THE WESTERN PACIFIC RAILROAD COMPANY

THE DIESEL ENGINE

OPERATING DEPARTMENT
TRAINING MANUAL

INTRODUCTION

In the 1860's, Alphonse Beau Du Rochas suggested several changes in the internal combustion engine to improve its thermal efficiency. One change was to ignite fuel by the heat of compression rather than by a spark. In 1892, Dr. Rudolph Diesel adopted the idea and patented an engine that burned powdered coal ignited by compression. The coal-burning engine didn't develop as Dr. Diesel had hoped; but in 1897 he built another compression-ignition engine -- one that burned oil. Although various methods were used to transmit the engine's power to driving wheels, electric drive proved most efficient. Combination of the diesel engine with electric drive is known as the diesel-electric assembly. Applied to a locomotive, the diesel-electric assembly may vary from model to model; but general construction principles are the same in all models.

The first application of the diesel engine to railroad stock is believed to have occurred in Sweden just before World War I. Then, in 1924, the Ingersoll-Rand, General Electric, and American Locomotive Companies built a diesel-electric switching locomotive for the Central Railroad Company of New Jersey. Use of the diesel-electric locomotive spread rapidly as it proved its economy and ease of operation and maintenance. The first completely dieselized railroad was the Birmingham Southern, in 1937. By 1955, diesel-electric locomotives were operating 88 percent of the passenger train miles, 85 percent of the total freight ton miles, and 91 percent of the total switching hours of United States railroads. In 1968, of all the locomotives in this country, 98.5 were diesel-electrics.

This text discusses the diesel engine.

BASIC DIESEL ENGINE THEORY

ENGINE

A diesel engine is an internal-combustion, oil-burning engine using compression ignition. Such an engine gets its power from the burning of a charge of fuel within a confined space called a cylinder. Ignition occurs when the fuel is ignited solely by the heat of compression, caused by injecting the fuel into the highly compressed air in the cylinder.

The engine is supported by the bedplate, mounted on the locomotive frame, which serves as a housing for the crankshaft and as a reservoir for the engine lubricating oil. The main structural part of the engine, the cylinder block, is shown below in Figure 1.

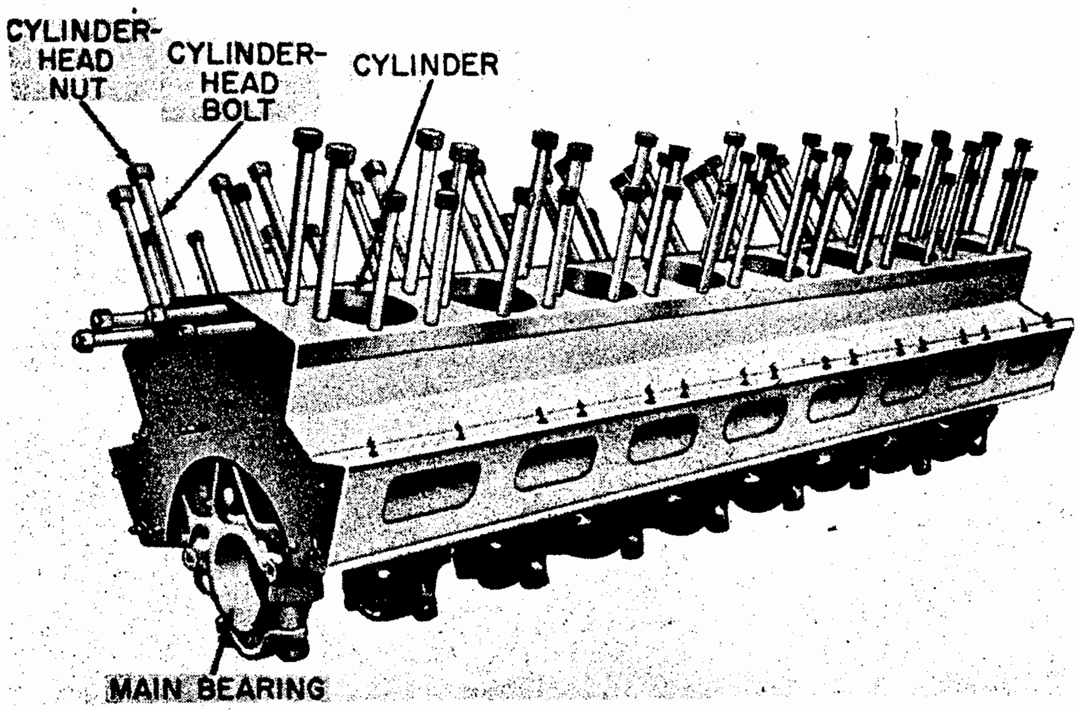


FIGURE 1

All diesel-electric locomotive engines have essentially the same parts and work the same way. The major difference among them is in the arrangement of the cylinders. The three most common cylinder arrangements are the V-type, the vertical in-line, and the horizontal.

Moving up and down inside the cylinders are pistons, connected by connecting rods to the crankshaft. The crankshaft, shown below transmits mechanical action from the pistons to drive the generator. The generator changes the mechanical action into electricity and transmits it through cables to the traction motors, which change it through a gear arrangement back into mechanical force to turn the wheels.

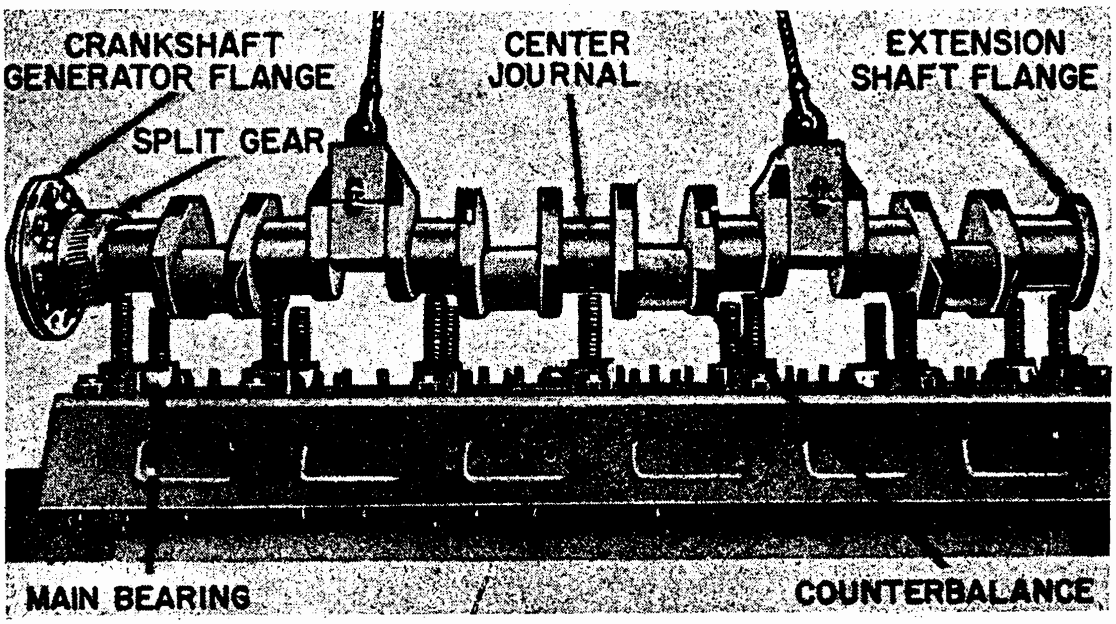


FIGURE 2

Figure 2 shows the main engine crankshaft raised from an inverted diesel engine for maintenance purposes.

ENGINE ACTION

To produce power through an interval of time, a diesel engine must perform a definite series of operations over and over again. This series is known as a cycle in which suction, compression, ignition, and exhaust take place in the order listed. If the engine requires four strokes of the piston and two revolutions of the crankshaft to complete a cycle, it is known as a four-stroke-cycle engine; one completing the cycle in two strokes of the piston and one revolution of the crankshaft is a two-stroke-cycle engine. Figure 3 below illustrates the operating cycles of the two-stroke-cycle engine.

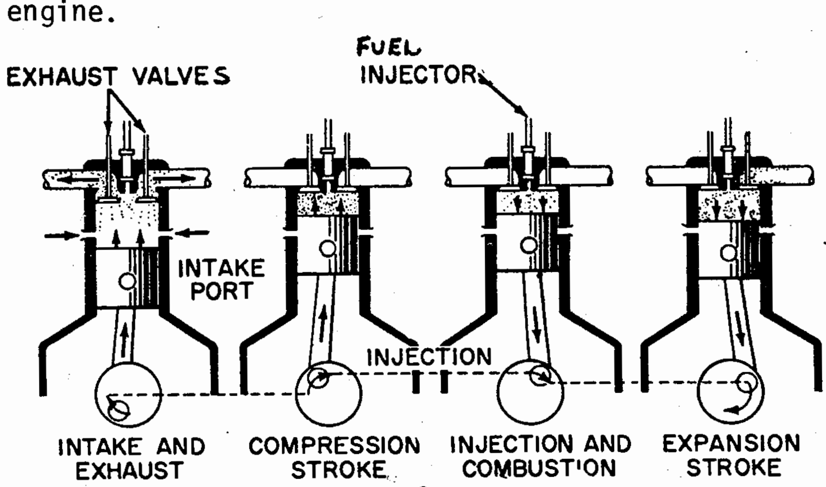
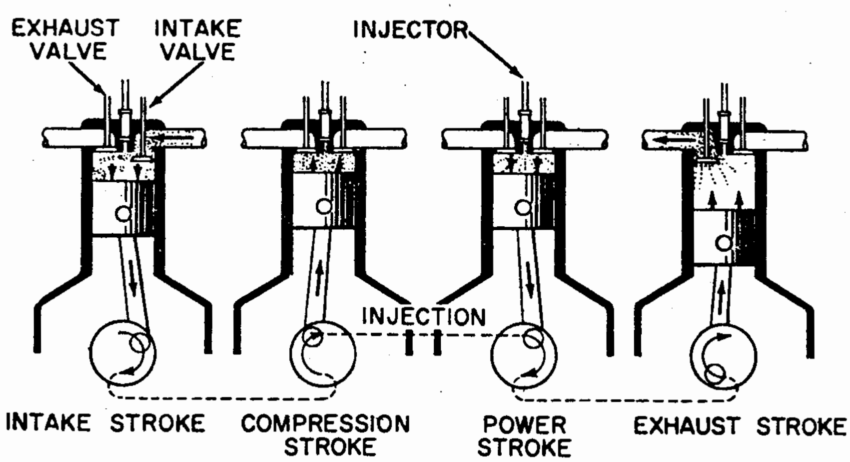


FIGURE 3

In the four-stroke-cycle engine, air is drawn into the cylinder through the intake valve as the piston descends on the intake stroke. The intake valve then closes and the piston goes up on the compression stroke, compressing the air within the cylinder. Fuel is injected through the injector while the air is compressed, and combustion occurs. The combustion, with resultant pressure, drives the piston back down on the power stroke. The piston rises again on the exhaust stroke and expels the air through the exhaust valve, a process called scavenging. (See Figure 4)

Piston action in the two-stroke-cycle engine is basically the same. A difference in scavenging accounts for two strokes rather than four. Air entering the intake port pushes the oxygen-depleted air, left from the previous combustion, out through the exhaust valves. The compression stroke then occurs. Notice, in the lower portion of Figure 3, that the piston itself closes the intake port on the compression stroke.



FOUR-STROKE CYCLE

FIGURE 4

PRESSURE CHARGING

Air ordinarily enters the cylinder at atmospheric pressure. The amount of fuel entering the cylinder is therefore limited because it has to be related to the amount of oxygen available to mix with it. If too much fuel enters the cylinder and is left unburned, it settles on the cylinder wall and piston and dilutes the lube oil film. This prevents a tight fit and causes leakage of air and loss of power. Therefore, the amount of entering fuel must be carefully regulated. Also, it must enter the cylinder so that the first fuel entering begins burning before the rest of the fuel enters, providing gradual, even combustion. If all the fuel enters the cylinder before ignition begins, it all burns at once -- explodes -- and a loud knock from the explosion, called combustion knock, occurs.

A pressure-charged engine provides a method of putting more air, more fuel and resulting greater power into the cylinder. By this method, sometimes called super- or turbo-charging, power can be increased 50 percent in a four-stroke engine and 35 percent in a two-stroke engine. Extra air is made to enter the intake valve or intake port by compression. A number of air-compressing devices have been used to furnish supercharging air. The kind most commonly used on diesel-electric locomotives is the turbine compressor, operated by a gas turbine in the exhaust system. It is the most logical place for this turbine because a great deal of energy is wasted through exhaust of burned gases. Heat balance figures show the loss to be as much as 40 percent of the energy liberated from the fuel by combustion. This energy is captured to run the turbine which is connected to the compressor that delivers air under pressure to the engine.

FUEL SYSTEM

The fuel system, often referred to as the heart of the diesel engine, squirts the proper amount of fuel into the cylinder at the proper time. The most important part of the system is the injector, which measures out the right amount of fuel, injects it into the cylinders under high pressure, and reduces it to a fine spray. Other parts of the fuel system are a tank to hold the fuel; a fuel-oil pump, driven by the motor, to get oil from the tank to the injectors; filters to clean the oil as it passes through the system; an injection nozzle to direct fuel into the combustion chamber in the best pattern for combustion; and an emergency fuel cutoff valve to stop fuel from flowing from the tank in an emergency.

Generally speaking, fuel begins to enter the combustion space of the cylinder when the piston is about 15 degrees before top dead center. When the kindling-combustion temperature of the fuel is reached, the sprayed droplets of fuel begin to burn. The fuel still being injected then burns as soon as it leaves the injection nozzle. When fuel is delivered by the injection pump under sufficient pressure, the nozzle valve lifts against spring pressure; fuel enters the nozzle and is sprayed from it into the combustion chamber. Several types of combustion chambers are used. The entire supply of air is in the cylinder, with a depression in the piston crown providing the combustion space. With this type of combustion chamber, heat loss is small and fuel consumption low. Also, the engine can start quickly during cold weather.

a. Fuel tank. The fuel is contained in a tank fitted with baffle plates which prevent surging and is also equipped with a sump to catch sludge and water so that it can be drained out. The fuel pump alone cannot raise the fuel to the cylinder's injector and two alternative methods of supplying fuel can be used. A small service tank can be located above the pumps and the fuel can enter the pumps by gravity or, if the service tank is not used, fuel can be pumped from the main tank by a mechanical or electric pump.

b. Fuel injection pump. A fuel injection pump, illustrated on Page 6, not only creates the injection pressure but determines the amount of fuel injected. Its toothed rack (Figure 5), controlled by the engine governor or by the speed control lever, varies the amount of fuel and actuates all the pump elements. The pump is primarily a piston or plunger, sliding in a barrel. The lower end of the plunger has two projections which engage slots in the control sleeve. Oil enters the intake port and is trapped above the helical groove and slot whenever it rises to cover the spill port. Various positions of the groove and slot are shown in Figure 5. Position (a) shows the plunger at its lowest point and position (b) shows it when both ports are closed during its rise in the cylinder. Positions (c), (d), and (e) show the plunger when the locomotive is at full load, half load, and idling. When the locomotive is at a full stop, the plunger is at position (f).

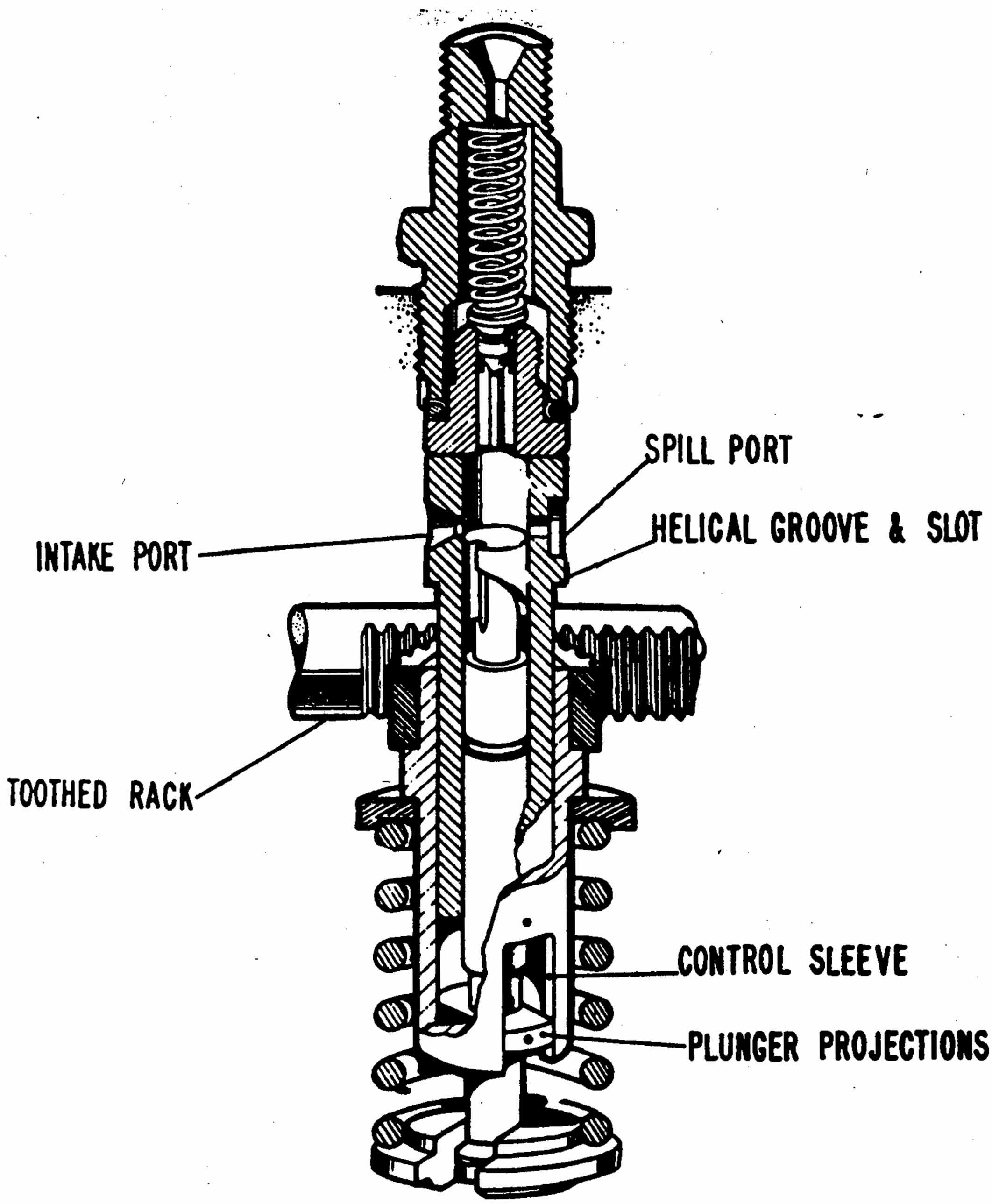
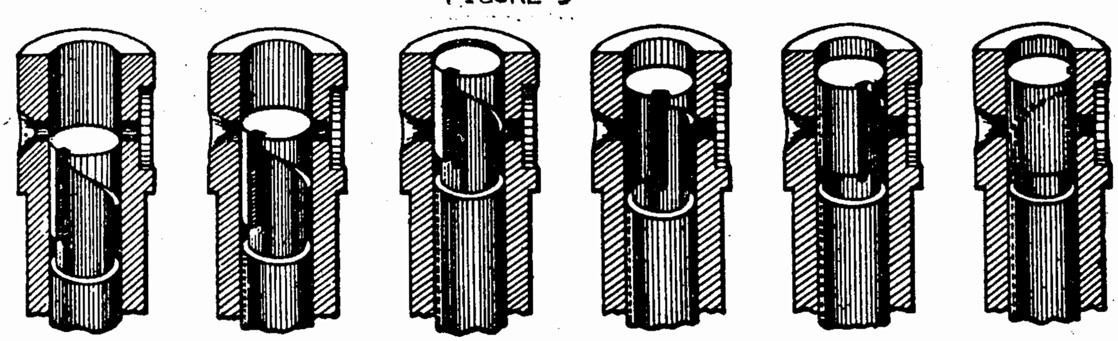

SPILL PORT
HELICAL GROOVE & SLOT
INTAKE PORT
TOOTHED RACK
CONTROL SLEEVE
PLUNGER PROJECTIONS

FIGURE 5


(a)
(b)
(c)
(d)
(e)
(f)

c. <u>Fuel filters</u>. Since dust and grit in the fuel are the main causes of diesel engine trouble, the most important of all precautions is fitting efficient filters in the fuel oil supply line. The equipment is quickly ruined if fine particles of dust and grit are allowed to enter the fuel line; irregular running, loss of power, and poor starting will result. The plunger in the fuel pump and the helix opposite the spill port are usually worn first when dirt is in the fuel.

Most diesel engines use two kinds of fuel filters: a primary or coarse filter between the supply tank and the fuel supply pump, and a main or fine filter between the supply pump and the injection pumps. They are made of either metal or fabric. Metal filters are used as primary filters because the fine particles that pass through them are not as harmful to the supply pump as they would be to the injection pump. They are cleaned by scraping the metal disks. Because of their greater filtering qualities, fabric filters are usually used as main filters to protect the fuel injection pump. They have bags which are turned inside out to get rid of dirt then washed and reinstalled.

WATER COOLING SYSTEM

Heat originating in engine is absorbed by circulating water and dissipated in a fan-cooled radiator. In a diesel-electric locomotive, the fan is driven by a motor powered by an auxiliary generator. Since heated water helps the engine to reach its best operating temperature more quickly, the radiator is not brought into the water circuit until the water is quite hot. Temperature of the water can be regulated by louvers on the front of the radiator.

The water is circulated by a pump driven from the engine. It goes through water jackets between the cylinders and cylinder liners, and is then routed through the radiator to be cooled. Because heat and cold cause metal to expand and contract, it is better to use a high rate of water circulation with a small difference in temperature of the water entering and leaving the engine than to circulate the water more slowly and have a larger difference in entering and leaving temperatures.

Water in the cooling system is treated to remove hardness, to minimize corrosion, and to remove suspended impurities. Hardness, a term used to express the presence of scale-forming salts in raw water, can be removed by a water softener. Dry compounds should not be poured into the radiator as they may clog the system. Water should be treated in a separate container first and solids allowed to settle before drawing solution off for the engine. If treatment is improper or ineffective, radiators and water jackets will become clogged and cylinder liners corroded.

LUBRICATING SYSTEM

Sometimes, oil is used for cooling as well as for lubricating. When this is done, a separate oil radiator with its own cooling fan is provided with the main radiator. Used for bearing lubrication, the oil's circulation rate is lower than when it is used for pistons in a fine spray. The crankshaft, end bearings, operating gear, and camshaft are lubricated by oil under pressure; oil without pressure, free return oil, lubricates the camshaft driving gears and cylinder walls. Contaminating particles can usually be filtered out.

a. Contamination. Some contamination of oil is inevitable. For example, the oil itself will oxidize and form corrosive acids. These acids are prevented from harming the engine by additives which either keep the oil from oxidizing or provide a protective coating on the parts they touch. In addition, the oil should possess some detergent properties to keep the contaminating matter in suspension so that it will be drained off when the crankcase is drained. Contaminating materials found in the oil may be any of the following: metal bits caused by wear of the engine, carbonaceous particles resulting from fuel incorrectly burned or caused by breakdown of the oil itself, unburnt fuel, cooling water that has leaked in, and acid water caused by cooling of burnt gases which have passed by the piston.

b. Filters. Oil circulation pumps are protected from contamination by gauze screens that remove the heavier substances from the oil; smaller particles are removed by metallic strainers made of very fine gauze, steel wool, or closely spaced plates. The finest materials and carbon carried in suspension in the oil are removed by absorbent filters made of special papers, cotton, or felt. Two methods of routing the oil through the filters are used: full-flow filtering, which passes all the oil through the filter; and bypass filtering where only a part of the oil is continuously by-passed through the filter. Full-flow filters have relief valves that can open to take the oil out of the filter's path when the pressure drop across the filter is excessive.