CHAPTER 8

SHIP PROPULSION

The primary function of any marine engineering plant is to convert the chemical energy of a fuel into useful work and to use that work in the propulsion of the ship. A propulsion unit consists of the machinery, equipment, and controls that are mechanically, electrically, or hydraulically connected to a propulsion shaft. After reading this chapter, you will have a basic understanding of how a ship's propulsion unit works. You will learn about the three main types of propulsion units used in the Navy. You will also learn how power is transmitted from the propulsion unit to the ship's propeller through the use of gears, shafts, and clutches.

PRINCIPLES OF SHIP PROPULSION

A ship moves through the water by propelling devices, such as paddle wheels or propellers. These devices impart velocity to a column of water and move it in the direction opposite to the direction in which it is desired to move the ship. A force, called reactive force because it reacts to the force of the column of water, is developed against the velocity-imparting device. This force, also called thrust, is transmitted to the ship and causes the ship to move through the water.

The screw-type propeller is the propulsion device used in almost all naval ships. The thrust developed on the propeller is transmitted to the ship's structure by the main shaft through the thrust bearing (fig. 8-1).

The main shaft extends from the main reduction gear shaft of the reduction gear to the propeller. It is supported and held in alignment by the spring bearings, the stern tube bearings, and the strut bearing. The thrust, acting on the propulsion shaft as a result of the pushing effect of the propeller, is transmitted to the ship's structure by the main thrust bearing. In most ships, the main thrust bearing is located at the forward end of the main shaft within the main reduction gear casing. In some very large ships, however, the main shaft thrust bearing is located farther aft in a machinery space or a shaft alley.

The main reduction gear connects the prime mover (engine) to the shaft. The function of the main reduction gear is to reduce the high rotational speeds of the engine and allow the propeller to operate at lower rotation speeds. In this way, both the engine and the propeller shaft rotate at their most efficient speeds.

TYPICAL PROPULSION UNITS

Various types and designs of prime movers are currently in use on naval ships. The prime movers

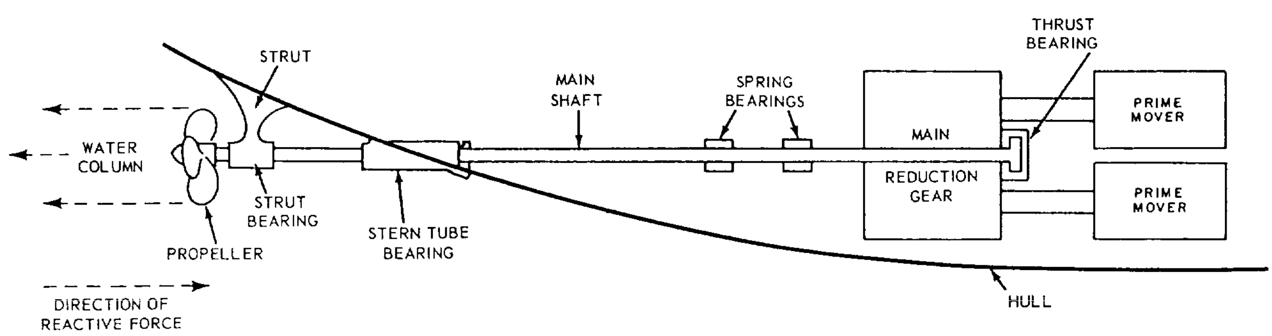

Figure 8-1.—General principle of geared ship propulsion.

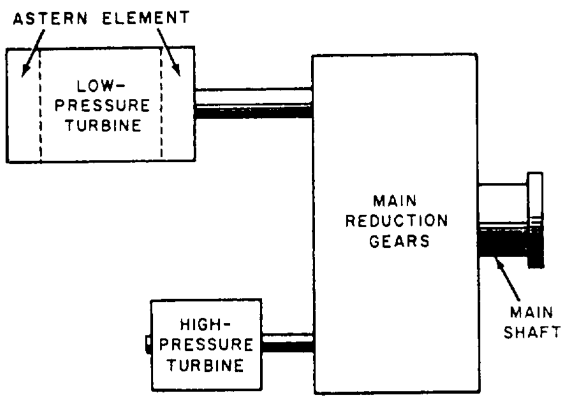

Figure 8-2.—Geared steam turbine drive.

may be either a geared turbine (steam or gas) or diesel engine.

STEAM TURBINE GEAR DRIVE

In the steam turbine gear drive, the individual propulsion units consist of the main turbines and the main reduction gear (fig. 8-2). These types of turbine drives are used on most types of naval ships. They provide a high power-to-weight ratio and are ruggedly constructed. When repairs are needed, they can usually be completed without removing the turbines from the ship. Steam turbine gear drives consist of one high-pressure turbine and one low-pressure turbine. They provide ahead propulsion. Smaller and simpler turbine elements inside the low-pressure turbine provide astern propulsion (fig. 8-2).

DIESEL GEAR DRIVE

In the diesel gear drive engine, the parts that make up the unit consist of the diesel engine, the reduction gear, and either the controllable-pitch propeller unit or the dc motor/generator drive unit. The diesel gear drive engine is used on auxiliary ships, minesweepers, fleet tugs, patrol crafts, and numerous other yard craft and small boats. Standardization of fuels, cheaper fuel, and reduction in fire hazards are the chief factors why the Navy favors diesel engines.

Some diesel engines are directly reversible. The propeller shaft is connected directly to the diesel engine so that the speed of the propeller shaft is controlled by the speed of the diesel engine. When it becomes necessary to reverse the direction of rotation of the propeller shaft, the diesel engine is stopped, the cam shaft of the engine is shifted for reverse rotation, and then the engine is

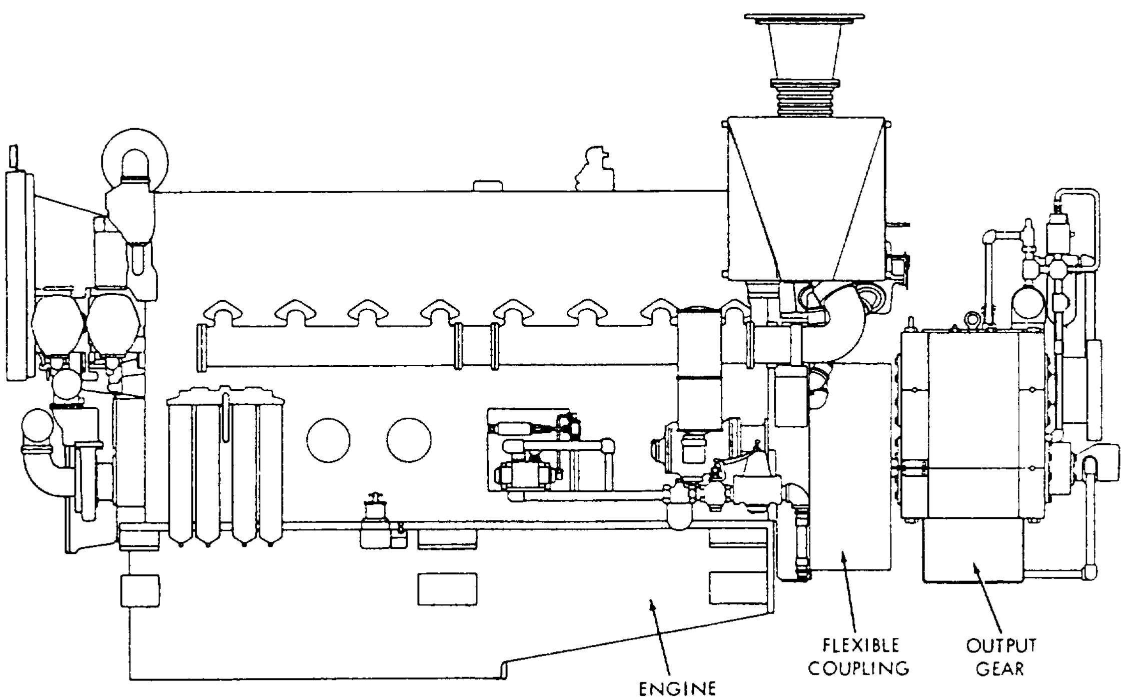

Figure 8-3.—Diesel engine and reduction gear.

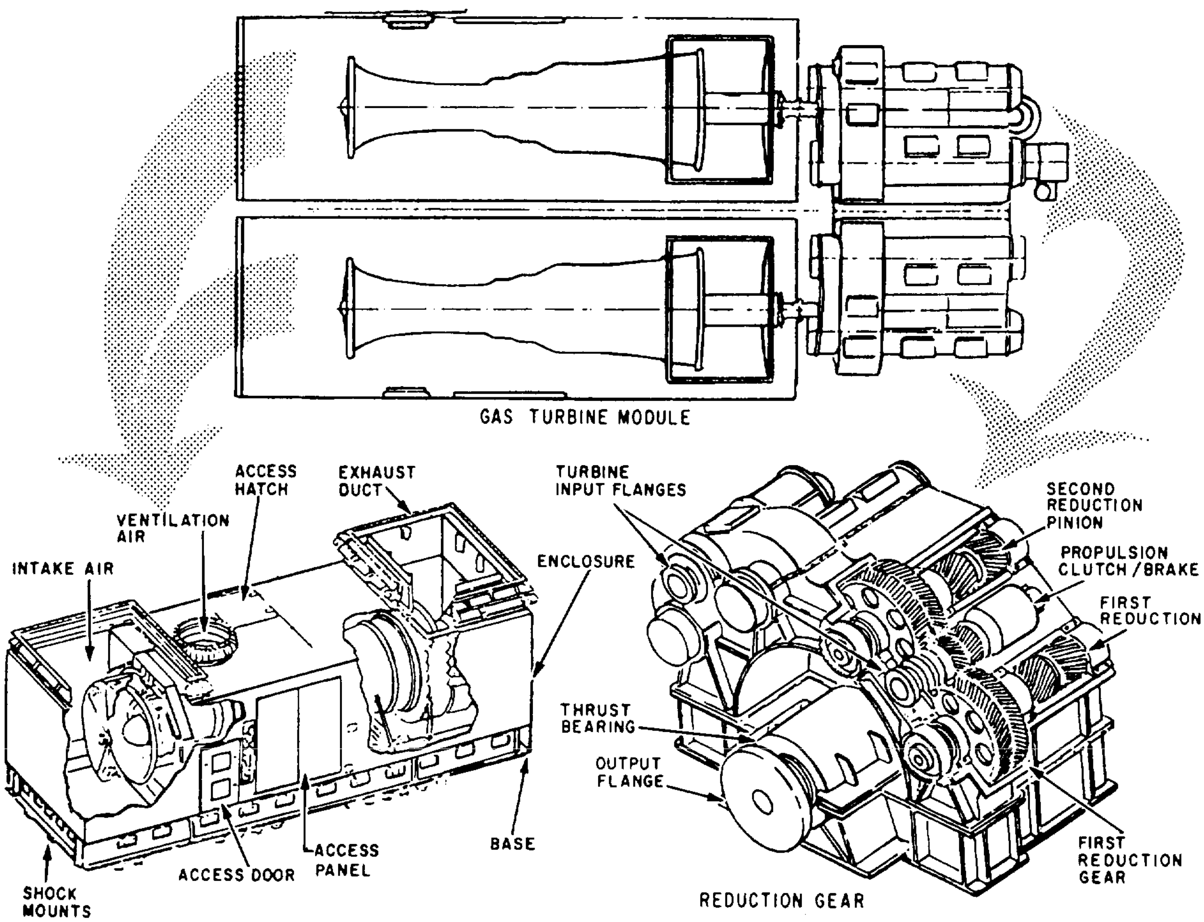

Figure 8-4.—Typical gas turbine reduction gear module arrangement.

restarted. This allows the engine to operate in the opposite direction. This operation takes time and presents a difficult situation if sudden changes in direction are required.

To eliminate this stopping-starting situation and to make a smoother transition from forward to reverse in less time, reverse-reduction gears, clutches, and controllable-pitch propellers are used. Figure 8-3 shows a typical diesel engine.

GAS TURBINE DRIVE

Gas turbines are used on patrol craft, destroyers, cruisers, frigates, amphibious craft, and auxiliary oilers. Compared to other propulsion units, they offer a high power-to-weight ratio.

Gas turbine gear drive units consist of gas turbines, reduction gears, and controllable-pitch propeller units. Figure 8-4 shows a typical gas turbine reduction gear arrangement.

CONVERTING POWER TO DRIVE

The basic characteristics of a propulsion unit usually make it necessary for the drive mechanism to change both the speed and the direction of shaft rotation. The engine in many installations includes a device that permits a speed reduction from the engine to the propeller shaft so that both the engine and the propeller may operate efficiently. This device is a combination of gears and is called a reduction gear.

REDUCTION GEARS

Engines must operate at relatively high speeds for maximum efficiency. Propellers must operate at lower speeds for maximum efficiency. Therefore, reduction gears are used to allow both the engine and the propeller to operate within their most efficient revolutions per minute (rpm)

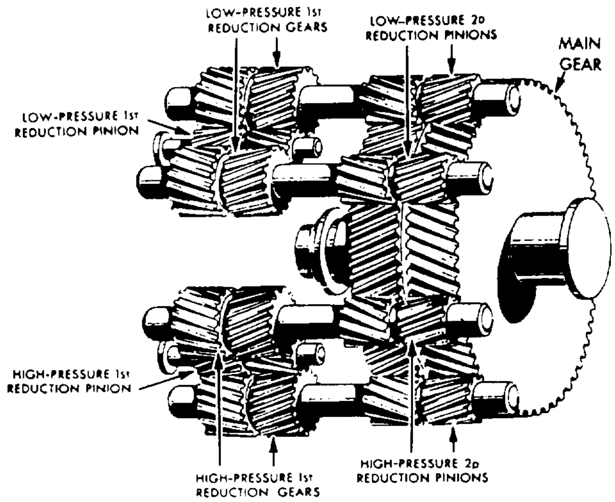

Figure 8-5.—Locked-train-type gearing.

ranges. A typical steam turbine reduction gear is shown in figure 8-5.

The use of reduction gears is by no means limited to ship propulsion. Other machinery, such as ship's service generators and various pumps, also have reduction gears. In these units, as well as in shipboard propulsion units, engine operating efficiency requires a higher rpm range than that suitable for the driven unit.

Reduction gears are classified by the number of steps used to bring about the speed reduction and the arrangement of the gearing. A gear mechanism consisting of a pair of gears or a small gear (pinion) driven by the engine shaft, which directly drives a large (bull) gear on the propeller shaft, is called a single-reduction gear. In this type of arrangement, the ratio of speed reduction is proportional to the diameter of the pinion and the gear. For example, in a 2-to-1 single-reduction gear, the diameter of the driven gear is twice that of the driving pinion. In a 10-to-1 single-reduction gear, the diameter of the driven gear is 10 times that of the driving pinion.

Steam propulsion-type ships built since 1935 have double-reduction propulsion gears. In this type of gear, a high-speed pinion, connected to the turbine shaft by a flexible coupling, drives an intermediate (first reduction) gear. This gear is connected by a shaft to the low-speed pinion that, in turn, drives the bull gear (second reduction) mounted on the propeller shaft. A 20-to-1 speed reduction might be accomplished by having a ratio of 2-to-1 between the high-speed pinion and the first-reduction gear, and a ratio of 10-to-1 between the low-speed pinion and the second-reduction gear on the propeller shaft.

For a typical example of a double-reduction application, let us consider the main-reduction gear shown in figure 8-6. The high-pressure and low-pressure turbines are connected to the propeller shaft through a locked-train type of double-reduction gear.

NOTE: This type of reduction gear is used aboard many naval combatant ships.

First-reduction pinions are connected by flexible couplings to the turbines. Each of the first-reduction pinions drives two first-reduction gears. A second-reduction (slow speed) pinion is attached to each of the first-reduction gears by a quill shaft and flexible couplings. These four pinions drive the second-reduction (bull) gear that is attached to the propeller shaft.

CLUTCHES AND REVERSE GEARS

Clutches are normally used on direct-drive propulsion engines to provide a means of disconnecting the engine from the propeller shaft. In small engines, clutches are usually combined with reverse gears and are used for maneuvering the ship. In large engines, special types of clutches are used to obtain special coupling or control characteristics and to prevent torsional (twisting) vibration.

Diesel-propelling equipment on a boat or a ship must be capable of providing backing-down power as well as forward power. There are a few ships and boats in which backing down is accomplished by reversing the pitch of the propeller. Most ships, however, back down by reversing the direction of rotation of the propeller shaft. In mechanical drives, reversing the direction of rotation of the propeller shaft may be accomplished in one of two ways. You can reverse the direction of engine rotation or use the reverse gears.

Reverse gears are used on marine engines to reverse the rotation of the propeller shaft during maneuvering without reversing the rotation of the engine. They are normally used on smaller engines. If a high-output engine has a reverse gear, the gear is used for low-speed operation only and does not have full-load and full-speed capacity. For maneuvering ships with large direct-propulsion engines, the engines are reversed.

The drive mechanism of a ship or a boat is required to do more than reduce speed and reverse

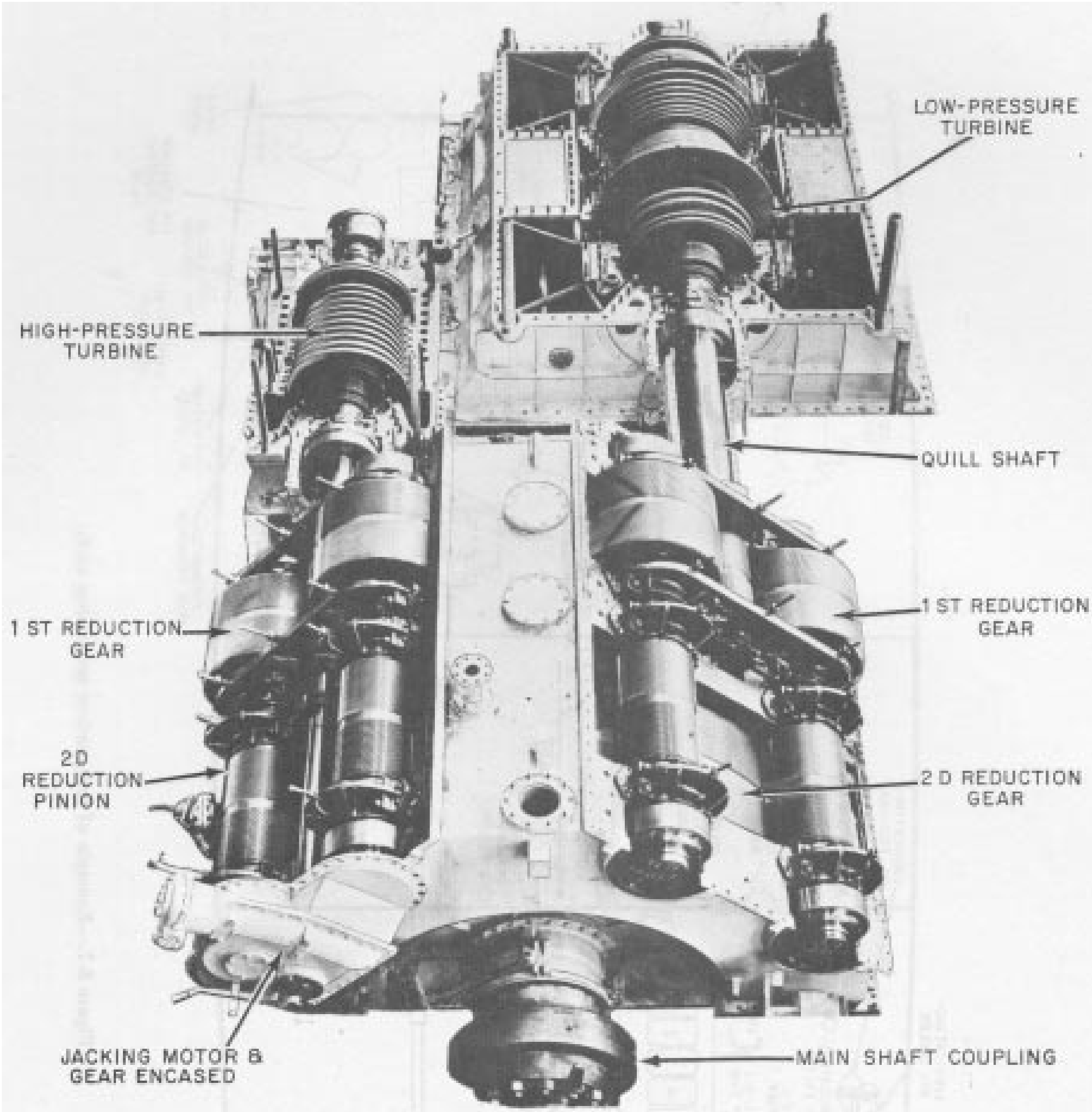

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Figure 8-6.—Typical steam ,turbine and reduction gear.

the direction of shaft rotation. It is frequently necessary to operate an engine without having power transmitted to the propeller. For this reason, the drive mechanism of a ship or boat must include a means of disconnecting the engine from the propeller shaft. The devices used for this purpose are called clutches.

The arrangement of the components depends on the type and size of the installation. In some small installations, the clutch, the reverse gear and the reduction gear may be combined in a single unit. In other installations, the clutch and the reverse gear may be in one housing and the reduction gear in a separate housing attached to the reverse-gear housing.

In large engine installations, the clutch and the reverse gear are sometimes combined and are sometimes separate units. They are located between the engine and a separate reduction gear,

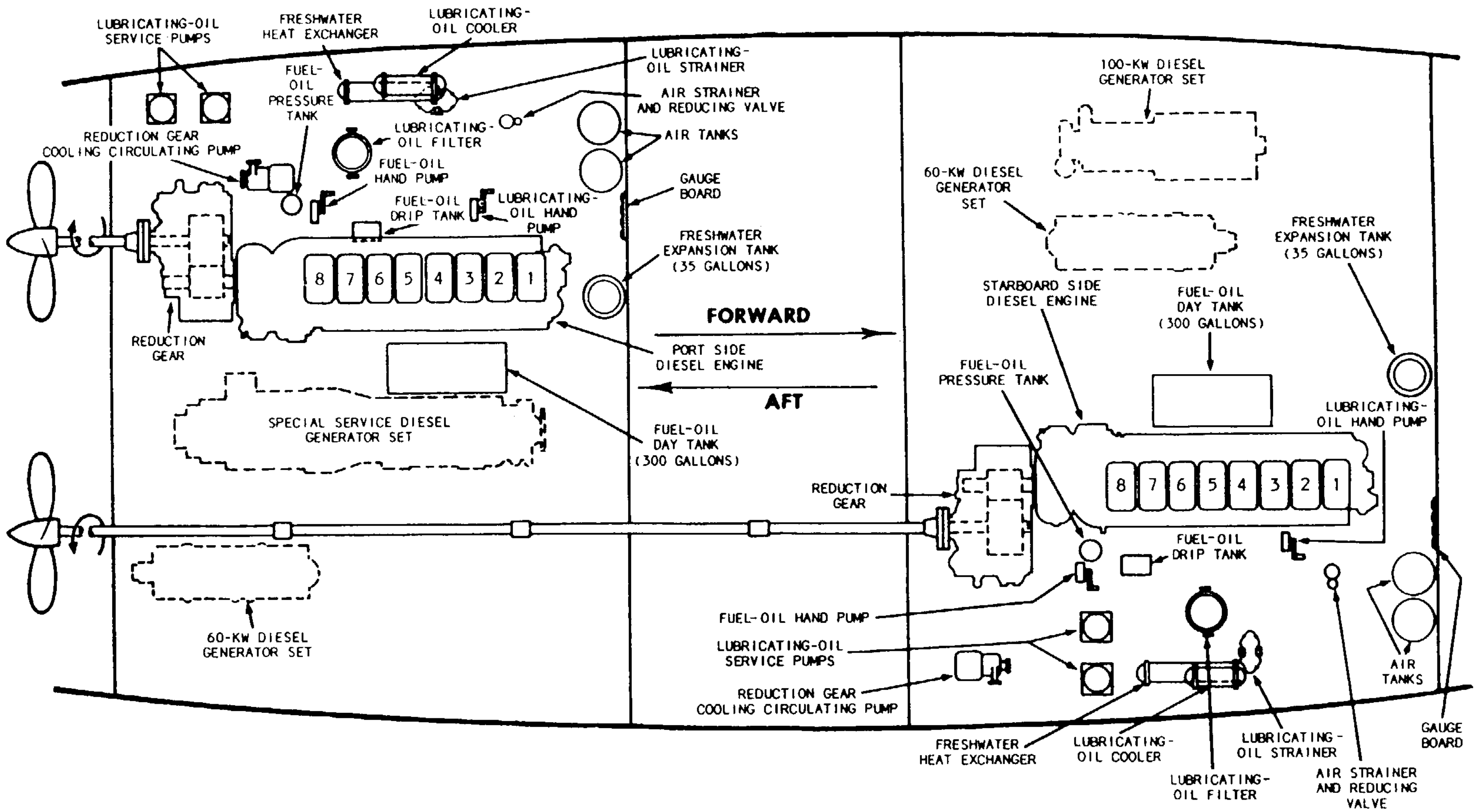

Figure 8-7.—Example of independent propulsion units.

or the clutch may be separate and the reverse gear may be combined.

In most geared-drive, multiple-propeller ships, the propulsion units are independent of each other. An example of this type of arrangement is shown in figure 8-7.

In some installations, the drive mechanism is arranged so that two or more engines drive a single propeller. This is accomplished by having the driving gear, which is on or connected to the crankshaft of each engine, transmit power to the driven gear on the propeller shaft.

Friction clutches are commonly used with smaller, high-speed engines, up to 500 horsepower (hp). Certain friction clutches, however, in combination with a jaw-type clutch, are used with engines up to 1400 hp; and pneumatic clutches with a cylindrical friction surface are used with engines up to 2000 hp.

Friction clutches are of two general styles—disk and band. In addition, friction clutches can be classified as dry or wet types, depending on whether the friction surfaces operate with or without a lubricant. The designs of both types are similar, except that the wet clutches require a large friction area. The advantages of wet clutches are smoother operation and less wear of the friction surfaces. Wear results from slippage between the surfaces during engagement and disengagement and, to a certain extent, during the operation of the mechanism. Some wet-type clutches are periodically filled with oil. In other clutches, the oil is a part of the engine-lubricating system and is circulated continuously.

Twin-Disk Clutch and Gear Mechanism

One of the several types of transmissions used by the Navy is the Gray Marine transmission mechanism. Gray Marine high-speed diesel engines are generally equipped with a combination clutch and a reverse and reduction gear unit, all contained in a single housing at the after end of the engine.

The clutch assembly of the Gray Marine transmission mechanism is contained in the part of the housing nearest the engine. It is a dry-type, twin-disk clutch with two driving disks. Each disk is connected through shafting to a separate reduction gear train in the after part of the housing. One disk and reduction train is for reverse rotation of the shaft and propeller, and the other disk and reduction train is for forward rotation.

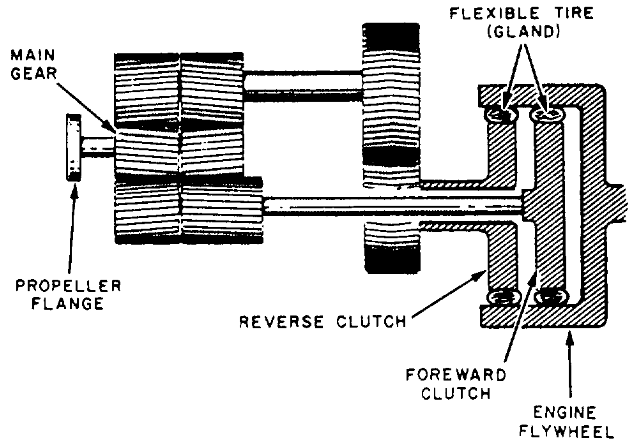

Figure 8-8.—Diagram of airflex clutch and reverse-reduction gear.

Airflex Clutch and Gear Assembly

On the larger diesel-propelled ships, the clutch, reverse, and reduction gear unit has to transmit an enormous amount of power. To maintain the weight and size of the mechanism as low as possible, special clutches have been designed for large diesel installations. One of these is the airflex clutch and gear assembly used with engines on LSTs.

A typical airflex clutch and gear assembly for ahead and astern rotation is shown in figure 8-8. There are two clutches, one for forward rotation and one for reverse rotation. The clutches, bolted to the engine flywheel, rotate at all times with the engine at engine speed. Each clutch has a flexible tire (or gland) on the inner side of a steel shell. Before the tires are inflated, they will rotate out of contact with the drums, which are keyed to the forward and reverse drive shafts. When air under pressure (100 psi) is sent into one of the tires, the inside diameter of the clutch decreases. This causes the friction blocks on the inner tire surface to come in contact with the clutch drum, locking the drive shaft with the engine.

Hydraulic Clutches or Couplings

The fluid clutch (coupling) is widely used on Navy ships. The use of a hydraulic coupling eliminates the need for a mechanical connection between the engine and the reduction gears. Couplings of this type operate with a small amount of slippage.

Some slippage is necessary for operation of the hydraulic coupling, since torque is transmitted because of the principle of relative motion between the two rotors. The power loss resulting from the small amount of slippage is transformed into heat that is absorbed by the oil in the system.

Compared with mechanical clutches, hydraulic clutches have a number of advantages. There is no mechanical connection between the driving and driven elements of the hydraulic coupling. Power is transmitted through the coupling very efficiently (97 percent) without transmitting torsional vibrations or load shocks from the engine to the reduction gears. This arrangement protects the engine, the gears, and the shaft from sudden shock loads that may occur as a result of piston seizure or fouling of the propeller. The power is transmitted entirely by the circulation of a driving fluid (oil) between radial passages in a pair of rotors. In addition, the assembly of the hydraulic coupling will allow for slight misalignment.

PROPELLER

The screw-type propeller consists of a hub and blades all spaced at equal angles about the axis. When the blades are integral with the hub, the propeller is known as a solid propeller. When the blades are separately cast and secured to the hub with studs, the propeller is known as a built-up propeller.

Some of the parts of the screw propeller are identified in figure 8-9. The face (or pressure face) is the afterside of the blade when the ship is moving ahead. The back (or suction back) is the surface opposite the face. As the propeller rotates, the face of the blade increases pressure on the water to move it in a positive astern movement. The overall thrust, or reaction force ahead, comes from the increased water velocity moving astern.

The tip of the blade is the most distant from the hub. The root of the blade is the area where the blade joins the hub. The leading edge is the edge that first cuts the water when the ship is going ahead. The trailing edge (also called the following edge) is opposite the leading edge.

A rake angle exists when the tip of the propeller blade is not precisely perpendicular to the axis (hub). The angle is formed by the distance between where the tip really is (forward or aft) and where the tip would be if it were in a perpendicular position.

A screw propeller may be broadly classified as either fixed pitch or controllable pitch. The pitch of a fixed-pitch propeller cannot be altered during operation. The pitch of a controllable-pitch propeller can be changed at any time, subject to bridge or engine-room control. The controllable-pitch propeller can reverse the direction of a ship without requiring a change of direction of the drive shaft. The blades are mounted so that each one can swivel or turn on a shaft that is mounted in the hub (as shown in fig. 8-10).

SUMMARY

This chapter has provided you with some basic information on several types of propulsion systems used on Navy ships. You should become familiar with the propulsion system on your ship. Keep in mind, the propulsion systems are usually a little different from ship to ship.

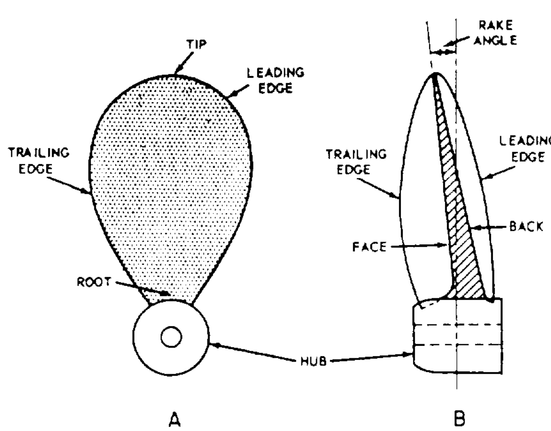

Figure 8-9.—Propeller blade.

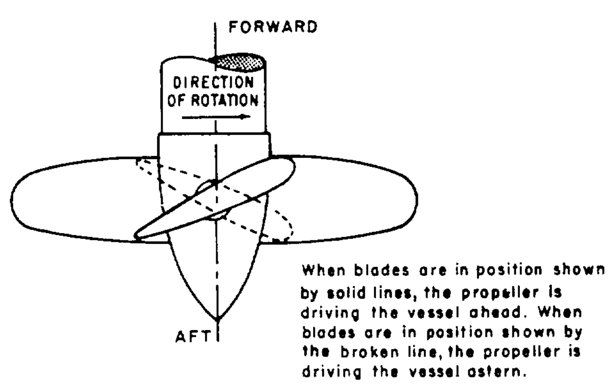

Figure 8-10.—Schematic diagram of a controllable-pitch propeller.