

Some Introductory Comments

1

In the course of our study of thermodynamics, a number of the examples and problems presented refer to processes that occur in equipment such as a steam power plant, a fuel cell, a vapor-compression refrigerator, a thermoelectric cooler, a turbine or rocket engine, and an air separation plant. In this introductory chapter, a brief description of this equipment is given. There are at least two reasons for including such a chapter. First, many students have had limited contact with such equipment, and the solution of problems will be more meaningful when they have some familiarity with the actual processes and the equipment. Second, this chapter will provide an introduction to thermodynamics, including the use of certain terms (which will be more formally defined in later chapters), some of the problems to which thermodynamics can be applied, and some of the things that have been accomplished, at least in part, from the application of thermodynamics.

Thermodynamics is relevant to many processes other than those cited in this chapter. It is basic to the study of materials, chemical reactions, and plasmas. The student should bear in mind that this chapter is only a brief and necessarily incomplete introduction to the subject of thermodynamics.

1.1 THE SIMPLE STEAM POWER PLANT

A schematic diagram of a recently installed steam power plant is shown in Fig. 1.1. High-pressure superheated steam leaves the steam drum at the top of the boiler, also referred to as a *steam generator*, and enters the turbine. The steam expands in the turbine and in doing so does work, which enables the turbine to drive the electric generator. The steam, now at low pressure, exits the turbine and enters the heat exchanger, where heat is transferred from the steam (causing it to condense) to the cooling water. Since large quantities of cooling water are required, power plants have traditionally been located near rivers or lakes, leading to thermal pollution of those water supplies. More recently, condenser cooling water has been recycled by evaporating a fraction of the water in large cooling towers, thereby cooling the remainder of the water that remains as a liquid. In the power plant shown in Fig. 1.1, the plant is designed to recycle the condenser cooling water by using the heated water for district space heating.

The pressure of the condensate leaving the condenser is increased in the pump, enabling it to return to the steam generator for reuse. In many cases, an economizer or water preheater is used in the steam cycle, and in many power plants, the air that is used for combustion of the fuel may be preheated by the exhaust combustion-product gases. These exhaust gases must also be purified before being discharged to the atmosphere, so there are many complications to the simple cycle.

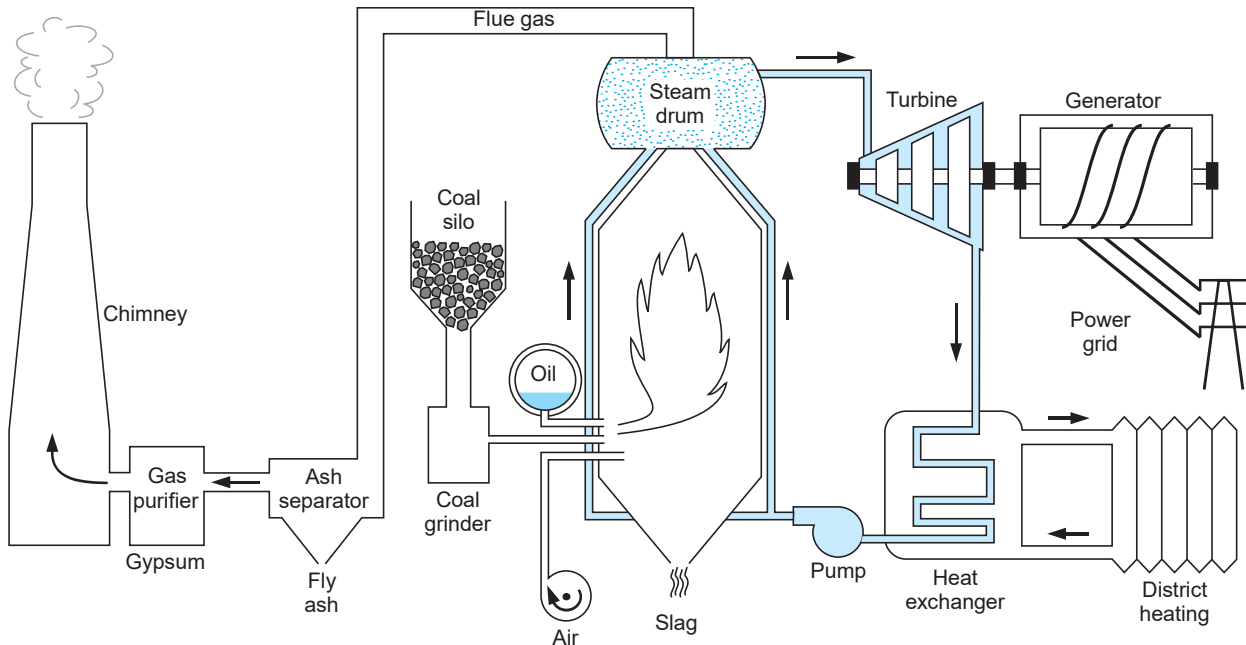


FIGURE 1.1 Schematic diagram of a steam power plant.

Figure 1.2 is a photograph of the power plant depicted in Fig. 1.1. The tall building shown at the left is the boiler house, next to which are buildings housing the turbine and other components. Also noted are the tall chimney, or stack, and the coal supply ship at the dock. This particular power plant is located in Denmark, and at the time of its installation it set a world record for efficiency, converting 45% of the 850 MW of coal combustion energy into electricity. Another 47% is reusable for district space heating, an amount that in older plants was simply released to the environment, providing no benefit.

The steam power plant described utilizes coal as the combustion fuel. Other plants use natural gas, fuel oil, or biomass as the fuel. A number of power plants around the world operate on the heat released from nuclear reactions instead of fuel combustion. Figure 1.3 is a schematic diagram of a nuclear marine propulsion power plant. A secondary fluid circulates through the reactor, picking up heat generated by the nuclear reaction inside. This heat is then transferred to the water in the steam generator. The steam cycle processes are the same as in the previous example, but in this application the condenser cooling water is seawater, which is then returned at higher temperature to the sea.

1.2 FUEL CELLS

When a conventional power plant is viewed as a whole, as shown in Fig. 1.4, fuel and air enter the power plant and products of combustion leave the unit. In addition, heat is transferred to the cooling water, and work is done in the form of electrical energy leaving the power plant. The overall objective of a power plant is to convert the availability (to do work) of the fuel into work (in the form of electrical energy) in the most efficient manner, taking into consideration cost, space, safety, and environmental concerns.



FIGURE 1.2 The Esbjerg, Denmark, power station. (Courtesy Vestkraft 1996.)

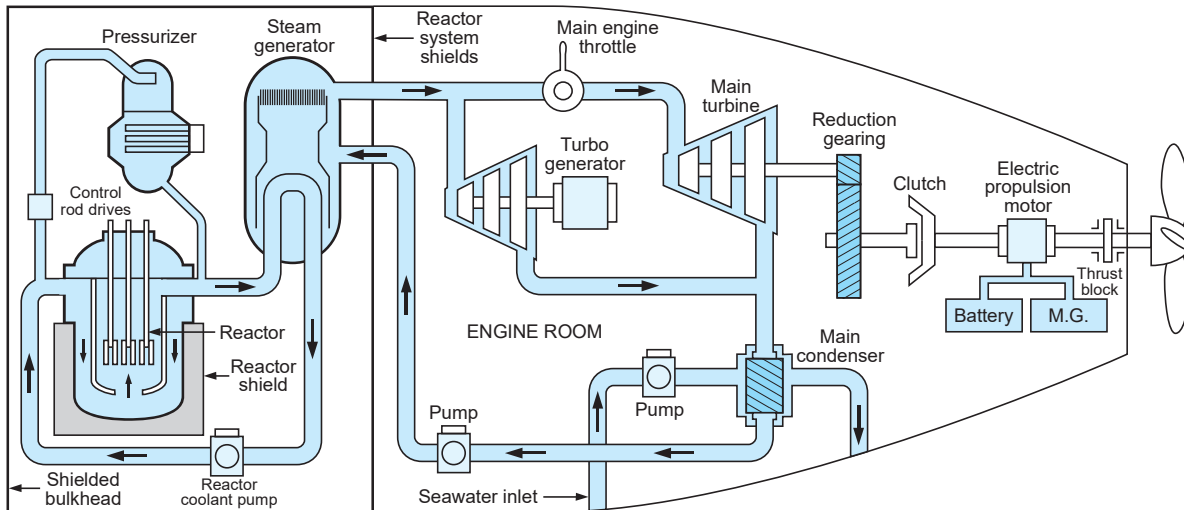


FIGURE 1.3 Schematic diagram of a shipboard nuclear propulsion system. (Courtesy Babcock & Wilcox Co.)

We might well ask whether all the equipment in the power plant, such as the steam generator, the turbine, the condenser, and the pump, is necessary. Is it possible to produce electrical energy from the fuel in a more direct manner?

The fuel cell accomplishes this objective. Figure 1.5 shows a schematic arrangement of a fuel cell of the ion-exchange membrane type. In this fuel cell, hydrogen and oxygen react to form water. Hydrogen gas enters at the anode side and is ionized at the surface of the ion-exchange membrane, as indicated in Fig. 1.5. The electrons flow through the external circuit to the cathode while the positive hydrogen ions migrate through the membrane to the cathode, where both react with oxygen to form water.

There is a potential difference between the anode and cathode, and thus there is a flow of electricity through a potential difference; this, in thermodynamic terms, is called *work*. There may also be a transfer of heat between the fuel cell and the surroundings.

At the present time, the fuel used in fuel cells is usually either hydrogen or a mixture of gaseous hydrocarbons and hydrogen. The oxidizer is usually oxygen. However, current development is directed toward the production of fuel cells that use hydrogen or hydrocarbon fuels and air. Although the conventional (or nuclear) steam power plant is still used in

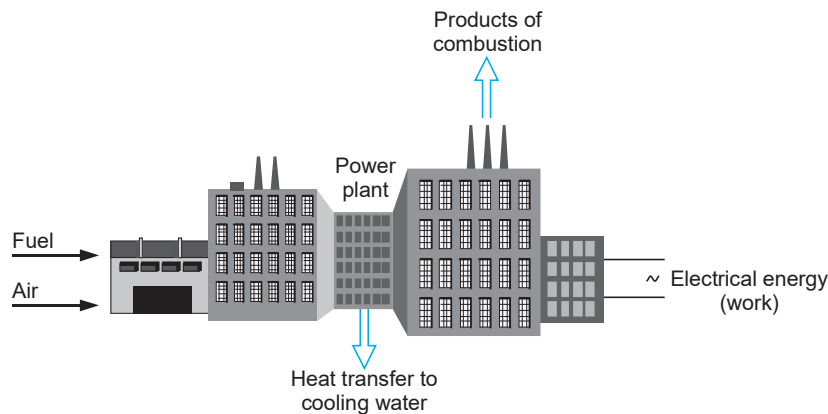


FIGURE 1.4 Schematic diagram of a power plant.