#15 Bach

ENGINES - DIESEL

GENERAL MOTORS - SERIES 71 SETS

KS-5574

1. GENERAL

1.01 The diesel engine is an internal combustion engine. It differs from the gasoline engine principally in the method used to introduce and ignite the fuel. The gasoline engine draws a mixture of fuel and air through the carburetor into the combustion chamber where it is compressed and ignited by an electric spark. In the diesel engine, air alone is compressed in the cylinder, then a charge of fuel is sprayed into the cylinder after the air has been compressed, and ignition is accomplished by the heat of compression. In some installations where extremely low temperatures may be encountered a flame primer, which is essentially a small pressure oil burner with electric ignition, is mounted in the engine air chamber to preheat the air before it enters the cylinders.

1.02 In an internal combustion engine the higher the compression ratio the greater the efficiency within certain limits. Compression ratio is nothing more than the volume of the space above the piston in the cylinder when the piston is at its lowest position in the cylinder divided by the volume of the space above the piston when it is at its highest point in the cylinder. As an example, if an engine has a compression ratio of 6 to 1, it means that the space above the piston when the piston is at the bottom of its stroke is six times the volume that it is when the piston is at the top of its stroke. Gasoline engines have a compression ratio of approximately 6 to 1. Diesel engines have a compression ratio of approximately 16 to 1.

1.03 These diesel engines operate on the two strokes per cycle principle. Gasoline engines usually operate on a four strokes per cycle basis, on the first or downward stroke an explosive mixture of gasoline and air is drawn into the cylinder. On the second or compression stroke the explosive mixture is compressed. On the third or power stroke the explosive mixture is ignited by the spark plug and expands as it burns forcing the piston down. On the fourth or exhaust stroke the burned gases are forced out of the cylinder and the cycle is then repeated for every two revolutions of the engine crank shaft. In the diesel engine each downward stroke is a power stroke and each upward stroke is a compression stroke. Exhaust and intake occur simultaneously near the bottom of each downward stroke and injection of fuel occurs at the top of each upward stroke. This cycle is repeated every revolution of the engine crank shaft. Two strokes per cycle is commonly known among engine operators as "2 cycle" and four strokes per cycle as "4 cycle".

1.04 A series of ports, in the cylinder liner above the piston in its lowest position, admits clean air under slight pressure from a blower into the cylinder as soon as the top face of the piston uncovers the ports. The unidirectional flow of air towards the exhaust valves produces scavenging effect, leaving the cylinders full of clean air when the piston again covers the inlet ports. As the piston continues on the upward stroke the exhaust valves close and the charge of fresh air is subjected to its final compression which approximates 600 pounds per square inch and results in a temperature within the cylinder approximating 1000 F. Shortly before the piston reaches its highest position, the

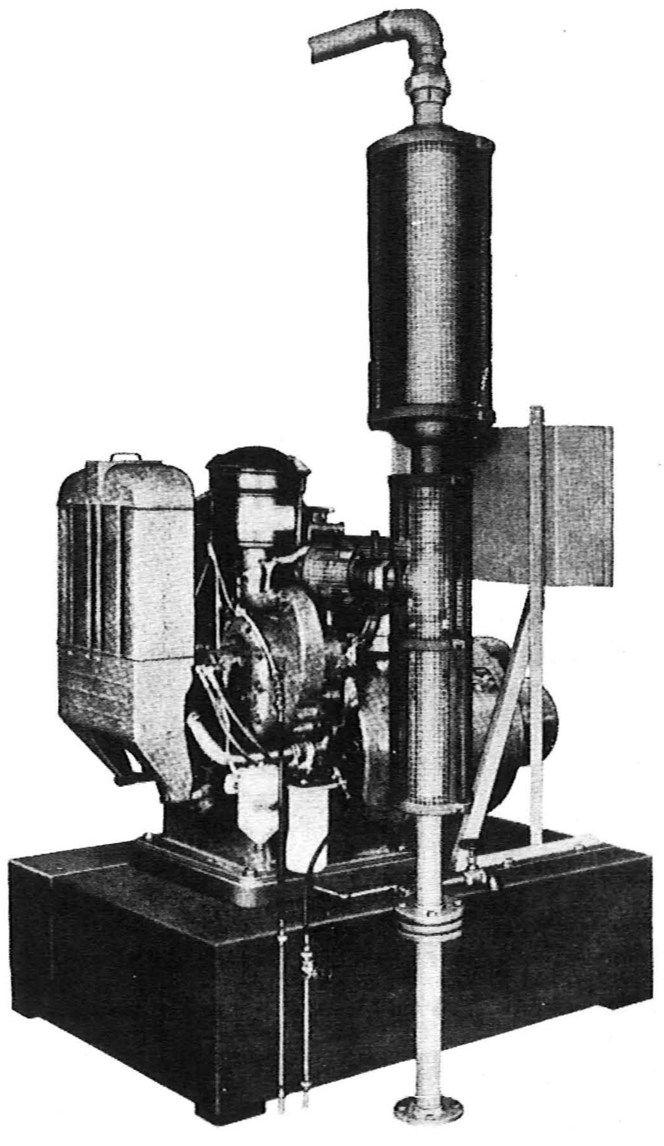

Fig. 1 - Typical Installation Single Cylinder Series 71

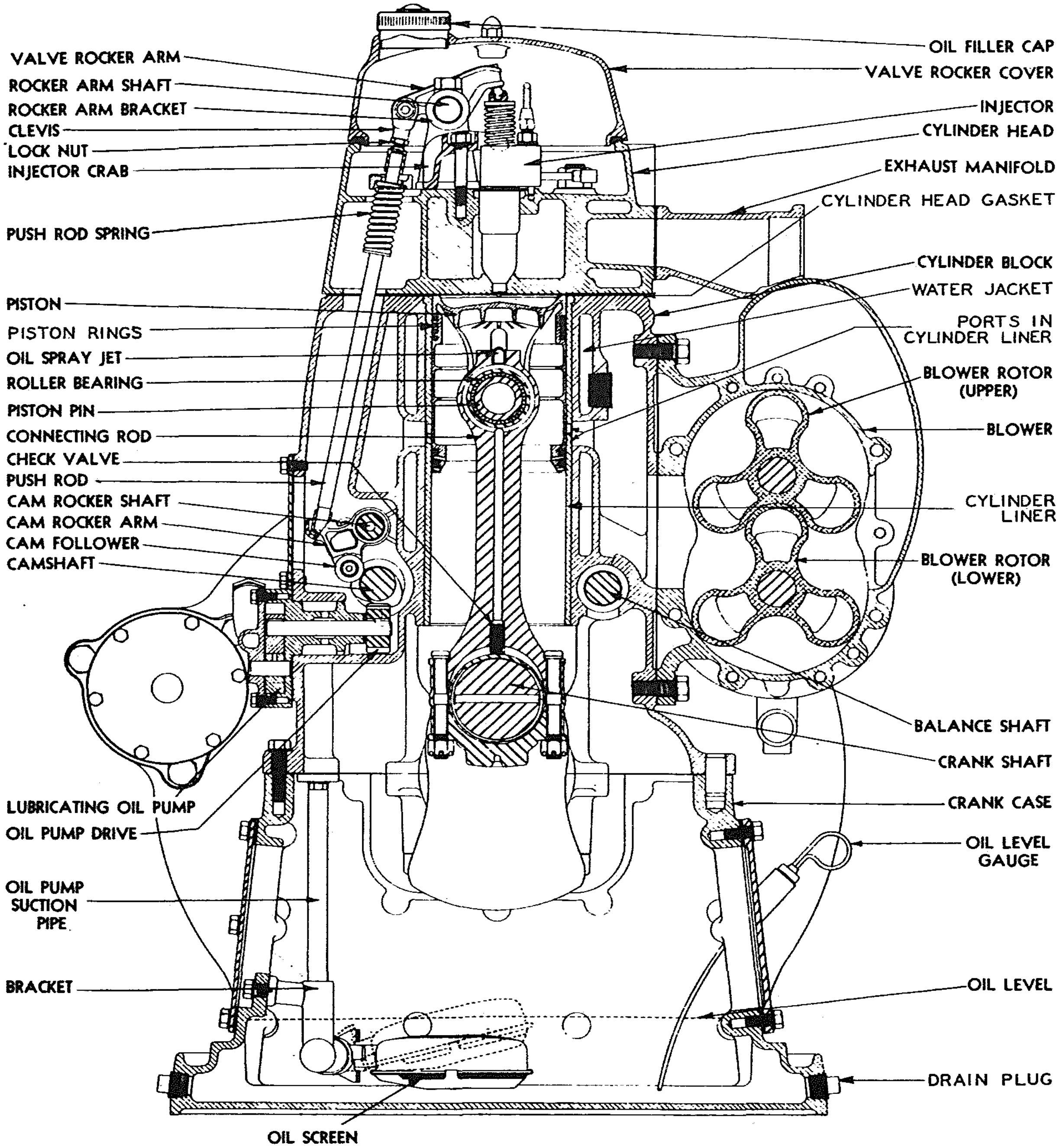

Fig. 2 - Typical Engine Assembly - Cross-section

required amount of fuel is sprayed into the combustion space by the unit fuel injector. The intense heat, due to the compression of the air, ignites the fine fuel spray immediately and the combustion continues as long as the fuel spray lasts. The resulting increase in pressure within the cylinder forces the piston downward until the exhaust valves are again opened. The exhaust valves open permitting the burnt gases to escape into the exhaust manifold just before the downward moving piston uncovers the inlet ports. When these ports are uncovered the cylinder volume is again swept with clean scavenging air from the blower, driving all burnt gases out of the cylinder and filling the cylinder with fresh air ready for a repetition of the steps outlined above.

1.05 These engines are provided in one, three, four, or six cylinder models all having the same bore and stroke and using the same parts wherever possible so that the major working parts such as injectors, pistons, connecting rods, bearings, and numerous other parts are interchangeable on all engines. Furthermore the blower, water pump, oil cooler, oil filter, governor, fuel pump, and starting motor form a group of standard accessories which are described hereafter and provided with the engine.

2. DESCRIPTION

Engine Proper

2.01 The Cylinder Block and Crank Case which forms the main part of the engine is a box-like, one-piece casting made of alloy cast iron. The blocks for all engines are similar in design and dimensions except the necessary length of the block and the blower mounting flanges which vary according to the number of cylinders in the unit. Rugged cross members in the casting insure the proper alignment of the cylinders and bearings. The cylinders are bored to receive the pressed-in cylinder liners, into the circumference of which a number of air inlet ports are drilled. The water jackets extend the full length of the bores and are divided into upper and lower sections, which are connected by hollow struts. Cooling water enters at the bottom of the water jacket from the water pump and leaves the jacket at the top through holes which register with corresponding openings in the cylinder head. Surrounding the water space is an air chamber which conducts the air from the blower to all of the ports. The upper half of the main bearing seats are cast integral with the block. Drilled passages in the block carry lubricating oil to all moving parts. Handhole plates on the side opposite the blower permit access to the air chamber, and provide some measure of inspection of pistons and rings through the air intake ports in the cylinder walls.

2.02 An easily replaceable Cylinder Liner is used in each cylinder and accurately honed to a smooth finish. A flange at the top of the liner fits into a recess in the cylinder block insuring proper positioning of the liner in the block. Even temperature and minimum distortion are insured by cooling each liner over its entire length except at the ports which are cooled by the scavenging air. To permit the introduction of fresh air into the cylinder, sixty-four 5/16" ports are drilled into the circumference of each cylinder liner in two rows, the ports being equally spaced and staggered.

2.03 The Crank Shaft is a drop forging carefully heat treated, and balanced. The crank shaft of the single cylinder engine is supported by two main bearings, that of the three cylinder engine by four, that of the four cylinder engine by five, and that of the six cylinder engine by seven main bearings. The design of the engine permits the use of a relatively light cast iron flywheel. The flywheel is bolted to a flange on the crank shaft and dowelled in place. A starter ring gear is shrunk onto the rim of the flywheel. The crank shaft is drilled for full pressure lubrication to the main and connecting rod bearings.

2.04 Malleable iron Pistons, accurately ground and plated with a coating of tin, permit close clearances. The top of the piston forms one end of the combustion chamber and is cooled by lubricating oil forced from a jet on top of the connecting rod. The piston pins are fitted with bronze bushings, pressed into place. The outer ends of each piston pin mounting hole are sealed with a cap to prevent loss of lubricating oil at this point. Each piston is fitted with six cast iron rings, four above the piston pin which act as compression rings and two near the bottom of the skirt which act as oil rings.

2.05 The Cylinder Head can be removed from the engine as an assembly containing cam followers, guides, rocker arms, and exhaust valves. Two exhaust valves, a fuel injector, and three rocker arms are provided for each cylinder. The two exhaust passages from each cylinder lead through a single port to the exhaust manifold. The exhaust passages, exhaust valve seats, and injector seats are completely surrounded by cooling water. Hardened valve seat inserts are employed.

2.06 Each Rocker Arm Assembly operates on a separate shaft supported by two brackets. The two outer arms operate the exhaust valves while the center arm operates the fuel injector. The rocker arms are operated from the cam shaft through push rods. The rocker arm assembly is lubricated from an oil passage on the cam shaft side of the cylinder head. Oil from this passage enters the rocker arm shafts through their brackets, for the lubrication of the rocker arm bearings and the push rod clevis bearings.

Lubrication System

2.07 The Lubrication System consists of an oil pump, oil strainer, and oil cooler, with a suitable relief valve in the oil pump and a by-pass valve between the oil pump and oil strainer to insure lubrication if the strainer becomes clogged. Oil circulation is furnished by the oil pump which delivers the oil to an oil strainer, after which it passes through an oil cooler and then to the main oil passages in the cylinder block from which the various engine and blower bearings are lubricated. A by-pass type sludge filter receives oil from the passages and returns it to the crank case after removing impurities. All bearings are pressure lubricated except the gear train which is lubricated by overflow oil from the cam shaft and balance shaft, the valves and valve tappets which are oiled by overflow oil from the rocker arms and the cams which are lubricated from oil pockets in the cylinder head. After reaching a certain level in the oil pockets the oil overflows into the blower housing providing lubrication for blower drive gears, governor drive gears, and water pump bearings, and then returns to the crank case by gravity. A slinger on the lower blower rotor throws oil into the governor weight assembly. The water cooling fan of the 10 kw set requires periodic oiling. On the other sizes the fan is mounted on the crank shaft and has no bearing surfaces. The starting motor, alternator, overspeed trip angle drive and governor control rod linkage have to be lubricated manually.

2.08 The Oil Pump is mounted in the crank case on one of the main bearing caps and is driven by a chain from the crank shaft. An integral plunger type relief valve by-passes excess oil to the inlet side of the pump when the pressure in the oil lines exceeds 60 pounds per square inch. A spring loaded by-pass valve placed in the line between the oil pump and oil strainer, by-passes oil directly from the pump to the lubricating system in the engine if the pressure at the strainer inlet becomes 15 to 20 pounds greater than the pressure at the cooler outlet. A pump screen is attached to the suction side of the lubricating pump.

2.09 The <u>Oil Strainer and Filter</u> are mounted on the side of the crank case. In order to obtain rapid cleaning with minimum pressure drops, the hot oil discharged by the pump is cleaned before it is cooled. Part of the oil that passes through the strainer is passed through a filter and back to the crank case. Most of the oil, however, goes from the strainer through the cooler to the various engine bearings and thence back to the crank case.

2.10 The <u>Oil Cooler</u> not only cools the hot engine lubricating oil but by means of cooling water temperature control provides a means of rapidly raising the oil temperature during the warming up period of the engine. The hot oil enters the cooling unit at the bottom, flows through the inside passages which are surrounded by the cooling water and is discharged at the top into the lubricating system in the engine.

2.11 <u>Crank Case Ventilation</u> is provided in all sizes of engines. The crank case and valve compartments are connected by means of a small vent pipe to the blower intake. This pipe keeps the air inside the crank case and valve chamber slightly below the normal outside atmospheric pressure. In this way oil fumes and water vapor caused by condensation are sucked into the blower, from there into the engine where they are burned and then expelled through the exhaust system.

2.12 The <u>Oil Level</u> in the crank case is indicated by an oil level gauge in the side of the cylinder block. The gauge is marked FULL and LOW. The oil level can be quickly determined by removing this gauge the same as in the ordinary automobile. The low mark indicates the point where oil should be added. The lubricating systems for the various sizes of engines require approximately 7 quarts of oil for the 10 kw, 8-1/2 quarts for the 30 kw, 10-1/2 quarts for the 40 kw, and 15-1/2 quarts for the 60 kw engine.

<u>Air Intake System</u>

2.13 An <u>Air Cleaner</u> is provided on each engine to remove dust and dirt from the large volume of air which is circulated through the cylinders. The air cleaner is installed on top of the air intake of the blower.

2.14 The <u>Blower</u> forces a charge of fresh air into the cylinders, which sweeps out the burnt gases through the exhaust valve ports and also helps to cool the internal engine parts, particularly the exhaust valves. At the beginning of compression, therefore, each cylinder is filled with fresh, clean air which permits highly efficient combustion. The blower consists of two hollow aluminum rotors, each with three lobes which revolve with very close clearances in the blower housing. To provide continuous and uniform displacement of air the rotor lobes are made

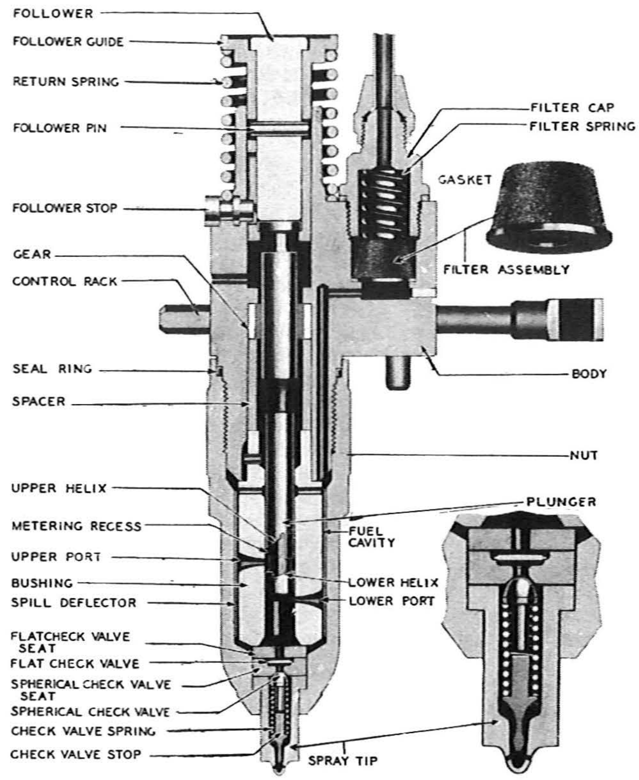

Fig. 3 - Typical Injector Assembly

with a twisted or helical form. The continuous discharge of fresh air from the blower creates an air pressure of about 7 pounds per square inch in the air chamber of the cylinder block. The size of the housing and length of the rotors vary with the size of the engine.

<u>Fuel System</u>

2.15 The <u>Fuel Injector</u> is a device which provides a small quantity of accurately measured, finely atomized fuel which is mixed, at the end of the compression stroke with the charge of air which has been forced into the cylinder by the blower. The injectors are mounted in the cylinder head directly above each cylinder with their spray tips projecting slightly below the top of the inside surface of the combustion chamber. A yoke bolted to the cylinder head and fitting into a machined recess in each side of the injector body, holds the injector in place. A dowel pin in the injector body registers with a hole in the cylinder head for accurately locating the injector assembly. The injector plunger is operated from the cam shaft through a rocker arm. The effective stroke of the plunger as well as the timing of the fuel injection is controlled by means of a rack and pinion operated from a common control shaft whose position is regulated by the governor. Two helices are machined into the lower end of the plunger. The plunger is rotated within the injector housing by means of the rack and pinion, changing the relative position of the two helices and the injector ports which retards or advances the closing of the ports and the beginning and end of the injection period, at the same time increasing or decreasing the amount of fuel which remains under the plunger for injection into the cylinder.

2.16 The Fuel Pump pumps fuel from the fuel tank through the fuel filters to the lower of two fuel manifolds on the side of the cylinder head and connected to the injectors by short feed lines. The fuel then passes to the injector where a portion is used and all excess fuel returns to the upper of two fuel manifolds and thence back to the fuel tank.

2.17 The Fuel Oil Filter consists of two elements, one a rough filter and an AC Kleer Kleen filter element. Neither element can be cleaned but both have to be replaced when dirty. The rough filter and the AC Kleer Kleen filter each have a drain valve in the bottom for removing any water which may accumulate. There is also a small filter in the fuel line in each injector.

2.18 The Fuel used should be a petroleum distillate coming within the American Society for Testing Materials classification limits for No. 1-D diesel fuel oil. The cetane number of the fuel oil should be at least 50 and the oil should be free enough from high boiling fractions to give clean combustion. It should have 90% distillation point at 500 F. with an end point not exceeding 600 F. It also must be free from alkali, mineral acid, gum, sediment, and fibrous or other foreign matter and therefore should only be bought from a reputable company.

Cooling System

2.19 The Cooling System of the engine consists of radiator and fan cooling only, on all sizes, or combined radiator and city running water cooled on sizes above 10 kw. In systems having both methods of cooling only one system should be used at a time, never a combination of the two. With city running water cooled installation a heat exchanger is used so that the city water does not run through the engine block directly and so that rust inhibitor may be used to keep rust and deposits within the cooling water jackets and piping on the engine down to a minimum. Rust inhibitor should also be used on radiator cooled engines.

2.20 Temperature Control of the cooling system is automatically controlled by a by-pass thermostat mounted in the outlet manifold from the engine head. Before the thermostat starts opening water circulation takes place in the cylinder block, cylinder head and oil cooler only by means of a water by-pass tube connecting directly from the water outlet to the water inlet, without going through the radiator or heat exchanger. By this method the engine comes up to operating temperature much more rapidly (approximately 5 to 10 minutes) and it also provides a means of warming up the lubricating oil at the start of the engine to insure more positive lubrication.

2.21 A Water Pump provides positive circulation of the cooling water through the system and is driven from the blower.

Governor

2.22 A Mechanical Governor (Handy) is furnished with the single cylinder 10 kw set. This governor is of the constant speed type in which movement of the governor weight is transmitted to the injector racks by a system of levers. The governor weights are mounted on a horizontal shaft attached to the blower rotor shaft. Movement of the weights is transmitted through a fork at the bottom and an operating lever at the top of a vertical shaft being opposed by suitable springs. The governor controls the idling speed of the engine and maintains a constant operating speed. There is no control of the speed between the idling and the constant operating speed. No speed-droop characteristic is provided with this governor.

2.23 The Hydraulic Governor (Woodward) is a governor with speed-droop stabilization. The hydraulic feature is brought about by oil in the base which by means of a small auxiliary pump furnishes the necessary pressure to actuate the mechanism. The fuel is decreased by action of a spring against a lever mechanism and increased by the opposing action of a hydraulic servo-cylinder, to which the admission of oil is controlled by a pilot valve. The pilot valve is controlled by the flyballs of the governor. The flyballs are mounted on a vertical shaft and driven from the upper rotor shaft of the blower. The centrifugal force of the flyballs is opposed by a spring, the compression of which determines the speed at which the governor will control the engine. As the engine speed drops the flyballs fall inward, lower the pilot valve plunger, admit oil to the servo-cylinder, raising the piston and increasing the fuel supply. As the speed increases the flyballs move outward, raise the pilot valve plunger, cut off the oil supply to the servo-cylinder whose piston will drop and decrease the fuel supply to the engine. Under operating conditions the ports are substantially closed, passing only enough oil to supply leakage and keep the servo-piston in a given position. A knob which projects through the governor housing and is mounted on the end of the fuel rod when pushed in as far as it will go takes the control away from the governor and facilitates starting. On most engines this knob is pushed in during starting by means of an electromagnet. In order to permit parallel operation of one set with another, the governor is provided with a speed-droop adjustment. By speed droop is meant the characteristic of decreasing or increasing the speed range from no load to full load. Where alternators are operated in parallel the speed droop in one of the engines may have to be changed to secure proper division of the load. The speed droop is adjusted by the movement of a slotted quadrant at the side of the governor body. The quadrant is raised to decrease and lowered to increase the speed droop.

Starting Equipment

2.24 The Starting Battery for engines of this type usually are of the 12 volt heavy duty type. The battery should be maintained at as nearly a full state of charge as practicable in order that it may be ready to start the engine on a moment's notice. If the battery fails in an emergency it can quickly be replaced by two 3 cell automobile batteries.

2.25 The Starting Motor provides for positive engagement of the starting motor pinion with the engine flywheel before the starting motor switch contacts are closed or the armature rotated. The pinion is thrown out of mesh with the flywheel as the engine starts.

2.26 Voltage Control of the associated alternator is obtained either by a Westinghouse Silverstat Jr. regulator or an Allis-Chalmers regulator. Both controllers are similar in operating principle although quite different in mechanical details. The Allis-Chalmers regulator is operated by a-c voltage through a transformer while the Silverstat is operated by a d-c solenoid from the alternator through a rectifier. The magnetic pull of the coil is balanced by a coil spring. The regulating resistance is stationary. In the Westinghouse it consists of an assembly of carbon discs to which are connected a series of leaf springs, fixed in position at one end and free on the other end, the free end of each spring being provided with silver contact buttons. In the Allis-Chalmers it consists of ribbon type resistors connected to a fixed commutator. Operation of the armature of the voltage coil causes a finger to open or close the silver contact buttons of the Westinghouse or to rock a contact sector over the commutator of the Allis-Chalmers, thereby increasing or decreasing the regulating resistance in the circuit. A small regulating rheostat is also connected in the circuit and provides a means of setting the voltage at the value at which it is desired to regulate. Where alternators are operated in parallel an added current transformer and resistor are connected in the control circuit.

Accessories

2.27 Each engine is directly connected to its associated alternator by means of a flexible coupling. The 10 kw set has the control cabinet mounted on the concrete block on which the set is mounted. In all other sets the engine, alternator, exciter, fuel tank, and electrical controls are mounted on a common subbase and the subbase mounted on rubber supports. All cooling fans are of the pusher type permitting the discharge of the heated air to the outside of the building.