface mines. The subsurface, or underground mines, are found primarily in the eastern United States and are used for bituminous and anthracite coals. Subsurface mining is one of the most dangerous occupations in the world. In the past miners died from asphyxiation due to toxic gases, methane explosions, and cave-ins. Mines now employ exhaust fans to help prevent buildup of toxic gases. Miners also wear protective masks to prevent pneumoconiosis, also known as black lung disease. Black lung disease results from the breakdown of lung alveoli due to inhalation of coal particles. Gas exchange becomes inefficient and respiratory failure results. Some coal mines catch on fire and remain smoldering for years. One fire in China has been burning for 400 years, and one in Pennsylvania has been burning for over 40 years.

Subsurface mines may strike groundwater and contaminate it with heavy metals. Surface mines, often found in the western United States, are used primarily for lignite as it often lies fairly close to the earth's surface. Surface mines are also called strip mines, because the miners remove the topsoil in a strip of land and reserve it. They then remove the overburden with huge machines called draglines. The exposed coal seam is removed. A parallel strip is cut, and the overburden from the new strip is moved into the mined area and topsoil is replaced. The topsoil is replanted with native vegetation. The Surface Mining Control and Reclamation Act of 1977 (SMCRA) requires that the mined lands are reclaimed and restored by replacing the overburden and replanting the area. SMCRA also prevents mining in national parks, wild and scenic rivers, and national wildlife refuges.

A new type of mining, known as mountain top removal, has developed in the Appalachians. This mining involves removing the overburden from the top of a seam of coal using draglines and placing it in a nearby valley. The coal is then extracted from the mine. The entire topography of an area is altered when mountaintop removal is used. Miners apply for a variance to the Surface Mining Control and Reclamation Act to be able to carry out mountaintop removal.

Environmental Impact of Mining

There are numerous environmental impacts of mining. Mining destroys the natural vistas, creating unsightly scars on the earth's surface and destroying the aesthetic value of a region. Mining disturbs habitat for countless species and increases erosion. Erosion can be minimized by carrying out immediate reclamation. Mining may contaminate groundwater, particularly with acids or heavy metals. The iron pyrite frequently found in coal mines in the eastern United States dissolves in water and migrates into streams, acidifying those ecosystems. Underground mining generates tremendous amounts of solid wastes, known as tailings. These tailings are often contaminated with heavy metals.

Coal Combustion and Environmental Damage

Coal combustion emits more CO_2 per unit of heat than any other fuel. CO_2 is a greenhouse gas and contributes to global warming. Coal combustion also releases SO_2 and NO_x, which contribute to acid deposition. Coal combustion releases more nuclear radiation than any nuclear power plant. The particulates released form the fly ash that can contain heavy metals, such as arsenic, lead, cadmium, mercury, and zinc. Coal combustion is responsible for 25 percent of the mercury released in the United States. The bottom ash must be disposed of in a landfill. Coal burning power plants use the energy released from combustion to create steam to spin a turbine. To cool the water, a water source is required. Frequently lakes or the ocean are used, thus resulting in thermal pollution.

Methods to Remove SO_2 and Particulates From Coal Emissions

Sulfur dioxide may be reduced precombustion, during combustion, and postcombustion. Precombustion methods include using a higher grade of coal (anthracite) and washing the coal to remove excess sulfur. Coal may also be converted into a gas (coal gasification) or oil (coal liquefaction), which removes the sulfur. The process results in less net energy, because energy is lost as the solid is converted to a liquid or gas. A combustion method of removing sulfur from coal emissions is using fluidized bed combustion. Fluidized bed combustion is carried out by burning the crushed coal with crushed limestone. The sulfur in the coal combines with the calcium in the limestone to form calcium sulfate, or gypsum. This bottom ash can then be disposed of in a proper fashion. Postcombustion methods include using catalytic converters to oxidize the sulfur to yield sulfur compounds. A lime scrubber in a smokestack may also be used. In a wet scrubber, a slurry of lime mixed with water is sprayed across the exiting gases. The sulfur mixes with the calcium, forming the calcium sulfate, which falls to the bottom of the smokestack as bottom ash.

Particulates can be removed from coal combustion by burning coal with a low ash content. Most particulate removal is postcombustion. The resultant particle mixture must often be discarded in a hazardous waste landfill. Bag filters are a series of bags, somewhat like a bag in vacuum cleaner, which catch the particulates as they rise in the smoke. The bags are periodically emptied of their ash. Electrostatic precipitators remove 99 percent of the particulates in coal emissions. They function by passing the coal emissions past a series of charged plates, thus charging the particulates, which then bind to an oppositely charged plate. Cyclone collectors create a vortex in a smokestack, causing the particles to collide and fall to the bottom of the stack as bottom ash.

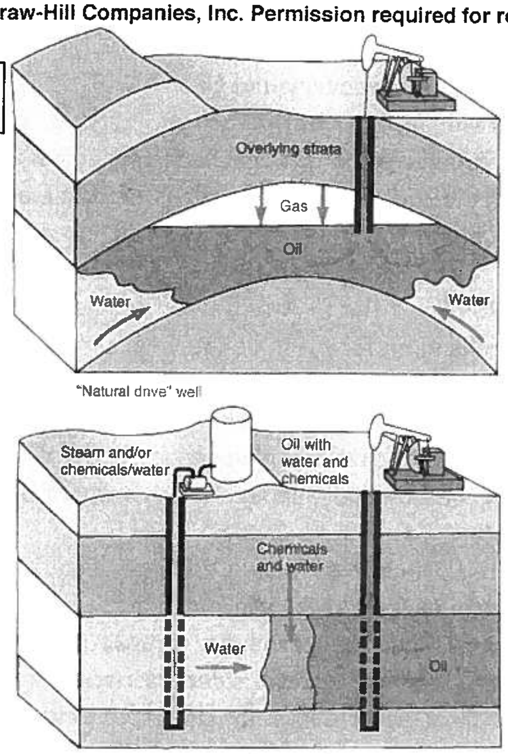
Oil

Oil is derived from ancient organisms buried in sediment and subjected to heat and pressure, which turned them into oil. Oil is usually found in conjunction with natural gas in porous rock, and they are held in place by impermeable sediments such as shale. In primary recovery, oil moves into wells, and it is pumped to the surface. By using secondary recovery, the yield is increased by injecting water into a second well to force oil toward the oil drilling well. Primary and secondary recovery allow 15-40 percent of a well's reserve to be removed. Tertiary recovery involves injecting steam or carbon dioxide into wells to stimulate the remaining heavy oil to flow to obtain another 5-15 percent of the oil remaining in the well.

Oil Reserves

Oil deposits have an uneven distribution throughout the world, but are present on every continent. Approximately two-thirds of proven oil reserves in the world are in the Middle East. The United States has about 3 percent of the world's proven reserves, primarily in the Gulf of Mexico, which provides 25 percent of U.S. oil and 20 percent of the natural gas. The oil in the Gulf is removed by deep wells situated below oil platforms, some stationary and some floating. The United States currently produces about 8 million barrels a day. As the price of oil continues to rise, current reserves considered too expensive to recover may become economically feasible.

Figure 19.2 Primary and secondary oil recovery



> **Take Note:** One of the 2005 essay questions on the AP exam addressed the controversial use of the oil lying beneath the Alaska Arctic National Wildlife Refuge (ANWR). Students had to be familiar with environmental damage associated with drilling for oil and how this environmental interference would cause damage to the tundra. Students were also expected to explain the uses of petroleum in the United States and propose mechanisms to decrease that usage.

ANWR Controversy

The coastal plain of the Alaska Arctic National Wildlife Refuge (ANWR) has a known reserve of oil that has not yet been tapped. The exact amount of oil in the plain is not known, but estimates run as high as 12 billion barrels. The plain is the calving ground of caribou and is the summering site for snow geese, swans, and numerous species of migratory waterfowl. In addition, polar bears, arctic foxes, and wolves are also found in this refuge. Preservationists worry that the traffic coming into the refuge may frighten the wildlife and cause them to leave. They say that improving the efficiency of internal combustion engines in cars will save far greater amounts of oil than ANWR will ever yield. Proponents of the drilling plan claim there will be little damage done to the fragile ecosystem. Many people in Alaska favor drilling, because they work on rigs and receive oil royalties. Many in Florida consider ANWR a test case, to evaluate if Congress will place the country's need for oil above environmental preservation. Floridians have managed to hold at bay the oil companies desiring to drill off the coast of pristine Florida beaches. Many Floridians are concerned that opening up ANWR to oil exploration means that their highly desirable tourist beaches may soon be covered in tar and other debris from oil drilling.

Environmental Costs of Oil Recovery and Use

Oil tankers and pipelines leak, causing environmental damage. For example, in 1989 the EXXON Valdez ran aground releasing millions of gallons of crude oil in Prince William Sound, Alaska. To date it is the largest oil spill in the United States. Birds, sea otters, orcas, and salmon were killed. The salmon fishery was severely damaged that season, because few fish were harvested. The Oil Pollution Act of 1990 allows the EPA to better regulate spills, oil storage facilities, and oil tankers. One of the worst spills in history was deliberate, as the Iraqi army in Kuwait dumped a huge volume of oil into the Persian Gulf in 1991. The exact volume of oil will never be known, but is estimated to be many times that of the Valdez. Drilling leads to environmental damage including erosion and habitat disruption; however, little land space is used for wells and pipelines, compared to the vast amount of land disturbed by coal mining. The transport and building of the rigs and pipelines disrupts the habitat.

Petroleum is heated to remove the various components that will be used in a process called distillation or refining. Gasoline, kerosene, diesel fuel, lubricating oil, heavy gas oil, and asphalt are separated during the refining process. Products made from petrochemicals include plastics, paraffin wax, mineral oil, petroleum jelly, dyes, pesticides, and industrial solvents.

When oil or gasoline is burned, CO_2, a greenhouse gas, is released, which leads to global warming. When gasoline is burned, NO_x are released, which contributes to smog formation and acid deposition.

Tar Sand and Oil Shale

Oil can also be derived from tar sand or oil shale. Tar sands are sand or sandstone deposits infused with a thick oil known as bitumen. The oil is too thick to pump out in an oil well, so it must be heated to remove it from a well as a liquid or mined. The addition of steam to the tar sand deposits contaminates large amounts of water. The oil has to be refined to remove the sand. Several U.S. states have tar sand deposits, and Canada has a tremendous amount of this resource, primarily in Alberta.

Oil shale is a sedimentary rock composed of a variety of heavy oils called kerogen. The oil shale is surface mined, then crushed and heated to remove the oil. There are fairly large deposits of oil shale in the U.S., particularly in Colorado, Utah, and Wyoming. Its recovery is not yet economically feasible. The process also requires large amounts of water to refine the oil, but the resource in the United States is located in arid regions.

Natural Gas and Natural Gas Reserves

Ninety percent of the gas in natural gas is methane, followed by propane, ethane, and butane. Natural gas is the cleanest burning of the fossil fuels, and it has the highest net energy value. Natural gas pipelines run throughout the United States, and the United States has abundant reserves. To transport natural gas, it is usually cooled and compressed until it becomes a liquid. This liquid is known as liquefied natural gas, or LNG. In the United States, LNG is frequently used in rural areas. In urban areas, methane is piped to homes directly. Russia has slightly more than 30 percent of the world's known reserves of natural gas. Because the Middle East has so much oil, it is no surprise that they have 36 percent of the world's natural gas.

Unconventional Methane Stores

Methane can be found frozen in ice as methane hydrate. This methane can be removed by dissolving the ice in methanol. It is of great concern that if the ice caps melt due to global warming, the methane in the ice sheets will enter the atmosphere. Because methane is a greenhouse gas, global warming will be significantly exacerbated.

Methane has also been found associated with coal deposits in the western United States. This methane is relatively close to the surface of the earth, making its extraction economically and technically feasible. The methane is under groundwater supplies, which must be removed to extract the methane. This water tends to have large amounts of salt and other minerals and is thus too contaminated to release onto fields and pastures in the area. The water withdrawal is also drying up local wells that ranchers rely upon for their livestock. Livestock and wildlife are being killed by the traffic and waste left around the drill sites. The large numbers of wells are rapidly contributing to ecosystem disruption.

> **Take Note:** There have been two essay questions on AP exams regarding nuclear energy. One was regarding Yucca Mountain and the disposal of radioactive isotopes. The other had students identify components of a nuclear power plant and explain their function. The question further asked students to identify problems associated with the use of nuclear power.

Nuclear Power

Despite all of the concerns, protests, and objections to U.S. nuclear power, the U.S. nuclear program has never had an accident at a plant where a significant amount of radiation was released into the environment. The Bush administration has renewed interest in the U.S. nuclear program, which had been waning in the last 25 years. Public concern, rising construction costs, and a declining demand for electricity have resulted in no new nuclear plants being built since 1975. Nuclear power is still nearly twice as expensive as coal energy. The 103 reactors in 31 U.S. states produce 20 percent of the country's electricity.

Nuclear Fuel Enrichment

Uranium exists in finite amounts and is therefore a nonrenewable resource. North America has roughly 22 percent of known uranium reserves in the world and Australia has 26 percent. The uranium must be mined, usually from sedimentary rock, which leads to all of the environmental impacts associated with mining a resource as discussed in chapter 14. The mine tailings are frequently radioactive and present additional dangers to the environment and surface water and groundwater supplies. Additionally, mine workers who work in uranium mines are susceptible to lung cancers induced by high radon levels in the mines. There are three isotopes of uranium. ^{238}U makes up 99.28 percent of all U in ore; ^{235}U makes up 0.71 percent, and ^{234}U makes up less than 0.01 percent. The desired isotope to use in a nuclear reactor is the fissionable ^{235}U, which must undergo a process known as enrichment to concentrate it to make up 3 percent or greater of the reactor fuel. The fuel is formed into pellets the width of a pencil and roughly one-inch long. The pellets are the equivalent of one ton of coal or four barrels of crude oil. There was an accident because of human error at an enrichment plant in 1999 in Tokaimura, Japan, which resulted in the deaths of two workers due to radiation exposure.

The pellets are placed in thin metal closed pipes approximately 12 to 16 feet long called fuel rods. These fuel rods are then bundled into clusters of 100-200 rods called fuel assemblies. A small reactor may have as few as 250 assemblies, but larger reactors can have up to 3,000 assemblies.

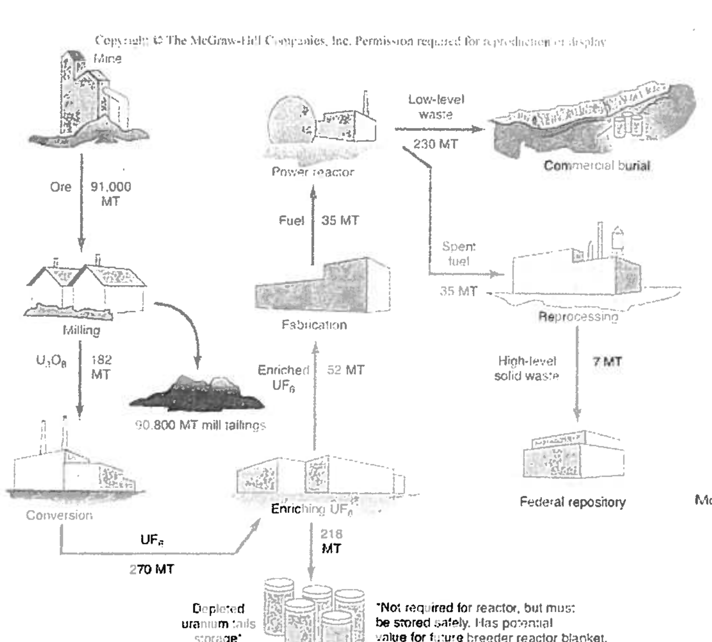


Figure 19.3 Uranium enrichment process

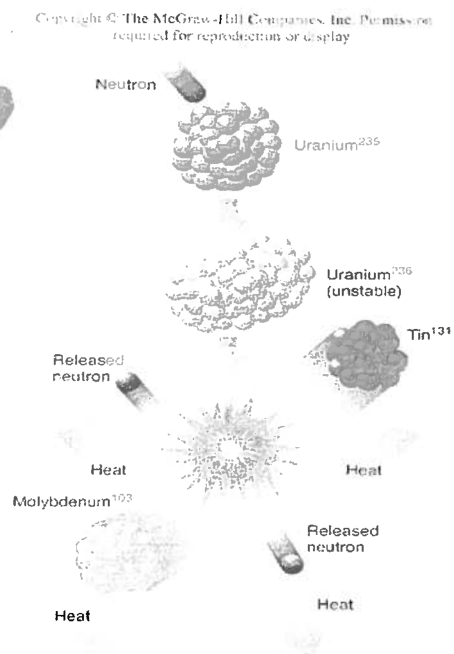


Figure 19.4 Nuclear fission in a nuclear reactor

Nuclear Fission

Nuclear fission is the splitting of an atom to release energy and particles. In nuclear reactors, the uranium is unstable, so when it is struck by a neutron, it splits into two smaller nonfissionable nuclei, releasing energy and more neutrons. These neutrons strike other nearby uranium atoms, initiating a chain reaction. To ensure that a chain reaction continues, the enrichment process increases the concentration of fissionable ^{235}U, and moderators are used. When the fuel rods are spent, they are replaced. Typically one-third of them are replaced at a time.

Moderators are needed because the rapidly moving neutrons created by the fission are readily caught by the ^{238}U still in the pellets. The fissionable ^{235}U is more likely to be struck by slower moving neutrons, therefore a moderator such as graphite, beryllium, H_2O (light water), or D_2O (heavy water containing deuterium [^{2}H] as the H, rather than hydrogen ^{1}H) is needed. Moderators slow rapidly moving electrons, which makes it more likely they will strike the ^{235}U.

Control rods are inserted in between the fuel rods to slow down a reaction or removed to increase the rate of fission. These control rods absorb neutrons, and therefore cadmium or boron is typically used.

Light Water Reactors

Seventy percent of nuclear reactors in the United States are pressurized-water reactors (PWR), with the rest boiling-water reactors (BWR). Both types are light water reactors, because they use light water (H_2O) as the moderator and coolant. In pressurized-water reactors, the energy from the nuclear reaction heats a primary water circuit that is under pressure and cannot boil. This water is piped to a secondary water circuit that does boil, creating steam to spin a turbine connected to an electrical generator. This secondary water circuit requires cooling to be reused, and the tertiary water circuit is used for this purpose. The tertiary circuit uses surface water from a lake or the ocean or a cooling tower's water to pass around the secondary water circuit, removing the excess heat. The tertiary circuit then is cooled in the tower, or replaced in the surface water, resulting in thermal pollution of the surface water. In boiling-water reactors, the water in the primary circuit boils to spin the turbine to generate electricity. The steam is brought back to liquid state in a condenser cooled by a secondary water circuit.

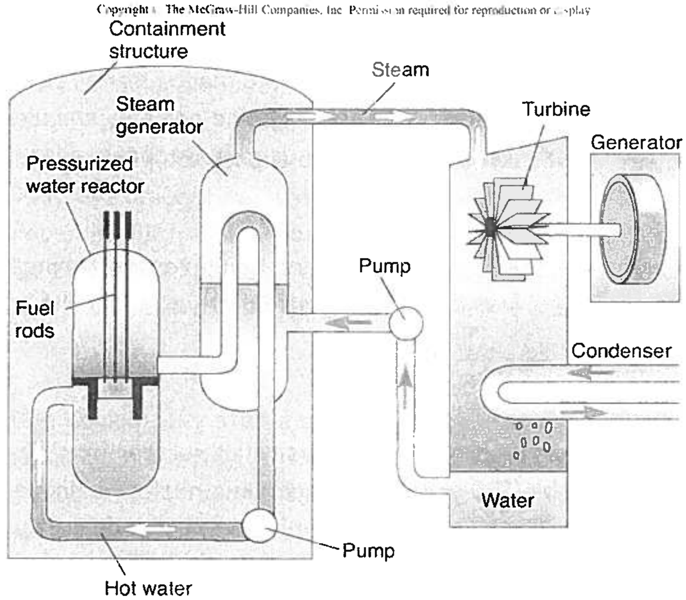


Figure 19.5 Light water reactor

The reactor vessel and the steam generator are contained within a stainless steel reactor vessel and a concrete containment building. The walls of the reactor vessel are up to 30 cm thick, and the reinforced concrete building is at least 1 m thick. The plants are constructed on geologically stable sites, and all plants in the United States have redundant safety measures and controls to prevent accidents. Many are concerned that terrorists will try to fly a plane into a nuclear plant. The air above a nuclear plant is considered a no-fly zone, with military planes at the ready should the airspace be breached. Additionally the plants are built to withstand damage, and the reinforced concrete and other safety features should withstand an attack.

It was discovered at a plant in Ohio that the boron in the control rods reacting with water in the reactor was forming boric acid and eating away at the surface of the stainless reactor vessel. Other plants have examined and rectified this problem as a result of the discovery.

Other Reactor Designs

Canada employs heavy-water reactors, because they use D_2O as their coolant and moderator. These Canadian deuterium (CANDU) reactors do not require uranium enrichment to function. France, Great Britain, and the former USSR use graphite as the moderator and structural material for the core of the reactor. British reactors cool using CO_2 to cool the fuel assemblies and carry heat to generators. These graphite-based designs have always been considered safe, because graphite captures neutrons while dissipating heat. Unfortunately, as seen at Chernobyl, the graphite catches fire if the cooling system fails.

Breeder reactors create fuel rather than consume it. They create fissionable plutonium and thorium as the reactions within take place. Very few breeder reactors are currently in operation in the world due to safety concerns. The coolant is liquid sodium metal, which is highly unstable. The plutonium created could also be used in weapons, as it is removed from the reactor in a weapons grade state.

Numerous other plant designs are being tested throughout the world in an attempt to make nuclear power a safe, less air polluting alternative to fossil fuels.

Nuclear Accidents

Nuclear plants cannot explode as will a nuclear bomb because the uranium is not as highly enriched as in a bomb. The greatest danger in a nuclear plant is the loss of coolant. In this instance, the fuel will overheat, melting not only the fuel rods, but potentially the containment vessel. This is known as a "meltdown." The effect is the release of radioactive material. In 1979 in Three Mile Island, Pennsylvania, a partial meltdown occurred without gas release due to the secure containment building. The fuel rod meltdown was primarily due to worker error in conjunction with equipment problems. The coolant leaked out, resulting in uncontrolled fission. To date, no increased incidence of disease or death has been associated with this accident. The accident prompted stringent operator training, emergency response training, and radiation protection at U.S. nuclear plants. It also caused greater oversight by the Nuclear Regulatory Commission.

In April of 1986, reactor number 4 at the Chernobyl Nuclear Plant in the former USSR (now Ukraine) experienced a loss of coolant, resulting in the released steam blowing the roof off of the building and a severe graphite fire. Thirty people died immediately, and 135,000 had to be evacuated. Since, the thyroid cancer rate in children has increased dramatically. Americans assisted the Soviet government in encasing reactor 4 in concrete. This concrete has begun to fail, and private American companies are working with the Ukrainian government to decommission Chernobyl. Chernobyl lacked an appropriate containment building, which would have prevented the escape of the radioactive gases and fallout for the most part.

Radioactive Wastes

Until the 1970s, countries with nuclear power plants disposed of all wastes in the ocean. The Ukraine has dumped far more wastes than any other nation, primarily in the Arctic Ocean. They dumped nuclear reactors in the Kara Sea, many loaded with radioactive fuel.

Mining waste accounts for a large proportion of the waste generated by nuclear power. The tailings are left adjacent to mines, allowing water to transport the radiation into surface water and groundwater. Low-level radioactive waste, such as tools, building materials, contaminated clothing, cleaning materials, syringes, and other medical wastes, are stored in low-level radioactive sites. There are three such sites in the United States, located in Barnwell, South Carolina, Hanford, Washington, and Clive, Utah. The high-level wastes are highly radioactive. They are components of power plants including spent fuel rods. They are currently stored on the site of the power plants in deep pools of water. The ponds were intended to be temporary, but have now been used for over forty years due to the lack of federal facilities. Some facilities have begun to store wastes in above ground dry casks, but concern regarding the safety of this method of storage persists.

There are only three options when a nuclear plant is no longer useful. The plant can be encased in concrete and guarded for centuries. The plant may be placed under guard, and then slowly dismantled as the radiation threat decreases. The most dangerous option, decommissioning, involves tearing down a reactor while it is still highly radioactive. One great problem that exists is that the materials must be disposed of in a proper facility, which does not yet exist in the United States. One decommissioned plant in California still has no place to ship its waste, although Russia, notorious for dumping highly radioactive wastes into the Arctic Ocean, has offered to take radioactive wastes from other nations.

Highly contaminated materials must be stored in geologically stable areas not near water resources. Many countries use stable rock formations that occur naturally in the earth or in secure above-ground facilities. Several locations have been suggested to store these highly radioactive wastes, none of which are feasible. Outer space or shooting the wastes into the sun, are not practical because there is no way to ensure that the rocket carrying the waste will exit our atmosphere. A rocket loaded with waste that explodes in the atmosphere could contaminate the entire earth. Antarctica is not a viable option, because it is a pristine area and countries have agreed to protect it from human-induced damage. Many countries used to dump nuclear waste into the bottom of the ocean, but the possibility of corrosion of the vessels in the salt water and releasing highly contaminated waste is far too dangerous. It has also been suggested that the wastes be placed into subduction zones, but such wastes would be irretrievable and highly unstable due to the geologic instability.

Yucca Mountain

In 1982 Congress passed the Nuclear Waste Policy Act, which delineated that the federal government was responsible for developing a permanent site for highly contaminated radioactive wastes. In 1987 an amendment to the act identified Yucca Mountain, about 100 miles away from Las Vegas, Nevada, as the location. Yucca Mountain was supposed to be open years ago, but changing presidential administrations have resulted in fluctuating policy regarding opening the facility. It is predicted that the site will be ready to open by 2010. It is located on an active fault line and is near some ancient extinct volcanoes. The water table is far below Yucca Mountain and any accidental leaks are unlikely to result in groundwater contamination. That it is located in a desert eliminates precipitation carrying radioactivity to surface water. Although a large city is fairly near by, the state of Nevada has fairly low population density overall. Yucca Mountain was also used for early nuclear testing in the United States. The people in the state of Nevada are not overjoyed at having the radioactive waste from the entire country transported to their state. Grave concerns exist over the transport of these wastes from throughout the country to Yucca Mountain. An accident in the middle of a large city, for example, could be extraordinarily dangerous. Due to the spate of terrorist attacks, many feel that wastes are much safer in ponds next to nuclear plants than being transported via water, rail, or interstate. Others feel the process of transport will be safe, and that having the waste in a monitored, retrievable repository will be much safer than its current "temporary" storage.

Nuclear Fusion

Nuclear fusion could produce unlimited amounts of power; however, at this time, we do not know how to maintain a controlled nuclear fusion reaction. Humans have devised hydrogen bombs, uncontrolled fusion reactions. These reactions occur when nuclei of two atoms fuse releasing large amounts of energy. In the sun, atoms of deuterium and tritium or two atoms of deuterium fuse at temperatures over 100 million°C and pressures over several billion atmospheres.

Chapter 19 Questions

Use the following for questions 1-4.

a. coal
b. oil
c. natural gas
d. nuclear power
e. methane hydrate

1. recovery of resource is not feasible with current technology and prices
2. combustion releases large amounts of mercury into the atmosphere
3. the most clean burning of the fossil fuels
4. must be distilled prior to use of the resource

5. Which of the following energy conversions is correct?
a. 1 BTU = energy required to heat 1 lb of water 1°F
b. 1 megawatt = 1,000 watts
c. 1 watt = 1 joule per second
d. 1 newton = force needed to accelerate a 1 lb mass 1 ft per second.
e. 1 kilowatt hour = number of megawatts used in an hour

6. The greatest proportion of U.S. electricity is provided by
a. coal power plants. b. nuclear power plants. c. oil burning power plants.
d. refuse derived power plants. e. hydroelectric power.

7. Which of the following nations has the greatest supply of natural gas?
a. United States b. Canada c. Saudi Arabia d. Russia e. China

8. Which of the following is associated with mining uranium?
a. mesothelioma
b. pneumoconiosis
c. lung cancer
d. radiation sickness
e. gastrointestinal disease

9. Which of the following pollutants is not released by coal combustion?
a. sulfur dioxide
b. carbon dioxide
c. ozone
d. mercury
e. particulates

10. Coal mining has all of the following environmental effects except
a. increased erosion due to topsoil removal.
b. subsidence due to collapse of subsurface mines.
c. acid mine drainage in abandoned mines.
d. transport of coal results in damage to aquatic systems if tanker is damaged.
e. increased habitat disruption due to deforestation.

11. Which of the following structures in a pressurized water nuclear power plant is correctly paired with its function?
a. primary water circuit cools the fission reaction
b. secondary water circuit is heated and spins the turbine to generate electricity
c. water in the cooling tower is used to cool the primary water circuit
d. moderator absorbs neutrons to stop the fission reaction
e. containment vessel encompasses the electrical generator to prevent explosions

12. Which of the following is not an argument against drilling in the Arctic National Wildlife Refuge?
a. growing season is very short making it difficult for the ecosystem to recover
b. permafrost makes soil formation very difficult, resulting in a long succession time
c. area is a calving ground for caribou
d. high levels of biodiversity will allow the ecosystem to recover quickly
e. cold temperatures decrease the rate of nutrient cycling

13. A typical oil well can extract what percentage of the oil in the reserve by using primary recovery and secondary recovery?
a. 10
b. 30
c. 50
d. 80
e. 100

14. All of the following methods will reduce NO_x emissions from gasoline combustion except
a. catalytic converters in automobiles.
b. controlling the combustion temperatures.
c. switch fuel to ethanol or ethanol mixed fuel.
d. switch to a hybrid vehicle.
e. decreasing the release of ozone from auto emissions.

15. The fissionable component of nuclear fuel in a conventional nuclear power plant is
a. Uranium - 238.
b. Uranium - 235.
c. Uranium - 234.
d. Plutonium - 239.
e. Radon - 222.