CHAPTER 5

STEAM TURBINES

In previous chapters we discussed the basic steam cycle and various types of naval boilers. At this point, we will bring together all you have learned by discussing the components inside the turbine casing.

In the following paragraphs we will discuss turbine theory, types and classifications of turbines, and turbine construction.

Upon completion of this chapter you will understand how stored energy (heat) in steam is transformed to mechanical energy (work).

TURBINE THEORY

The first documented use of steam power is credited to a Greek mathematician, Hero of Alexandria, almost 2000 years ago. Hero built the first steam-powered engine. His turbine design was the forerunner of the jet engine and demonstrated that steam power could be used to operate other machinery. Hero's turbine (aeolipile) (fig. 5-1) consists of a hollow sphere and four canted nozzles. The sphere rotates freely on two feed tubes that carry steam from the boiler. Steam generated in the boiler passes through the feed tubes, into the sphere, and out through the nozzles. As the steam leaves the nozzles, the sphere rotates rapidly.

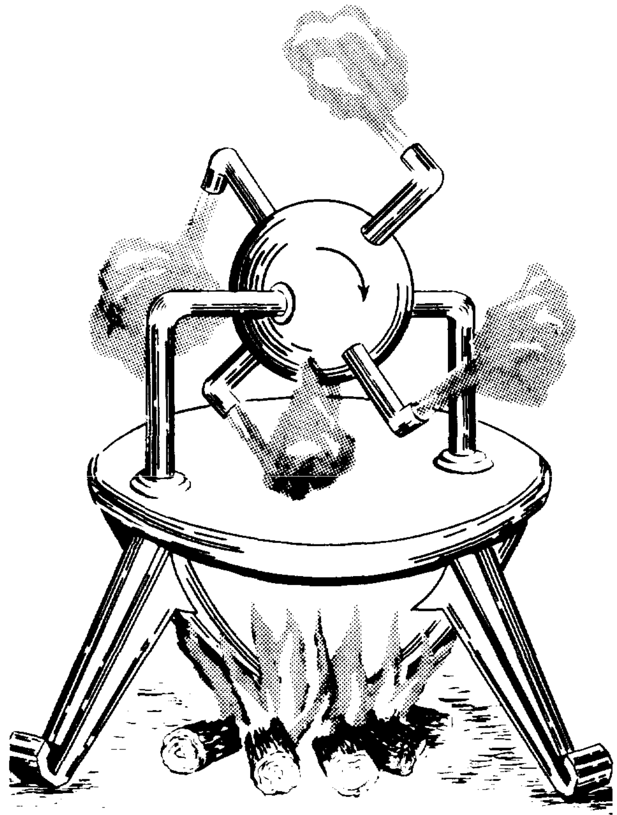

Figure 5-1.—Hero's turbine (aeolipile).

Down through the ages, the application of the turbine principle has been used in many different types of machines. The water wheel that was used to operate the flour mills in colonial times and the common windmill used to pump water are examples of the turbine principle. In these examples, the power comes from the effect of the wind or a stream of water acting on a set of blades. In a steam turbine, steam serves the same purpose as the wind or the flowing water.

Two methods are used in turbine design and construction to get the desired results from a turbine. These are the impulse principle and the reaction principle. Both methods convert the thermal energy stored in the steam into useful work, but they differ somewhat in the way they do it. In the following paragraphs we will discuss the two basic turbine principles, the impulse and reaction.

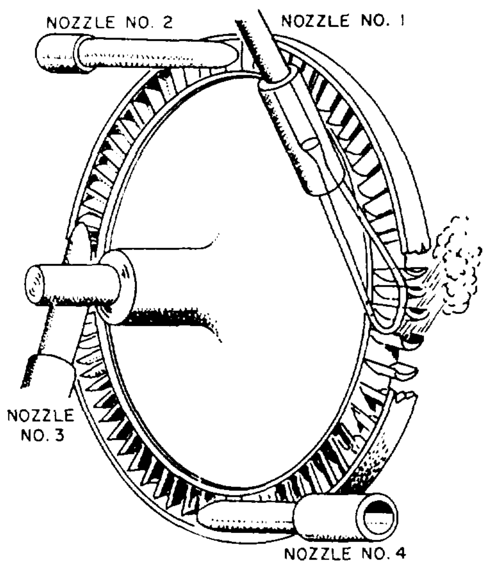

Figure 5-2.—Impulse turbine.

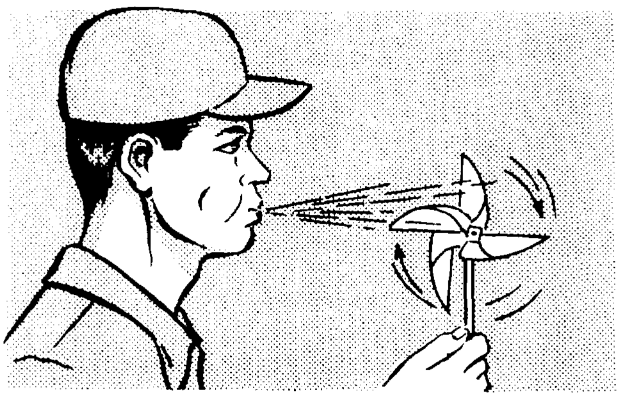

Figure 5-3.—Simple impulse turbine principle.

IMPULSE PRINCIPLE

The impulse turbine (fig. 5-2) consists basically of a rotor mounted on a shaft that is free to rotate in a set of bearings. The outer rim of the rotor carries a set of curved blades, and the whole assembly is enclosed in an airtight case. Nozzles direct steam against the blades and turn the rotor.

The energy to rotate an impulse turbine is derived from the kinetic energy of the steam flowing through the nozzles. The term *impulse* means that the force that turns the turbine comes from the impact of the steam on the blades. The toy pinwheel (fig. 5-3) can be used to study some of the basic principles of turbines. When you blow on the rim of the wheel, it spins rapidly. The harder you blow, the faster it turns. The steam turbine operates on the same principle, except it uses the kinetic energy from the steam as it leaves a steam nozzle rather than air.

Steam nozzles (hereafter referred to as nozzles or stationary blades) are located at the turbine inlet. As the steam passes through a nozzle, potential energy is converted to kinetic energy. This steam is directed toward the turbine blades and turns the rotor. The velocity of the steam is reduced in passing over the blades. Some of its kinetic energy has been transferred to the blades to turn the rotor.

Impulse turbines may be used to drive forced draft blowers, pumps, and main propulsion turbines.

Figure 5-2 shows an impulse turbine as steam passes through the nozzles.

REACTION PRINCIPLE

The ancient turbine built by Hero operated on the reaction principle. Hero's turbine was invented long before Newton's time, but it was a working model of Newton's third law of motion, which states: *"For every action there must bean equal and opposite reaction."*

If you set an electric fan on a roller skate, the roller skate will take off across the room (fig. 5-4). The fan pushes the air forward and sets up a breeze (velocity). The air is also pushing backward on the fan with an equal force, but in an opposite direction.

If you try to push a car, you will push back with your feet as hard as you would push forward with your hands. Try it sometime when you are standing on an icy road. You will not be able to move the car unless you can dig in with your feet to exert the backward force. With some thought on your part, you could come up with examples to prove to yourself that Newton's third law of motion holds true under all circumstances.

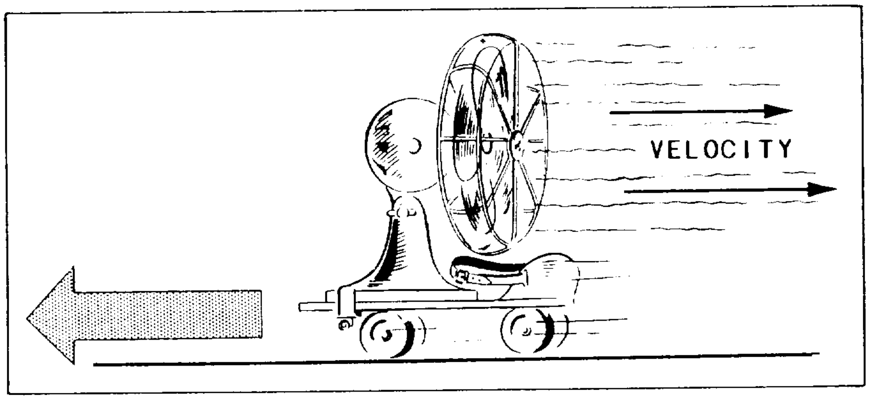

Figure 5-4.—Demonstration of the velocity of the reaction principle.

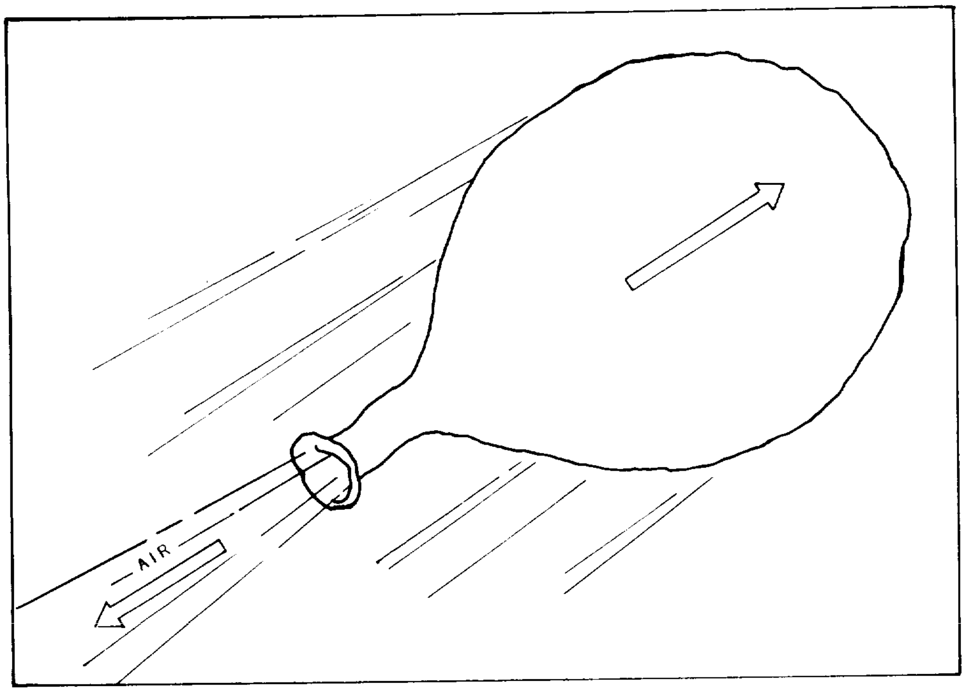

Figure 5-5.—Demonstration of the kickback of the reaction principle.

The reaction turbine uses the reaction of a steam jet to drive the rotor. You learned that an impulse turbine increases the velocity of steam and transforms that potential energy under pressure into kinetic energy in a steam jet through nozzles. A forward force is applied to the steam to increase its velocity as it passes through the nozzle. From Newton's third law of motion, you see that the steam jet exerts a force on the nozzle and an equal reactive force on the turbine blades in the opposite direction. THIS IS THE FORCE THAT DRIVES THE TURBINE.

In the reaction turbine, stationary blades attached to the turbine casing act as nozzles and direct the steam to the moving blades. The moving blades mounted on the rotor act as nozzles. Most reaction turbines have several alternating rows of stationary and moving nozzle blades.

You can use a balloon to demonstrate the kickback or reaction force generated by the nozzle blades (fig. 5-5). Blow up the balloon and release it. The air will rush out through the opening and the balloon will shoot off in the opposite direction.

When the balloon is filled with air, you have potential energy stored in the increased air pressure inside. When you let the air escape, it passes through the small opening. This represents a transformation from potential energy to kinetic energy. The force applied to the air to speed up the balloon is acted upon by a reaction in the opposite direction. This reactive force propels the balloon forward through the air.

You may think that the force that makes the balloon move forward comes from the jet of air blowing against the air in the room, not so. It is the reaction of the force of the air as it passes through the opening that causes the balloon to move forward.

The reaction turbine has all the advantages of the impulse-type turbine, plus a slower operating speed and greater efficiency. The alternating rows of fixed and moving blades transfers the heat energy of the steam to kinetic energy, then to mechanical energy.

We have discussed the simple impulse and reaction turbines. Practical applications require various power outputs. Turbines are constructed with one or more simple turbines made as one. This is done in much the same way that the varying cylinder size of a car engine varies power. Figures 5-6 and 5-7 show typical naval turbines.

TURBINE CLASSIFICATION

So far we have classified turbines into two general groups: IMPULSE TURBINES and REACTION TURBINES, depending on the method used to cause the steam to do useful

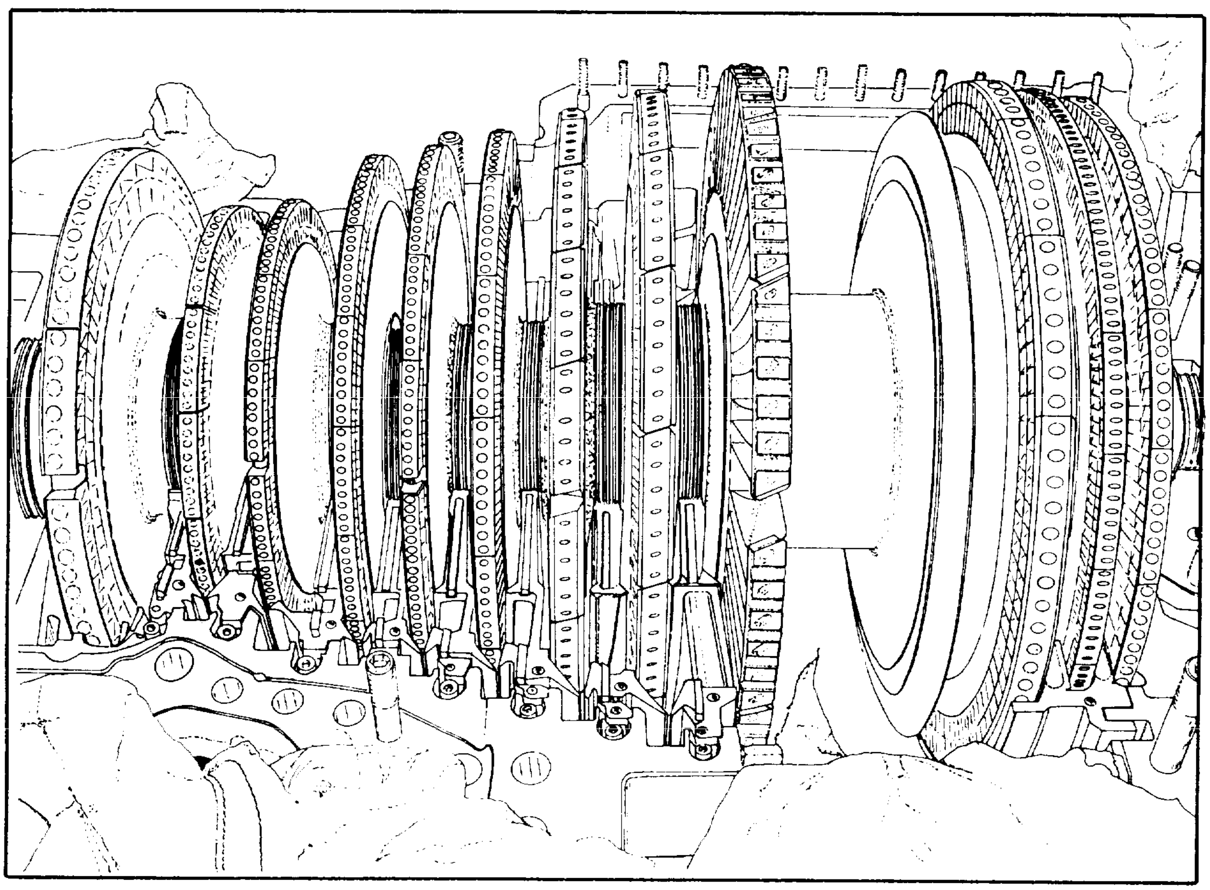

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Figure 5-6.—Impulse main propulsion turbine.

work. Turbines may be further classified according to the following:

- Type and arrangement of staging
- Direction of steam flow
- Repetition of steam flow
- Division of steam flow

A turbine may also be classified by whether it is a condensing unit (exhaust to a condenser at a pressure below atmospheric pressure) or a non-condensing unit (exhausts to another system such as the auxiliary exhaust steam system at a pressure above atmospheric pressure).

CONSTRUCTION OF TURBINES

Other than the operating and controlling equipment, similarity exists in both the impulse and reaction turbines. These include foundations, casings, nozzles, rotors, bearings, and shaft glands.

Foundations

Turbine foundations are built up from a structural foundation in the hull to provide a rigid supporting base. All turbines are subjected to varying degrees of temperature—from that existing during a secured condition to that existing during full-power operation. Therefore, means are provided to allow for expansion and contraction.

At the forward end of the turbine, there are various ways to give freedom of movement. Elongated bolt holes or grooved sliding seats are used so that the forward end of the turbine can move fore and aft as either expansion or contraction takes place. The forward end of the turbine may also be mounted with a flexible I-beam that will flex either fore or aft.

Casings

The materials used to construct turbines will vary somewhat depending on the steam and power conditions for which the turbine is designed. Turbine casings are made of cast carbon steel for nonsuperheated steam applications. Superheated

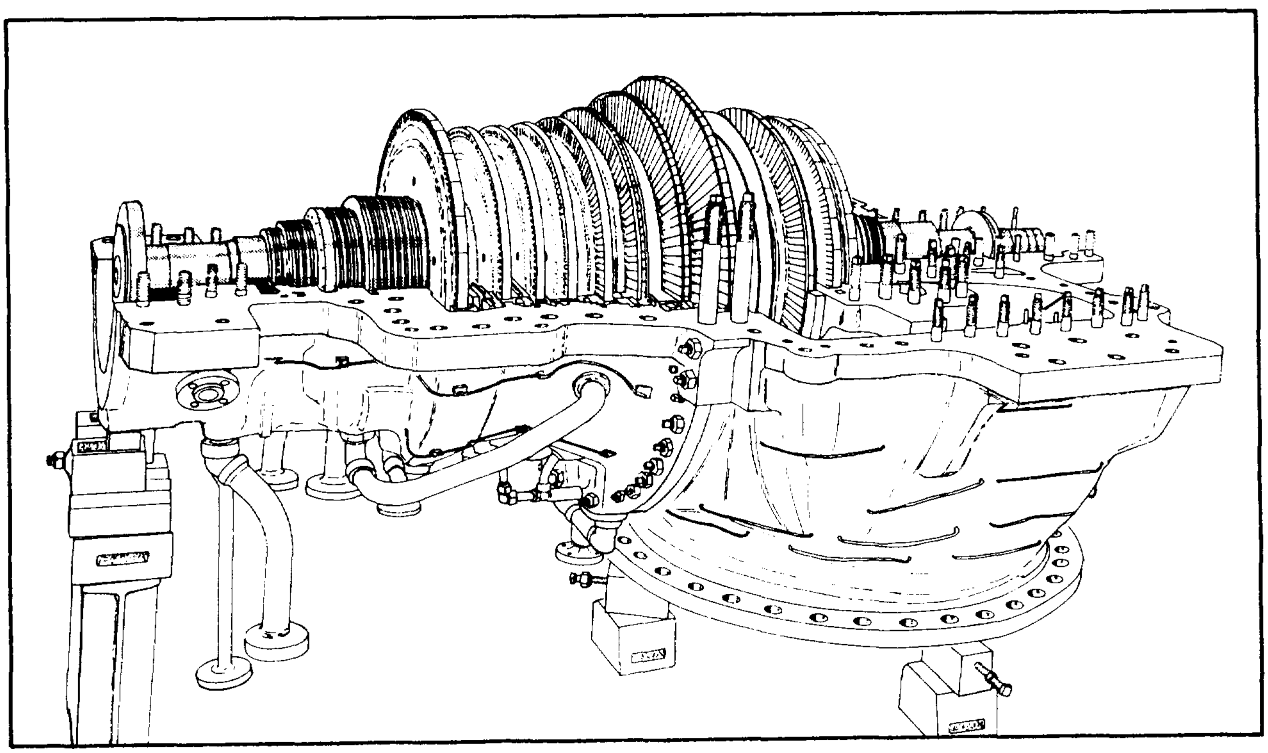

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Figure 5-7.—Turbine assembly in a machine shop.

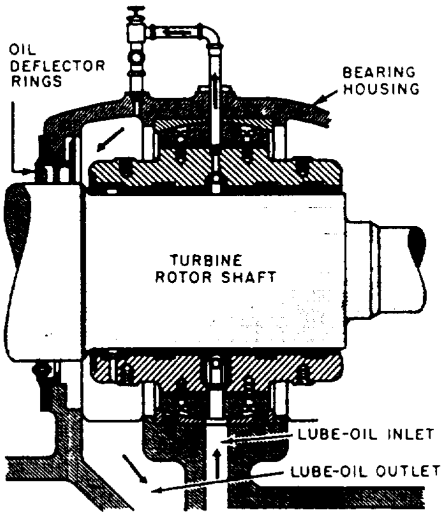

Figure 5-8.—Typical sliding surface bearing.

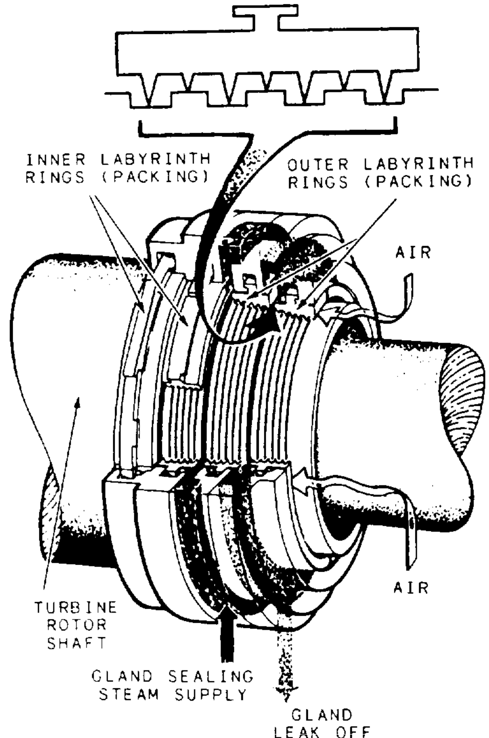

Figure 5-9.—Labyrinth packing gland.

applications use casings made of carbon molybdenum steel. For turbine casings used on submarines, a percentage of chrome stainless steel is used, which is more resistant to steam erosion than carbon steel. Each casing has a steam chest to receive the incoming high-pressure steam. This steam chest delivers the steam to the first set of nozzles or blades.

Nozzles

The primary function of the nozzles is to convert the thermal energy of steam into kinetic energy. The secondary function of the nozzles is to direct the steam against the blades.

Rotors

Rotors (forged wheels and shaft) are manufactured from steel alloys. The primary purpose of a turbine rotor is to carry the moving blades that convert the steam's kinetic energy to rotating mechanical energy.

Bearings

The rotor of every turbine must be positioned radially and axially by bearings. Radial bearings carry and support the weight of the rotor and maintain the correct radial clearance between the rotor and casing.

Axial (thrust) bearings limit the fore-and-aft travel of the rotor. Thrust bearings take care of any axial thrust, which may develop on a turbine rotor and hold the turbine rotor within definite axial positions.

All main turbines and most auxiliary units have a bearing at each end of the rotor. Bearings are generally classified as sliding surface (sleeve and thrust) or as rolling contact (antifriction ball or roller bearings). Figure 5-8 shows a typical sliding surface bearing.

Shaft Packing Glands

Shaft packing glands prevent the leaking of steam out of or air into the turbine casing where the turbine rotor shaft extends through the turbine casing. Labyrinth and carbon rings are two types of packing. They are used either separately or in combination.

Labyrinth packing (fig. 5-9) consists of rows of metallic strips or fins. The strips fasten to the gland liner so there is a small space between the strips and the shaft. As the steam from the turbine casing leaks through the small space between the packing strips and the shaft, steam pressure gradually reduces.

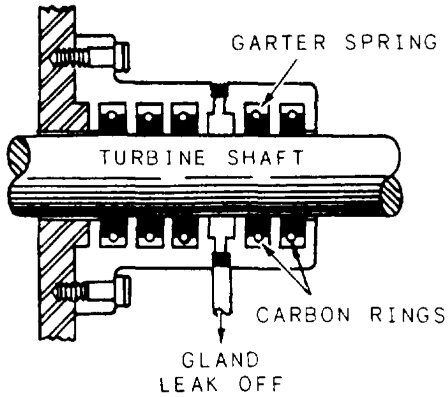

Figure 5-10.—Carbon packing gland.

Carbon packing rings (fig. 5-10) restrict the passage of steam along the shaft in much the same manner as labyrinth packing strips. Carbon packing rings mount around the shaft and are held in place by springs. Three or four carbon rings are usually used in each gland. Each ring fits into a separate compartment of the gland housing and consists of two, three, or four segments that are butt-jointed to each other. A garter spring is used to hold these segments together. The use of keepers (lugs or stop pins) prevent the rotation of the carbon rings when the shaft rotates. The outer carbon ring compartment connects to a drain line.

SUMMARY

In this chapter, you have learned about the components inside a steam turbine casing. You have also learned the basics of how the steam turbine works. For more information on steam turbines, refer to *Machinist's Mate 3 & 2*, NAVEDTRA 10524-F1, chapter 2.