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DIESEL ENGINES
A BRIEF HISTORY

PHASE 14

In 1892, while a student at a technical college, Dr. Rudolph Diesel began work on the design of an internal combustion engine which he believed would be more efficient than existing steam engines and capable of burning cheap grades of fuel. An untiring worker, well grounded in the theory of machine design, he lost no time in developing his first successful engine. Although he is reputed to have harbored high hopes for the future of his brain-child, it is improbable that Diesel ever envisaged the widespread acceptance of the engine types, all outgrowths of his original design, which are known to this day as "diesels."

Convinced that hot-tube and open-flame ignition devices were unreliable, and unaware of the possibilities of electric ignition, Diesel planned to ignite the fuel by bringing it in contact with a body of very hot air. At first he attempted to use powdered coal dust dumped into a cylinder and mixed with air heated, by the upward stroke of a piston, to a temperature high enough to cause ignition. But this first attempt ended in dismal failure. The engine exploded and Diesel barely escaped death.

As an alternative, he then tried injection of liquid fuel by pressure built up in the fuel line by an injection pump. But the results were still unsatisfactory. In his next attempt, a successful one, Diesel injected a liquid fuel by using the force of high-pressure air supplied by an auxiliary compressor. Although this method is still used in some types of diesel engines burning the heavier grades of fuel oil, most modern diesels use pump injection, the very method Diesel discarded.

By 1897 Diesel had constructed his first successful engine, a single-cylinder, 25-hp model, which immediately attracted world-wide interest. In 1898 the first diesel engine was built in the United States. It was a 60-hp, two-cylinder, Busch-Sulzer engine installed in the Anheuser-Busch brewery in St. Louis.

In the spring of 1912 Dr. Diesel delivered a paper on diesel engines before the American Society of Mechanical Engineers in which he predicted "that nowhere in the world are the possibilities for this prime mover as great as in this country." The rapid development and wide application of the diesel engine in the United States verified his prophecy.

One of Dr. Diesel's oldest collaborators, Dr. Franz Lang, was the inventor of the first compressorless diesel engine, known as the Vogel diesel, which was exhibited in 1911.

Realizing after World War 1 that there was a wide field for higher-speed diesels, Dr. Lang began his research work on the design and development of injection pumps and nozzles, as well as combustion chambers suitable for high-speed performance. By 1922 he had completed the diesel engine which embodied his patented design known as the Acro or air-chamber system. Fuel-injection systems for engines embodying this patent and others are made in the United States by the American Bosch Corporation.

But what was considered as "high-speed" in those years soon became "medium" and even "low-speed" as diesel engine designers succeeded in developing the modern and highly efficient light-weight diesel engines which power trucks and tractors, fast streamlined trains, small and large ships, tankers, and submarines. They have also been successfully applied to aircraft. Marine designers, however, were the first ones to employ diesel engines on a large scale. By 1929 diesel engines were specified for more than half of the gross tonnage of ships constructed in that year.

Second in total horsepower to marine engines, in the same year, were the diesels driving generators, water pumps, air compressors, oil-well rigs, and many other types of stationary equipment.

The first diesel-powered locomotive went into service as a switch engine in 1925, and in 1929 the first large diesel-powered passenger locomotive was built. The first diesel engines developing 3000 hp weighed approximately 801,000 lbs, or 267 lbs per hp. In 1938 the weight of an engine of the same horsepower was only one-tenth of the original weight, or about 25 lbs per hp.

The first diesel-powered commercial vehicle was built in 1929. Ten years later, over 50,000 such trucks were in service. Yet in 1930 only one diesel-powered bus was in regular operation.

At the Century of Progress Exhibition in Chicago (1931) the General Motors Corporation exhibited the first light-weight diesel engine for passenger locomotives. It was an eight-cylinder, 600-hp engine, which was soon followed by bigger engines of 1200 hp.

The first streamlined diesel-electric train in the United States, the Pioneer Zephyr, was placed in service by the Burlinton Railroad in 1934. The train is still in service between St. Louis and Burlington, Ia. The diesel engines of the locomotive develop 660 hp and weigh about 23 lbs per hp. It has long ago passed the million-mile mark. The first diesel-powered mainline freight locomotive went into service in 1940.

In 1938 General Motors started production of their light-weight, two-cycle, Series 71 diesel engines, which are small enough for use in trucks and coaches. The engine weighed only 20 pounds per continuous horsepower. Efforts are continuing to reduce further the weight per horsepower.

During World War II diesels powered many types of war equipment. New designs were developed, and older types were redesigned for higher output and efficiency. Their satisfactory performance under the most severe conditions has doubtlessly contributed to the widespread interest in post-war applications of diesel power.

SUPPLEMENTAL DIESEL GLOSSARY

ABSOLUTE PRESSURE: Total or true pressure. Gauge pressure plus atmospheric pressure.

ABSOLUTE TEMPERATURE: Temperature in degrees above absolute zero. Adding 460 to Fahrenheit temperature converts it to Fahrenheit absolute.

AIR-FUEL RATIO: Ratio of the weight of air to the weight of fuel supplied for combustion.

AIR STARTING VALVE: A valve which admits compressed air to an engine cylinder for starting purposes. Air starting valves remain closed or inoperative after the engine is started.

ALIGNMENT: Act or state of being in a straight or true line.

ALLOWABLE PAYLOAD: Body and payload allowance less the body weight.

ALLOY: Mixture of two or more different metals. Most common metals, such as iron and aluminum, can be improved in physical characteristics by alloying with other metals.

ATTRITION: Wearing down by rubbing or by friction; abrasion.

AVAILABLE HORSEPOWER: Maximum brake horsepower rating of engine at the flywheel with accessories.

AVAILABLE TORQUE: Twisting or rotary force developed by an engine at a given RPM.

AXIS: The center line of a rotating part, a body of symmetrical cross-section, or a circular bore.

AXLE RATIO: Ratio of axle to drive line. The number of turns of the drive line in relation to one full turn of the rear wheel. The higher the numerical ratio, the slower the road speed.

BABBITT: White metal used for lining bearing. Consists of tin, antimony, copper and other metals.

BACKLASH: The lost motion between the teeth of two gears before actual driving contact begins.

BEARING GROOVE: Channel cut in bearing surface to distribute oil.

BEARING LOAD SURFACE AREA: Area of bearing against shaft which supports the pressures transmitted from the piston to the crank expressed in pounds per square inch. The larger the bearing area, the lower the pressure per square inch load when a given load is applied.

BEARING SURFACE AREA:. Entire area of contact of bearing to shaft expressed in square inches.

BEVEL GEAR: Gear having teeth cut along a conical surface.

BOGIE: A Tandem axle.

BOTTOM DEAD CENTER (BDC): A point in crankshaft rotation when the piston is at the lower end of its stroke.

BREATHABILITY: Ease of air induction and exhaust expulsion of an engine. Effected by:

Air Cleaner restriction, including piping
Manifold restriction
Valve area and lift
Intake and Exhaust port size
Exhaust System, including muffler and piping

BUSHING: A liner of bearing material, inserted into a hole to insure a good wearing surface.

CA: Rear of cab to center of rear axle.

CAM: Device for producing controlled motion of any characteristic from a shaft, for example, which rotates at a uniform speed. Most common application in diesel work is for opening and closing valves at proper points in the engine cycle. (See camshaft.)

CAM DWELL: Portion of the cam holding the valve stationary in some particular position for a time.

CAM FOLLOWER: An intermediate part which is held in contact with the cam and to which motion is imparted by the cam. Cam followers are sometimes called valve lifters.

CAM NOSE: Portion of the cam holding the valve widest open.

CAM ROLLER: One type of the follower where a roller makes contact with the cam.

CENTRIFUGAL BLOWER: Blower which, by means of a rapidly rotating impeller, displaces air or gas by centrifugal force.

CENTRIFUGAL GOVERNOR: Governor which employs varying force with change of speed in order to control the amount of fuel supplied to the combustion chambers.

CENTRIFUGAL PUMP: A pump using the centrifugal force produced by a rapidly rotating impeller to displace liquid.

CG: Center of gravity.

CHASSIS RESISTANCE: Resistance of vehicle components (power train) from the engine to the wheels. A parasitic load on the net Hp of the engine at the traction wheels.

CL: Center line.

COMPRESSION PRESSURE: Pressure in the combustion chamber at the end of the compression stroke, but without any fuel being burned.

COMPRESSION RELEASE: Usually a device for preventing the intake valves from completely closing, thereby, permitting the engine to be turned over without compression.

COMPRESSION RING: Piston ring designed to reduce gas leakage by the piston to a minimum.

COMPRESSION STROKE: That stroke of the operating cycle during which air is compressed into the space remaining above the piston.

CONNECTING ROD BEARING: The bearing surface for the end of the rod that is connected to the crankshaft. This bearing, due to physical characteristics, is usually referred to as an insert or shell.

CONTINUOUS HORSEPOWER: Horsepower an engine is capable of carrying at a given speed for full load operation of more than 24 hours.

COOLING SYSTEM: Complete system for circulating coolant through the engine jackets, through a medium to cool the coolant (radiator) and returning it to the engine.

CORROSION: An eating or gradual wearing away, as by the effect of chemical action. Something produced by corroding.

COUNTERWEIGHT: A weight mounted on the crankshaft opposite each crank throw to reduce vibration and also bearing loads due to inertia of moving parts.

CRANKPIN: That part of a crankshaft to which the con rods are connected.

CRANK THROW: One crankpin with its two webs. The distance from the center of the crankshaft to the center of the crankpin is indicative of one half of the engine's stroke.

CRANK WEB: That part of the crankshaft which lies between the crankpin and the main bearing of the crankshaft.

CRITICAL COMPRESSION RATIO: The lowest compression ratio at which any particular fuel will ignite by compression under prescribed test procedure. The lower the critical compression ratio, the better ignition qualities of the fuel.

CRITICAL SPEEDS: Speed at which the frequency power strokes synchronize with the crankshaft's natural frequency of torsional vibration. Unless the crankshaft carries a torsional vibration damper, running the engine at one of its critical speeds for any length of time may result in a broken crankshaft.

CROSSHEAD: Device to operate valves in pairs. The crosshead bridges a pair of valves to allow one valve rocker lever to operate both valves.

CYLINDER LINER: Inner part of the cylinder; a sleeve forming the cylinder bore, which may be inserted or removed, may be wet or dry.

DEAD AXLE: An axle having no power applied to it.

DECELERATION: Implying the slowing down of a speed. The opposite of acceleration. Also called negative acceleration.

DIAPHRAM: A thin dividing membrane or partition.

DOUBLE REDUCTION REAR AXLE: A rear end which reduces the drive line RPM in relation to the rear wheel RPM by means of a double reduction of gears. Used where very slow speed is needed. Two reductions are made in the differential. To accomplish this reduction with a single reduction would require an extremely large and bulky rear end housing.

DOWEL: A metal pin attached to one object which when inserted into a hole in another object insures proper alignment.

DRIVE AREA: The number of square inches available to transmit power from a drive to a driven member or component. Area must increase as torque increases. Must be considered in clutch and belt applications. Drive area determines gear size and design. Helical gears have more drive area than a straight cut gear (spur gear) of equal width. Larger drive components are needed with a diesel engine because of high torque characteristics. More square inches of drive area required to lower pounds per square inch load on drive componenets enabling them to withstand the additional twisting action of the additional torque. Charts supplied by manufacturers aid in selecting proper drive equipment which will match the engine torque characteristics to the drive component characteristics to provide trouble-free operation.

DROP-FORGING: A process of heating metal, placing it in a die, and shaping it by force from a drop hammer which operates on the principle of a pile driver.

DURALUMIN: An aluminum alloy of great strength and lightness. Is made up of aluminum plus copper, magnesium and manganese.

DYNAMICALLY BALANCED CRANKSHAFT: Balanced in motion to operate smoothly within the RPM range of the engine.

DYNAMOMETER: An instrument for measuring the power output of an engine. The power output may be measured in terms of torque or horsepower.

EFFICIENCY: The proportion of energy going into an engine which comes out in the desired form, or the proportion of the ideal which is realized.

ELECROLYSIS: When two different metals, such as iron and copper are placed in contact with each other and immersed in water, electric currents flow through the water from one metal to the other in exactly the same manner as in a battery, and a corrosive action called electrolysis takes place. Although these currents are very weak, over a period of time they cause localized corrosion.

FULL FLOATING PISTON PIN. Piston pin free to turn in the piston bosses and in the connecting rod eye.

FUROL: The Saybolt Furol Viscosimeter is used to test fuel and road oils, while the Saybolt Universal Viscosimeter is used to test lubricating oils.

GA: Center of gravity to rear axle.

GALLERY: Passageway inside a wall or casting. The main oil gallery within the clock supplies lubrication to all parts of the engine.

GASKET: Layer of material used between machined surfaces in order to seal them against leakage.

GCW: Gross combination weight. Total weight of fully equipped tractor, trailer or trailers and payload.

GEAR PUMP: Pump using the spaces between the adjacent teeth of gears for moving liquid.

GLOW PLUG: Heater plug, used in the cold starting aid, having a coil of resistance wire heated by a low voltage current, to ignite fuel sprayed into intake manifold.

GRADE RESISTANCE HP: Required horsepower to overcome grade resistance ONLY on any given grade, any given load and any given road speed.

GRADEABILITY: The ability of a unit to perform on a given grade, at a given speed and given load.

GRAPHITE: An iron-gray colored form of natural carbon. It is soft and is used as a lubricant.

GROMMET: An endless ring.

GROSS HORSEPOWER: Maximum horsepower developed by the engine without parasitic load connected.

GROSS TORQUE: Rotary force or twist force generated by the engine.

GVW: Gross vehicle weight. Total weight of fully equipped truck and payload.

HELIX: A spiral formed on a circular object such as the thread on a screw.

HEXAGON: A fugure having six sides and six corresponding angles.

HOMOGENOUS: Having identical structure throughtout. One portion of a substance having the same chemical make-up as another portion of the same substance.

HORSEPOWER: The power necessary to raise 33,000 pounds one foot in one minute. Term used to denote amount of work done in a given period of time.

Continuous Horsepower: The horsepower an engine is capable of carrying at the corresponding stated speed for continuous full-load operation of more than 24 hours.

Intermittent Horsepower: The power an engine will develop at the stated speed and with good operating conditions. The engine must be capable of carrying this load for periods not exceeding 30 minutes if immediately followed by loads not exceeding the continuous horsepower rating, and the latter decreased load should exist for at least two times the period of the intermittent load.

Peak Horsepower: The maximum horsepower which the engine will develop and maintain without drop in speed for at leat one minute, with a reasonably clean exhaust when the engine is in proper adjustment.

HORSEPOWER-HOUR: Unit of energy equivalent to that expended in one horsepower applied for one hour. Equal to 2545 B.T.U. (approximately).

HYDRAULIC: The use of liquids as a means of operation.

HYDRAULIC LOCK: Filling air space above piston with liquid which will not allow the piston to complete its stroke.

IGNITION TIME LAG: Time between start of injection and ignition.

IMPELLER: The blade or disc in a centrifugal pump.

IMPINGING: To physically strike or dash.

IMPREGNATED: Saturated or permeated with another substance.

INJECTION SYSTEM: Apparatus for delivering the correct quantity of fuel to the combustion chamber at the correct time and in the condition for efficient burning.

INJECTOR CUP: Part containing several orifices through which fuel is injected into the combustion chamber.

KINEMATIC CENTI STOKES: An alternate method of measuring the viscosity of an oil.

KINGPIN: The pivot point of the 5th wheel.

KINGPIN WEIGHT: Imposed weight corresponding to the front portion of the trailer and payload weight applied to the kingpin of the 5th wheel.

KNURL: A series of ridges milled on the outer circumference of a piston or nut.

LINER PROTRUSION: Distance the liner flange extends above the top of the block. Important in gasket sealing between the head and block.

MAIN BEARING: A bearing supporting the crankshaft.

MODERATE REAR AXLE: Generally used for speeds 55 to 60 MPH. Requires a moderate axle ratio.

MOLECULE: The smallest part of a substance that can exist separately.

MUFFLER: Device for reducing noise of the exhaust.

MURIATIC ACID: Hydrochloric acid.

NECK: That portion which is turned down to a smaller diameter than the main shaft of which it is part.

NEOPRENE: A synthetic rubber that is not affected by various chemicals harmful to natural rubber.

NET TORQUE: "Usable Torque" - Gross Torque less torque used by accessories.

NOMINAL RATING: Arbitrary classification of a truck in tons--1/2 ton, 2 ton, 10 ton. A misnomer as it does not indicate the true capacity of the vehicle.

ODOMETER: An instrument which when attached to a wheel of a vehicle, measures the distance traveled by counting wheel revolutions, has to be calibrated for each tire size. Error will increase in proportion to load.

OFF HIGHWAY COMBINATION: Generally 5 speed main transmission 3 or 4 speed auxiliary transmission driving through a single or double reduction rear end or automatic transmission through <u>single</u> or <u>double</u> reduction.

OFFSET KINGPIN: A kingpin set forward or to the rear of the centerline of the axle or axles.

OIL CONTROL RING: Piston ring designed to keep excess oil off the cylinder walls.

OIL COOLER: A heat exchanger for lowering the temperature of oil.

OIL FILTER: Filter intended to remove impurities from oil.

OSCILLATING MOTION: To move back and forth as the swinging of a pendulum.

OXALIC ACID: A white crystalline compound used in solution with other compounds as a cleaner to remove heavy mineral deposits in an engine.

PAWL: A hinged piece made to engage with ratchet teeth to prevent reverse motion.

PARASITIC LOAD: Load consisting of certain named accessories which consume horsepower from the engine.

PAYLOAD: Actual weight of the cargo only.

PEAK HORSEPOWER: Maximum horsepower engine will attain for one minute without a drop in RPM.

PEAK TORQUE: Highest torque developed by an engine.

PENETROMETER: An instrument used to measure the consistency of greases.

PITCH DIAMETER: (Gear) Is equal to 3.1416 divided by the pitch circle. The pitch circle is the circumference measured along the pitch points (one-half the working depth of each tooth).

PROJECTED AREA (MAIN BEARING): That part of the bearing which comes in actual contact with the shaft journal.

PRUSSIAN BLUE: A blue pigment, useful in determining area of contact between two surfaces.

PUSHER AXLE: A dead axle ahead of the drive axle.

PUROMETER: A gauge used to measure very high temperatures accurately.

REBORE: Bore out a cylinder slightly larger than original size.

REQUIRED HORSEPOWER: Horsepower needed to make a truck perform properly at any given speed after applying all resistances.

RHEOSTAT: An instrument which permits manually varying the amount of electric current.

RING GROOVE: Groove machined in piston to receive piston ring.

ROLLING RESISTANCE: Varies with load, road speed and composition of roadway. A frictional resistance between the vehicle and the road way. Includes wheel bearings, flex in tire walls and tread, surface irregularities and churning of the air by the wheels.

ROOTS BLOWER: An air pump or blower similar in principle to a gear type pump (supercharger).

SERRATED: Notched or having teeth like a saw.

SINGLE REDUCTION REAR AXLE: A rear end which reduces the drive line RPM in relation to the rear wheel RPM by means of a single combination of gears.

SLOW REAR AXLE: Generally used for speeds below 55 MPH. Requires a high axle ratio.

SPHERICAL: In the shape of a sphere or ball.

SPLINED SHAFT: A grooved shaft which will allow movement with a meting splined surface which it is engaged with while rotating.

STATICALLY BALANCED CRANKSHAFT: Balanced at rest.

STEERING PUSHER AXLE (JAKE LEG): Found on a tractor using two wheels forward for steering and a two wheel pusher axle which is also steered on a tracking radius compatible with the front steering. Generally located just forward of the rear driving wheels. Used where short wheelbase tractors are required and tractor weight distribution calls for an additional axle for additional load.

STRESS: The cohesive force within a material to resist strain or deformation.

STROBOSCOPE: An instrument which, with the aid of a beam of light, can enable a person to examine a point on a rapidly revolving body. The light beam is interrupted and when it flickers at the same RPM as the revolving part, the part seems to stand still (synchronized).

SUMP: A receptacle into which liquid drains, such as the portion of the engine crankcase which carries the lubricating oil.

SWEPT VOLUME: The volume above the piston after it has reached the top of its stroke.

SYMMETRICAL: Equally balanced or evenly proportioned.

TAG AXLE: A dead axle behind the drive axle.

TANDEM AXLE: Any combination of two axles.

TANDEM DRIVE: Two rear axles complete with differentials of same reduction.

TANDEM SIX WHEEL: Truck having two wheels forward for steering and four wheels (on two axles) rear.

TANDEM TEN WHEEL: Having two wheels forward for steering and eight wheels (on two axles) rear.

TEMPLATE: A pattern.

TENSILE: The resistance of a material to be pulled apart in the direction of its grain.

THROTTLING: Restricting the flow of a liquid, usually by cutting down the free area of passage.

THRUST BEARING: A bearing which restrains end-wise motion of a turning shaft, or withstands axial loads instead of radial loads as does a common bearing such as the connecting rod bearing.

TIMING GEAR: The gear by which the camshaft is driven from the crankshaft.

TIRE RESISTANCE: Resistance increases with the size of tire and the rolling radius. Larger tires result in lower engine RPM and therefore, fewer HP are available at a given speed. Unless available HP is sufficient to supply the required HP at that speed, the truck performance suffers.

TOCCO HARDENING: A process of hardening steel parts by first electrically heating and then quenching in water.

TOTAL ENGINE DISPLACEMENT: Piston displacement times number of cylinders expressed in cubic inches.

TRACTOR PLATE: Same as bedplate.

TRACTOR - TRAILER CLEARANCES AND LENGTHS: Must be considered to conform to States weight and length regulations. Factors are:

1. Front bumper to back of cab dimension.
2. Back of cab to front of trailer.
3. Length of trailer.

Back of cab to front of trailer varies according to shape of trailer corners, placement of 5th wheel and Kingpin offset. Kingpin location is measured from the front of the trailer and the actual distance determined from charts which will deal with the varying shapes of trailer fronts. Once determined, this is the maximum the 5th wheel and Kingpin can be moved forward and still have adequate clearance between tractor and trailer for turning 90° right or left. States Bridge Formula must be considered when deciding axle loads. These formulas effect the permissible axle loadings and GVW or GCW and are usually based on distance between axles.

TRACTOR WEIGHT DISTRIBUTION: Division of load to the axles of the tractor. Proper location of the 5th wheel obtains the best weight distribution.

TRAILER PLATE: Same as soleplate.

TRUCK PERFORMANCE: Determined from the difference between required horsepower and available horsepower. This difference or excess horsepower is available to make the truck accelerate for passing or handling increased resistances.

TUNGSTEN: A heavy metallic element of steel grey color.

TWIN SCREW: Tandem drive consisting of two differentials of the same reduction.

"V" BELT DRIVE: Power transmitted from the drive wheels to a dead axle by means of a "V" belt connection.

VALVE-IN-HEAD: Valves seating in cylinder head and opening downward into combustion chamber.

WB: Wheelbase.

WHEELBASE: Distance between front and rear axles, center to center of axles. Two axle rear trucks are figured from center of front axle to center of the two rear axles.

UNIVERSAL TECHNICAL INSTITUTE

PHASE 14
BASIC DIESEL ENGINES

PIPE, TUBING AND HOSES

1. Pipes:

   A. Materials:
      (1) Steel
      (2) Black galvanized
      (3) Brass
      (4) Plastic

   B. Sizes:

Nominal Size	1/8	1/4	3/8	1/2	3/4
O/D	.405	.540	.675	.840	1.050
I/D	.269	.364	.493	.627	.824
* Threads per inch	27	18	18	14	14

*Tapered pipe threads

2. Tubing:

   A. Materials:
      (1) Steel
      (2) Copper
      (3) Plastic

   B. Sizes: Measured by outside diameter and are found in 3/16" - 1/4" - 5/16" - 3/8" - 1/2" - 3/4" sizes.

3. Hoses:

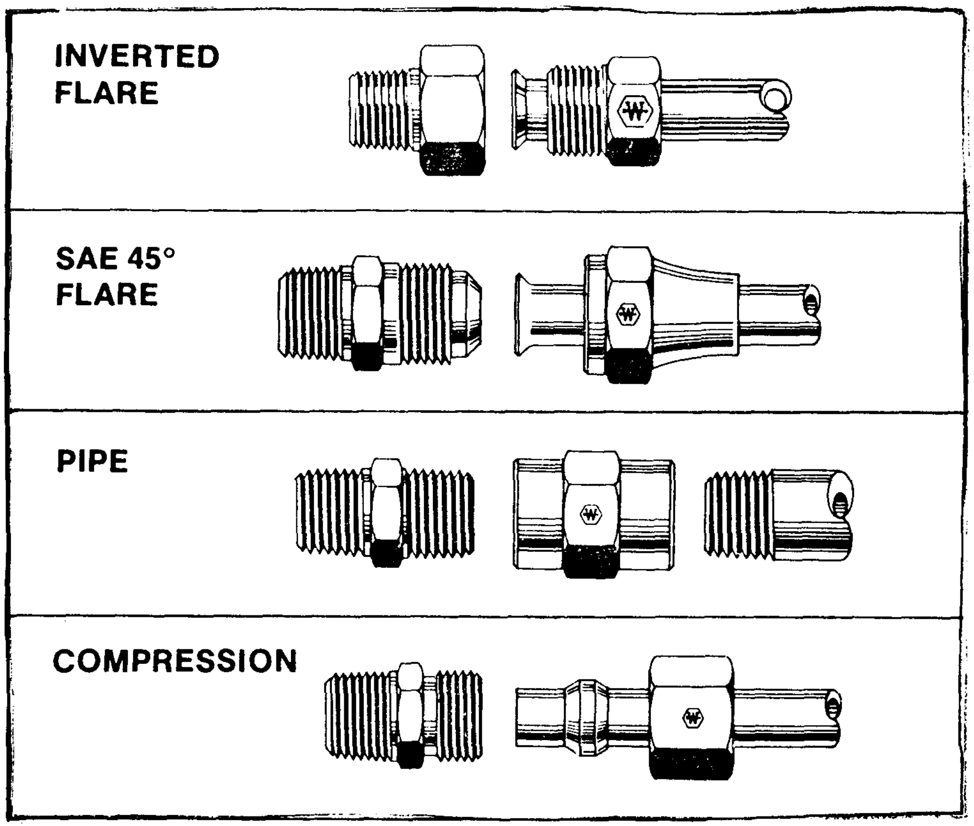
   A. Types: Water, oil, fuel and vacuum hoses:

   B. Sizes: Measured by inside diameter and are found in 7/4" - 5/16" - 3/8" - 1/3" - 5/8" - 3/4" sizes.

4. Pressure or Multi-ply hoses: Reinforced with nylon or steel are measured by inside diameter. NOTE: Hose size numbers are the numerator of the fraction of equivalent tubing size measured in sixteenths of an inch.

   EXAMPLES: #5 Hose = 5/16" tubing
   #6 Hose = 3/8" tubing
   #8 Hose = 1/2" tubing

BRASS FITTINGS



Diesel Fuel Systems

Introduction

Unlike many other engine areas, fuel systems do vary quite drastically. We will attempt to describe the different types of fuel systems and their operation by using illustrations taken from engines which use the particular type of system. It is to be remembered that several of the engine manufacturers do use very similar fuel systems.

It is a general practice in the Diesel service industry, however, that fuel system work is a specialty field. By this we mean that normally each service shop has only one or two people who work with fuel system components. This arrangement has grown out of the technicality and individuality of the activity related to a particular engine maker's fuel system adaptations. Therefore, while general information and some fuel system lab experience is valuable to the student and apprentice Diesel technician, specific training in fuel system maintenance and repair is perhaps better left for specialty training later in the carreer.

Fuel systems for Diesel engines have five principal functions: supply, control, metering, timing of injection and injection.

The first two functions are designed quite similarly in all comparable types of Diesel engines:

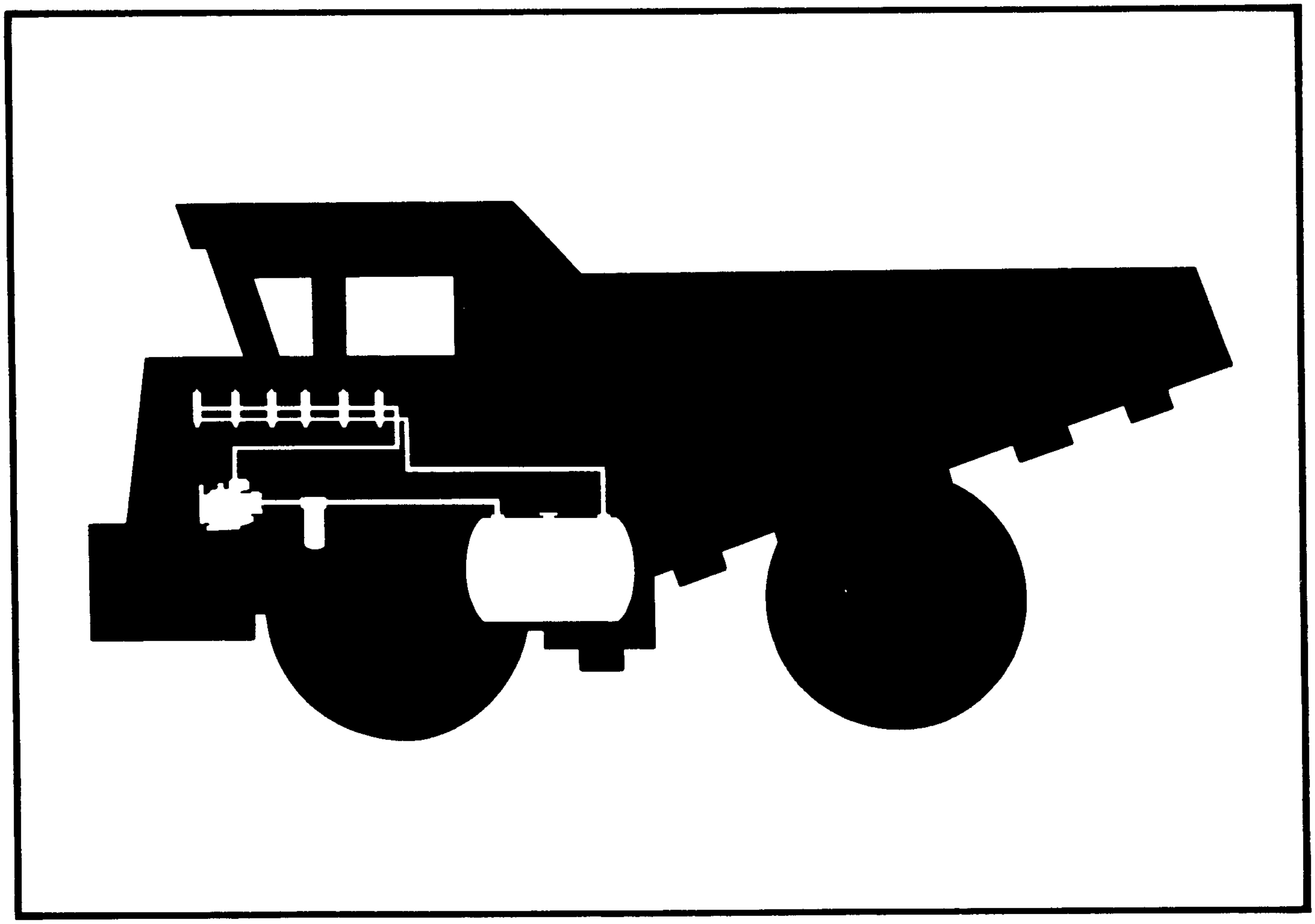
Supply — Fuel is supplied by tanks, lines, filters and creation of flow by fuel transfer pump – usually a gear type pump.

Control — Fuel flow is regulated by an electric solenoid, the throttle linkage and/or a governor which is usually included in the fuel pump.

The chief differences, then, between the several Diesel engine fuel systems is the manner in which fuel is metered, injection timed, and injection mechanically accomplished. These functions may vary as to details between engines of each manufacturer, or from model to model, because each manufacturer adapts a fuel system to his engine design, and often to the operational conditions of the individual unit as well.

Supply And Control

We will be able to cover the first two fuel system functions in a general way, because, in so far as the technician is concerned, they are similar. Specific instruction will, of course, be required in the case of the various governing mechanisms, but you will only be required to work with this device as you progress towards fuel system work in the shop of a particular manufacturer, dealer, or engine user.



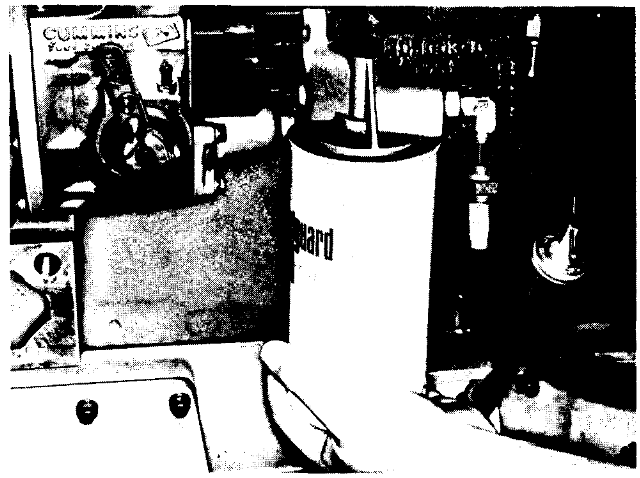
Supply

The first requirement in the arrangement of fuel system components is that the fuel be made available to the engine. This means first of all that the suction generated by the fuel pump will be able to draw fuel through the lines.

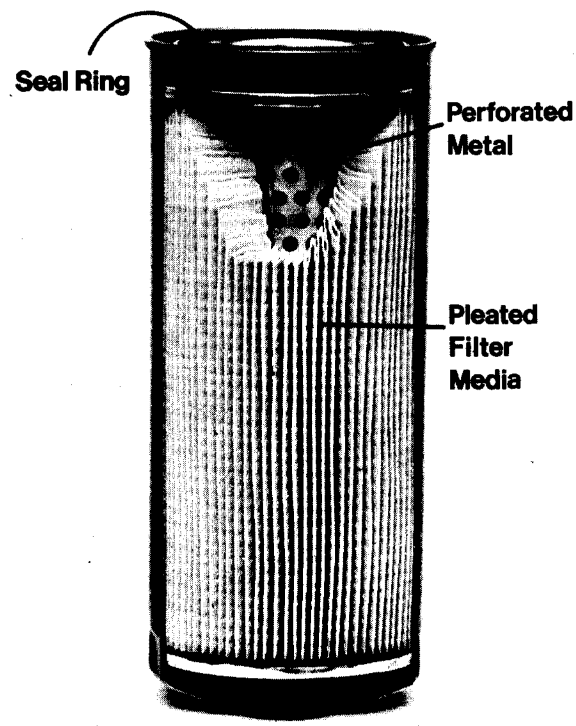
To assure this, the tank must be near enough for pick up, and not low enough to create lift or drain-back problems.

(If tanks are located above the level of the engine fuel pump the system will require some arrangement which will prevent fuel draining into the engine.)

The next requirement is that enough fuel be available — the lines must be the correct size, bends must be wide, and the filter and fittings not unduly obstructive to the fuel flow.



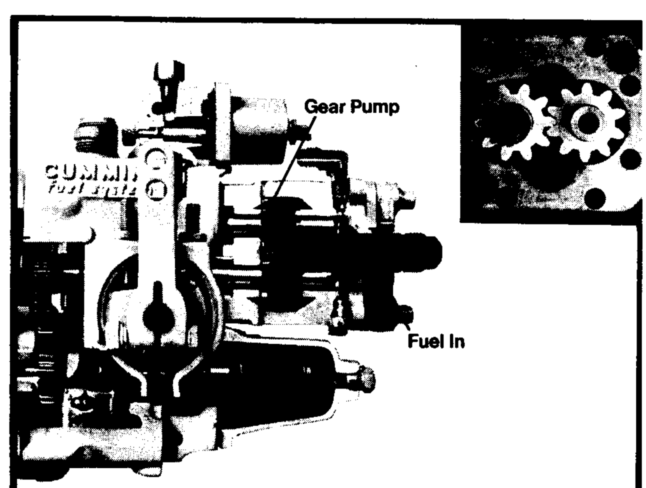
In most Diesel fuel systems the next requirement is fuel filter adequacy; because Diesel fuel often acts as the lubricant for the system, and the intricate working parts of the pump and injectors need adequate protection. Dirt or any type of abrasive, and even water in the fuel can lead to several fuel system problems and parts failure.



SPIN-ON FUEL FILTER

Courtesy of Fleetguard, Inc.

Now if the fuel pump, usually a gear pump, is not worn to an extent which prevents it from creating a vacuum, fuel can be drawn to the engine.



Metering, Injection Timing, And Injection

The last three functions of a fuel system, metering, injection timing, and injection, do vary among the engine makes with regard to the technical details of operation. Generally speaking, however, they are performed by the fuel pump and the injectors, into which all the required controls and regulatory equipment can be designed.

Many hours of study and experience are required to prepare the technician for effective repair and adjustment of any one of the various diesel fuel systems. Fuel system work is normally a specialized field within a Diesel shop and frequently is done only by the most experienced personnel. In order to acquaint the student with the general operation and the parts involved, however, each type of system will be described briefly.

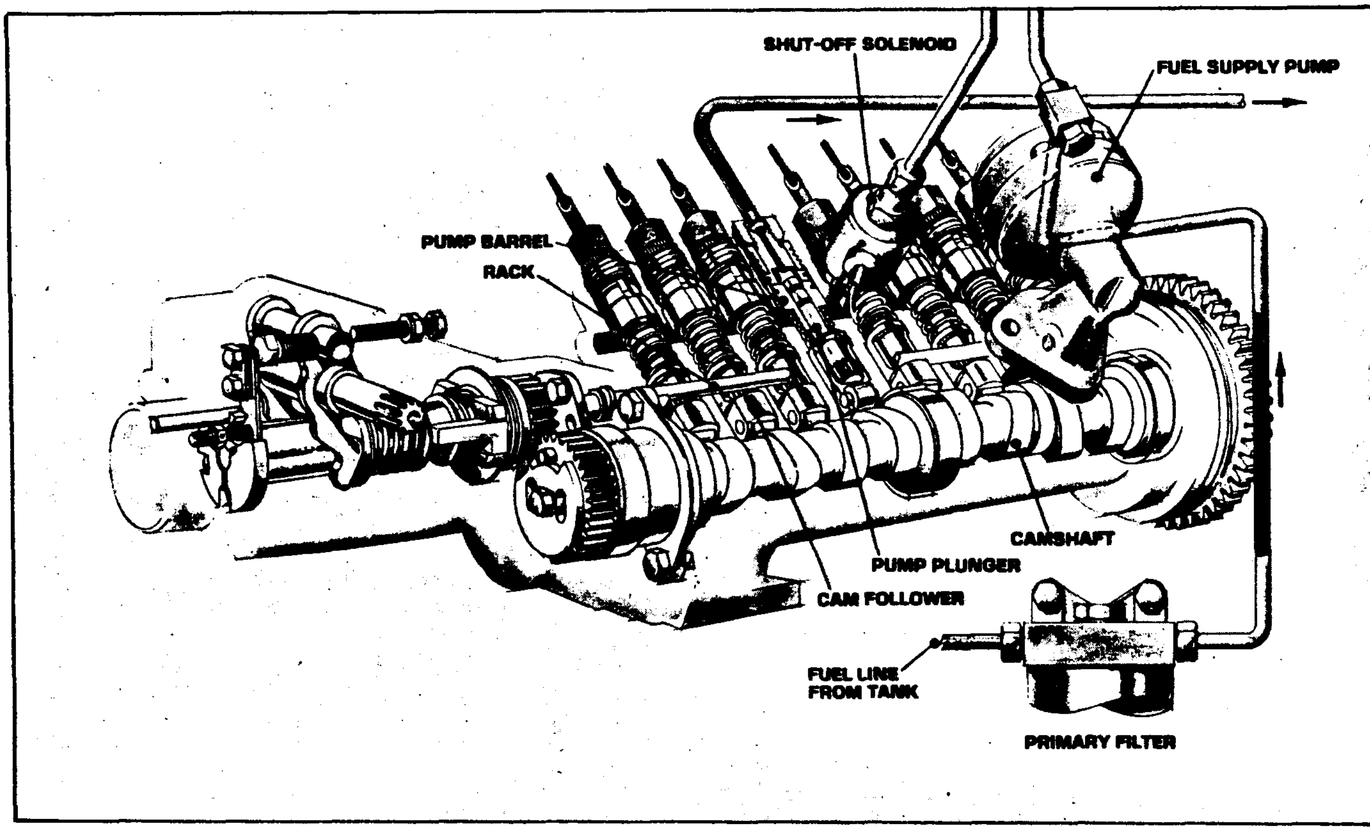
High Pressure Fuel Systems

Most Diesel fuel systems are high pressure fuel systems, where the fuel pump assembly develops high pressure in the flowing fuel and routes the pressurized fuel to the engine, through lines, manifolds and injectors.

Low Pressure Fuel Systems

There is only one low pressure system in general use at the present time. This is the Cummins PT fuel system. In this system the pressure created by the fuel pump and highway or *automotive* governor is quite low – under 200 psi – and the high pressure required for atomizing fuel is created only as the fuel is actually injected.

High Pressure Fuel Systems



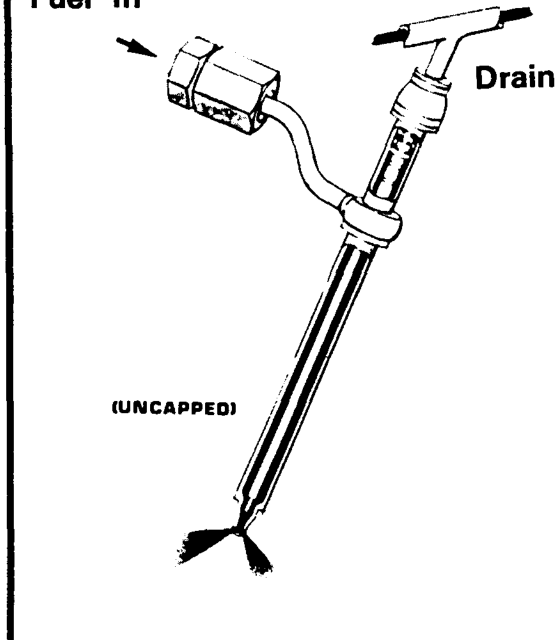
Courtesy of Caterpillar Tractor Co.

Multi-pump Systems

The multi-pump systems usually have a pump housing which contains a positive displacement gear pump to draw fuel from the tank; a camshaft, driven by gears from engine rotation; and the individual pump assemblies which meter and send fuel to each of the individual injectors.

One injector serves each engine cylinder. This type of system is represented in these illustrations of the Caterpillar fuel system.

Also contained in the pump housing in the Caterpillar system is the control unit or *governor*; which is typically composed of sensing weights and regulatory springs.

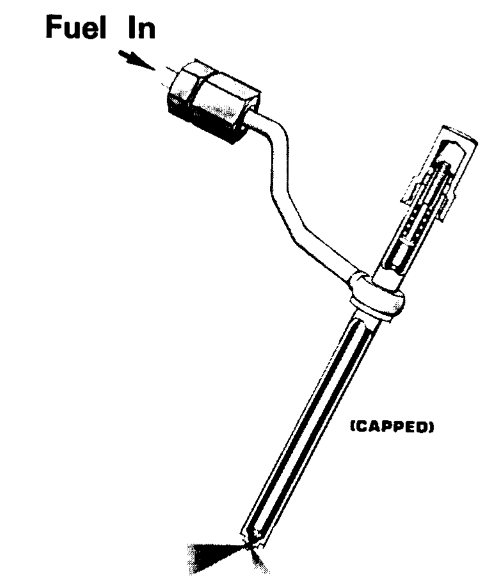


DIRECT INJECTION NOZZLE

Courtesy of Caterpillar Tractor Co.

As the pump camshaft is turned in this type of fuel system, fuel is drawn into the pump and highly pressurized. As the pump unit for each cylinder pressurizes fuel it also meters the amount of fuel called for by the control device. This amount of fuel is then pumped into the fuel line and to the injectors.

In this type of fuel system, fuel lines to the injectors must be the same length and size. This is necessary because pressure at the injectors will vary if different lengths and sizes change the restrictions to fuel flow.



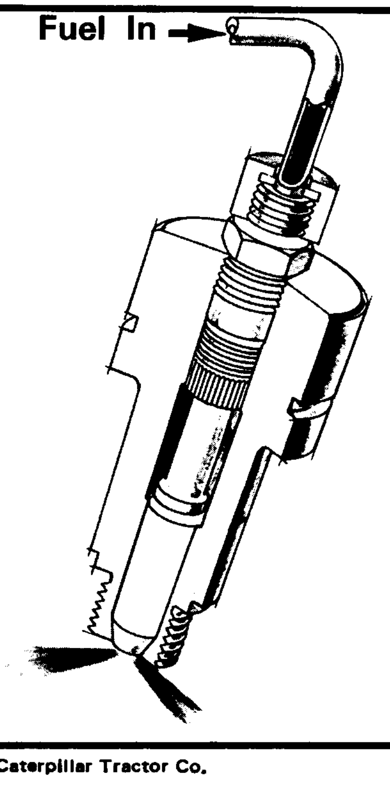
DIRECT INJECTION NOZZLE

Courtesy of Caterpillar Tractor Co.

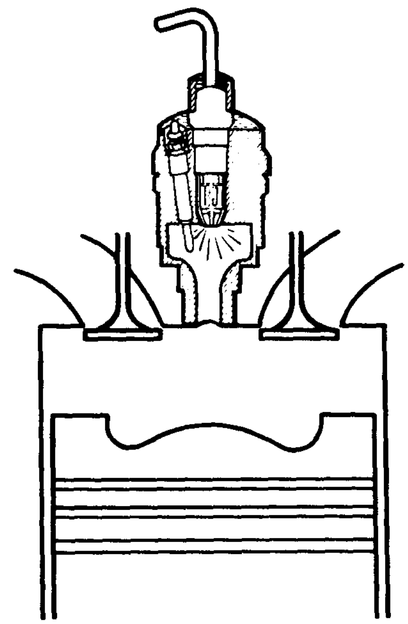
The injectors, hydraulically operated by the pressurized fuel, sense pressure by means of a spring and move to inject the amount of fuel sent them by the pumping unit.

As the pressurized fuel reaches the injector a poppet valve in the injector releases, and the fuel is injected in a fine spray.

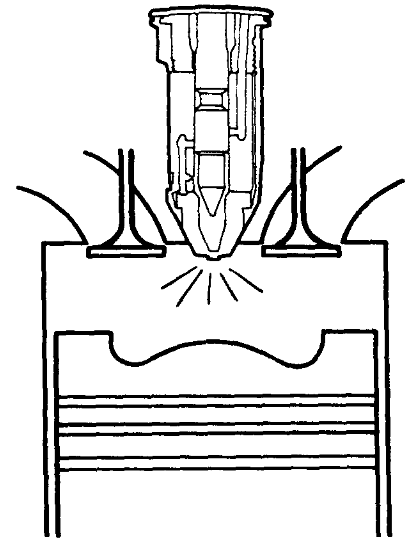
Fuel can be injected into either a pre-chamber or directly into the cylinder, depending upon the design of the system. Caterpillar uses both types of injection in its range of engine models. The injector shown is used with a pre-combustion chamber system.



Courtesy of Caterpillar Tractor Co.



PRE-COMBUSTION CHAMBER



OPEN COMBUSTION CHAMBER

Pre-Chamber Ignition

In the pre-chamber method, fuel is injected into a small open space outside the combustion chamber proper. A heated glow plug, which extends into the pre-chamber, starts the atomized fuel burning.

The partially ignited fuel travels on towards the combustion chamber and enters the hot compressed air above the piston. Burning becomes more intense as the fuel mixes with air which provides the needed oxygen, and high combustion pressures are created to force the piston down in the cylinder.

Open Chamber Ignition

In the open chamber system of fuel ignition the injector tip extends slightly into the combustion chamber just above the piston. Fuel is injected directly into the heated air swirl created by the piston compression stroke. The air has been trapped in the cylinder by closed valves and the rising pistons. The atomized fuel is ignited solely by the heat of the compressed air and gradually ignites until it is completely burned. This gradual burning of the fuel results in constant pressure against the piston as it is forced downward.

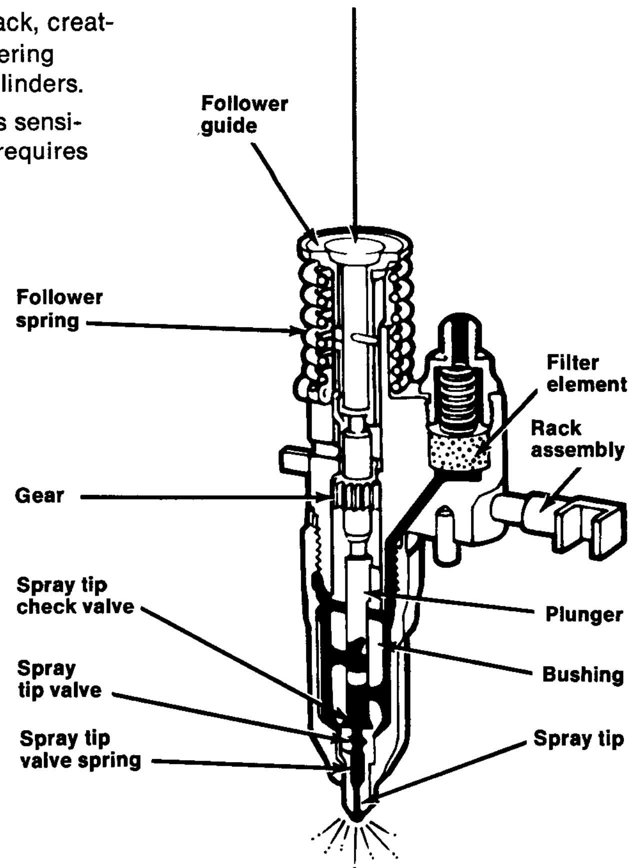
The unit injector system

The unit injector system places both the metering and injection functions in the injector. The principle of metering with a plunger pump, helix, and fuel rack is similar to the multiple pump system, but takes place in the individual injector.

Rotation of the plunger by the fuel rack changes the helix position and controls metering. The plunger pump forces fuel past the spray tip valve (injection valve) and into the combustion chamber.

This system is complicated because each injector has a fuel rack, creating problems of even metering and synchronization of cylinders.

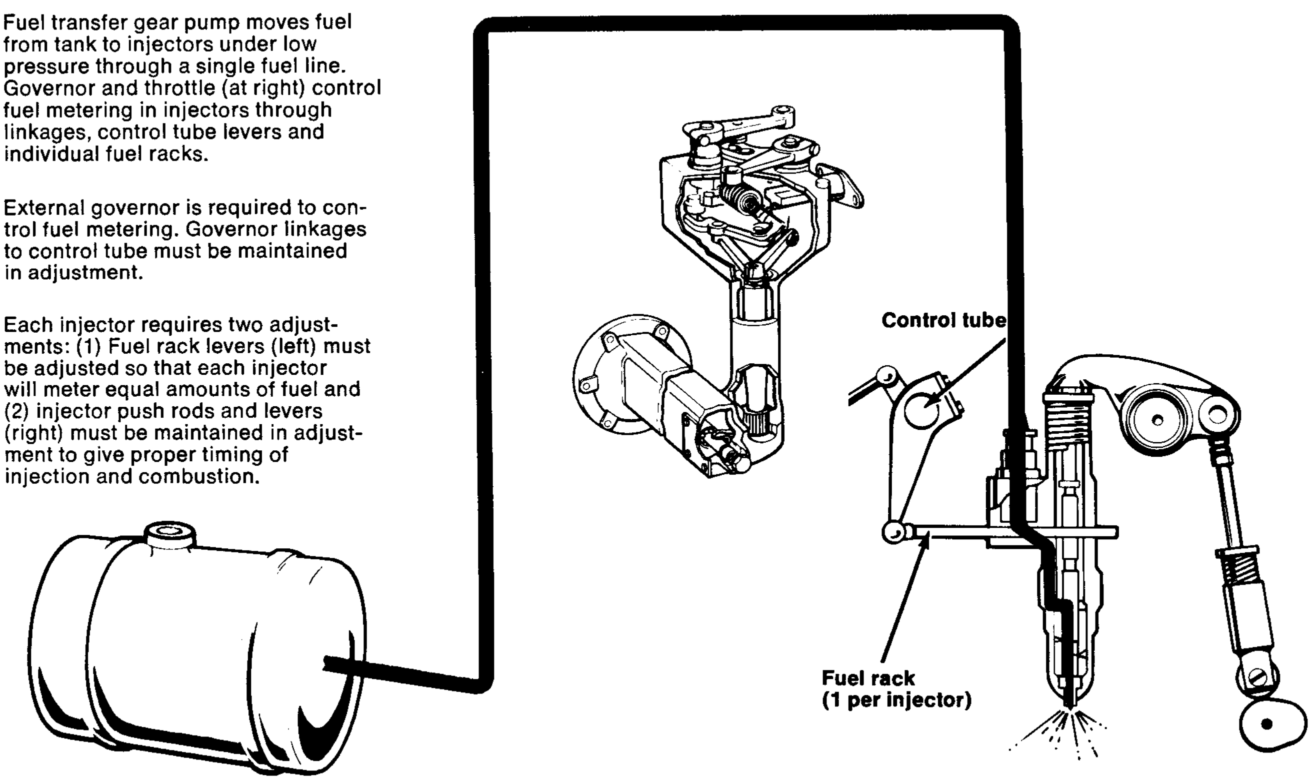
The unit injector system is sensitive to fuel grades and requires premium fuel.



Fuel transfer gear pump moves fuel from tank to injectors under low pressure through a single fuel line. Governor and throttle (at right) control fuel metering in injectors through linkages, control tube levers and individual fuel racks.

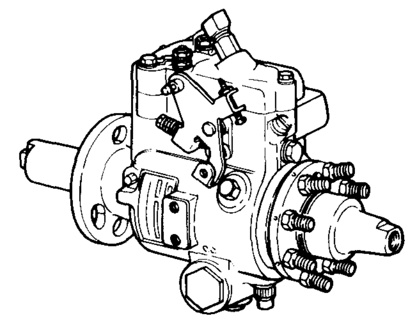
External governor is required to control fuel metering. Governor linkages to control tube must be maintained in adjustment.

Each injector requires two adjustments: (1) Fuel rack levers (left) must be adjusted so that each injector will meter equal amounts of fuel and (2) injector push rods and levers (right) must be maintained in adjustment to give proper timing of injection and combustion.



Distributor Injection System. The operation of this pump is similar to that of an automotive distributor. In addition, the hydraulic head of the pump resembles a distributor cap (Fig. 106). Unlike the pump-controlled system and the common rail system, the internal operation of the distributor injection system is rotary rather than reciprocating. The fuel enters this pump through the center tube in the hydraulic head (Fig. 107) and goes through a metering valve controlled by the accelerator pedal and governor.

The fuel is fed through a charging port to the two pumping plungers. These plungers are actuated by a rotating, circular cam, which has two lobes on it for each cylinder in the engine. The cam pushes the two plungers together, pressurizing the fuel. The pressurized fuel opens the delivery valve, exposing it to a rotor. The fuel is then distributed to the proper injector by the alignment of the ports on the rotor to the head of the pump. This action is similar to the way a rotor distributes the high-tension voltage to the different spark plugs in an automotive distributor. From the head of the pump, the fuel flows through the high-pressure lines to the injector.



DISTRIBUTOR INJECTION SYSTEM

FIGURE 106

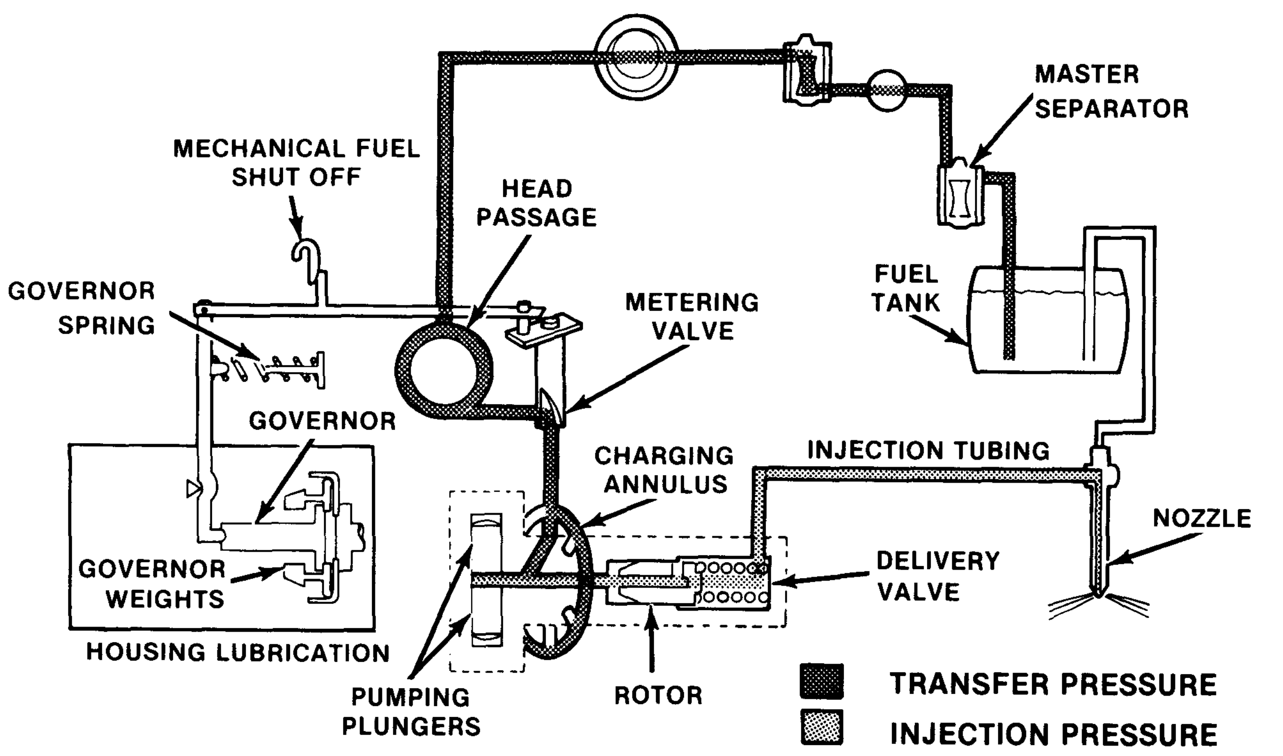
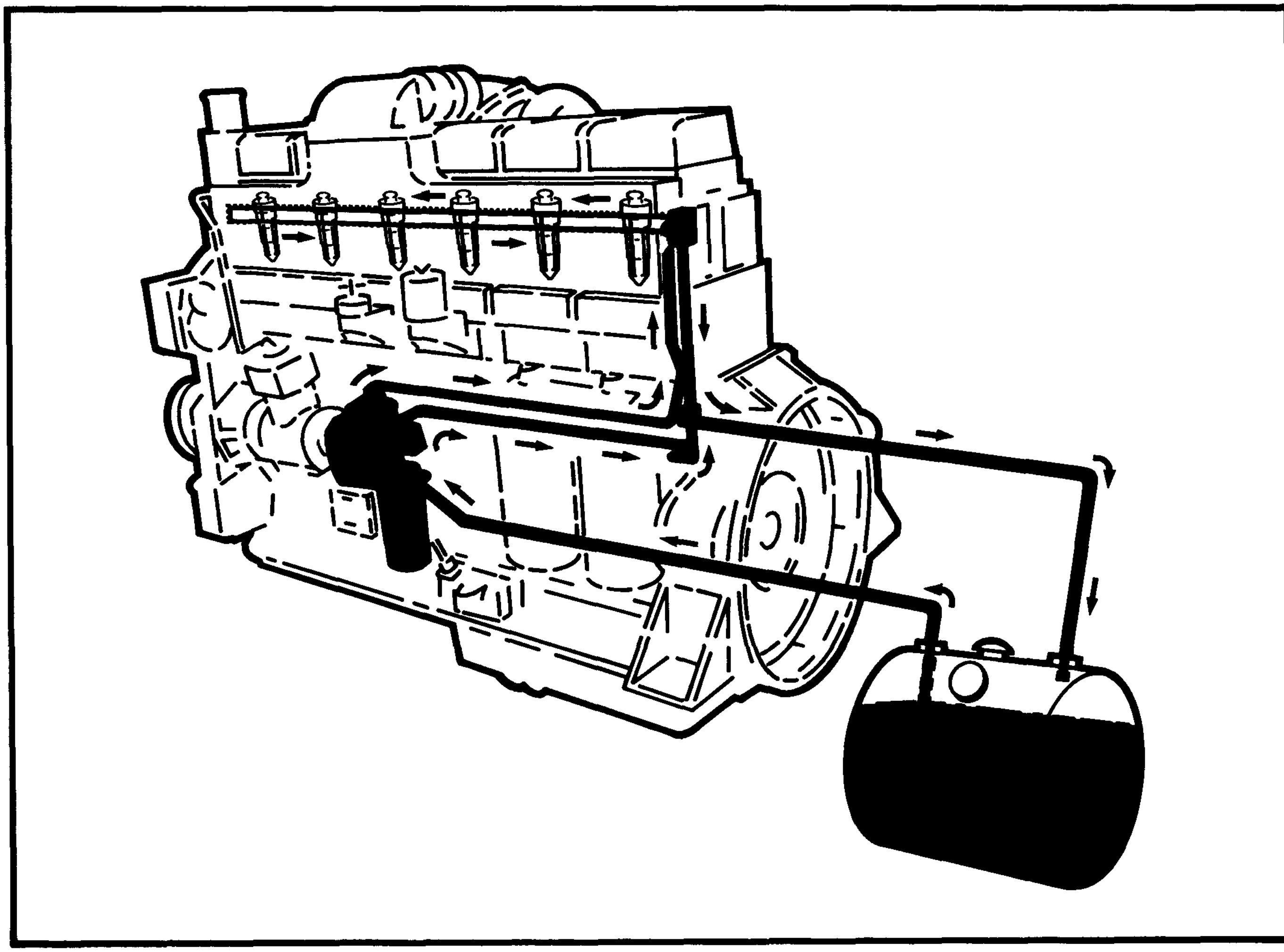


FIGURE 107

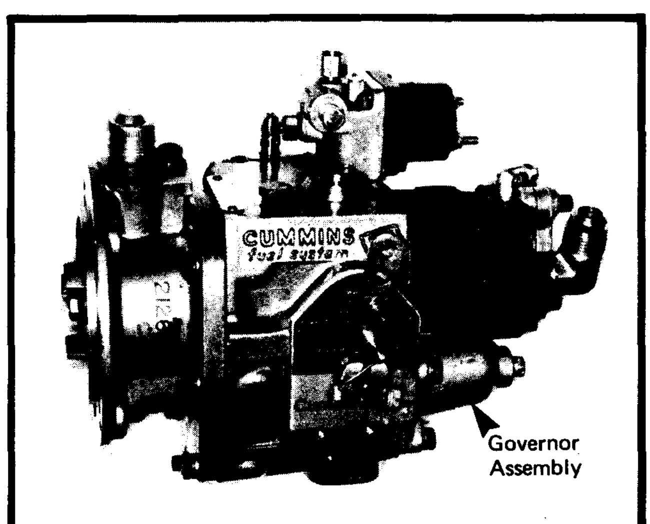
Low Pressure Fuel System



PT Fuel System

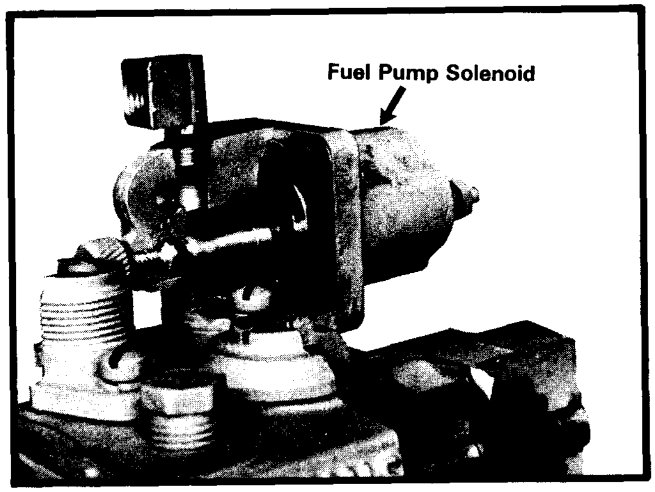
At the present time the only Diesel engine using a low pressure fuel system is the Cummins engine. The Cummins PT system uses a distributor type fuel pump, with a positive displacement gear pump to provide fuel flow.

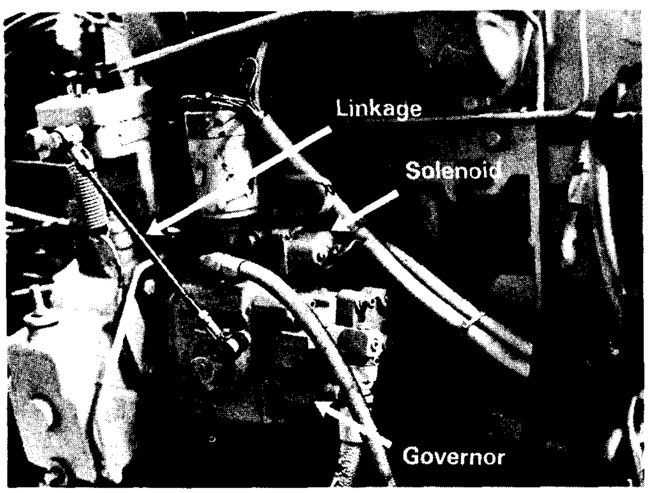
A governing device, which is part of the pump, increases or decreases fuel pressure to a fuel manifold which serves all injectors equally.



Control

Control of the fuel system is generally linked with the ignition switch of the engine, in relation to its activation. There is normally a solenoid of some type which, when activated electrically, will permit fuel to flow from the supply system to the engine fuel manifold and injectors, thus being available for combustion.

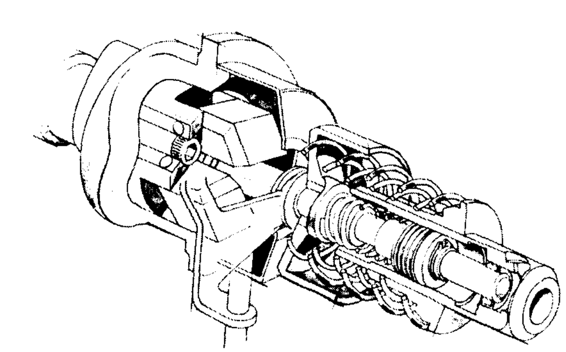




Once the fuel system is activated, the amount of fuel which flows in the system can be varied in one of two ways:

(1) Linkage

By a manually operated linkage which increases or decreases the fuel sent to the engine as required by the operator, as we normally see in an automotive (highway truck) operation; the throttle linkage, as it is called.



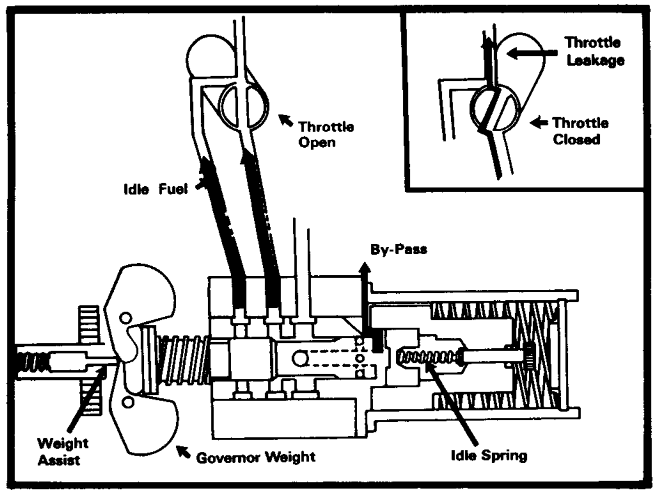
SECTION THRU GOVERNOR

Courtesy of Caterpillar Tractor Co.

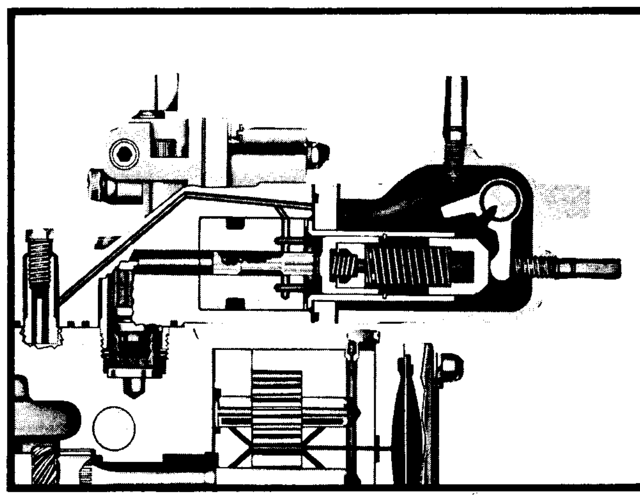
(2) Governor

By an automatic device called a *governor* which is composed of some type of speed or pressure sensing mechanism, along with a spring-regulated restriction which can increase or decrease fuel to the engine. Such a governor is activated by engine speed, or loss of speed. For instance, if the throttle is open but engine speed slows due to an up-hill grade or similar load on the engine, the governor will increase the amount of fuel to bring the engine back up to speed.

This type of governor is normally called a *highway* governor, because it is the type chiefly used for over-the-road vehicles.



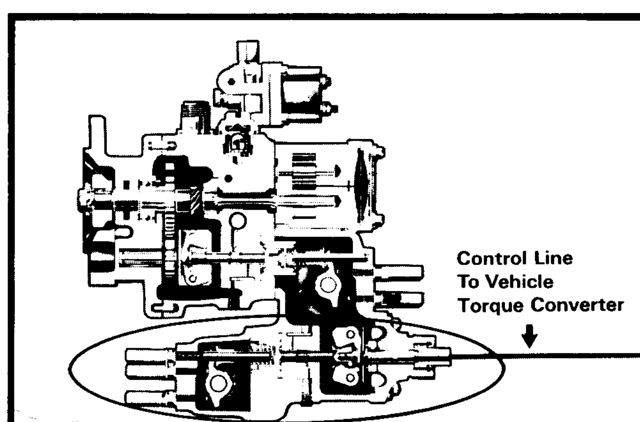
Another type of governor is designed to control engines which must respond totally to engine speed or torque needs, rather than to a throttle linkage controlled by an operator. This type of governor is called a *variable speed* governor.



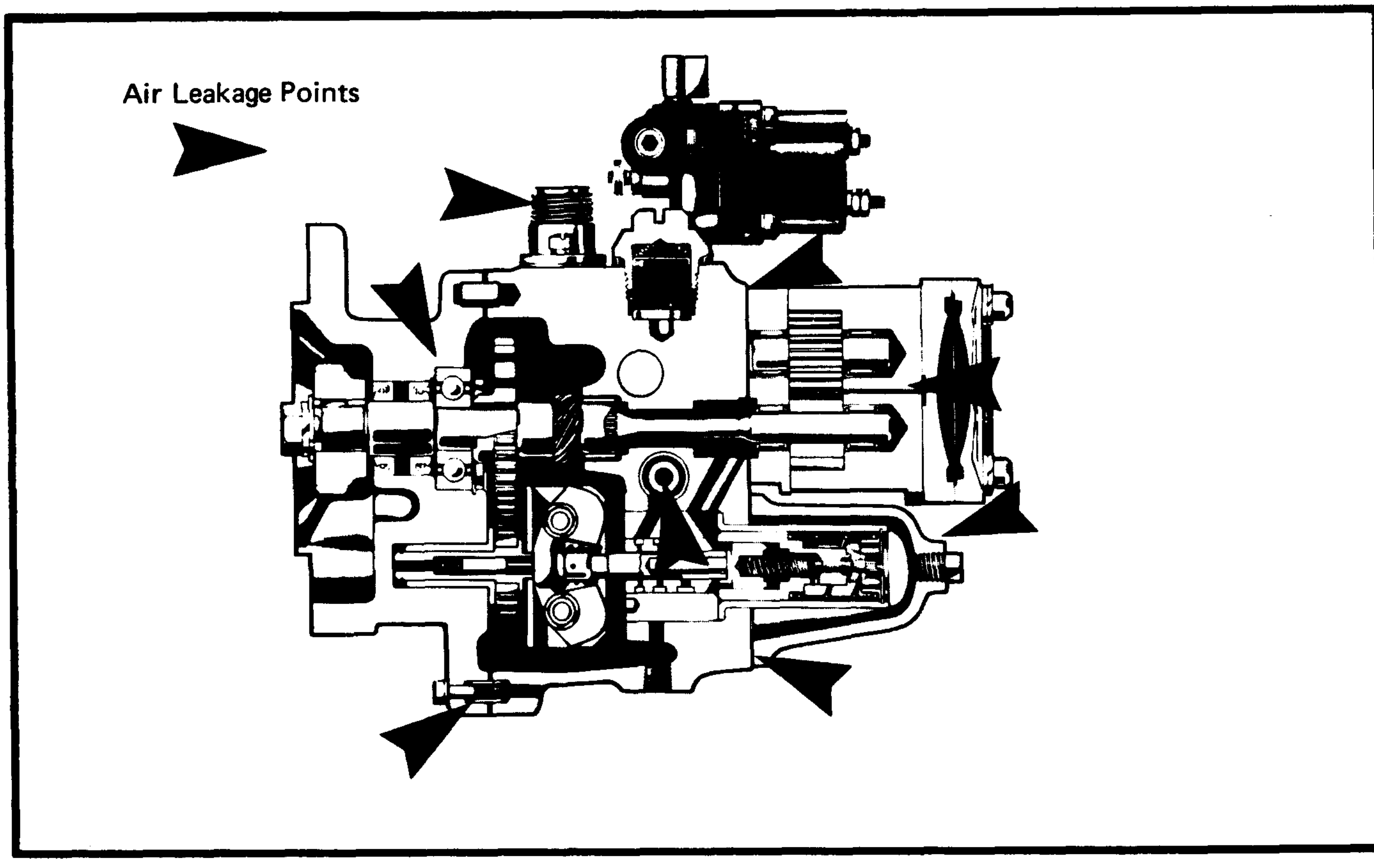
There are several types and makes of variable speed governors, of course. Some sense engine speed and some sense the pressure on the fuel.

The variable speed governors are used on generator sets which must start when electric current is called for, or in pumping operations when water pressure drops, and in other such installations where, very often, no operator is present.

One type, used on cranes, drag-lines, and similar construction machines, senses the speed of the shaft or driveline which attaches the engine crankshaft to the driveshaft of the operating shovel, drag-line or similar machinery. Such a governor is normally called a *torque converter* governor because it senses the change of speed at the torque converter in the driveline.



TORQUE CONVERTER GOVERNOR



Fuel Pump Air Leakage Points

The final aspect of the fuel supply system which is applicable to any of the various models of engine, is that all seals and fittings must be air tight.

This is true, of course, because along with the fact that fuel induction requires a vacuum, or suction, comes the fact that almost anything exposed to atmospheric pressure tends to be drawn into such a vacuum. Therefore, a break in a line, a loose or cut thread at a fitting, or a broken seal will draw air (or even water) into the system as well as it will draw fuel.

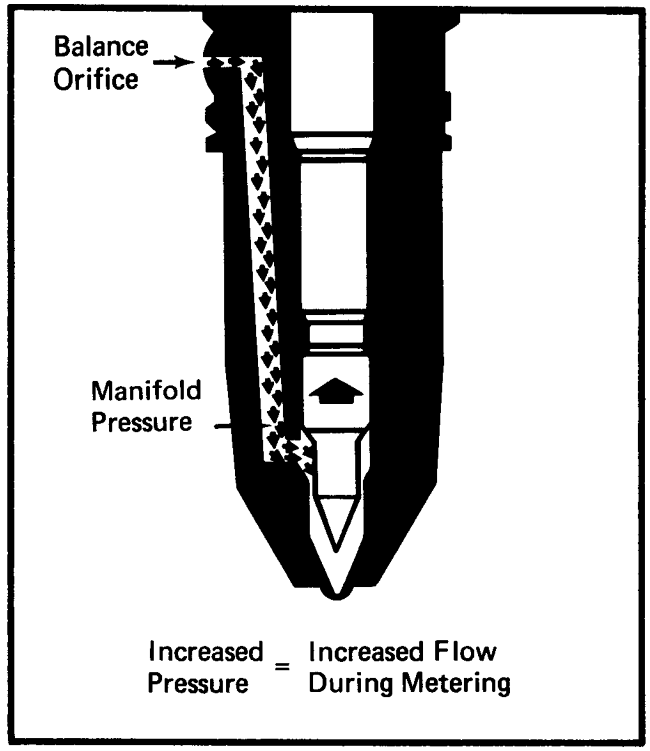
And, of course, anything that can be drawn in more easily than the fuel will displace fuel. The presence of water or air in the fuel will be indicated during engine operation by hard starting, uneven engine operation and low power, and even engine dying after start-up.

PT injectors are operated mechanically by the engine camshaft, with the time for injection determined by the shape of the cam.

The metering function of the PT injector is the result of two things:

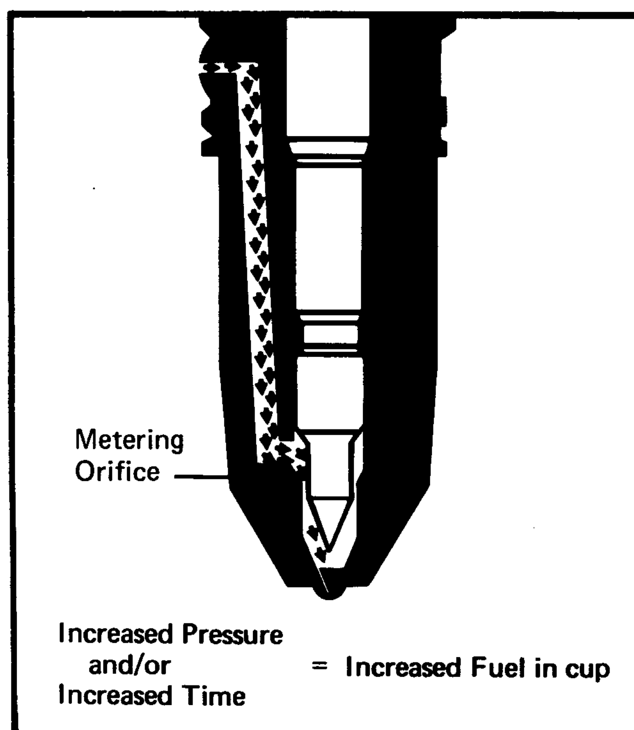
- The amount of time allowed for injection of fuel by the engine cam lobe and injector design.
- And the pressure on the fuel in the manifold, as created by the governor.

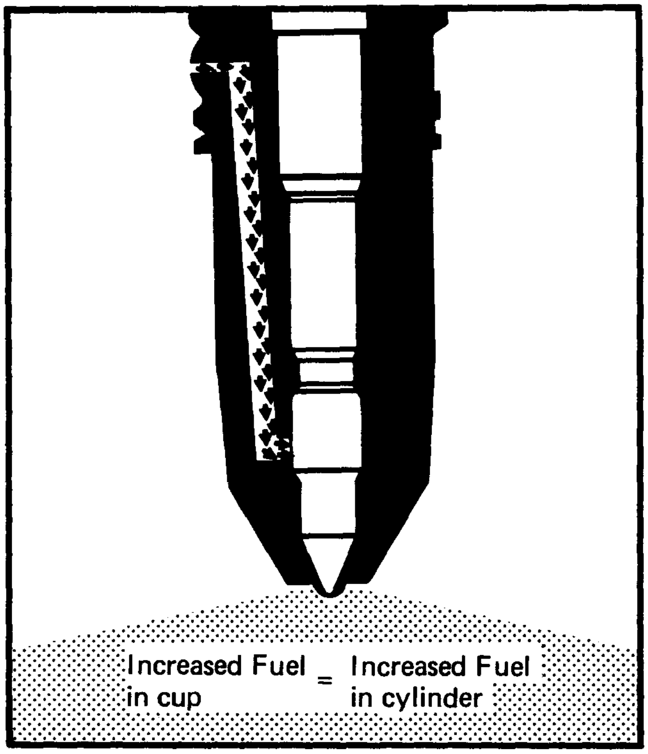
(The PT system gets its name from the first letters of pressure and time.)



For any one engine, then, this timed opening of the metering orifice corresponds to the floodgate. Fuel pump pressure is felt in the injector from balance orifice to metering orifice, so the time the metering orifice is uncovered plus the amount of pressure, will determine how much fuel is pushed into the cup.

All the fuel in the cup is injected into the cylinder. If all cylinder requirements – adequate air at correct temperatures, complete scavenging, and proper seal – are met, the cylinder will produce the power it was intended to deliver.



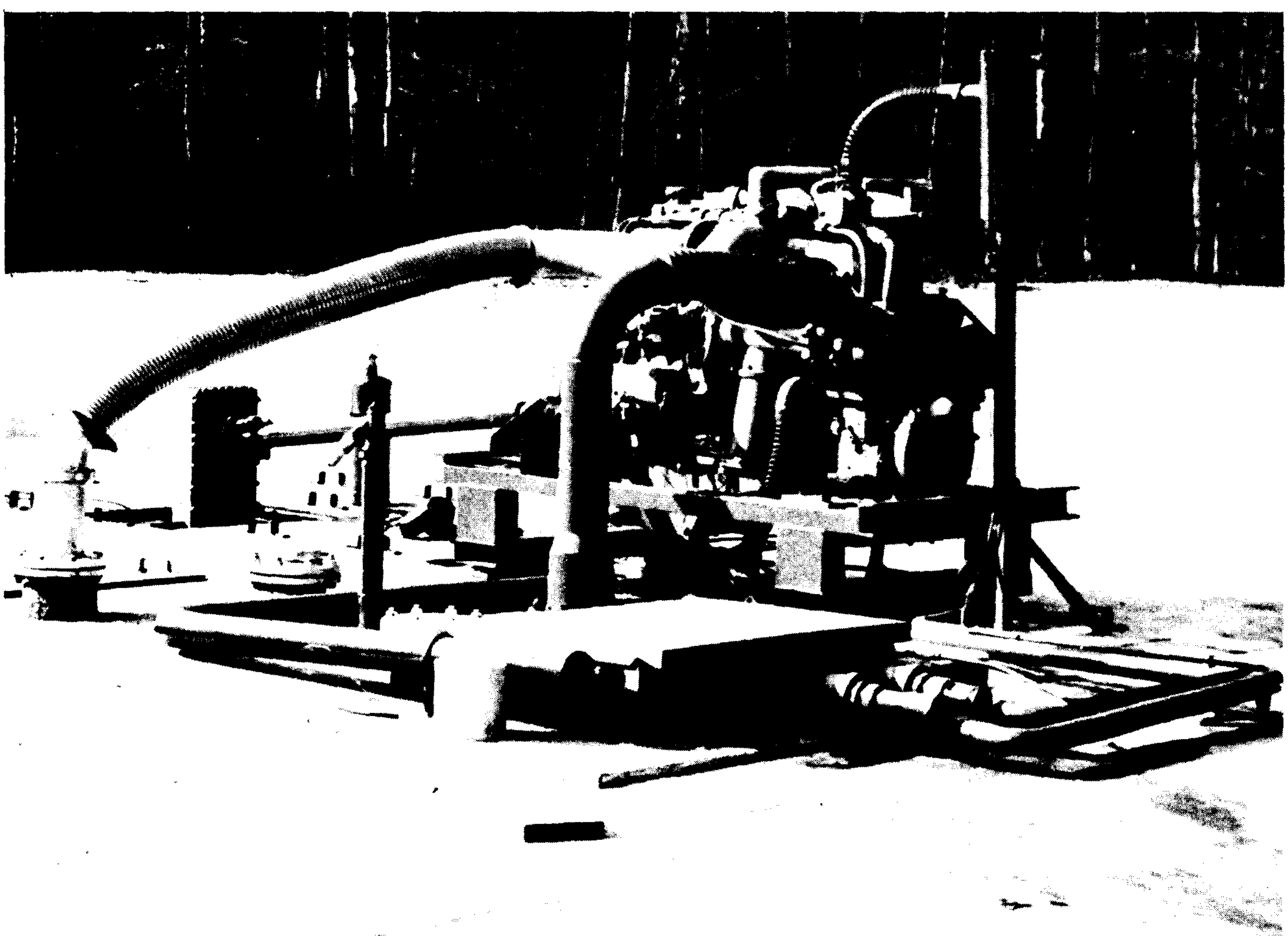


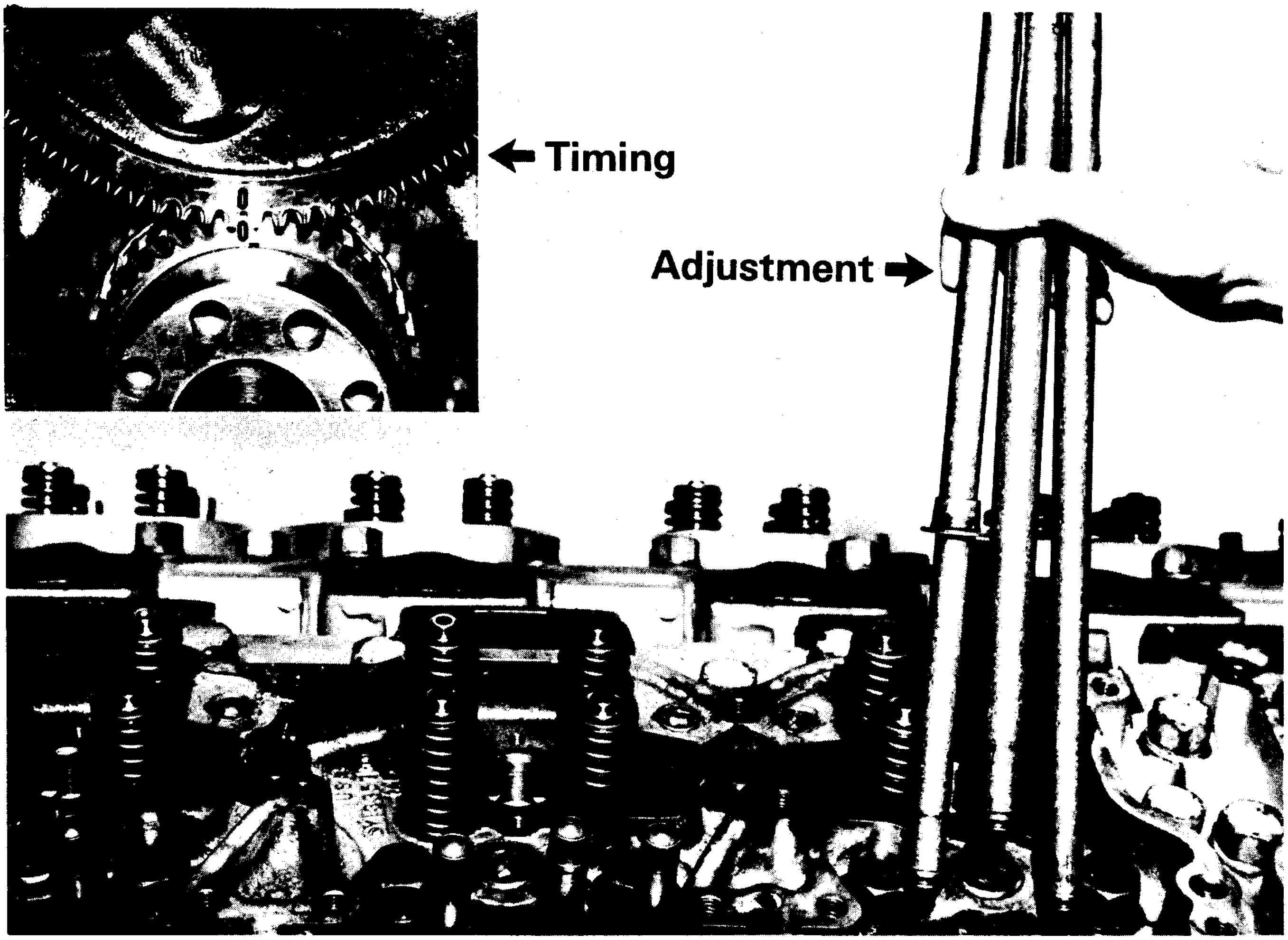
As with the high pressure systems the descending injector plunger creates tremendous pressure on the fuel which atomizes it into a fine spray as it is forced through the tiny holes in the cup into the combustion chamber.

(Note that the Cummins engine also uses an open combustion chamber.)

From this point, engine operation resumes a general similarity regardless of make, as noted for the preceding operation and construction items.

At this point the engine with low pressure fuel system resumes its similarity with a high pressure type engine.





Engine Timing

Engine timing by means of crankshaft and camshaft gear alignment, or similar arrangement dependent upon engine model, generally is accomplished during engine assembly by the manufacturer or at rebuild time.

Since the relationship between camshaft lobe operation of valves and injectors, and the crankshaft operation of pistons and rods is designed into the engine, the technician is chiefly concerned that the correct parts are selected during assembly of a rebuilt engine. He should, however, realize that inspection of the shafts and gears, their proper handling to prevent damage, and check and correction of end play are critical to the operation and life of the engine.

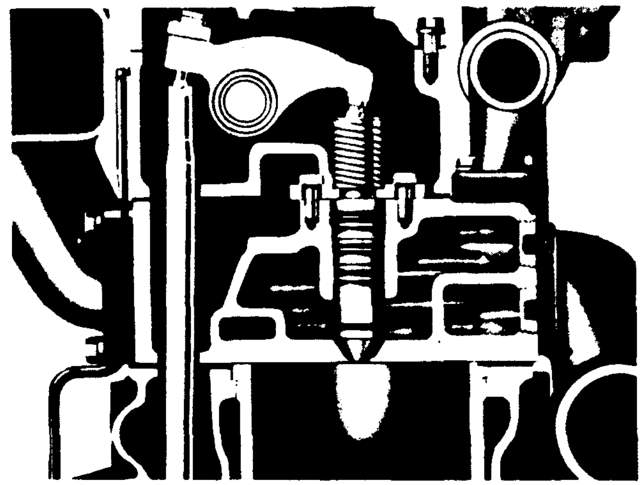
Injection Timing

During engine start up, after rebuild, and during engine tune-ups, adjustment of injector and valve trains is necessary to keep the correct pressure on all parts of the assembly.

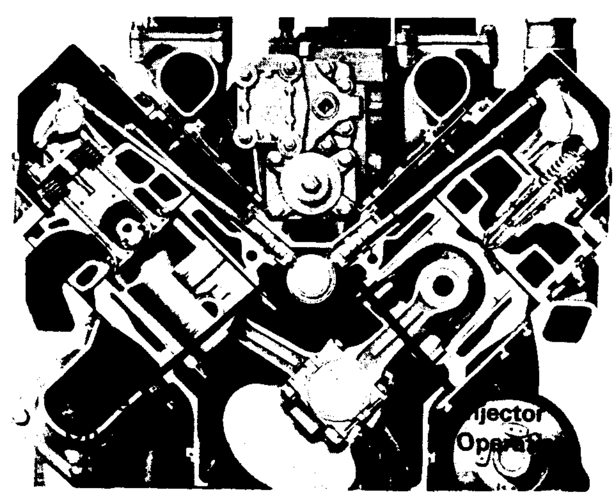
Looseness in valve or injector train, or uneven adjustment, permits injection to be slightly out of time, or valves to remain open or closed too long. Looseness or over-tight conditions in the train also affect lubrication of ball and socket joints and of rockers on shafts, etc. These conditions lead to early engine wear.

Fuel And Combustion In The Cylinder

The combustion of fuel as it is injected into the compressed (heated) air provides pressure against the piston and turns the crankshaft. The condition under which fuel is injected and ignited regulate the amount of *power* or torque produced by the cylinder.



Fuel must be injected into the cylinder while all valves are closed, piston rings seated against the liner wall, and the piston is at top center. At this time the air is tightly compressed and temperatures are high enough to start burning of the fuel – start ignition, in other words.



The relationship between piston movement and the movement of valves and injectors is of prime importance for a Diesel engine.

Engine timing is the process which assures the relationship is correct.

But in addition, the type and condition of the fuel and its atomization drastically affect the completeness of combustion, and so the power exerted on the piston and crankshaft.

Let us look at each of these critical areas separately – starting with the matter of time.

Type and Condition of Fuel

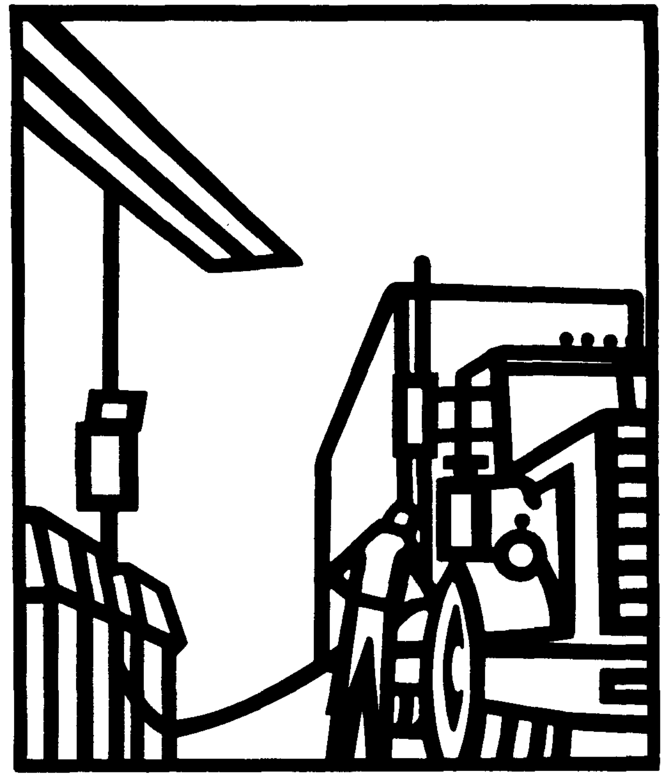
Diesel engine compression pressures are quite high – which means that temperatures are high enough in the cylinder at peak compression to cause combustion of almost any type of fuel which can be finely sprayed into it.

However, the Diesel engine is designed to obtain high pressure from low cost fuels.

Diesel Fuel Origins

Millions of years ago large amounts of organic matter – which means growing things such as trees, grass, sea weed, etc., were laid down during very warm, damp periods of the earth's history. This swamp type layer of organic material often became covered by sea water or earth during periods of violent changes such as earthquakes, floods, etc. As it lay compressed over many centuries it became a solid layer of decomposed matter made up of the water and carbon which are the chief elements present in any vegetation.

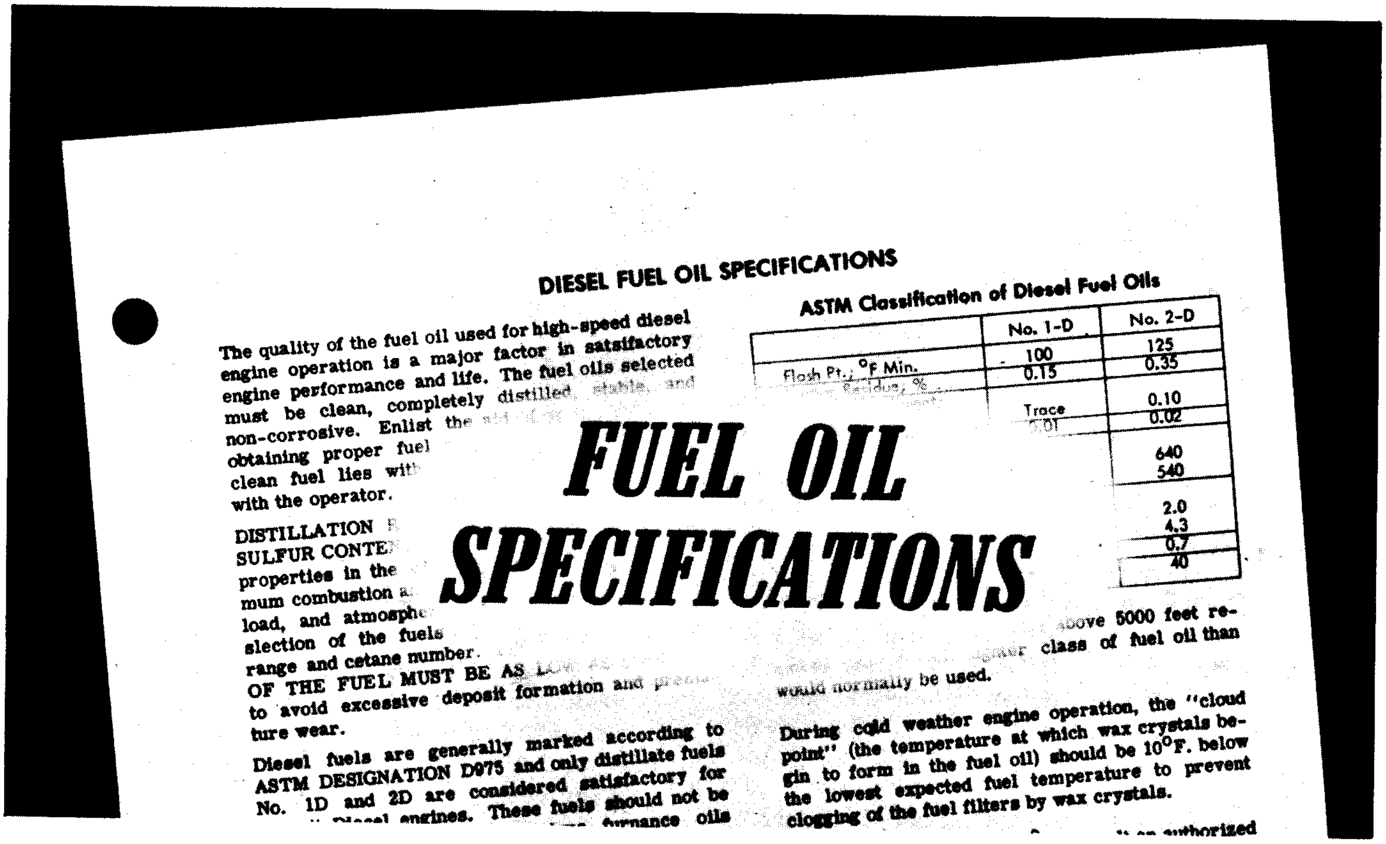
The substance composed of these long compressed organic fluids, called hydrocarbons, is the source of modern petroleum. Diesel fuel is one of the distillates of crude petroleum, along with natural gas, naptha, gasoline, kerosene and other products. For a long time it was much less in demand than gasoline and so much cheaper. It's burning creates fewer harmful emissions than does burning gasoline; this fact, along with the difference in price, has made diesel fuel a popular commodity.



While high temperatures are required to ignite diesel fuel, it will burn gradually rather than instantaneously and provide constant pressure on the piston – thus allowing high engine torque at slower engine speeds as required by heavy duty engines.

Of course, the kinds of steps in the refining processes for various grades of fuel create differences in the final product. Diesel engines are designed to operate at their maximum efficiency on a particular type of fuel. So while the engine will operate on several grades and types of diesel fuel or fuel oil of most any kind, best performance and service life can be obtained by using the fuel grade specified by the manufacturer.

The *condition* of fuel oil which was mentioned earlier refers to age and dilution of fuel – either one of which can reduce fuel efficiency.



Courtesy of Detroit Diesel Allison

Age

Age is not a general problem at this stage of development of diesel fuels – most refiners use additives to prevent rapid breakdown of elements or growth of bacteria in diesel fuel – and use is normally rapid enough to prevent storage age problems.

Dilution

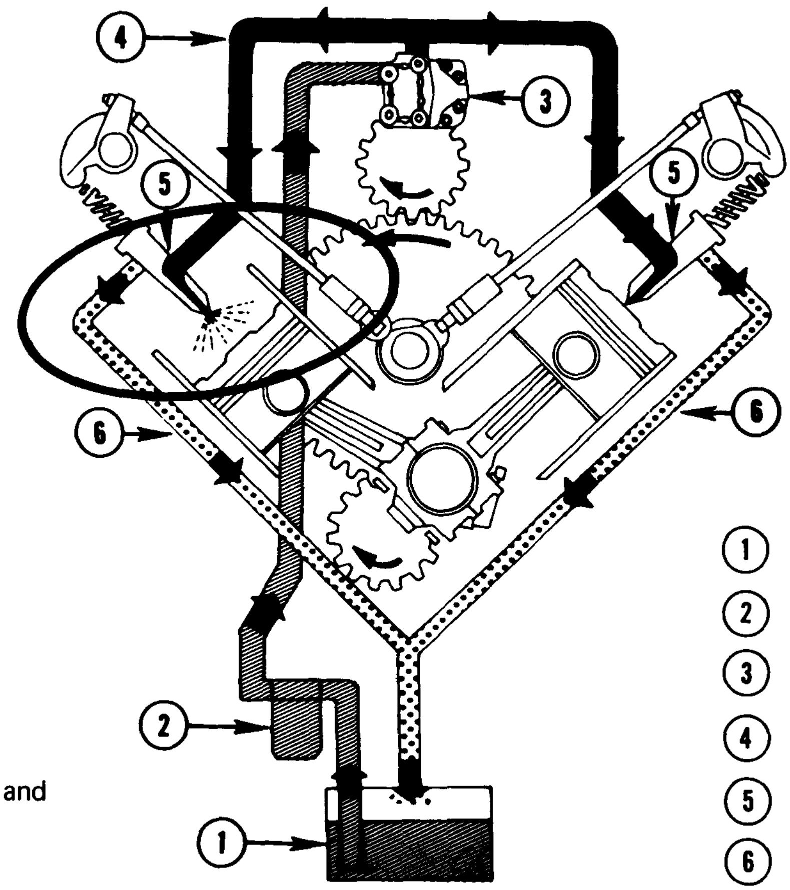
Dilution, however, – by whatever element may be present – is a current problem. Chief among the contaminants causing fuel problems for most diesel engines is dirt. Even small amounts of dirt in a fuel system can be harmful.

This is true mostly because fuel is ordinarily the self-lubricant of fuel system parts in the diesel engine. If fuel is dirty, the lubrication of close-tolerance parts in the system is inadequate and wear is high.

Water dilution also decreases the lubrication property of the fuel, and, in addition, can cause rust on close-tolerance surfaces.

Among fuel contaminants we must list air* – because air bubbles in the fuel stream on the suction side of the pump reduces the amount of fuel and interferes with creation of correct fuel pressure. Air in fuel as it reaches the injector leads to incorrect fuel and air mix and lower combustion pressures; hence lower engine *power*. It can also create *missing* if the injector receives air in large quantities.

*See for suction leakage points in a fuel pump.



Fuel System Components and Fuel Flow

Atomization

The correct atomization of fuel being injected is quite important in most diesel engine systems, since the mixture of air and fuel is required to support combustion.

In pre-chamber injection, fuel will be ignited by the heated glow-plug and then carried into the heated air. In this instance, atomization is somewhat less critical; but in those instances in which fuel is directly injected, ignition is greatly facilitated by atomization which breaks the fuel spray into almost microscopic droplets.

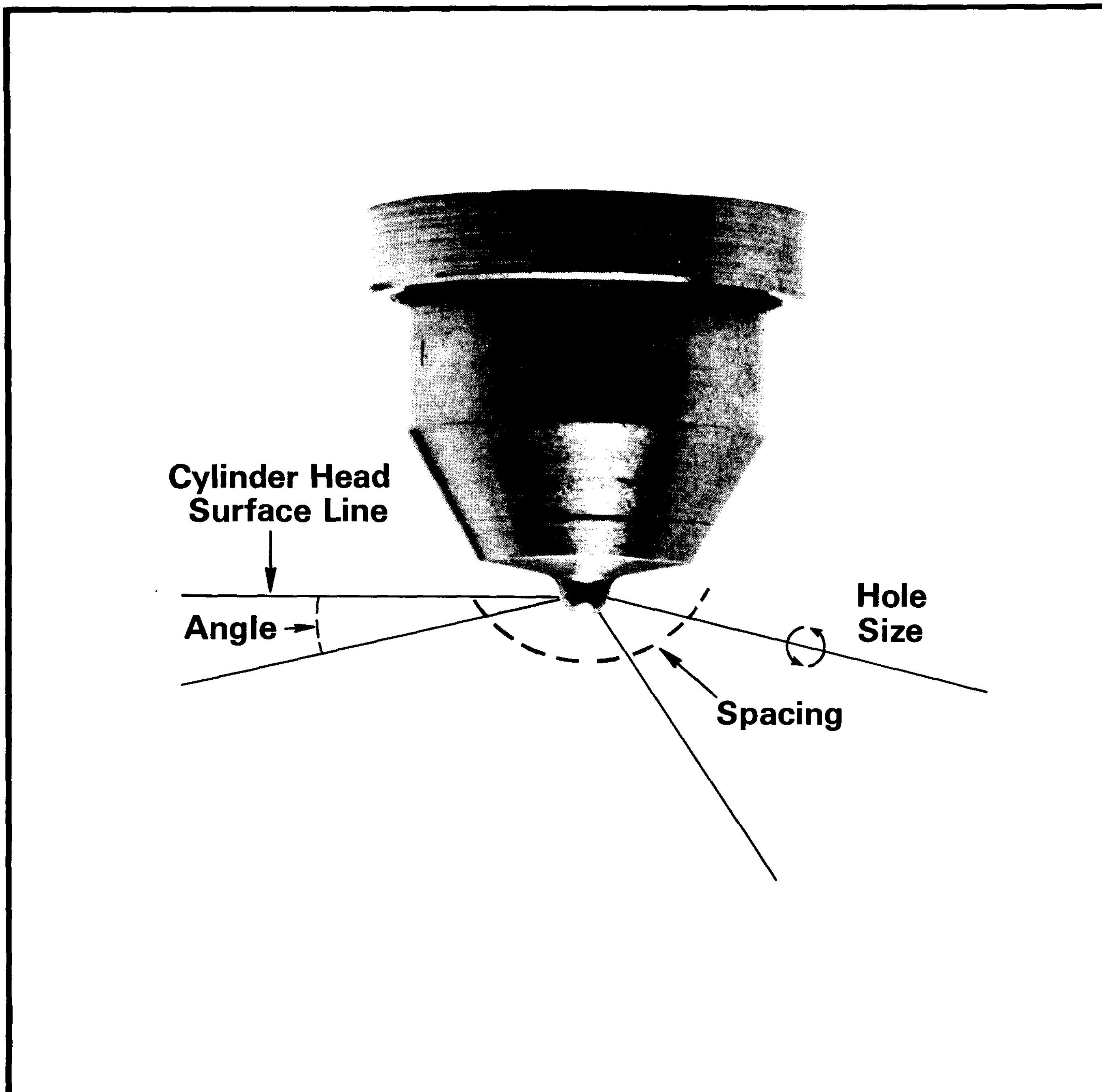
Since complete burning of the fuel depends upon having oxygen to unite with it and support combustion, the fuel will burn most thoroughly when it is evenly and finely distributed throughout the combustion chamber area.

The object of atomization in the Diesel engine is to provide *sustained* combustion rather than instantaneous and short-lived burning of fuel. When fuel can be properly mixed with the air it will continue to ignite all during the downward stroke of the piston. Continued combustion during the power stroke provides the consistent pressure which in turn provides the consistent *power* available from the Diesel cylinder in comparison to the shorter-lived pressures available in other types of internal combustion engines.

Mechanical Aspects of Injection

The mechanical aspects which assure correct injection are:

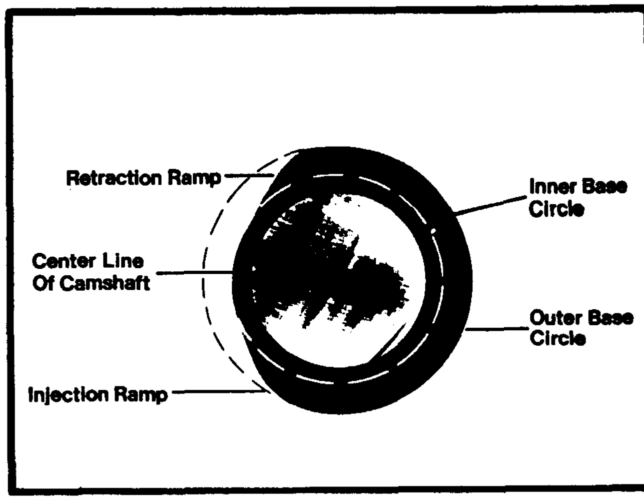
- The right type of hole and correct number of holes in the injector tip, as well as their cleanliness and regularity of surface.
- Correct angle of injection — which requires not only the above, but the correct depth of protrusion of the injector into the combustion chamber.
- Correct injector condition and adjustment.
- The engine parts which accomplish the mechanical operation of the injector. (The injector train parts you learned about in Book 4.)



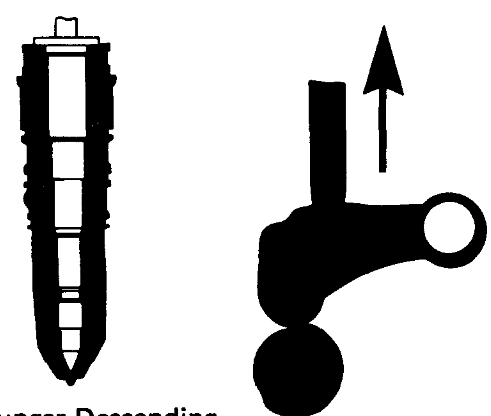
Injector Cam

The eccentric shape of the camshaft lobe which activates the injector has been mentioned but should be looked at more closely. It is much the same in diesel engines in which the injector plunger is mechanically operated, and is illustrated here by a cross-section of a Cummins cam.

The shape of the cam is based on two circles, both concentric to a circle around the centerline of the camshaft. One circle is called the outer base circle and the other the inner base circle, as shown.

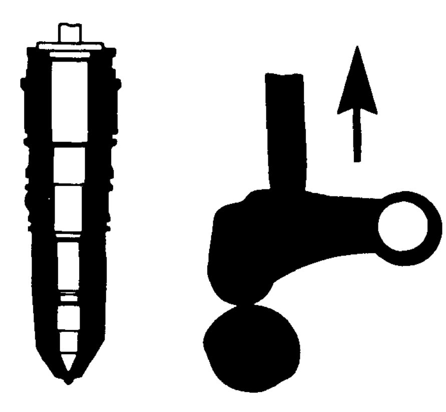


During the time the injector follower rolls over the part of the surface called the injection ramp, the push tube assembly is being lifted – because the follower roller is being moved away from the center point of the cam lobe; and the injector plunger is driven down through its travel distance in the injector; to seat in the cup – injecting fuel.


Plunger Descending

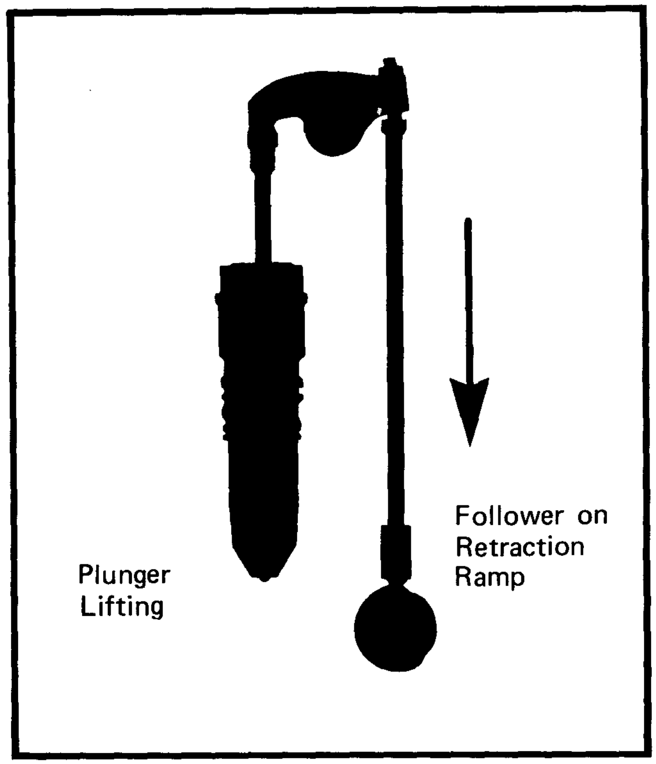
As the roller reaches the outer base circle, it is as far away from the centerline as it will be.

The outer base circle, which forms roughly half of the total cam surface contour, holds the follower assembly in a lifted position because it is furthest from the centerline of the camshaft. This means the rocker is tipped forward and the injector plunger is seated, or bottomed, in the cup. This seals the injector so the combustion pressure and smoke cannot enter the injector body.


Plunger Seated

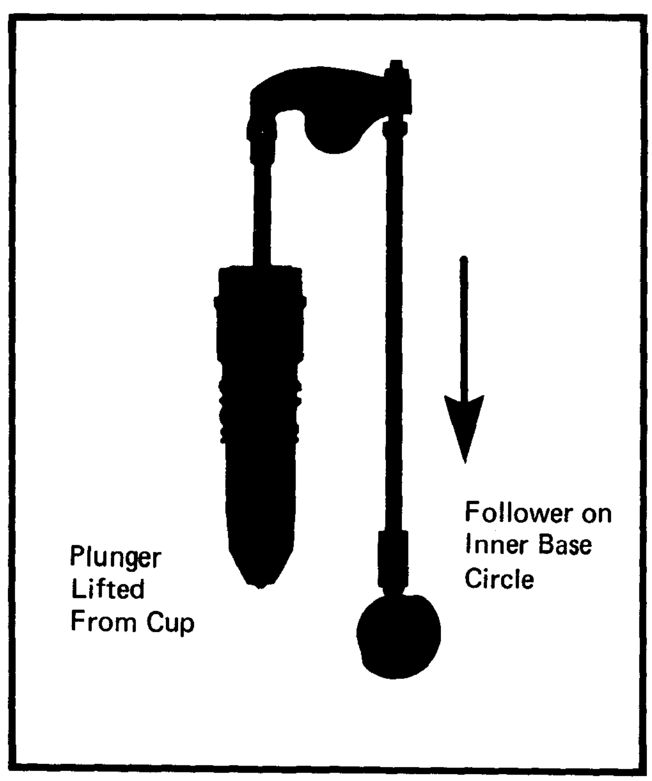
As the follower reaches the retraction ramp it moves from the outer base circle to the surface of the inner base circle which is exposed by the machining of the lobe.

This lowers the follower, the push tube or rod, and the push tube side of the rocker lever. The injector plunger travels upward because as pressure is released on the spring, spring tension raises the plunger.



Now, for the very short time that the follower rides the inner base circle, the plunger is held near the top of its travel and fuel is forced into the cup through the uncovered drilling (is metered, in other words).

And we're back at the injection ramp ready to begin the cycle again.



In Book 4 we learned that in 4-cycle engines the camshaft rotates once to each two (2) crankshaft rotations. Since the piston is activated by the crankshaft, it has risen to top center in the cylinder, and returned to the bottom of travel twice during the above – described camshaft and injector action.

JACOBS BRAKES
SUPPLEMENTARY BRAKING SYSTEM

The use of supplementary braking on vehicles equipped with diesel engines is now common. Jacobs Brakes are the most popular supplementary braking systems used.

1. WHERE THE BRAKING COMES FROM USING AN ENGINE BRAKE

When the engine power is removed from a moving vehicle by removing the throttle input to the engine, vehicle weight and momentum continue to turn the tires against the road surface. This creates a rolling resistance, removing some of the momentum from the moving vehicle.

As the wheels turn, they provide power to turn the rear axles, rear ends (differentials) drive lines, transmission gears, flywheel and crankshaft. The crankshaft in turn moves all the moving engine parts normally moved by the engine when it is under power. These include the water pump, oil pump, fuel pump, air compressor, valve train, pistons and accessories.

The effort to move all these parts absorbs part of the horsepower produced by the turning wheels, and adds to the removing of some of the momentum from the moving vehicle.

The braking effort on the diesel engine driven vehicle is not dramatic.

What is needed is more "load" to enable the engine to effectively remove momentum from the moving vehicle.

The Jacobs Engine Brake does just this--and it accomplishes the additional braking by doing what comes naturally for a Diesel Engine.

2. WHERE THE BRAKING COMES FROM USING A "JAKE" BRAKE

When the engine is producing power, the ignition is supplied by highly compressed air of the compression cycle. Even with the power removed from the engine (such as in releasing the throttle to slow the vehicle) the same compression cycle occurs. The Jacobs Engine Brake modifies the normal engine cycles and enables the act of compressing air to absorb horsepower and dramatically remove momentum from the moving vehicle.

It takes horsepower to compress air! As the piston comes upward on its compression cycle it meets considerable resistance squeezing the large volume of entrapped air into a very small volume.

This absorbs horsepower from the moving vehicle. However, if the engine's normal cycles are allowed to continue the power cycle literally "cancels" the retarding effect. The "Jake" Brake modifies the power producing cycles to power absorbing cycles by changing the engine to an air compressor.

The "Jake" opens the exhaust valves toward the end of the compression cycle releasing the compressed air and the horsepower used to compress it. This "cancels" the power cycle, and only wheel originated horsepower returns the piston to the bottom of the cylinder. The result is a dramatic braking effect.

In the absence of the power cycle due to releasing the compressed air, the momentum of the crankshaft must perform the work of engine rotation to again fill the cylinder with intake air. This amount of work, multiplied by the number of cylinders, plus the already outlined work necessary to drive the other engine components, will absorb much of the horsepower produced by the turning wheels.

Vehicle momentum will thus be efficiently and safely reduced. When properly installed and used, the Jake will provide up to 100% of the braking ability required to hold vehicular speed within safe limits in downgrade operation. Through proper gear selection, consideration for amount of total weight of vehicle and cargo, safe descent speed for conditions, the vehicle braking can be controlled entirely by the "Jake", leaving the friction brakes of the vehicle out of service and on standby for any emergency situation.

3. WHAT CONTROLS THE OPERATION OF THE JACOBS BRAKE (SEE FIGURE A)

Off-On Switch:
Gives the driver initial control-Used during idling to shut "automatic" off. Used to turn brake on.

Free Play Clutch Pedal Switch:
A microswitch attached to the clutch pedal machanism. The switch is "on" when the clutch pedal is all the way up.

Throttle Control Switch:
A microswitch attached to the fuel pump. The switch is on when the throttle pedal is released. (Such as in braking)

The "on-off", the Clutch Pedal Switch and the Throttle Control Switch must all be "on" for the brake to function "automatically".

In normal driving the Off-On and Clutch switch are on. When the driver removes his foot from the accelerator pedal, the fuel pump switch comes on and the brake functions "automatically."

4. HOW THE JACOBS BRAKE CONNECTS TO THE ENGINE (SEE FIGURE B)

As camshaft rotation lifts the injector push tube, lowering the injector for fuel injection, the Jacobs master piston is lifted.

As will be illustrated later, this action lowers the slave piston.

Lowering of the slave piston pushes the exhaust valve crosshead down, opening the exhaust valves at a time when they would ordinarily still be closed for air compression, injection and combustion.

When the valves open, all the air trapped in the cylinder during the time the intake valves were open (the air the piston had to push against on its way up for the compression stroke) is expelled.

Once the brake is installed, an overhead hydraulic "cam" can change the engine from power producer to power absorber.

Crankshaft rotation, when powered by the wheels, is transmitted to the camshaft, just as it is during combustion-powered engine operation.

The camshaft lobes lift injector and valve push rods in sequence as they do during normal operation.

HOWEVER, when a Jacobs brake is installed on an engine, Its action interrupts normal exhaust valve operation.

5. WHAT ARE THE PARTS AND HOW DO THEY OPERATE? (SEE FIGURE B)

A. Solenoid Valve

The electrical impulse forces the plunger down, uncovering the oil inlet drilling. Oil flows through the solenoid into passages leading out to the control valves over each engine cylinder.

At the same time, the solenoid plunger blocks the oil drain line thus holding the oil in the brake housing. This plunger will not return to position until throttle is applied.

When throttle is reapplied the brake is de-energized and oil drains out when the plunger lifts. The inlet line is then closed.

B. Control Valve

Oil from the solenoid enters this valve at the bottom, flows around the floating check ball and out to both the master and the slave cylinder oil cavities.

As the oil cavities above the brake pistons fill, the check ball seats. This maintains oil over both the master and slave piston.

When the rotating cam lifts the injector push tube on the next compression strike, the rocker adjusting screw on the injector rocker is lifted.

This lowers the injector into the cup, ready for fuel injection.

C. Master Piston

The Jacobs master piston, seated against the injector rocker adjusting screw is forced upward as the push tube lifts.

The oil being held in the cylinder above the master piston and across to the slave cylinder is thus compressed. The resulting pressure of oil in the oil cavity (with check ball still seated) forces the slave piston down against the crosshead on which it seats.

D. Slave Piston

Downward movement of the slave piston, forcing early descent of the exhaust valve, opens them prior to their normal function in the cycle.

The piston is near top dead center, the injector is seated preparatory to injection of fuel, and all intake air is compressed in the top 1/16 of cylinder area.

But throttle release has cut off fuel supply--there is little or no combustion. The slave piston has opened the exhaust valves and the compressed air escapes.

The power which normally turns the engine crankshaft has been eliminated.

JACOBS BRAKES

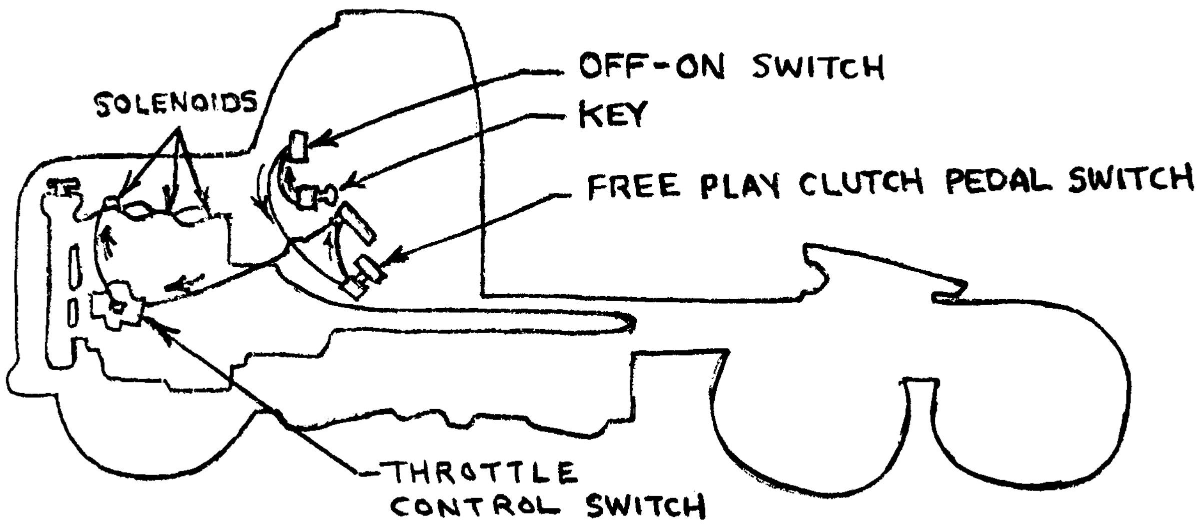


FIGURE A

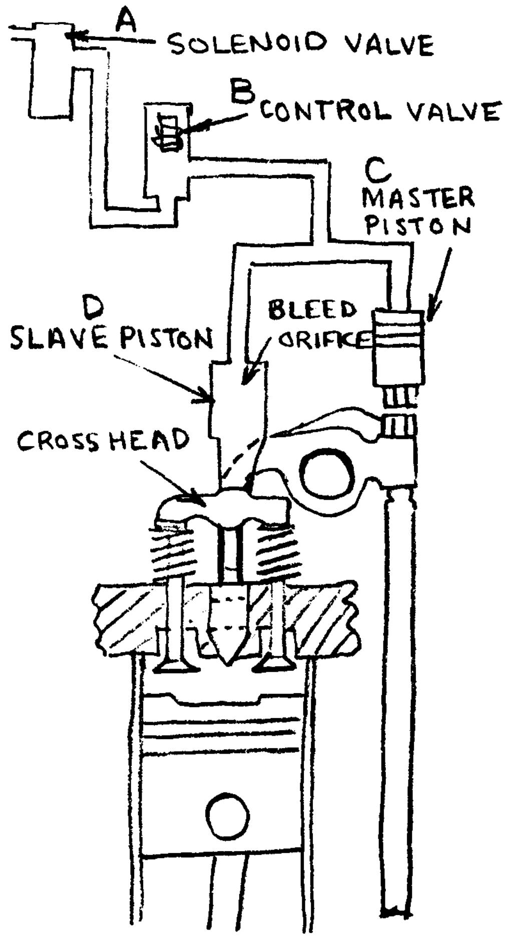
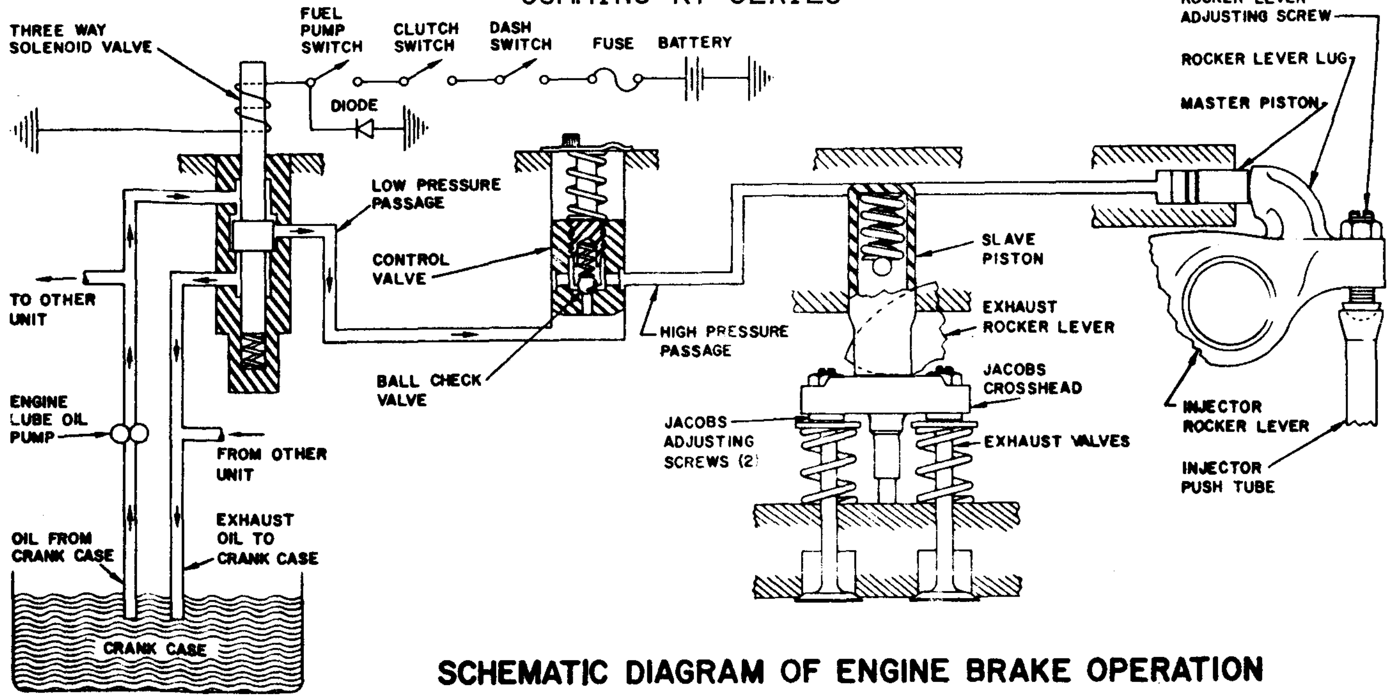


FIGURE B



SCHEMATIC DIAGRAM OF ENGINE BRAKE OPERATION

THEORY OF OPERATION - Simply stated, energizing the Engine Brake effectively converts a power producing diesel engine into a power absorbing air compressor. This is accomplished when desired by motion transfer through a master-slave piston arrangement which opens cylinder exhaust valves near the top of the normal compression stroke releasing the compressed cylinder charge to exhaust.

The blowdown of compressed air to atmospheric pressure prevents the return of energy to the engine piston on the expansion stroke, the effect being a net energy loss since the work done in compressing the cylinder charge is not returned during the expansion process.

EXHAUST BLOWDOWN - Referring to the schematic drawing, exhaust blowdown occurs as follows:

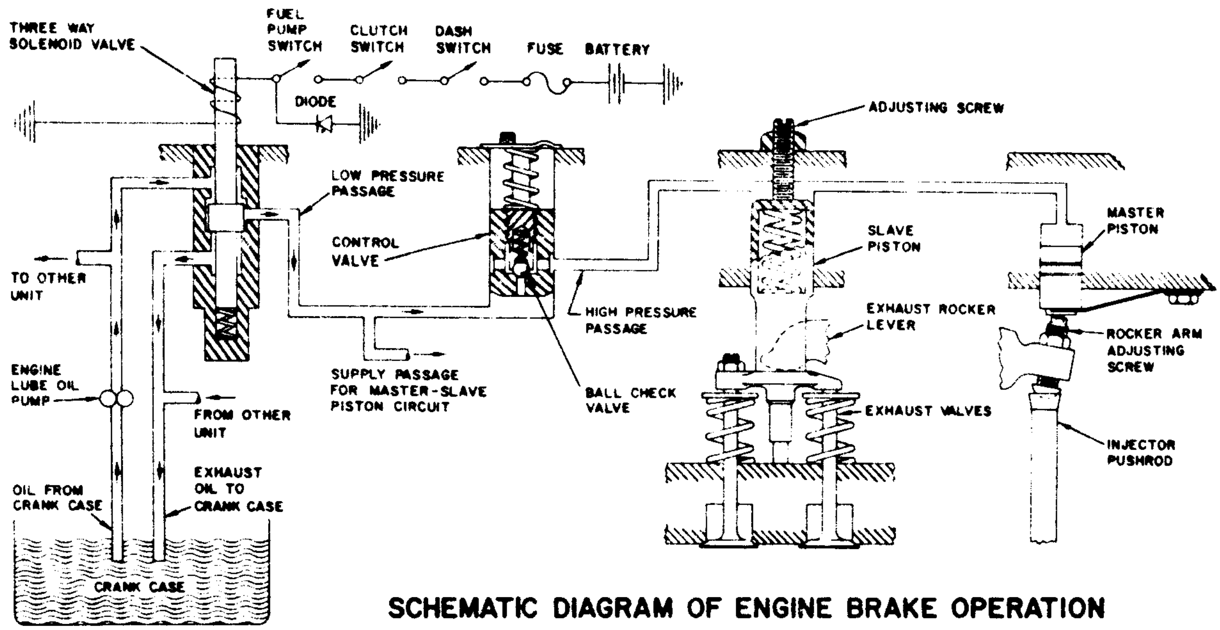
1. Energizing the solenoid valve permits engine lube oil to flow under pressure through the control valve to both the master piston and the slave piston.

2. Oil pressure causes the master piston to move out and follow the motion of the injector rocker lever lug.

3. The injector rocker lever begins upward travel (as in normal injection cycle) forcing the master piston in and creating a high pressure oil flow to the slave piston. The ball check valve in the control valve imprisons high pressure oil in the master-slave piston circuit.

4. The slave piston under the influence of the high pressure oil flow moves down, momentarily opening the exhaust valve, while the engine piston is near its top dead center position, releasing compressed cylinder air to the exhaust manifold.

5. Compressed air escapes to atmosphere completing a compression braking cycle.



SCHEMATIC DIAGRAM OF ENGINE BRAKE OPERATION

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EXHAUST BLOWDOWN - Referring to the schematic drawing, exhaust blowdown occurs as follows:

1. Energizing the solenoid valve permits engine lube oil to flow under pressure through the slave piston control valve to both the master piston and the slave piston.

2. Oil pressure causes the master piston to move down, coming to rest on the injector rocker arm adjusting screw.

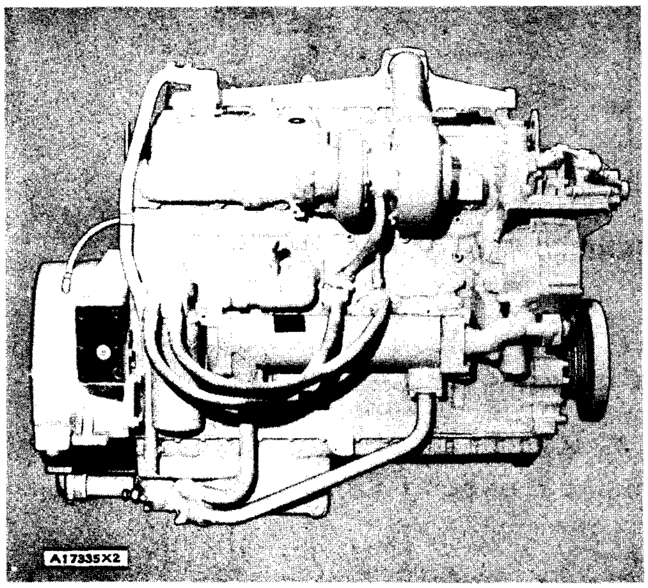
3. The injector rocker arm adjusting screw begins upward travel (as in normal injection cycle) forcing the master piston upward and creating a high pressure oil flow to the slave piston. The ball check valve in the control valve imprisons high pressure oil in the master-slave piston system.

4. The slave piston under the influence of the high pressure oil flow moves down, momentarily opening the exhaust valve, while the engine piston is near its top dead center position, releasing compressed cylinder air to the exhaust manifold.

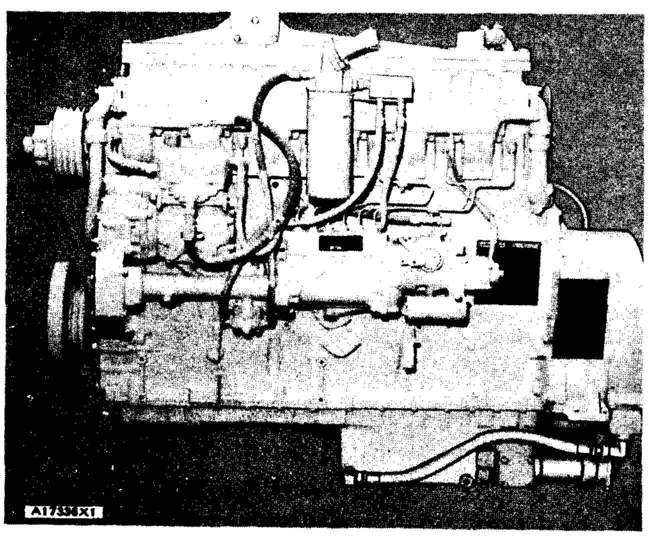
5. Compressed air escapes to atmosphere completing a compression braking cycle.

BRAKESAVER

The BrakeSaver permits the operator to control the speed reduction of the vehicle on grades, curves, or at any time when speed reduction is necessary but long applications of the service brakes are not desired.



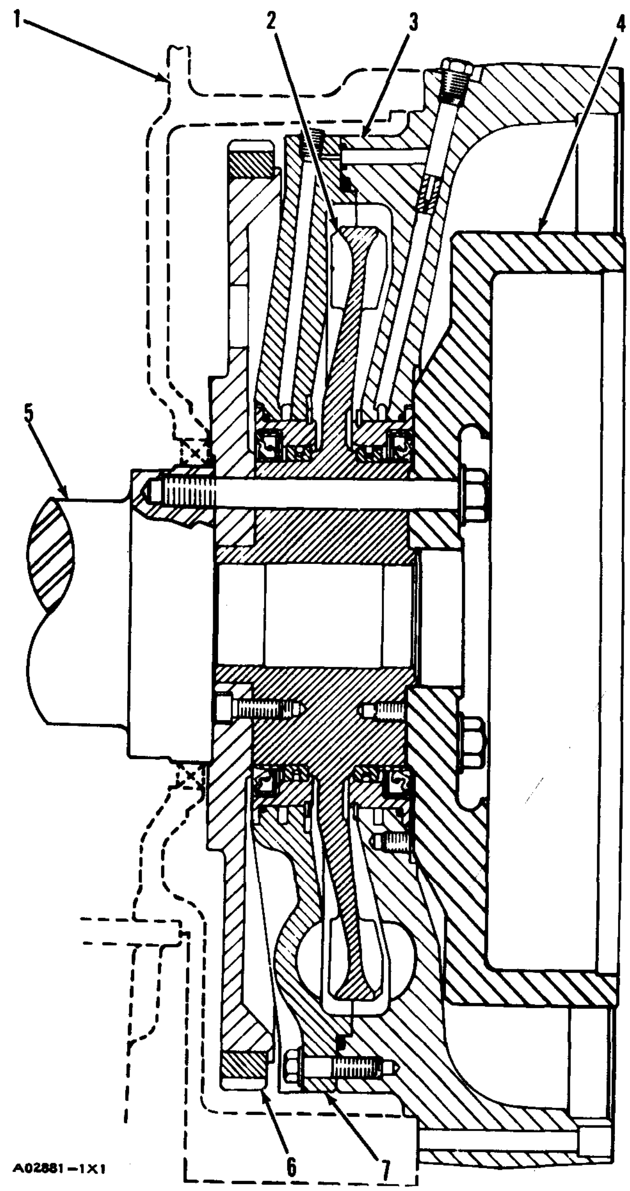
ENGINE WITH BRAKESAVER (RIGHT SIDE)



ENGINE WITH BRAKESAVER (LEFT SIDE)

BRAKESAVER COMPONENTS

The BrakeSaver housing (3) is fastened directly to the rear face of the flywheel housing (1). The BrakeSaver adds approximately four inches to the length of the engine drive train. A rotor (2) and a ring gear plate (6) are installed between the rear flange of the crankshaft (5) and the flywheel (4). The ring gear plate (6) permits the use of the standard engine starting motor. The rotor turns in a space between the stator (7) and the BrakeSaver housing (3).



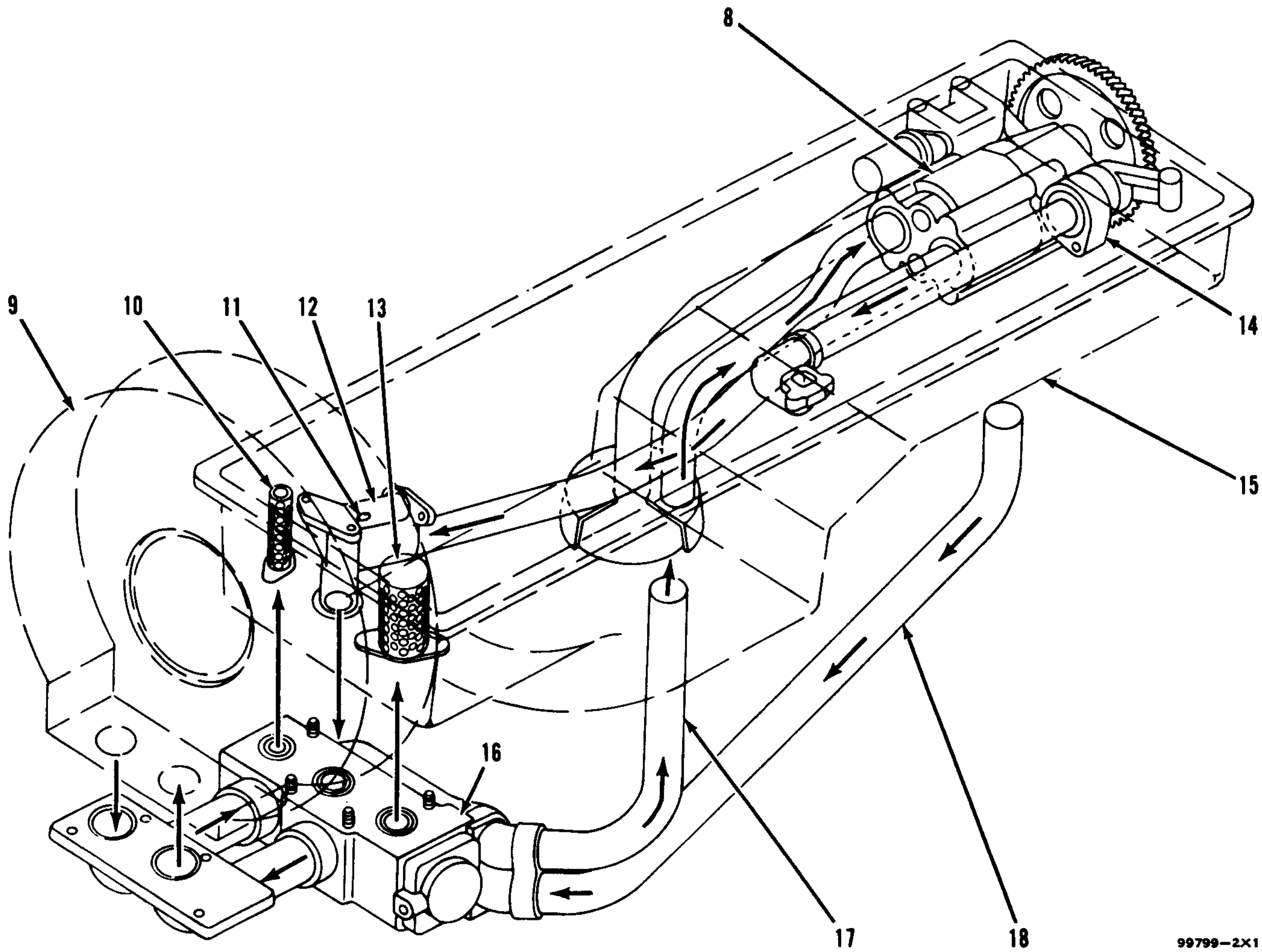
BRAKESAVER COMPONENTS

1. Flywheel housing. 2. Rotor. 3. BrakeSaver housing. 4. Flywheel. 5. Crankshaft flange. 6. Ring gear plate. 7. Stator.

The engine oil pump has two sections. The front section (14) of the oil pump gives oil to the engine for lubrication. The rear section (8) of the oil pump sends engine oil through the BrakeSaver control valve (16) to the BrakeSaver (9). The rear section of the oil pump also sends oil through line (17) to the engine oil cooler (not shown). From the oil cooler, the cool oil goes through line (18), through the baffle (13) and back into the engine oil pan (15).

When the BrakeSaver is turned off, tube (10) lets the oil in the BrakeSaver rapidly go out of the BrakeSaver and back into the engine oil pan.

When the engine is cold (starting conditions), the oil has a high viscosity. This high viscosity causes a restriction to the oil flow through the oil cooler. When there is a restriction in the oil cooler, an oil pressure difference in the bypass valve (12) causes the valve to open. When the bypass valve is open, oil from the rear section of the oil pump can go through hole (11) in the bypass valve (12) and drain back into the engine oil pan (15).



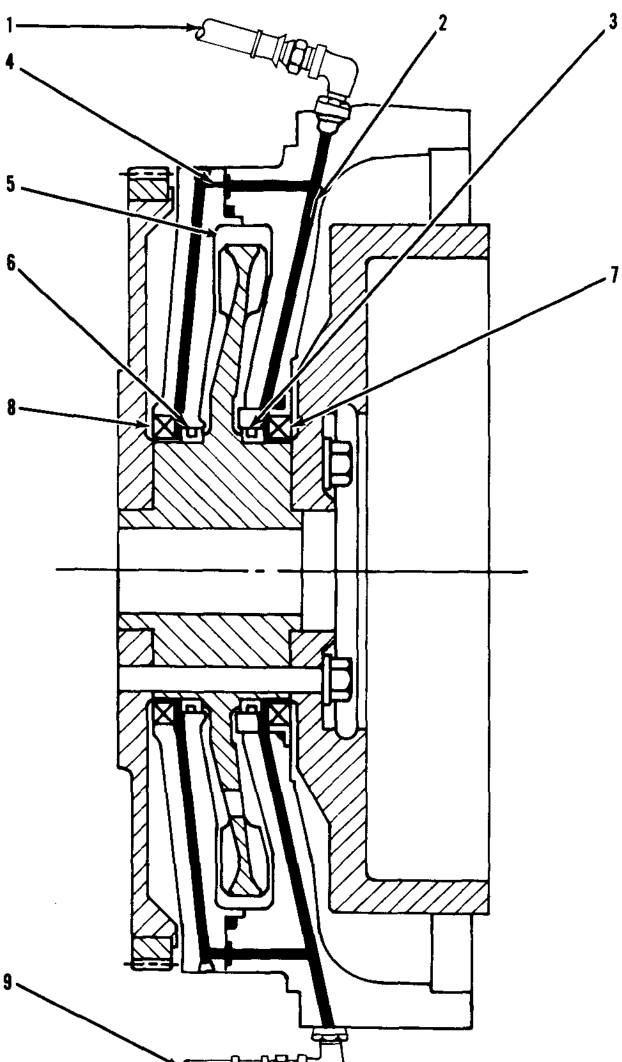
BRAKESAVER COMPONENTS

8. Oil pump (rear section). 9. BrakeSaver. 10. Tube. 11. Hole. 12. Bypass valve. 13. Baffle. 14. Oil pump (front section). 15. Engine oil pan. 16. BrakeSaver control valve. 17. Line. 18. Line.

BRAKESAVER LUBRICATION

Piston ring seals (3) and (6) keep pressure oil in the chamber (5) around the rotor during operation. Lip-type seals (7) and (8) prevent oil leakage from the BrakeSaver. An outside oil line (1) from the engine lubrication system sends engine oil to the BrakeSaver housing. Orifices (2) and (4) in the BrakeSaver send oil to a space between the lip seals and the piston-type ring seals at a rate of .33 U.S. gpm (1.24 liter/min). This oil gives lubrication to the seals under all conditions of operation.

The spaces between the lip-type seals and the piston-type ring seals are connected to an outside drain line (9) that lets the oil go back to the engine oil pan.



BRAKESAVER LUBRICATION

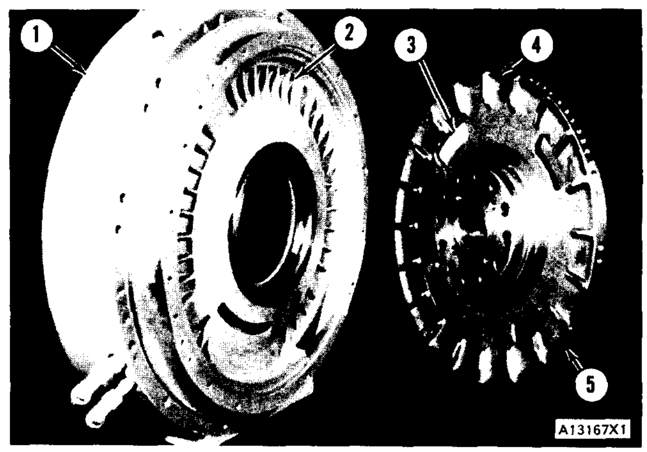
1. Oil line. 2. Orifice. 3. Piston-type ring seal. 4. Orifice. 5. Chamber. 6. Piston ring seal. 7. Lip-type seal. 8. Lip-type seal. 9. Oil line.

BRAKESAVER OPERATION

In downhill operation, the crankshaft is turned by the rear wheels (through the differential, driveshaft, transmission, and clutch). To reduce the speed of the vehicle, an application of a braking force can be made to the crankshaft. The BrakeSaver does this through the conversion of the energy of rotation into heat which is removed by the engine cooling system.

The rotor (5) is fastened to and turns with the engine crankshaft. The rotor has pockets (4) on the outer circumference of both sides and four holes (3) to permit equal oil flow to both sides of the rotor.

The BrakeSaver housing (1) and the stator are fastened to the flywheel housing and can not turn. Both the BrakeSaver housing and the stator have pockets (2) on their inside surfaces in alignment with the pockets (4) in the motor.

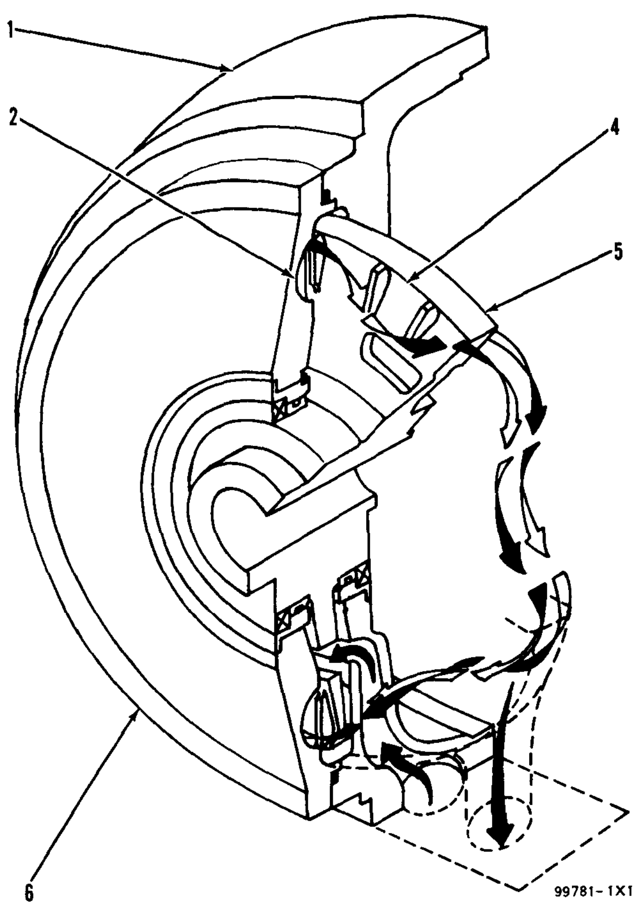


BRAKESAVER HOUSING AND ROTOR

1. BrakeSaver housing. 2. Pockets. 3. Hole. 4. Pocket. 5. Rotor.

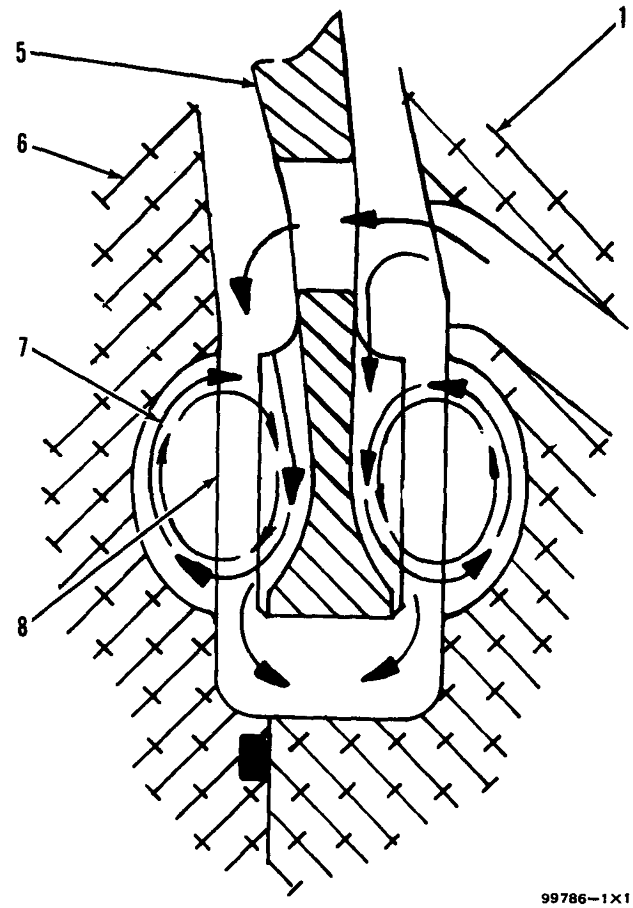
The rotor (5) turns in the compartment made by the stator (6) and the BrakeSaver housing (1). When the BrakeSaver housing is in operation, engine oil comes into this compartment near the center through a passage from the bottom of the BrakeSaver housing. The rotor, turning with the crankshaft, throws this oil outward. As the oil flows outward, the shape of the rotor pockets (4) send it into the pockets (2) of the stator and BrakeSaver housing. As the rotor turns and the oil flows around the BrakeSaver compartment, it takes the shape of a spiral.

As the oil flows around the BrakeSaver compartment, it is constantly cut by the vanes (the material between the pockets) of the rotor. This cutting action gives resistance to the rotor and changes the



OIL FLOW THROUGH BRAKESAVER

1. BrakeSaver housing. 2. Pocket. 4. Pocket. 5. Rotor. 6. Stator.



OIL FLOW IN BRAKESAVER

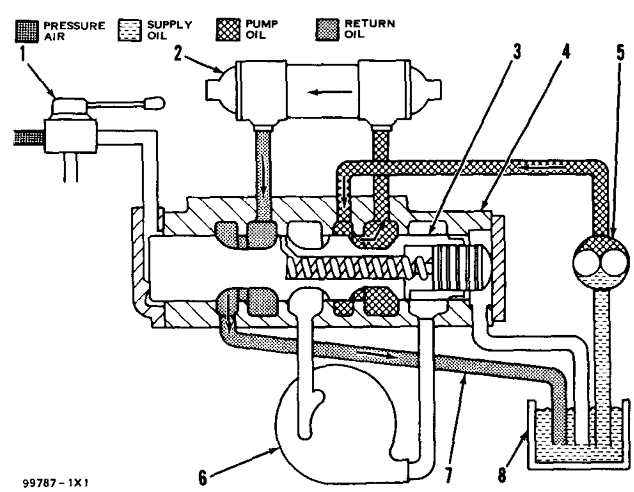
1. BrakeSaver housing. 5. Rotor. 6. Stator. 7. Spiral flow. 8. Air pocket.

energy of the rotor into heat in the oil. The heat is removed by the oil cooler and goes into the engine cooling system.

As the BrakeSaver inlet passage opens, more oil starts to flow in a spiral shape between the rotor and the stator. Inside this spiral flow (7) of oil is an air pocket (8). As the pressure in the rotor compartment increases, the amount of oil in the spiral flow increases in thickness and the air pocket has compression. As this air pocket has compression, the amount of oil being cut by the rotor vanes has an increase.

When the BrakeSaver is in operation, the level of braking can be controlled by the inlet oil pressure, since the braking force available is in direct relation to the amount of oil that is cut by the rotor vanes. When the BrakeSaver is not in operation, the inlet passage to the rotor compartment is closed by the control valve, and there is no oil in the BrakeSaver compartment.

BRAKESAVER CONTROL



BRAKESAVER OIL FLOW (OFF)

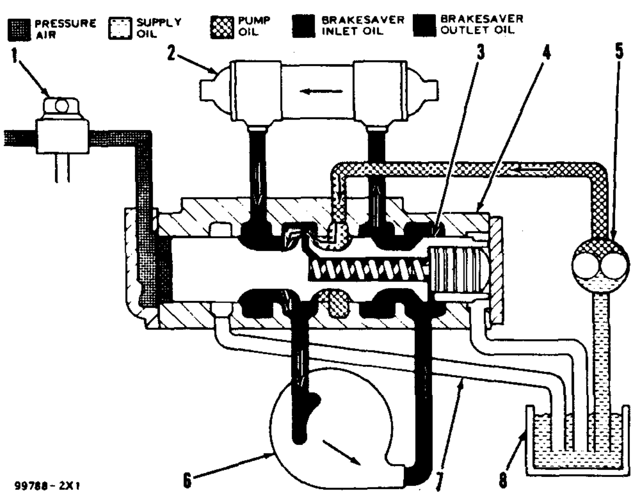
1. BrakeSaver control lever. 2. Oil cooler. 3. Valve spool. 4. BrakeSaver control valve. 5. Oil pump. 6. BrakeSaver. 7. Line. 8. Oil pan.

When the BrakeSaver control lever (1) is in the OFF position, spring force holds the valve spool (3) against the cover at the air inlet end of the control valve (4). With the valve spool (3) in this position, the oil pump (5) sends engine oil from the oil pan (8) through the control valve (4) to the oil cooler (2). From the oil cooler, the oil goes through the control valve, through line (7), and back to the engine oil pan (8). With the BrakeSaver control valve in this position, no oil is sent to the BrakeSaver (6).

When the BrakeSaver control lever (1) is moved to the ON position, pressure air moves the valve spool (3) to the right against the spring force. With the valve spool in this position, engine oil from the oil pump (5) is sent through the control valve (4) to the rotor compartment of the BrakeSaver (6). From the BrakeSaver, the oil goes through the control valve, through the oil cooler (2), back through the control valve, and back into the BrakeSaver.

The oil cannot go back to the engine oil pan (8) because the passage through the control valve to line (7) is closed by the valve spool.

The time required to fill the BrakeSaver with pressure oil to the point of maximum braking in the BrakeSaver is approximately 1.8 seconds.

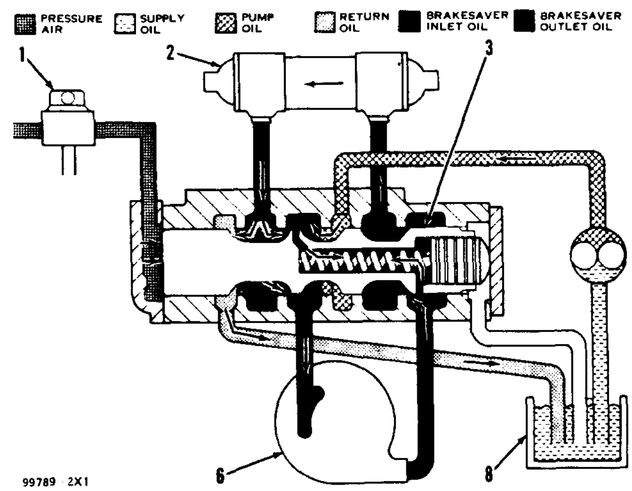


BRAKESAVER OIL FLOW (FILL)

1. BrakeSaver control lever. 2. Oil cooler. 3. Valve spool. 4. BrakeSaver control valve. 5. Oil pump. 6. BrakeSaver. 7. Line. 8. Oil pan.

As the BrakeSaver (6) fills, the turning rotor causes an increase in the oil pressure in the BrakeSaver. Inlet oil to the BrakeSaver and outlet oil from the BrakeSaver both go into the spring bore in the valve spool (3). The average of the inlet oil pressure and the outlet oil pressure in the spring bore plus the force of the spring work against the pressure air on the left end of the valve spool. When the force of the pressure oil plus the spring force become larger than the force of the pressure air, the valve spool moves to the left. This movement causes a restriction in the passage for the inlet oil and an oil pressure decrease in the BrakeSaver.

A decrease in rotor speed (normally with a decrease in vehicle speed) causes a decrease in the oil pressure in the BrakeSaver. This causes a decrease in oil pressure in the spring bore in the valve spool which lets the pressure air on the left end of the spool move the spool to the right. This movement farther opens the passage for the inlet oil and the oil pressure in the BrakeSaver has an increase.



BRAKESAVER OIL FLOW (OPERATE)

1. BrakeSaver control lever. 2 Oil cooler. 3. Valve spool. 6. BrakeSaver. 8. Oil pan.

An increase in rotor speed will cause an increase in the oil pressure in the BrakeSaver. This increase in oil pressure will cause the valve spool to move to the left to give a restriction to the inlet oil to the BrakeSaver.

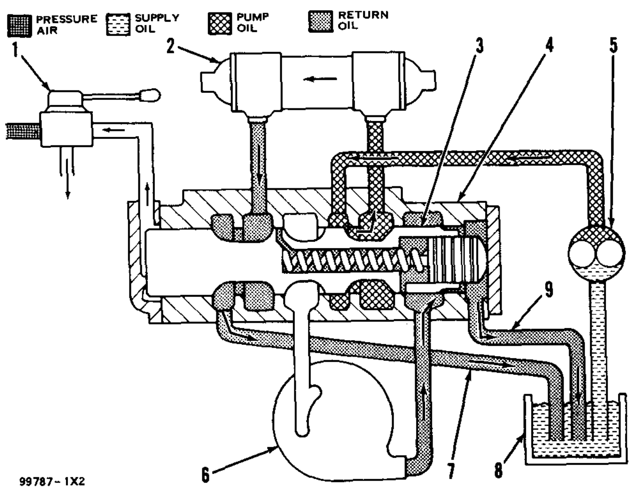
The valve spool is constantly moving to make adjustments to the BrakeSaver inlet pressure for compensation of the changing rotor speeds caused by normal operation of the vehicle. This constant movement of the valve spool is necessary to keep the amount of braking force in the BrakeSaver at the level set by the control lever (1).

During normal operation, the outlet oil from the BrakeSaver goes to the oil cooler (2). From the oil cooler, some of the oil (approximately 60%) goes back to the BrakeSaver inlet and the remainder of the oil from the oil cooler goes to the engine oil pan (8).

When the BrakeSaver control lever (1) is moved to the OFF position, the pressure air on the left end of the valve spool (3) goes out of the control valve (4). With no pressure air in the valve, the pressure oil in the spring bore plus the spring force move the valve spool against the cover at the air inlet end of the control valve. This movement closes the BrakeSaver inlet passage. The rotor in the BrakeSaver (6) now pushes the oil out of the BrakeSaver, through the control valve, through line (9), and back to the oil pan (8).

The time required to move the oil from the BrakeSaver is approximately 1.5 seconds.

With the control valve in this position, the oil pump (5) sends oil through the oil cooler (2) and through line (7) back to the oil pan.



BRAKESAVER OIL FLOW (DRAIN)

1. BrakeSaver control lever. 2. Oil cooler. 3. Valve spool. 4. BrakeSaver control valve. 5. Oil pump. 6. BrakeSaver. 7. Line. 8. Oil pan. 9. Line.

OPERATOR CONTROLS

Two types of controls are available for the BrakeSaver: a manual control and an automatic control.

Manual Control

Pressure air from the truck air system is sent to the pressure reducing valve (1) where the air pressure is controlled to 50 psi (345 kPa). This controlled pressure air goes to the manual control valve (2).

When the operator moves the BrakeSaver control lever (3) toward the ON position, pressure air is sent to the BrakeSaver control valve (6). The farther the lever (3) is moved toward the ON position, the higher the pressure of the air sent to the BrakeSaver control valve. An increase in air pressure in the BrakeSaver control valve causes an increase in the oil pressure in the BrakeSaver. An increase in the oil pressure in the BrakeSaver causes an increase in the braking force in the BrakeSaver. The operator can give modulation to the braking force in the BrakeSaver through the movement of the BrakeSaver control lever (3).

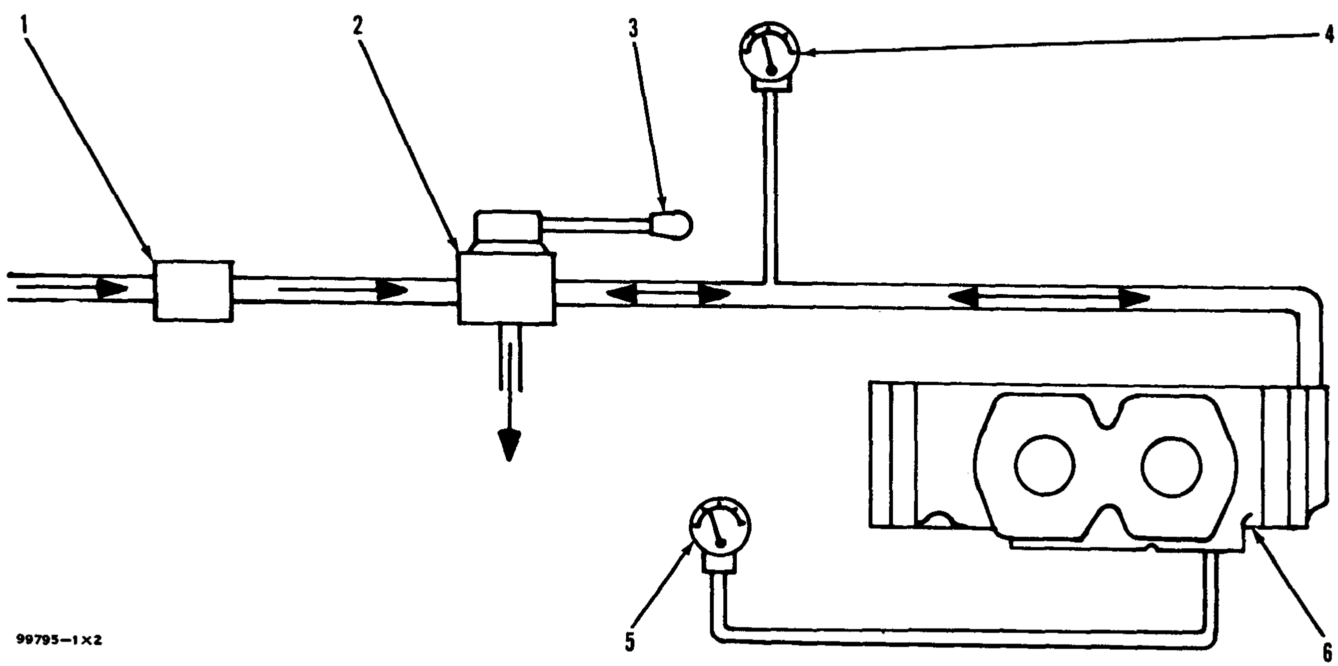
When the BrakeSaver is turned off, the pressure air goes out of the system through a passage in the manual control valve (2). This lets the pressure air out of the BrakeSaver control valve (6) and removes the braking force from the BrakeSaver.

An air pressure passage gauge (4) gives the operator a relative indication of the air pressure being sent to the BrakeSaver control valve. Through the use of the indication on the air pressure gauge in relation to engine rpm, the operator can get approximately the same braking effect from the BrakeSaver time after time. This lets the operator more easily control the desired wheel speed of the vehicle.

An oil temperature gauge (5) gives the operator an indication of the ability of the engine cooling system to control the heat in the BrakeSaver during its operation. If the gauge reads too HOT, move the BrakeSaver control lever (3) to the OFF position and use the service brakes to control the wheel speed of the vehicle. With the BrakeSaver off, the oil temperature will rapidly become normal again and the BrakeSaver can be used.

CAUTION

Do not manually engage the BrakeSaver and control the wheel speed with the accelerator. The design of the cooling system is for the control of the temperature of the oil at full engine power or full BrakeSaver capacity, but not both at the same time.



MANUAL CONTROL

1. Pressure reducing valve. 2. Manual control valve. 3. BrakeSaver control lever. 4. Air pressure gauge. 5. Oil temperature gauge. 6. BrakeSaver control valve.

Automatic Control

All the components of the manual control are in the automatic control and their functions are the same. In the automatic control, there is also a solenoid valve (8), a double check valve (7), and three switches (10), (11), and (12). The solenoid valve (8) (when activated) sends pressure air from the pressure reducing valve (1) to the BrakeSaver control valve (6). The solenoid valve is connected to three switches: mode selector switch (10), accelerator switch (11), and clutch switch (12). The switches are connected to each other in series (all switches must be closed to activate the solenoid). The source of electric current is from the key switch (9) which prevents the solenoid valve from being activated when the key switch is OFF.

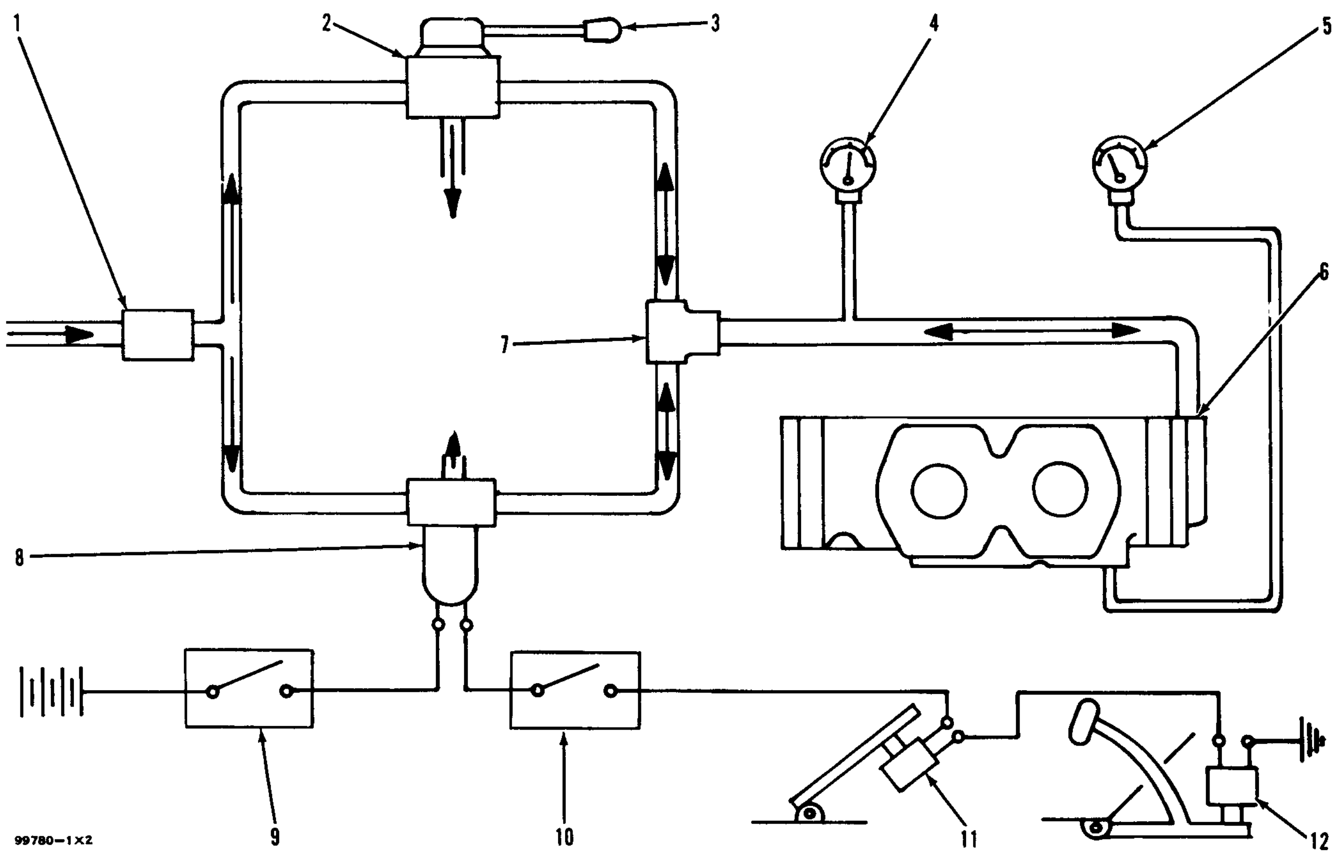
The mode selector switch (10) has two positions: MANUAL and AUTOMATIC-MANUAL. For automatic operation of the BrakeSaver, the mode selector switch must be in the AUTOMATIC-MANUAL position.

The clutch switch (12) is connected to the clutch linkage. When the clutch is engaged (clutch pedal up), the switch is closed. For automatic operation of the BrakeSaver, the clutch switch must be CLOSED (pedal up).

NOTE: In vehicles with no clutch pedal, the clutch switch is removed from the circuit.

The accelerator switch (11) is installed in the governor. When the accelerator is released (accelerator pedal up), the switch is closed. For automatic operation of the BrakeSaver, the accelerator switch must be closed (accelerator pedal up).

When the switches are closed, the electric current from the key switch (9) opens the solenoid valve (8). When the solenoid valve is open, full air pressure [50 psi (345kPa)] is sent through the double check valve (7) to the BrakeSaver control valve (6). The double check valve keeps the pressure air from going out of the system through the manual control valve (2) when the BrakeSaver control lever (3) is not in use. It also keeps the pressure air from going out of the system through the solenoid valve (8) when the manual control is in use.



AUTOMATIC CONTROL

1. Pressure reducing valve. 2. Manual control valve. 3. BrakeSaver control lever. 4. Air pressure gauge. 5. Oil temperature gauge. 6. BrakeSaver control valve. 7. Double check valve. 8. Solenoid valve. 9. Key switch. 10. Mode selector switch. 11. Accelerator switch. 12. Clutch switch.

Because the solenoid valve sends full air pressure to the BrakeSaver control valve, there is no modulation in the AUTOMATIC-MANUAL position.

When the mode selector switch (10) is in the AUTOMATIC-MANUAL position and the accelerator pedal is released (pedal up), the BrakeSaver is operating at its maximum capacity. When the clutch is released (pedal down) the BrakeSaver goes off. When the clutch is engaged again (pedal up), the BrakeSaver comes back on. A light pressure on the accelerator pedal turns the BrakeSaver off and lets the vehicle run freely. More pressure on the accelerator pedal sends fuel to the engine.

When the BrakeSaver is turned off, the pressure air goes out of the system through a passage in the manual control valve (2) or in the solenoid valve (8). This lets the pressure air out of the BrakeSaver control valve (6) and removes the braking force from the BrakeSaver.

The manual control valve (2) can be operated with the mode selector switch (10) in the AUTOMATIC-MANUAL position. During normal operation, the solenoid valve will send full air pressure to the BrakeSaver control valve and remove the effect of the manual control valve. If there is a failure in the electrical system when the mode selector switch is in the AUTOMATIC-MANUAL position, the manual control valve will have an effect.

MEASURING RESTRICTION IN DRY AIR CLEANERS

PHASE 16 DIESEL DIVISION

As a dry air cleaner element becomes loaded with dust, the vacuum on the "engine side" of the air cleaner (at the air cleaner outlet) increases. This vacuum is generally measured as "restriction in inches of water".

The engine manufacturer often places a recommended limit on the amount of restriction the engine will stand without loss in performance before the element must be cleaned or replaced.

Mechanical gauges, warning devices, indicators, and water manometers are available to tell the operator when the air cleaner restriction reaches this recommended limit. These gauges and devices are generally reliable, but the water manometer is the most accurate and dependable.

To use the manometer, hold vertically and fill both legs approximately half full with water. One of the upper ends is connected to the restriction tap on the outlet side of the air cleaner by means of a flexible hose. The other end is left open to atmosphere.

Maximum restriction in the air cleaner occurs at maximum air flow. On a naturally aspirated or supercharged (not turbocharged) diesel, the maximum air flow occurs at maximum (high idle) speed without regard for engine power. On a gasoline, LP, or turbocharged diesel engine, the maximum air flow occurs only at maximum engine power.

With the manometer held vertically and the engine drawing maximum air, the difference in the height of the water columns in the two legs, measured in inches, is the air cleaner restriction. Restriction indicators are generally marked with the restriction at which the red signal flag "locks up".

Most engine manufacturers suggest a maximum restriction of between 15 inches and 20 inches for gas and LP engines, and from 20 inches to 30 inches for diesels. Exceeding these maximums affects only engine performance. The operator should not be alarmed when the red signal on the restriction indicator begins to appear. The air cleaner manufacturer furninshing your factory-approved service element has safety factors built into the element to withstand several times these recommended maximums without collapsing or leaking dirt into the engine.

SERVICING DRY AIR CLEANERS

PHASE 16

When to service?

Many users do not know the answer to this question. No matter what system or method you use for determining air cleaner element service intervals, it should be geared around restriction figures.

What is restriction?

Restriction is the resistance to air flow through the air cleaner system into the engine.

What instruments do we use to measure restriction?

Restrictions are best recorded by a water manometer, a dial indicator calibrated in inches of water, or an air cleaner service indicator.

How are restrictions measured?

Restrictions are measured in the air cleaner outlet tap (if provided), at a tap in the air transfer tube, or within the engine intake manifold.

Since some users will not have a water manometer or dial gauge available, the use of permanently mounted service indicators should be considered. The indicator can be mounted on the air cleaner or remote mounted in an area where the operator can monitor the condition of the element constantly.

The element in the air cleaner should be serviced when the maximum allowable restriction, established by the engine manufacturer, has been reached. The element should not be serviced on the basis of visual observation because this will lead to over service.

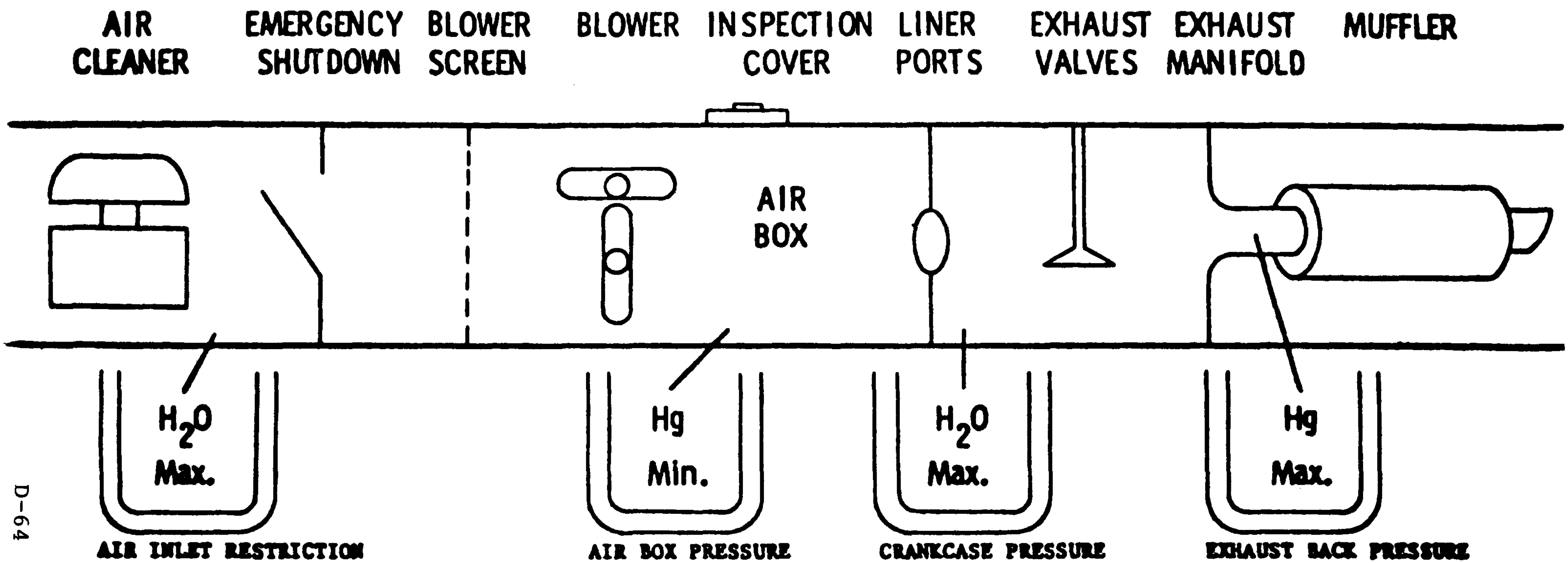
The excess handling that is a result of overservice can cause:

1. Element damage,
2. Improper installation of element,
3. Contamination from ambient dust,
4. Increased service cost, time and material.

	1200 rpm	1800 rpm	2100 rpm
Lubrication System			
Lubricating oil pressure (psi):			
Normal	35-55	50-70	50-70
Min. for safe operation	25	28	30
†Lubricating oil temperature (degrees F.):			
Normal	200-235	200-235	200-235
Air System			
Air box pressure (inches mercury) - min. full load:			
At zero exhaust back pressure:			
N injector	1.0	3.3	5.0
C and 7E injector	1.0	2.7	4.5
At max. exhaust back pressure (clean ports):			
N injector	2.1	5.8	8.0
C and 7E injector	2.1	5.2	7.5
Air inlet restriction (inches water) - max. full load:			
Dirty air cleaner (oil or dry)	12.4	25.0	25.0
Clean air cleaner (with pre-cleaner) (oil or dry)	8.7	13.4	15.9
Clean air cleaner (less pre-cleaner) (dry type)	5.2	9.1	11.5
Crankcase pressure (inches water) - max.	1.0	2.2	3.0
Exhaust back pressure (inches mercury) - max.:			
Full load	1.5	3.3	†4.0
Fuel System			
Fuel pressure at inlet manifold (psi):			
Normal (.080" orifice - 6, 8 and 12V engines)	45-70	45-70	45-70
Normal (.106" orifice - 12V-71 with 3/8" pump)	45-70	45-70	45-70
Normal (.070" orifice - 16V engines)	30-65	45-70	45-70
Minimum	30	30	30
Fuel spill (gpm) - min. at no load:			
(6, 8 and 12V engines)	0.8	0.9	0.9
(16V engines)	1.2	1.4	1.4
Pump suction at inlet (inches mercury) - max.:			
Clean system	6.0	6.0	6.0
Dirty system	12.0	12.0	12.0
Cooling System			
Coolant temperature (degrees F.) - normal	160-185	160-185	160-185
Vehicle engines built 1976 and later	170-195	170-195	170-195
Compression			
Compression pressure (psi at sea level):			
Average - new engine at 600 rpm ... 565			
Minimum at 600 rpm ... 515			

†The lubricating oil temperature range is based on the temperature measurement in the oil pan at the oil pump inlet. When measuring the oil temperature at the cylinder block oil gallery, it will be approximately 10° lower than the oil pan temperature.

§ Marine Engines Only: 4.4" mercury at 2100 rpm.



D-64

MANOMETER READINGS

Inlet Restriction	Air Box Pressure	Crankcase Pressure	Exhaust Back Pressure	Probable Trouble

VALVE ADJUSTMENT

POWER BY CATERPILLAR

1673C

Make valve adjustment with engine stopped and cold. Remove the flywheel timing cover and rotate flywheel in direction of engine rotation until "TC 1-6 cyl" mark aligns with timing pointer. Remove valve cover and observe position of valves to determine if No. 1 or No. 6 piston is on compression stroke. Both the inlet and exhaust valves will be closed on compression stroke.

1. With No. 1 piston at TDC on compression, check lash on exhaust valves for cylinders 1, 3 and 5, and inlet valves for cylinders 1, 2 and 4.
2. To adjust, loosen valve adjusting locknut and turn adjusting screw to allow feeler gauge to pass between top of valve stem and the valve rocker arm.
3. Set lash at .015″ (0.38 mm) for inlet and .025″ (0.63 mm) for exhaust valves.
4. Tighten adjusting screw locknut and check lash clearance.
5. Turn flywheel 360° in direction of engine rotation. Align flywheel timing mark with pointer. No. 6 cylinder will be at TDC compression stroke (valves closed).
6. Check lash on exhaust valves for cylinders 2, 4 and 6, and inlet valves for cylinders 3, 5 and 6. Adjust valves if necessary.

1674

Make valve lash adjustment with engine stopped. TDC of the No. 1 piston on the compression stroke is the reference point. The No. 1 piston will be at TDC when the No. 1 and No. 6 flywheel timing mark aligns with the timing pointer. Compression stroke is when all the No. 1 piston valves are closed.

1. With No. 1 piston at TDC compression stroke, adjust lash on 1, 3 and 5 exhaust and 1, 2 and 4 inlet valves.
2. Turn adjusting screw counterclockwise 2 clicks or more to provide clearance between rocker assembly and valve.
3. Turn adjusting screw clockwise to obtain zero lash. **There should be no free rocker movement or adjusting screw button lateral movement.**

   NOTE

   The adjusting screw button can still be rotated by finger pressure even when it is in contact with valve stem and clearance is zero. Turning the adjusting screw clockwise beyond this point will force the valve off its seat, and final lash setting will be incorrect.
4. To adjust, turn adjustment screw counterclockwise 10 clicks (.020″) (0.51 mm) for the exhaust valves and 4 clicks (.008″) (0.20 mm) for the inlet valves. (One click is equal to .002″) (0.05 mm).
5. Turn crankshaft 360° clockwise, (direction of normal rotation) viewing from front. Align flywheel timing mark with timing pointer.
   a) Adjust 2, 4 and 6 exhaust .020″ (10 clicks).
   b) Adjust 3, 5 and 6 inlet .008″ (4 clicks).

1693

Make valve lash adjustment with engine stopped and cold. TDC of the No. 1 piston on the compression stroke is the reference point. No. 1 piston is at TDC compression stroke when the No. 1 and No. 6 flywheel timing bolt aligns with the threaded timing hole in the flywheel and No. 1 valves are closed.

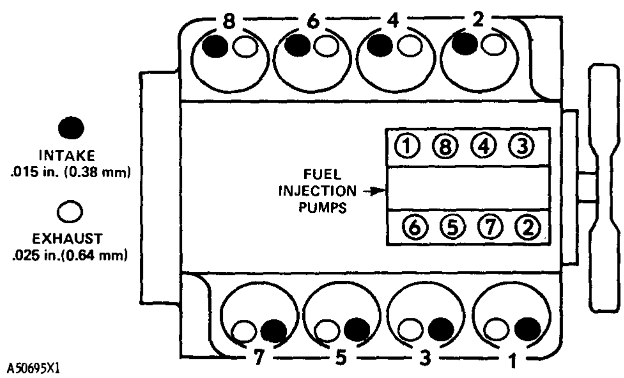
1. With No. 1 piston at TDC compression stroke, adjust lash on 1, 3 and 5 exhaust and 1, 2 and 4 inlet valves.
2. Turn cam follower on valve being adjusted until the slanted hole in the follower faces the center of the engine.
3. Insert a Phillips screwdriver in the slanted hole and turn screwdriver clockwise to increase valve lash or counterclockwise to decrease the valve lash. With a clearance gauge measure valve lash between the cam follower and the cam. Correct valve lash is .030″ (0.76 mm) for exhaust valves and .018″ (0.45 mm) for inlet valves.
4. Turn crankshaft 360° clockwise. Align flywheel timing marks with timing pointer.
5. Adjust lash on 2, 4 and 6 exhaust and 3, 5 and 6 inlet valves.

CHEÇKING ADJUSTMENT OF THE VALVE LASH

Check the adjustment of the valve lash during the first 3000 miles of operation and every 24,000 miles of operation after the first adjustment. If the engine is not used for 24,000 miles in six months, check the adjustment of the valve lash after every six months.

To check and make adjustment to the valve lash, use the following procedure:

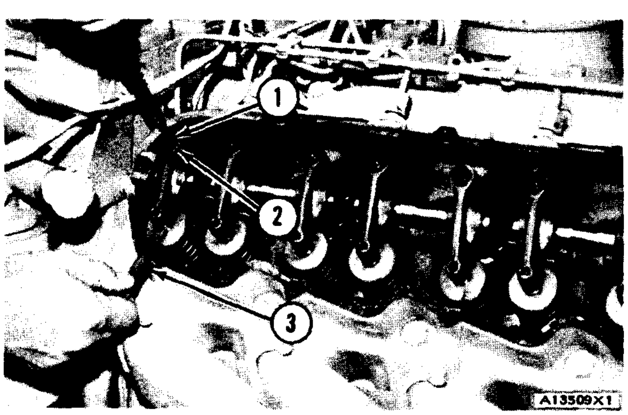
1. Remove the valve covers.



CYLINDER, VALVE, AND PUMP LOCATION

2. Turn the crankshaft CLOCKWISE (as seen from front of engine) until No.1 piston is at top center on the compression stroke. The TDC-1 mark on the damper assembly will be in alignment with the timing pointer.

3. Make adjustment to the valves for No.1 and No.2 cylinders. To make the adjustment, loosen locknut (2). Turn the adjustment screw (1) until the feeler gauge (3) will go between the end of the valve stem and the rocker arm.

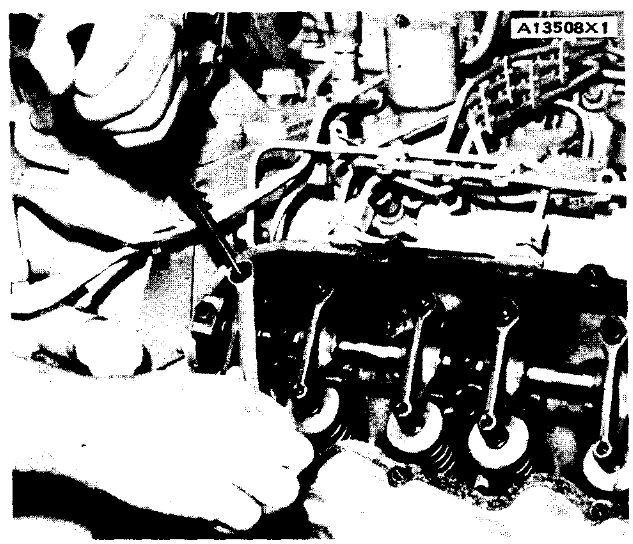


VALVE LASH ADJUSTMENT

1. Adjustment screw. 2. Locknut. 3. Feeler gauge.

NOTE: Use a .015 in. (0.38 mm) feeler gauge for the intake valves. Use a .025 in. (0.64 mm) feeler gauge for the exhaust valves.

4. After the adjustment is complete, hold adjustment screw (1) and tighten locknut (2) to 24 ± 5 lb. ft. (32 ± 7 N·m). After the locknut is tightened, check the adjustment again.



TIGHTENING LOCKNUT

5. Turn the crankshaft 180° CLOCKWISE (as seen from front of engine). The VS mark on the damper assembly will be in alignment with the timing pointer. Make adjustment to the valves for No.3 and No.7 cylinders.

6. Turn the crankshaft 180° CLOCKWISE (as seen from front of engine). The TDC-1 mark on the damper assembly will be in alignment with the timing pointer. Make adjustment to the valves for No.4 and No.5 cylinders.

7. Turn the crankshaft 180° CLOCKWISE (as seen from front of engine). The VS mark on damper assembly will be in alignment with the timing pointer. Make adjustment to the valves for No.6 and No.8 cylinders.

When the adjustment of the valve lash needs to be done several times in a short period of time, it can be an indication of wear in a different part of the engine. Find the problem and make any necessary repairs to prevent more damage to the engine.

BRIDGE ADJUSTMENT

When the head is disassembled, keep the bridges with their respective cylinders. Adjustment of the bridge will be necessary only after grinding the valves or other reconditioning of the cylinder head is done. Make an adjustment to the bridge using the following procedure.

NOTE: Valves must be fully closed.

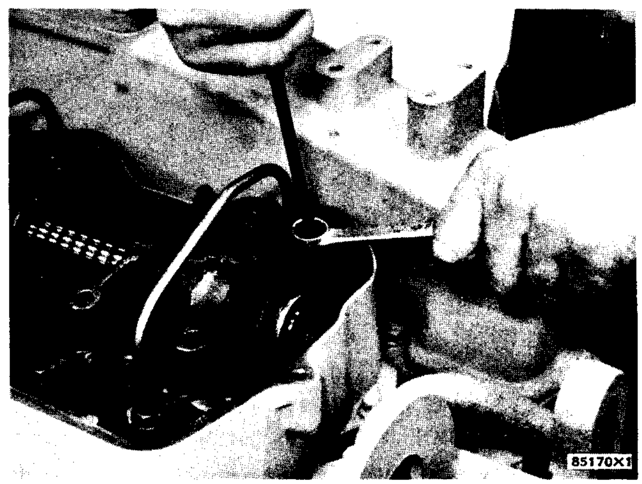
BRIDGE ADJUSTMENT

1. Put engine oil on the bridge dowel in the cylinder head and in the bore in the bridge.
2. Install the bridge with the adjustment screw toward the exhaust manifold.
3. Loosen the locknut for the adjustment screw and loosen the adjustment screw several turns.
4. Put a force on the bridge with a finger to keep the bridge in contact with the valve stem opposite the adjustment screw.
5. Turn the adjustment screw clockwise until it just makes contact with the valve stem. Then turn the adjustment screw 30° more in a clockwise direction to make the bridge straight on the dowel and to make compensation for the clearance in the threads of the adjustment screw.
6. Hold the adjustment screw in this position and tighten the locknut to 22 ± 3 lb.ft. (3.0 ± 0.4 mkg).
7. Put engine oil at the point where the rocker arm makes contact with the bridge.

VALVE CLEARANCE SETTING

VALVE CLEARANCE SETTING: ENGINE STOPPED	
Exhaust	.030 in. (0.76 mm)
Intake	.015 in. (0.38 mm)

To make an adjustment to the valve clearance, turn the adjustment screw in the rocker arm. It is not necessary to change the bridge adjustment for normal valve clearance adjustments. Valve clearance adjustments can be made by using the following procedure:



VALVE ADJUSTMENT

1. Put No. 1 piston at top center (TC) on the compression stroke. Make reference to FINDING TOP CENTER COMPRESSION POSITION FOR NO. 1 PISTON.
2. Make an adjustment to the valve clearance on the intake valves for cylinders 1, 2, and 4. Make an adjustment to the valve clearance on the exhaust valves for cylinders 1, 3, and 5.
3. Turn the flywheel 360° in the direction of engine rotation. This will put No. 6 piston at top center (TC) on the compression stroke.
4. Make an adjustment to the valve clearance on the intake valves for cylinder 3, 5, and 6. Make an adjustment to the valve clearance on the exhaust valves for cylinders 2, 4, and 6.

NOTE: Valve clearance is measured between the rocker arm and the bridge for the valves.

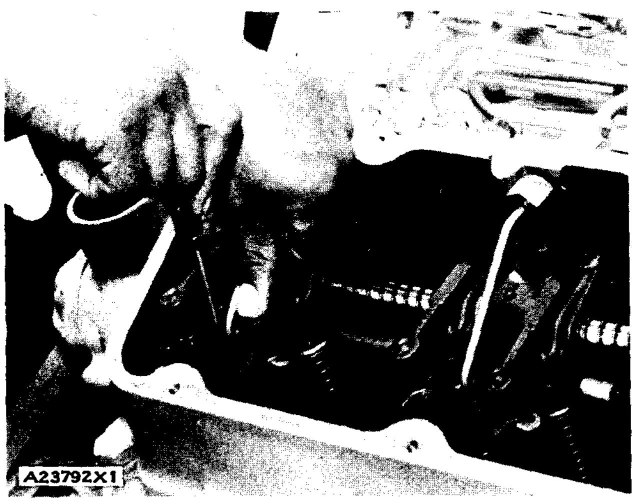
5. After valve adjustment is correct, tighten the nuts for valve adjustment screws to 22 ± 3 lb.ft. (3.0 ± 0.4 mkg).

Bridge Dowel

Use a 5P944 Dowel Puller Group with a 5P942 Extractor to remove the bridge dowels. Install a new bridge dowel with a 5P2406 Dowel Driver. This dowel driver installs the bridge dowel to the correct height.

BRIDGE ADJUSTMENT

When the head is disassembled, keep the bridges with their respective cylinders. Adjustment of the bridge will be necessary only after the valves are ground or other reconditioning of the cylinder head is done. Use the procedure that follows to make an adjustment to the bridge.



BRIDGE ADJUSTMENT

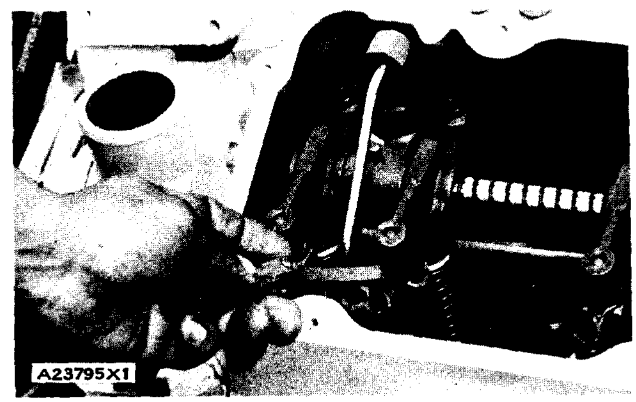
NOTE: Valves must be fully closed.

1. Put engine oil on the bridge dowel in the cylinder head and in the bore in the bridge.
2. Install the bridge with the adjustment screw toward the exhaust manifold.
3. Loosen the locknut for the adjustment screw and loosen the adjustment screw several turns.
4. Put a force on the bridge with a finger to keep the bridge in contact with the valve stem opposite the adjustment screw.
5. Turn the adjustment screw clockwise until it just makes contact with the valve stem. Then turn the adjustment screw 30° more in a clockwise direction to make the bridge straight on the dowel, and to make compensation for the clearance in the threads of the adjustment screw.
6. Hold the adjustment screw in this position and tighten the locknut to 22 ± 3 lb. ft. (28 ± 4 N·m).
7. Put engine oil at the point where the rocker arm makes contact with the bridge.

VALVE CLEARANCE SETTING

NOTE: Valve clearance is measured between the rocker arm and the bridge for the valves.

VALVE CLEARANCE CHECK: ENGINE STOPPED	
Exhaust	.027 to .033 in. (0.69 to 0.84 mm)
Intake	.012 to .018 in. (0.30 to 0.46 mm)

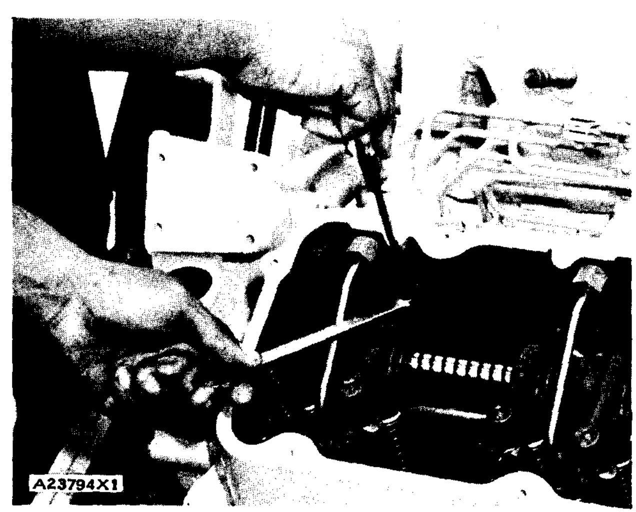


VALVE CLEARANCE CHECK

NOTE: When the valve lash (clearance) is checked, adjustment is NOT NECESSARY if the measurement is in the range given in the chart for VALVE CLEARANCE CHECK: ENGINE STOPPED. If the measurement is outside this range, adjustment is necessary. See the chart for VALVE CLEARANCE SETTING: ENGINE STOPPED, and make the setting to the nominal (desired) specifications in this chart.

VALVE CLEARANCE SETTING: ENGINE STOPPED	
Exhaust	.030 in. (0.76 mm)
Intake	.015 in. (0.38 mm)

To make an adjustment to the valve clearance, turn the adjustment screw in the rocker arm. It is not necessary to change the bridge adjustment for normal valve clearance adjustments. Valve clearance adjustments can be made by using the procedure that follows:



VALVE ADJUSTMENT

1. Put No. 1 piston at top center (TC) on the compression stroke. Make reference to FINDING TOP CENTER COMPRESSION POSITION FOR NO. 1 PISTON.

2. Make an adjustment to the valve clearance on the intake valves for cylinders 1, 2, 5 and 7. Make an adjustment to the valve clearance on the exhaust valves for cylinders 1, 3, 4 and 8.

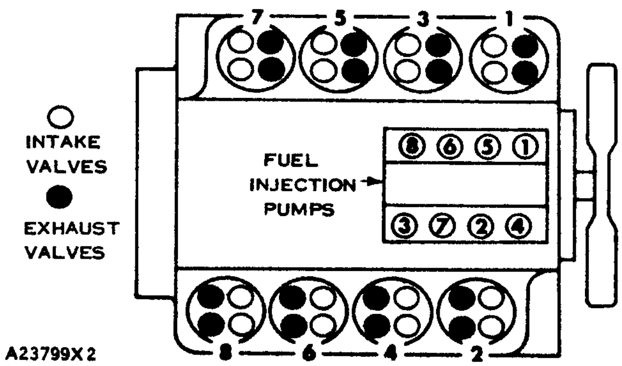
3. After each adjustment, tighten the nut for valve adjustment screw to 22 ± 3 lb. ft. (28 ± 4 N·m), and check the adjustment again.

4. Remove the timing bolt and turn the flywheel 360° in the direction of engine rotation. This will put No. 6 piston at top center (TC) on the compression stroke. Install the timing bolt in the flywheel.

5. Make an adjustment to the valve clearance on the intake valves for cylinders 3, 4, 6 and 8. Make an adjustment to the valve clearance on the exhaust valves for cylinders 2, 5, 6 and 7.

6. After each adjustment, tighten the nut for valve adjustment screw to 22 ± 3 lb. ft. (28 ± 4 N·m), and check the adjustment again.

7. Remove the timing bolt from the flywheel when all valve clearances are correct.



CYLINDER AND VALVE LOCATION

SMALL BORE CUMMINS TUNE UP

Adjust Injectors, Crossheads and Valves

Before adjusting injectors and valves be sure to determine if rocker housings are cast iron or aluminum and use appropriate setting.

Two methods of adjusting injectors and valves are described in this manual. The preferred method is Uniform Plunger Travel. This method involves adjusting plunger with ST-1270 Injector Indicator Kit (consists of ST-1170 Dial Indicator and ST-1193 Actuator) to a specified travel. The second method involves setting plunger adjusting screw to a specified torque setting. It is essential that injectors and valves be in correct adjustment at all times.

Injector "Plunger Free Travel", as described below, must be checked before adjustments are made.

Check Plunger Free Travel

In order to prevent excessive loading of injector actuating train and possible failure, check as follows:

1. Back injector adjusting screw out 1-1/2 turns from normal operating position, tighten locknut.

2. With ST-1170 Dial Indicator extension on injector plunger top, bar engine and record total amount of each plunger travel. This is called "Plunger Free Travel" and MUST NOT exceed 0.206 inch [5.23 mm] on any one (1) cylinder of engine.

3. On engines with Plunger Free Travel exceeding 0.206 inch [5.23 mm] the Torque Method of adjustment must be used unless component changes (rocker levers and/or cam followers) are made which will allow 0.206 inch [5.23 mm] limit of Free Travel to be obtained.

Temperature Settings

The following temperature conditions provide the necessary stabilization of engine components to assure accurate adjustments.

Cold Setting

Engine must have reached a stabilized temperature (oil and/or component temperature to be within 10 deg. F or ambient air temperature).

Note: At rebuild period this setting is obtained through normal room temperature.

Hot Setting

Engines With Non-Slotted Thread Injector Adjusting Screws

1. Adjust injectors and valves immediately after the engine has been operated at 210 deg. F [99 deg. C] oil sump temperature for a period of 10 minutes minimum or until normal oil operating temperature has been obtained.

2. If oil temperature gauge is unavailable, set injectors and valves immediately after engine has operated at rated speed and load or at high idle for a period of 40 minutes minimum.

Engines With Slotted Thread Injector Adjusting Screws

1. Set injectors and valves immediately after the engine oil sump temperature has reached 210 deg. F [99 deg. C] or when normal oil operating temperature has been obtained.

2. If oil temperature gauge is unavailable, set injectors and valves immediately after engine has operated at rated speed and load or at high idle for a period of 20 minutes.

Adjustment After Engine Rebuild

During rebuild adjust injectors and valves using appropriate values in the "Cold Set" column. The engine must then run until normal oil operating temperature has been obtained to allow stability of structural components as affected by gasket replacements. Recheck injectors and valves. See Phase 4, Engine Test Procedure.

Note: The uniform plunger travel method of injector adjustment **must not** be used on engines with the following camshafts: 1599-1, 10859-1, 10875-1, 70515, 104336, 108358, 108965, 111882 and 111884.

Injector and Valve Adjustment Using ST-1170 Dial Indicator

1. If used, pull compression release lever back and block in open position while barring engine, this allows crankshaft to be rotated without working against compression.

2. Bar engine until "A" or 1-6 "VS" mark on pulley, Fig's. 14-98 and 14-99, is aligned with pointer on gear case cover. Remove block from compression release. In this position, both valve rocker levers for cylinder No. 5 must be free (valves closed). Injector plunger for cylinder No. 3 must be at top of travel; if not, bar engine 360 deg., realign marks with pointer.

3. Turn adjusting screw down on cylinder being adjusted until plunger contacts cup and advance an additional 15 degrees to squeeze oil from cup. Loosen adjusting screw two full turns.

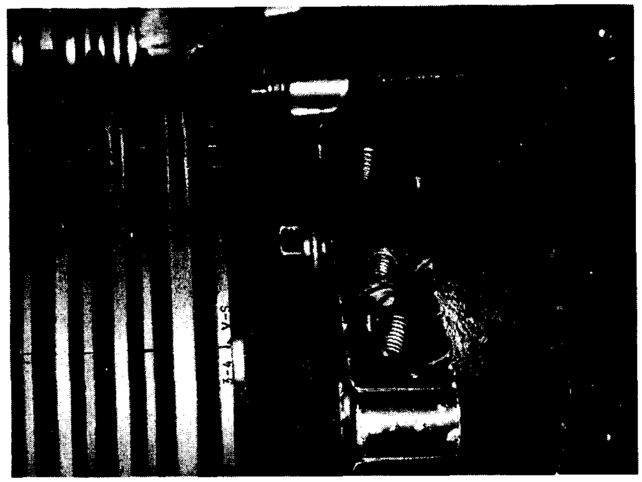


Fig. 14-98, (N114220). Valve set timing marks

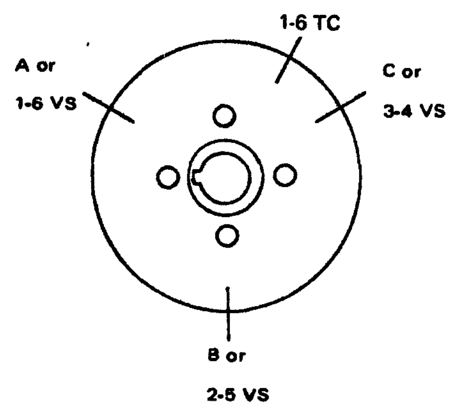


Fig. 14-99, (N114230). Accessory drive pulley marking

Table 14-11: Injector and Valve Set Position

Bar in Direction	Pulley Position	Set Cylinder Injector	Set Cylinder Valve
Start	A or 1-6VS	3	5
Adv. To	B or 2-5VS	6	3
Adv. To	C or 3-4VS	2	6
Adv. To	A or 1-6VS	4	2
Adv. To	B or 2-5VS	1	4
Adv. To	C or 3-4VS	5	1

4. Set up ST-1170 Indicator Support with indicator extension on injector plunger top at No. 3 cylinder. Make sure indicator extension is secure in indicator stem and not against rocker lever.

Note: Cylinder No. 3 for injector setting and cylinder No. 5 for valve setting are selected for illustration purposes only. Any cylinder combination may be used as a starting point, see Table 14-11 and firing order Table 14-12.

Table 14-12: Engine Firing Order – Inline
Right Hand Rotation
1-5-3-6-2-4

5. Using ST-1193 Rocker Lever Actuator, or equivalent, bar lever toward injector until plunger is bottomed. Allow injector plunger to rise, bottom again, set indicator at zero (0). Check extension contact with plunger top, turn adjusting screw until Adjustment Value, Table 14-13 is obtained.

6. Bottom plunger again, release lever; indicator must show travel as indicated.

7. Tighten locknut to 30 to 40 ft-lbs [41 to 54 N• m] and actuate injector plunger several times as a check of adjustment. Tighten to 25 to 35 ft-lbs [34 to 47 N• m] when using ST-669 Adapter.

Table 14-13: Uniform Plunger Travel Adjustment Limits

Oil Temp.	Injector Plunger Travel Inch [mm]		Valve Clearance Inch [mm]	
	Adj. Value	Recheck Limit	Intake	Exhaust
Aluminum Rocker Housing				
Cold	0.170 [4.32]	0.169 to 0.171 [4.29 to 4.34]	0.011 [0.28]	0.023 [0.58]
Hot	0.170 [4.32]	0.169 to 0.171 [4.29 to 4.34]	0.008 [0.20]	0.023 [0.58]
Cast Iron Rocker Housing				
Cold	0.175 [4.45]	0.174 to 0.176 [4.42 to 4.47]	0.011 [0.28]	0.023 [0.58]
Hot	0.175 [4.45]	0.174 to 0.176 [4.42 to 4.47]	0.008 [0.20]	0.023 [0.58]

Crosshead Adjustment

1. Loosen valve crosshead adjusting screw locknut and back off adjusting screw, Fig. 14-100, one turn.

2. Use light finger pressure at rocker lever contact surface (1) to hold in contact with valve stem (2). Turn down adjusting screw until it touches valve stem (3).

3. Advance setscrew an additional 20 to 30 deg. to straighten stem on its guide. Using ST-669 Torque Wrench Adapter, tighten locknuts to 22 to 26 ft-lbs [30 to 35 N• m]. If ST-669 is not available, hold screws with screwdriver and tighten locknuts to 25 to 30 ft-lbs [34 to 41 N• m].

4. Check clearance between crosshead and valve spring retainer with wire gauge. There must be a minimum of

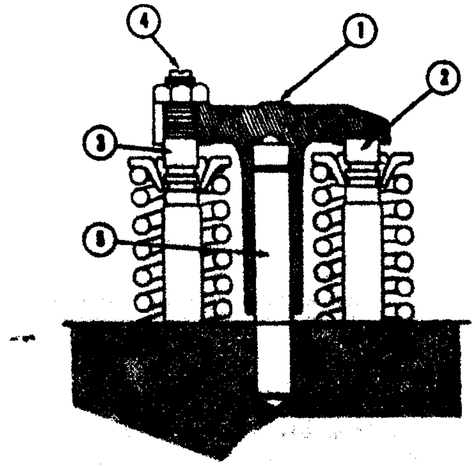


Fig. 14-100, (N21461). Adjusting valve crossheads

0.020 inch [0.51 mm] clearance.

Valve Adjustment

The same engine position (VS Mark) used to adjust injectors is used for setting intake and exhaust valves, however, the valves to be adjusted are not the same cylinder as injectors. In this position adjust valves for cylinder No. 5. See Table 14-11.

1. While adjusting valves, make sure compression release, on those engines so equipped, is in running position.

2. Loosen locknut and back off adjusting screw. Insert feeler gauge between rocker lever and crosshead. Valve clearances are shown in Table 14-13. Turn screw down until lever just touches gauge and lock in this position. Tighten locknut to 30 to 40 ft-lbs [41 to 54 N• m] torque. When using ST-669, torque to 25 to 35 ft-lbs [34 to 47 N• m].

3. Always make valve adjustment after injector adjustment. Move to next cylinder as indicated in Table 14-11 and repeat adjustments.

Adjust Injectors and Valves (Torque Method)

1. If used, pull compression release lever back and block in open position while barring engine, this allows crankshaft to be rotated without working against compression.

2. Loosen the injector rocker lever adjusting nut on all cylinders. This will aid in distinguishing between cylinders adjusted and not adjusted.

3. Bar engine in direction of rotation until a valve set mark (Fig's. 14-98 and 14-99) aligns with the boss on the gear case cover. Example: A or 1-6 "VS".

4. Check the valve rocker levers on the two cylinders

aligned as indicated on pulley (Example: 1 and 6 cylinders for A or 1-6 "VS"). On one cylinder of the pair, both rocker levers will be free and valves closed, this is cylinder to be adjusted.

5. Adjust injector plunger first, then crossheads and valves to clearances indicated in the following paragraphs.

Injector Plunger Adjustment – Torque Method

The injector plungers are adjusted with a torque wrench and a screwdriver adapter to a definite torque setting. See Fig. 14-101.

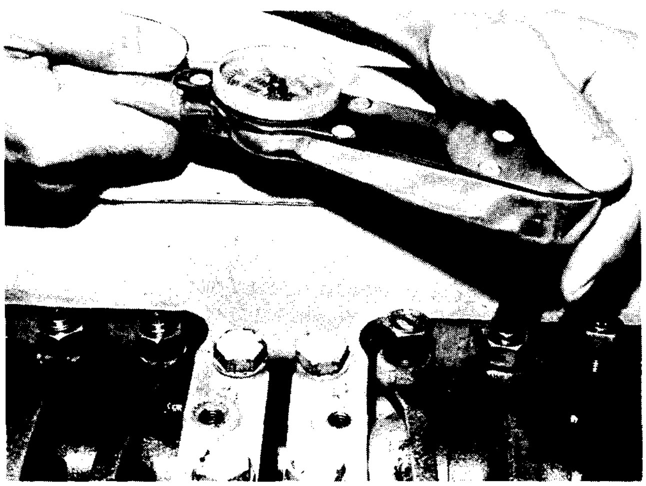


Fig. 14-101. (N11466). Adjusting injector plunger

1. Turn adjusting screw down until plunger contacts cup and advance an additional 15 degrees to squeeze oil from cup.

2. Loosen adjusting screw one turn; then, tighten adjusting screw making two or three passes with torque wrench, to values shown in Table 14-14.

Table 14-14: Injector Adjustment (Oil Temperature)

Cold Set	Hot Set
Cast Iron Rocker Housing	
48 inch-lb [5.4 N• m]	72 inch-lb [8.1 N• m]
Aluminum Rocker Housing	
72 inch-lb [8.1 N• m]	72 inch-lb [8.1 N• m]

Note: Set torque wrench on value required and pull to "0". Break adjusting screw loose and pull torque to value shown on each tightening pass.

3. Tighten locknut to 30 to 40 ft-lbs [41 to 54 N• m] torque. If ST-669 Torque Wrench Adapter is used, torque to 25 to 35 ft-lbs [34 to 47 N• m].

Crosshead Adjustment

See Crosshead Adjustment (Dial Indicator Method).

Valve Adjustment – Torque Method

The same engine position used in adjusting injectors is used for setting intake and exhaust valves.

1. While adjusting valves, make sure that the compression release, on those engines so equipped, is in running position.

Table 14-15: Valve Clearance – Inch [mm]

Intake Valves		Exhaust Valves	
Cold Set	Hot Set	Cold Set	Hot Set
Aluminum Rocker Housing			
0.014 [0.36]	0.014 [0.36]	0.027 [0.69]	0.027 [0.69]
Cast Iron Rocker Housing			
0.016 [0.41]	0.014 [0.36]	0.029 [0.74]	0.027 [0.69]

2. Loosen locknut and back off adjusting screw. Insert feeler gauge between rocker lever and crosshead. Valve clearances are shown in Table 14-15. Turn screw down until lever just touches gauge and lock in this position. Tighten locknut to 30 to 40 ft-lbs [41 to 54 N• m] torque. When using ST-669 torque to 25 to 35 ft-lbs [34 to 47 N• m].

3. Continue to bar engine to next "VS" mark and adjust each cylinder in firing order. See Table 14-12.

After injector and valve adjustment is completed, bar or crank (in chassis overhaul) engine several revolutions to properly seat adjusting screws, plunger links, push tubes, etc. to mating surfaces. Take break-away torque reading on injector plunger adjusting screws. Break-away torque must be the same as adjustment torque. See Table 14-14. Re-adjust as necessary.

Jacobs Brake

Install Jacobs Brake, if used. See Group 20.

Adjust the Valves and Injectors

The valves and injectors must always be in the correct adjustment for the engine to operate efficiently.

The adjustment value for the injectors is determined by which type of rocker lever housings are used on the engine. See Table 14 to find the correct value for the aluminum and the cast iron rocker housings.

Note: When you adjust the valves and injectors for a left hand rotation engine, make sure that you use the correct sequence shown in Table 12.

The Dial Indicator Method to Adjust the Injectors

Caution: Do not use this method to adjust the top-stop injectors.

1. Rotate the crankshaft in the direction of engine rotation. Align the "A" or "1-6 VS" mark on the accessory drive pulley with the pointer on the gear cover, Fig. 14-70 and Fig. 14-71.

Crosshead Adjustment

Loosen the adjusting screw locknut. Loosen the adjusting screw one full turn.

Note: Engines equipped with Jacobs Brake use special crossheads for the exhaust valves. See Group 20.

Hold the crosshead down against the valve stem that is nearest to the push rod. Use light pressure to hold the cross head. Turn the adjusting screw in until it touches the valve stem, Fig. 14-66.

Hold the crosshead adjusting screw in position and tighten the locknut. Tighten the locknut to 25 to 30 ft.-lbs. [34 to 41 N•m] torque.

Note: When the Part No. ST-669 Torque Wrench Adapter is used, tighten the locknut to 22 to 26 ft.-lbs. [30 to 35 N•m] torque.

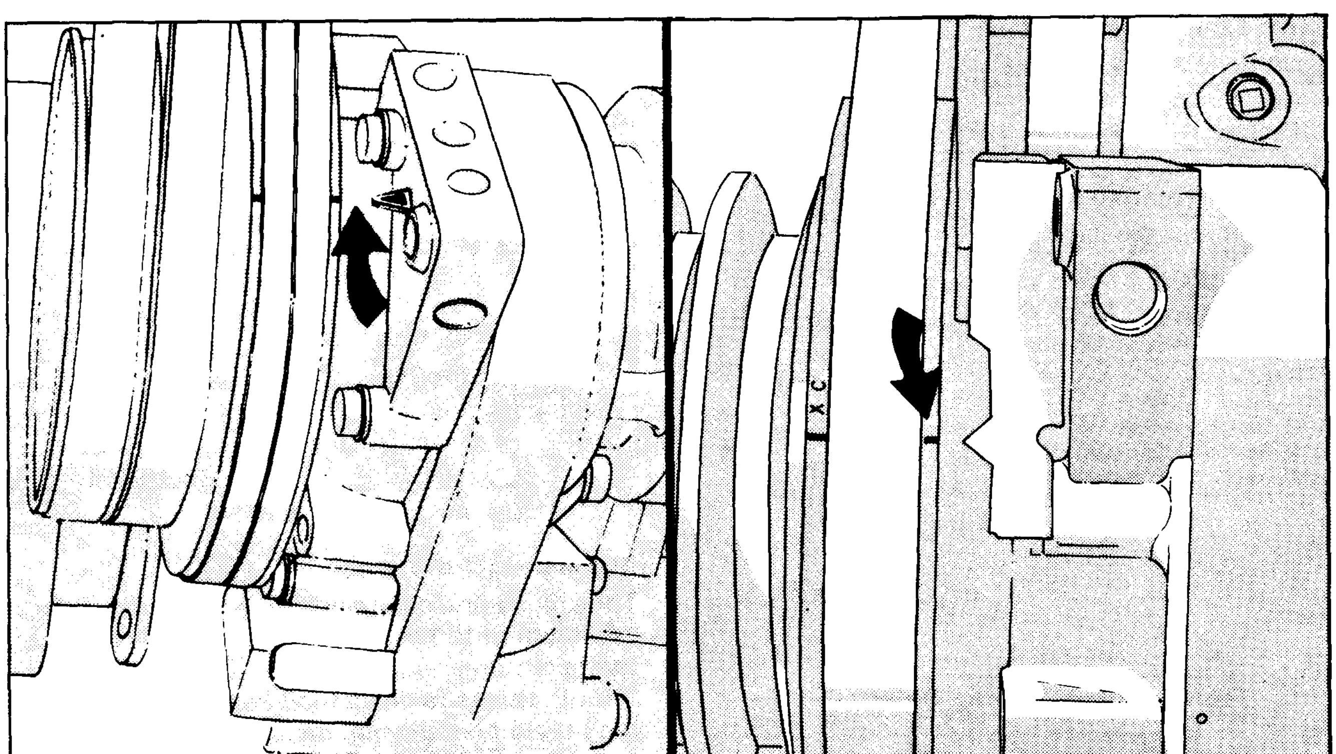


Fig. 14-70 (OM1050L). Align The Timing Marks With Pointer On The Gear Cover.

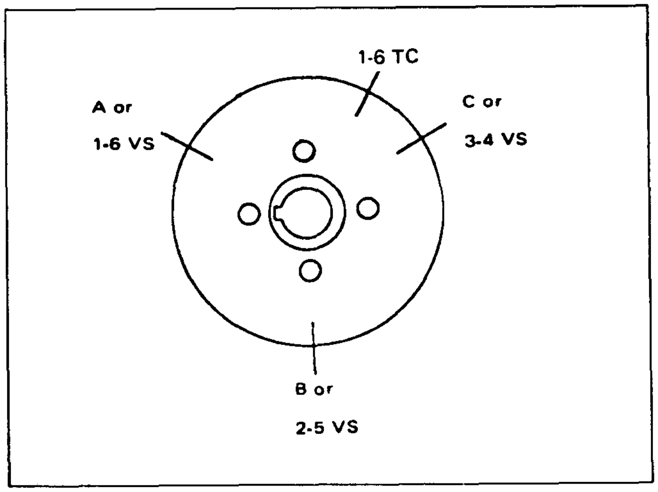


Fig. 14-71 (N114230). The Timing Marks On The Accessory Drive Pulley.

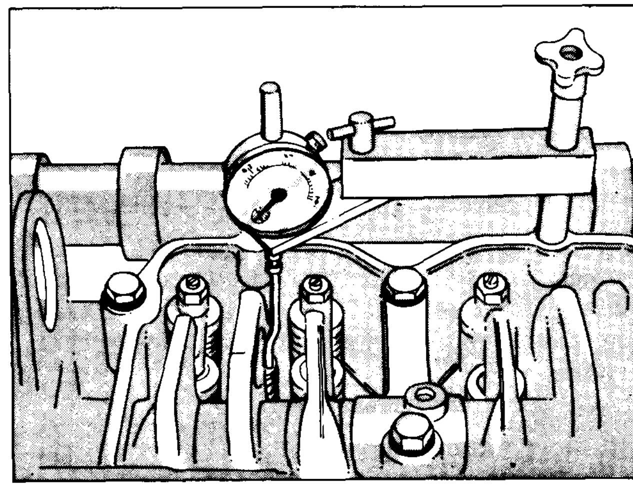


Fig. 14-72 (OM1051L). Check The Travel Of The Injector Plunger.

2. When the "A" or "1-6 VS" mark is aligned with the pointer, the intake and exhaust valves for cylinder number 5 must be in the closed position. The injector plunger for cylinder number 3 must be at the top of its travel. When the valves are closed, the rocker levers for cylinder number 5 will be loose. If they are not, rotate the crankshaft 360 degrees and align the marks on the pulley with the pointer.

Note: The instructions using cylinder No. 3 to begin the injector adjustments are for illustration purposes. You can begin the adjustments with any of the cylinders as shown in Table 12.

Table 12: Injector and Valve Set Position

Right Hand Rotation Engine

Bar In Direction	Pulley Position	Set Cylinder Injector	Set Cylinder Valve
Start	A or 1-6 VS	3	5
Adv. To	B or 2-5 VS	6	3
Adv. To	C or 3-4 VS	2	6
Adv. To	A or 1-6 VS	4	2
Adv. To	B or 2-5 VS	1	4
Adv. To	C or 3-4 VS	5	1

Table 13: Engine Firing Order

Right Hand: 1-5-3-6-2-4

Table 14: Adjustment Limits Using Dial Indicator Method — Inch [mm]

Oil Temp.	Injector Plunger Travel	Valve Clearance Intake	Valve Clearance Exhaust
Aluminum Rocker Housing			
Cold	0.170 ± 0.001	0.011	0.023
	[4.32 ± 0.03]	[0.28]	[0.58]
Hot	0.170 ± 0.001	0.011	0.023
	[4.32 ± 0.03]	[0.28]	[0.58]
Cast Iron Rocker Housing			
Cold	0.175 ± 0.001	0.013	0.025
	[4.45 ± 0.03]	[0.33]	[0.64]
Hot	0.170 ± 0.001	0.011	0.023
	[4.32 ± 0.03]	[0.28]	[0.58]
NTE-855 (European Big Cam Only)			
	0.225	0.011	0.023
	[5.72]	[0.28]	[0.58]
NT-855 (Australian Big Cam Only)			
	0.228	0.011	0.023
	[5.79]	[0.28]	[0.58]

Note: Always check the engine dataplate for the injector and valve adjustment values.

Definition of "Cold"

The engine must be at any stabilized water temperature of 140°F [60°C] or below.

Definition of "Hot"

The oil sump (oil pan) temperature must be a minimum of 190°F [88°C] and the water (coolant) temperature a minimum of 185°F [85°C]. The "Hot" values are given for when the engine is being tested on a dynomometer. At these times the adjustments must be made quickly.

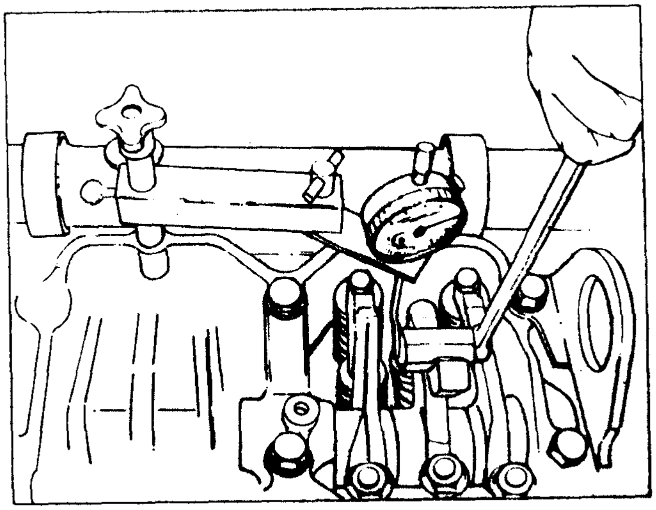


Fig. 14-73 (OM1052L). Actuate The Rocker Lever.

3. Use the Part No. 3375842 Injector Adjustment Kit to check the travel of the injector plunger. Install the dial indicator and support so that the extension for the dial indicator is against the injector plunger, Fig. 14-72. Make sure that the extension is correctly installed into the indicator stem and that it does not touch the rocker lever.
4. Actuate the rocker lever to push the injector plunger to the bottom of its travel. Use the ST-1193 Rocker Lever Actuator from the 3375842 Adjustment Kit to actuate the rocker lever, Fig. 14-73. Let the plunger rise to the top of its travel. Actuate the lever again and set the indicator at zero as you hold the plunger at the bottom of its travel.
5. Tighten the rocker lever adjusting screw until the injector plunger has the correct travel as shown in Table 14.
6. Hold the adjusting screw in position and tighten the locknut to 40 to 45 ft.-lbs. [54 to 61 N•m] torque. Actuate the rocker lever two or three times to make sure that the adjustment is correct. When you use the ST-669 Adapter to tighten the locknut, tighten the locknut to 30 to 35 ft.-lbs. [41 to 47 N•m] torque.

Adjust the Valves

After you adjust the injector, the valves must be adjusted for the cylinder shown in Table 12 **before** you rotate the crankshaft to the next adjustment mark.

1. Make sure that the locknuts for the adjusting screws are loose.
2. Put a feeler gauge between the rocker lever and the contact surface of the crosshead, Fig. 14-74. See Table 14 to find the correct thickness of the feeler gauge.

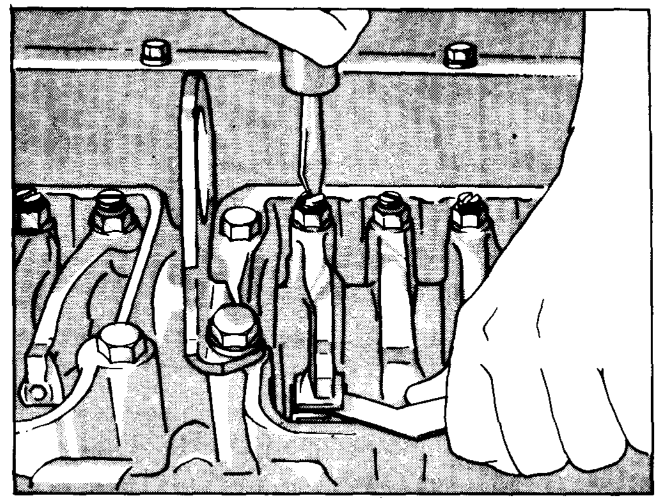


Fig. 14-74 (OM1055L). Adjust The Valves.

3. Tighten the adjusting screw until the rocker lever touches the feeler gauge. Hold the adjusting screw in position and tighten the locknut to 40 to 45 ft.-lbs. [54 to 61 N•m] torque. When you use the ST-669 Adapter, tighten the locknut to 35 to 40 ft.-lbs. [47 to 54 N•m] torque.
4. Repeat the procedure to adjust all of the remaining valves.

To Adjust the Top-Stop Injectors

Note: To adjust the injectors for engines with MVT, the MVT actuator must be in the fully retarded position.

Caution: The top-stop injector plunger travel can only be adjusted when the injectors are removed from the engine. Use the Part No. 3379160 Adjusting Tool to adjust the plunger travel.

1. Rotate the crankshaft in the direction of engine rotation and align the "VS" mark on the accessory drive pulley with the pointer on the gear cover.
2. Loosen the locknut for the rocker lever adjusting screw. Tighten the adjusting screw until all of the clearance is removed from between the rocker lever and injector link. Then tighten the adjusting screw one additional turn.
3. Loosen adjusting screw until the spring washer is against the stop of the injector, Fig. 14-75.

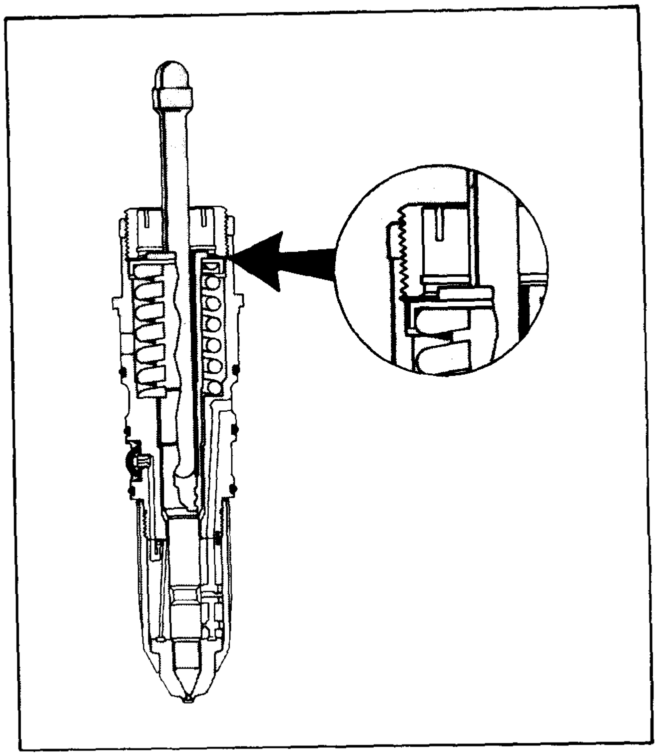


Fig. 14-75. Top-Stop Injector — The Washer Against The Stop.

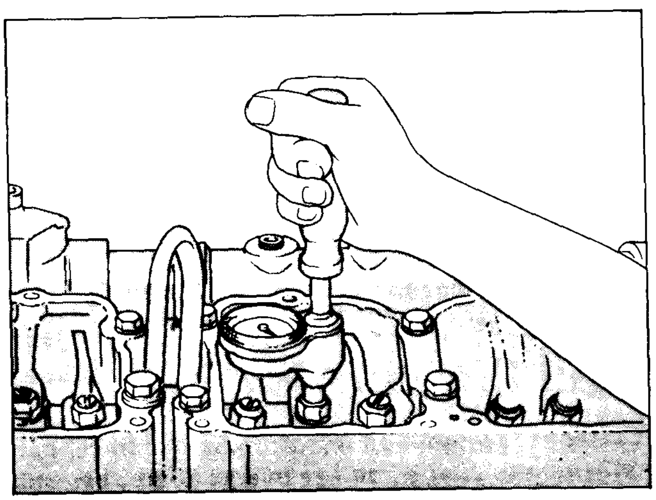


Fig. 14-76. Tighten The Adjusting Screw.

4. Tighten the adjusting screw to 5 to 6 in.-lbs. [0.56 to 0.68 N•m] torque. Use the Part No. 3375232 Torque Wrench to tighten the screw, Fig. 14-76. If you do not have a torque wrench, tighten the screw until there is light pressure against the injector link. The link must be free enough that you can rotate it with your hand.
5. Hold the adjusting screw in position and tighten the locknut to 40 to 45 ft.-lbs. [54 to 61 N•m] torque. When you use the ST-669 Adapter tighten the locknut to 30 to 35 ft.-lbs. [41 to 47 N•m] torque.

The Torque Method to Adjust the Injectors

1. Rotate the crankshaft in the direction of engine rotation. Align the mark on the pulley with the pointer on the gear cover. Check both cylinders indicated on the pulley (Fig. 14-71) to see which valve rocker levers are loose. Adjust the injector of the cylinder in which the rocker levers are loose.
2. Loosen the adjusting screw locknut. Tighten the adjusting screw until the injector plunger is at the bottom of its travel. Tighten the adjusting screw an additional 15 degrees to remove all of the oil from the injector cup. Loosen the adjusting screw one full turn.
3. Use a torque wrench that is calibrated in inch-lbs. to adjust the injectors. The torque wrench must have a screwdriver adapter. Tighten the adjusting screw to the correct torque value shown in Table 15. Loosen the adjusting screw and adjust it to the torque value two or three times to make sure that it is correctly adjusted.

Table 15: Injector Adjustment (Torque Method)

Cold Set	Hot Set
Cast Iron Rocker Housing	
48 inch-lb. [5.4 N•m]	72 inch-lb. [8.1 N•m]
Aluminum Rocker Housing	
72 inch-lb. [8.1 N•m]	72 inch-lb. [8.1 N•m]

4. Hold the adjusting screw in position and tighten the locknut to 40 to 45 ft.-lbs. [54 to 61 N•m] torque. When you use the ST-669 Adapter, tighten the locknut to 30 to 35 ft.-lbs. [41 to 47 N•m] torque.

Valve Adjustment

When using the Torque Method, the valves and injector are adjusted on the same cylinder before rotating the crankshaft for the next cylinder. See Table 16 to find the correct valve clearance. Tighten the locknuts to 40 to 45 ft.-lbs. [54 to 61 N•m] torque.

Table 16: Valve Clearance (Torque Method) — Inch [mm]

Intake Valves		Exhaust Valves	
Cold Set	Hot Set	Cold Set	Hot Set
Aluminum Rocker Housing			
0.014 [0.36]	0.014 [0.36]	0.027 [0.69]	0.027 [0.69]
Cast Iron Rocker Housing			
0.016 [0.41]	0.014 [0.36]	0.029 [0.74]	0.027 [0.69]

DETROIT DIESEL

ENGINE TUNE-UP PROCEDURES

There is no scheduled interval for performing an engine tune-up. As long as the engine performance is satisfactory, no tune-up should be needed. Minor adjustments in the valve and injector operating mechanism, governor, etc. should only be required periodically to compensate for normal wear on parts.

To comply with emissions regulations, injector timing, exhaust valve clearance, engine idle and no-load speeds, and throttle delay or fuel modulator settings must be checked and adjusted if necessary, at 50,000 miles (80 467 km) intervals (refer to Section 4).

The type of governor used depends upon the engine application. Since each governor has different characteristics, the tune-up procedure varies accordingly.

The governos are identified by a name plate attached to the governor housing. The letter D.W.-L.S. stamped on the name plate denote a double-weight limitng speed governor.

Normally, when performing a tune-up on an engine in service, it is only necessary to check the various adjustments for a possible change in the settings. However, if a cylinder head, governor or injectors have been replaced or overhauled then certain prelimimary adjustment are required before the engine is started.

The preliminary adjustments consist of the first four items in the tune-up sequence. The procedures are the same except that the valve clearance is greater for a cold engine.

> **NOTE:** If a supplementary governing device, such as throttle delay mechanism, is used, it must be disconnected prior to the tune-up. After the governor and injector rack adjustments are completed, the supplementary governing device must be reconnected and adjusted.

To tune up an engine completely, perform all of the adjustments, in the tune-up sequence given below after the engine has reached normal operating temperature. Since the adjustments are normally made while the engine is stopped, it may be necessary to run the engine between adjustments to maintain normal operating temperature.

Use new valve rocker cover gasket(s) after the tune-up is comleted.

Tune-Up Sequence

> **NOTE:** Before starting an engine after an engine speed control adjustment or after removal of the engine governor cover, the serviceman must determine that the injector racks move to the no-fuel position when the governor stop lever is placed in the stop position. Engine overspeed will result if the injector racks cannot be postioned at no-fuel with the governor stop lever.

> **CAUTION:** An overspeeding engine can result in engine damage which could cause personal injury.

1. Adjust the exhaust valve clearance.
2. Time the fuel injectors.
3. Adjust the governor gap.
4. Position the injector rack control levers.
5. Adjust the maximum no-load speed.
6. Adjust the idle speed.
7. Adjust the Belleville spring for "TT" horsepower.
8. Adjust the buffer screw.
9. Adjust the supplementary governing device, if necessary.

EMISSION REGULATIONS FOR ON-HIGHWAY VEHICLE ENGINES

On-highway vehicle and coach engines built by Detroit Diesel Allison are certified to be in compliance with Federal and California Emission Regulations established for each model year beginning with 1970.

Engine certification is dependent on five physical characteristics:

1. Fuel injector type.
2. Maximum full-load engine speed.
3. Camshaft timing.
4. Fuel injector timing.
5. Throttle delay (orifice size).

Tables 1 through 12 summarize all of the pertinent data concerning the specific engine configurations required for each model year.

When serviced, all on-highway vehicle and coach engines should comply with the specifications for the specific model year in which the engine was built.

Trucks in a fleet containing engines of various model years can be tuned to the latest model year, provided the engines have been updated to meet the specifications for that particular year.

Family	L-53N & V-53N	L-71N (4 Valve) & V-71N (4 Valve)			V-71N (2V)	V-71T	
Engine	3 & 4-53N 6V & 8V-53N	3, 4 & 6-71N 6V, 8V & 12V-71			6V-71N (2V)	8V-71T	
Injector	N40 N45 N50**	71N5 N55 N60	N65	N70	71N5 N55 N60	N65	N70 N75
Maximum Engine Speed	2800	2100	2100	2300	2100	2100	2100
Camshaft Timing	Adv.	Std.	Adv.	Adv.	Std.	Std.	Std.
Injector Timing	1.460	1.460	1.484	1.460	1.460	1.484	1.460
* Throttle Delay	No	No	No	No	Yes	Yes	Yes

* Throttle delays must have .022 in. diameter orifice.
** Exempt for fire fighting apparatus.

TABLE 1 - 1970 Engines

Family	L-53N & V-53N	L-71N (4 Valve) & V-71N (4 Valve)			V-71N (2V)	L-71T & V-71T	
Engine	3 & 4-53N 6V & 8V-53N	3, 4 & 6-71N 6V, 8V & 12V-71N			6V-71N (2V)	6-71T 6V & 8V-71T	
Injector	N40 N45 N50 *'*	71N5 N55 N60	N65	N70	71N5 N55 N60	N65	N70 N75
Maximum Engine Speed	2800	2100	2100	2300	2100	2100	2100
Camshaft Timing	Adv.	Std.	Adv.	Adv.	Std.	Std.	Std.
Injector Timing	1.460	1.460	1.484	1.460	1.460	1.484	1.460
* Throttle Delay	No	No	No	No	Yes	Yes	Yes

* Throttle delays must have .022 in. diameter orifice.
' Exempt for fire fighting apparatus.

TABLE 2 - 1971 Engines

Engine Family	L-53N & V-53N	L-71N (4 Valve) & •V-71N (4 Valve)			V-71N (2V) Coach & V-71N (4V) Coach	L-71T & V-71T		* Fire Trucks
Engine	3 & 4-53N 6V & 8V-53N	3, 4, & 6-71N 6V, 8V & 12V-71N			6V-71N (2V) 6V & 8V-71N (4V)	6-71T 6V, 8V, & 12V-71T		6-71T 8V-71T
Injector	N40 N45 N50	71N5 N55 N60	N65	N70	71N5 N55 N60	N65	N70 N75	N75
XX Maximum Full Load Engine Speed	2800	2300	2300	2300	2100	2100	2100	2300
Camshaft Timing	Adv.	Std.	Adv.	Adv.	Std.	Std.	Std.	Std.
$ Injector Timing	1.460"	1.460"	1.484"	1.460"	1.470"	1.484"	1.460"	1.460"
Throttle Delay	.016" Orifice	No	No	No	.016" Orifice	.016" Orifice	.016" Orifice	.016" Orifice

• Includes certain highway coach engines.
$ The adjusted height of the fuel injector follower in relation to the injector body.
XX No load engine speed will vary with injector size and governor type.
* 6-71T and 8V-71T Fire Truck Application exempt from certification.

The 6V-71N two valve and 6V and 8V-71N four valve coach engines now have a fuel injector timing of 1.470" and will use injector timing gage J 24236.

TABLE 3 - 1972 Engines

Family	L-53N & V-53N	@ L-71N (4 Valve) & V-71N (4 Valve)			V-71N (2V) Coach & V-71N (4V) Coach		L-71T & V-71T		Exempt Engines***	
Engine	3 & 4-53N 6V & 8V-53N	3, 4 & 6-71N 6V, 8V & 12V-71N			6V-71N (2V) 6V & 8V-71N (4V)		6-71T 6V, 8V & 12V-71T		6-71T 8V-71T	
** Injector	C40 C45 C50	71C5	C55 C60	C65 C70	71C5	C55 C60	C65	N70 N75	C65	N70 N75
** Maximum Full Load Engine Speed	2800	2300	2300	2300	2100	2100	2100	2100	2300	2300
Camshaft Timing	Adv.	Std.	Std.	Adv.	Std.	Std.	Std.	Std.	Std.	Std.
Injector Timing	1.460	1.484	1.460	1.484	1.484	1.470	1.460	1.484	1.460	1.484
* Throttle Delay	Yes	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes

* Throttle delays must have .016" diameter orifice.
** No load engine speed will vary with injector size and governor type.
*** Exempt engine rating for fire truck application only (Code No. 351).
@ Includes certain highway coach engines.
Use minimum idle speed of 500 rpm on all engines, except coach engines where a minimum of 400 rpm is allowed.

TABLE 4 - 1973 Engines

Engine	4-53N	6V-53N	6L-71N •	6V-71N •	8V-71N •	12V-71N •	6V-71N (2V) Coach ••	8V-71N Coach ••	6L-71T	8V-71T	6V-92	8V-92	6V-92T	8V-92T
Injectors	C40 C45 C50	C40 C45 C50	71C5 C55 C60 C65 C70	71C5 C55 C60 C65 C70	71C5 C55 C60 C65 C70	71C5 C55 C60 C65	71C5 C55 C60	71C5 C55 C60	C65 N70 N75	C65 N70 N75	70 75 80 85	70 75 80 85	80 85 90	80 85 90
Maximum Full-Load Engine Speed †	2800	2800	2300	2300	2300	2100	2100	2100	2100	2100	2100	2100	2100	2100
Camshaft Timing	Advanced	Advanced	71C5, C55, C60 Standard C65 and C70 % Advanced				Standard	Standard	Standard	Standard	Standard	Standard	Standard	Standard
Injector Timing	1.470	1.470	71C5, C65, C70 % - 1.484 C55, C60 - 1.460				71C5 - 1.484 C55, C60 - 1.470		C65 - 1.460 N70, N75 - 1.484		1.460	1.460	1.484	1.484
Throttle Delay	Yes *	Yes *	No	No	No	No	Yes *	Yes *	Yes **	Yes **	No	No	Yes **	Yes **
Yield Link	Yes	Yes	No	No	No	No	Yes	Yes	Yes	Yes	No	No	Yes	Yes

• Includes Certain Parlor and Suburban Coach Engines
•• Uses No. 1 Diesel Fuel for City Coaches
* .250" Diameter Fill Hole, .016" Diameter Discharge Orifice
** .078" Diameter Fill Hole, .016" Diameter Discharge Orifice
% Not Certified for 12V-71N
† Not to exceed fuel injector size and maximum operating rpm that has been established for the specific application of the engine.

Use minimum idle speed of 500 rpm on all engines, except coach engines where a minimum of 400 rpm is allowed.

TABLE 5 - 1974 Engines

ENGINE	6L-71N	8V-71N	6V-71N 2 Valve Coach @	8V-71N 4 Valve Coach @	8V-71TA	6V-92TA *	8V-92TA *
Injectors	71B5 B55 B60	71B5 B55 B60 B65	7B5E B55E B60E	71B5 B55 B60	N65 N70 N75	9280 9285 9290	9280 9285 9290
†Maximum Full-Load Eng. Spd.	2300	2300	2100	2100	2100	2100	2100
Camshaft Timing	71B5, B55, B60-Std. B65-Adv.		Std.	Std.	Std.	Std.	Std.
Injector Timing	71B5, B55, B60-1.500 B65-1.484		1.500	1.500	N65-1.520 N70, N75- 1.496	1.484	1.484
Throttle Delay	No	No	Yes #	Yes #	Yes ##	$ Yes ##	$ Yes ##
Yield Link	No	No	Yes	Yes	Yes	Yes	Yes

† Not to exceed fuel injector size and maximum operating rpm that had been established for the specific application of the engine.
* 6V-92TA available September, 1975—8V-92TA available May, 1975 pending certification tests.
# .250" Diameter fill hole
.078" Diameter fill hole
$ Offset piston linkage
@ Uses No. 1 diesel fuel for city coaches.

Use minimum idle speed of 500 rpm on all engines, except coach engines where a minimum of 400 rpm is allowed.

TABLE 6 - 1975 Federal and California Engines

Engine	4-53N	6V-53N	6L-71N @	6V-71N @	8V-71N @	12V-71N @	6V-71N 2 Valve Coach @@	8V-71N 4 Valve Coach @@	6L-71T	8V-71T	6V-92	8V-92	6V-92T	8V-92T
Injectors	C40 C45 C50	C40 C45 C50	71C5 C55 C60 C65 C70	71C5 C55 C60 C65 C70	71C5 C55 C60 C65 C70	71C5 C55 C60 C65	71C5 C55 C60	71C5 C55 C60	C65 N70 N75	C65 N70 N75	9270 9275 9280 9285	9270 9275 9280 9285	9280 9285 9290	9280 9285 9290
+Maximum Full-Load Eng. Spd.	2800	2800	2300	2300	2300	2100	2100	2100	2100	2100	2100	2100	2100	2100
Camshaft Timing	Adv.	Adv.	71C5, C55, C60 Standard C65, C70% Advanced				Std.	Std.	Std.	Std.	Std.	Std.	Std.	Std.
Injector Timing	1.470	1.470	71C5, C65, C70% - 1.484 C55, C60, - 1.460				71C5-1.484 C55, C60 - 1.470		C65 1.460 N70, N75 - 1.484		1.460	1.460	1.484	1.484
Throttle Delay	Yes #	Yes #	No	No	No	No	Yes #	Yes #	Yes ##	Yes ##	No	No	Yes ##	Yes ##
Yield Link	Yes	Yes	No	No	No	No	Yes	Yes	Yes	Yes	No	No	Yes	Yes

@ Includes certain highway coach engines.
@@ Uses No. 1 Diesel Fuel for City Coaches.
+ Not to exceed fuel injector size and maximum operating rpm that had been established for the specific application of the engine.
% Not certified for 12V-71N
# .250" Diameter fill hole
##.078" Diameter fill hole

Use minimun idle speed of 500 rpm on all engines, except coach engines where a minimum of 400 rpm is allowed.

TABLE 7 - 1975 Federal Engines

1976 CALIFORNIA CERTIFIED AUTOMOTIVE CONFIGURATIONS

ENGINE FAMILIES	6L-71N	8V-71N	(e) 6V-71N COACH	(e) 8V-71N COACH	8V-71TA AFTERCOOLED		6V-92TA AFTERCOOLED		8V-92TA AFTERCOOLED	
					TA	TTA	TA	TTA	TA	TTA
INJECTORS (a)	71B5 B55 B60 B65	71B5 B55 B60 B65	7B5E B55E B60E	71B5 B55 B60	N65 N70 N75	N75	9A80 9A85 9A90	9A90	9280 9285 9290	9290
APPROVED CONSTANT HORSEPOWER FOR TTA ENGINES						305		270		365
MAXIMUM (b) FULL LOAD ENGINE SPEED	2300	2300	2100	2100	2100	(d) 1900-MIN. 1950-MAX.	2100	(d) 1900-MIN 1950-MAX.	2100	(d) 1900-MIN. 1950-MAX.
CAMSHAFT TIMING	STD. (B65-ADV.)	STD. (B65-ADJ.)	STD.	STD.	STD.	STD.	STD.	STD.	STD	STD
INJECTOR TIMING	1.500 (B65-1.484)	1.500 (B65-1.484)	1.500	1.500	1.496 (N65-1.520)	1.496	1.500	1.500	1.484	1.484
THROTTLE DELAY YIELD LINK	NOT REQ. (B65-REQ.) (g)	NOT REQ.	(f) REQ.	(f) REQ.	(g) REQ.	(g) REQ.	(g) REQ.	(g) REQ.	(g) REQ.	(g) REQ.
TURBOCHARGER A/R					TV 8101 1.39	TV 8101 1.39	TV 8102 1.08	TV 8102 1.08	TV 8101 1.60	TV 8101 1.60

(a) -See Engine Application Rating (Tech. Data Book I, Vol. I) for specific application usage of injector size and full-load speed combination. No-load speed will vary with injector size and governor type.
(b) -Use a minimum idle speed of 400 RPM on all coach engines with throttle delay, and a minimum idle speed of 500 RPM on all other automotive applications.
(c) -Includes certain highway coach engines.
(d) -TT (TTA) must have full load RPM within the range shown.
(e) -Uses No. 1 Diesel Fuel.
(f) -Large fill hole (.250 Dia.)-.016 discharge orifice.
(g) -Small fill hole (.078 Dia.)-.016 discharge orifice.

1976 FEDERAL CERTIFIED AUTOMOTIVE CONFIGURATIONS

ENGINE FAMILIES	4L-53N	6V-53N	(c) 6L-71N	(c) 6V-71N	(c) 8V-71N	(c) 12V-71N	(e) 6V-71N COACH	(e) 8V-71N COACH	6L-71T	8V-71T		
										T	OTM	TT
INJECTORS (a)	C40 C45 C50	C40 C45 C50	71C5 C55 C60 C65 C70	71C5 C55 C60 C65 C70	71C5 C55 C60 C65 C70	71C5 C55 C60 C65	71C5 C55 C60	71C5 C55 C60	C65 N70 N75	C65 N70 N75	C65 N70 N75	N75
APPROVED CONSTANT HORSEPOWER TT ENGINES												305
MAXIMUM (b) FULL LOAD SPEED	2800	2800	2300	2300	2300	2100	2100	2100	2100	2100	2100	(d) 1900-MIN. 1950-MAX.
CAMSHAFT TIMING	ADV.	ADV.	71C5, C55 and C60 - Standard C65 and C70 - Advanced				STD.	STD.	STD.	STD.	STD.	STD.
INJECTOR TIMING	1.470	1.470	71C5, C65 and C70 - 1.484 C55 and C60 - 1.460				71C5 - 1.484 C55, C60 - 1.470		C65-1.460 N70, N75 - 1.484			
THROTTLE DELAY YIELD LINK	(f) REQ.	(f) REQ.	NOT REQ.	NOT REQ.	NOT REQ.	NOT REQ.	(f) REQ.	(f) REQ.	(g) REQ.	(g) REQ.	(g) REQ.	(g) REQ.
TURBOCHARGER A/R									T18A40 1.00 4MF-782 4.70 sq. in.	T18A40 1.50 4MF-782 6.54 sq. in.	TV 8101 1.60	TV 8101 1.39

ENGINE FAMILIES	6V-92	8V-92	6V-92T			8V-92T		
			T	OTM	TT	T	OTM	TT
INSTRUCTORS (a)	9270 9275 9280 9285	9270 9275 9280 9285	9280 9285 9290	9280 9285 9290	9290	9280 9285 9290	9280 9285 9290	9290
APPROVED CONSTANT HORSEPOWER FOR TT ENGINES					240-270			365
MAXIMUM (b) FULL LOAD SPEED	2100	2100	2100	2100	(d) 1900-MIN 1950-MAX	2100	2100	(d) 1900-MIN. 1950-MAX
CAMSHAFT TIMING	STD.	STD.	STD.	STD.	STD.	STD.	STD.	STD.
INJECTOR TIMING	1.460	1.460	1.484	1.484	1.484	1.484	1.484	1.484
THROTTLE DELAY YIELD LINK	NOT REQ.	NOT REQ.	(g) REQ.	(g) REQ.	(g) REQ.	(g) REQ.	(g) REQ.	(g) REQ.
TURBOCHARGER A/R			T18A40 1.14	TV 8102 1.23	TV 8102 1.23	T18A90 1.50	TV 8101 1.84	TV 8101 1.84

TABLE 8 – 1976 Federal and California Engines

1977 CALIFORNIA CERTIFIED AUTOMOTIVE CONFIGURATIONS

ENGINE FAMILIES	6L-71N	6V-71TAE		8V-71TAE	6V-92TA		8V-92TA	
		TAE	TTAE		TA	TTA	TA	TTA
(a) INJECTORS	71B5 B55 B60	7A65 7A70 7A75	7A75	7A50 7A55 7A60	9A80 9A85 9A90	9A90	9A80 9A85 9A90	9A90
(a) APPROVED MINIMUM CONSTANT HORSEPOWER			305			MIN-MAX 240-270		335
(a) MAXIMUM RATED SPEED	2300	2100	2100	2100	2100	1950	2100	2100
(a) MINIMUM RATED SPEED	71B5-2300 B55-2100 B60-2100	1950	1900	1800	1950	1900	1950	1800
GEAR TRAIN TIMING	STD.	STD.	STD.	STD.	STD.	STD.	STD.	STD.
INJECTOR TIMING	1.500	1.480	1.480	7A50-1.486 7A55-1.488 7A60-1.480	1.484	1.484	1.484	1.484
THROTTLE DELAY (YIELD LINK) SETTING (IN)	NONE	(f) REQ .586	(f) REQ .586	# REQ .686	(f)% REQ .636-9A90 .570-9A80 & 9A85	(f)% REQ .636	(f)% REQ .836-9A90 .570-9A80 & 9A85	(f)% REQ .836
LINER PORTHEIGHT (IN)	1.05	.95	.95	.95	.95	.95	.95	.95
COMPRESSION RATIO	18.7:1	17:1	17:1	17:1	17:1	17:1	17:1	17:1
BLOWER DRIVE RATIO	2:1	1.95:1	1.95:1	1.95:1	2.05:1	2.05:1	2.05:1	2.05:1
GOVERNOR TYPE	LIMITING SPEED							
THERMOSTAT	170° -180° F NOMINAL OPENING TEMPERATURE							
TURBOCHARGER A/R		TV7101 1.23	TV7101 1.23	TV7101 1.23	TV8102 1.06	TV8102 1.06	TV8101 1.60	TV8101 1.60

EMISSION STANDARDS

YEAR	FEDERAL (EPA) (1): OPACITY (%): ACCELERATION	LUG DOWN	PEAK	GASEOUS EMISSIONS GRAMS/BHP-HR: CO	HC	$HC + NO_x$	CALIFORNIA GASEOUS EMISSIONS GRAMS/BHP-HR: CO	$HC + NO_x$	OR (2): NO_x	HC	OR (2): $HC + NO_x$	HC
1977	20%	15%	50%	40	–	16	25	5	7.5	1.0	–	–
1978	20%	15%	50%	40	–	16	25	5	7.5	1.0	–	–
1979	20%	15%	50%	25	1.5	10	25	5	7.5	1.5(3)	–	–
1980	20%	15%	50%	25	1.5	10	25	5	–	–	6.0	1.0
1981	20%	15%	50%	25	1.5	10	25	5	–	–	6.0	1.0
1982	20%	15%	50%	25	1.5	10	25	5	–	–	6.0	1.0
1983	N/A	N/A	N/A	N/A	N/A	N/A	25	–	–	–	4.5	0.5

NOTES: 1 Federal standards for 1979 and later are currently proposed.
2 California legislation allows the engine manufacturer to decide on the following:
(a) 1977-1979 – choose between combining $HC + NO_x$ or certify individual values of HC and NO_x.
(b) 1980-1982 – choose between combining $HC + NO_x$ or certify a value of HC along with a combination of $HC + NO_x$

(a) – See Engine Application Rating (Tech Data Book I, Vol. I) for specific application usage of injector size and full-load speed combination. No-load speed will vary with injector size and governor type.

(b) – Use a minimum idle speed of 400 RPM on all coach engines with Transit Coach Application Code No. 345, and a minimum idle speed of 500 RPM on all other automotive applications.

(c) – Includes certain highway coach engines.

(d) – Uses No. 1 Diesel Fuel.

(e) – Large fill hole (.250 Dia.) .016 discharge orifice.

(f) – Small fill hole (.078 Dia.) .016 discharge orifice.

(C70) – Not available on 12V-71N.

% – Offset piston linkage.

– Use (e) with Transit Coach Appl. Code No. 345.
Use (f) with Parlor Coach Appl. Code No. 341 & 346.

1977 FEDERAL CERTIFIED AUTOMOTIVE CONFIGURATIONS

ENGINE FAMILIES	4L-53N	6V-53N	(c) 6L-71N	(c) 6V-71N	(c) 8V-71N	(c) 12V-71N	(d) 6V-71N COACH	(d) 8V-71N COACH
(a) INJECTORS	C40 C45 C50	C40 C45 C50	71C5 C55 C60 C65 C70	71C5 C55 C60 C65 C70	71C5 C55 C60 C65 C70	71C5 C55 C60 C65	71C5 C55 C60	71C5 C55 C60
(a) APPROVED MINIMUM CONSTANT HORSEPOWER								
(a) MAXIMUM RATED SPEED	2800	2800	2300	2300	2300	2100	2100	2100
(a) MINIMUM RATED SPEED	C40-2800 C45-2400 C50-2500	C40-2600 C45-2500 C50-2100	71C5-2300 C55-1950 C60-1900 C65-1950 C70-2100	71C5-2100 C55-2100 C60-1950 C65-2100 C70-2300	71C5-2100 C55-1950 C60-1950 C65-1950 C70-2100	71C5-2100 C55-1950 C60-1800 C65-2100	2000	71C5-1800 C55-2000 C60-1800
GEAR TRAIN TIMING	ADV.	ADV.	STD	71C5, C55, C60 – STD. C65 and (C70) – ADV.			STD	STD
INJECTOR TIMING	1.470	1.470	C55, C60 – 1.480 71C5, C65 and (C70) – 1.484				71C5 – 1.484 C55, C60 – 1.470	
THROTTLE DELAY (YIELD LINK) SETTING (IN)	(e) REQ 454	(e) REQ 454	NONE	NONE	NONE	NONE	(e) REQ 570	(e) REQ 570
LINER PORT HEIGHT (IN)	.84	.84	1.05	1.05	1.05	1.05	1.05	1.05
COMPRESSION RATIO	21:1	21:1	18.7:1	18.7:1	18.7:1	18.7:1	18.7:1	18.7:1
BLOWER DRIVE RATIO	2.487:1	2.487:1	2:1	2.05:1	2.05:1	2.05:1	2.05:1	2.05:1
GOVERNOR TYPE	LIMITING SPEED							
THERMOSTAT	170° -180° F NOMINAL OPENING TEMPERATURE							
TURBOCHARGER A/R								

ENGINE FAMILIES	6L-71T T	6L-71T T	6L-71T TT	8V-71T T	8V-71T OTM	8V-71T TT	6V-92	8V-92	6V-92T T	6V-92T OTM	6V-92T TT	8V-92T T	8V-92T OTM	8V-92T TT	8V-92TA T	8V-92TA TT
(a) INJECTORS	C65 N70 N75	C65 N70 N75	N75	C65 N70 N75	C65 N70 N75	N75	9270 9275 9280 9285	9270 9275 9280 9285	9280 9285 9290	9280 9285 9290	9290	9280 9285 9290	9280 9285 9290	9290 9A90	9290	9290
(a) APPROVED MINIMUM CONSTANT HORSEPOWER			220			305					MIN-MAX 240-270			9290-365 9A90-335		365
(a) MAXIMUM RATED SPEED	2100	2100	2100	2100	2100	2100	2100	2100	2100	2100	1950	2100	2100	9290-2100	2100	2100
(a) MINIMUM RATED SPEED	2100	1900	1900	2100 N75-1900	2100 N75-1900	1900	9270-2100 9275-1950 9280-1950 9285-2100	9270-2100 9275-1950 9280-1950 9285-2100	9280-2100 9285-1950 9290-1950	9280-2100 9285-1950 9290-1900	1900	9280-2100 9285-1950 9290-1950	9280-2100 9285-1950 9290-1900	9A90-1800	1900	1900
GEAR TRAIN TIMING	STD	STD	STD	STD	STD	STD	STD	STD	STD	STD	STD	STD	STD.	STD	STD	STD
INJECTOR TIMING	C65 – 1.460 N70 and N75 – 1.484						1.460	1.460	1.484	1.484	1.484	1.484	1.484	1.484	1.484	1.484
THROTTLE DELAY (YIELD LINK) SETTING (IN)	(f) REQ 570						NONE	NONE	(f)% REQ 636-9290 570-9280, 9285		(f)% REQ 636	(f)% REQ 636-9290 570-9280, 9285		(f)% REQ 636-9290 570-9A90	(f)% REQ 636	(f)% REQ 636
LINER PORT HEIGHT (IN)	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05
COMPRESSION RATIO	17:1	17:1	17:1	17:1	17:1	17:1	19:1	19:1	17:1	17:1	17:1	17:1	17:1	17:1	17:1	17:1
BLOWER DRIVE RATIO	1.95:1	1.95:1	1.95:1	1.95:1	1.95:1	1.95:1	2.6:1	2.6:1	2.05:1	2.05:1	2.05:1	2.05:1	2.05:1	2.05:1	2.05:1	2.05:1
GOVERNOR TYPE	LIMITING SPEED															
THERMOSTAT	170° -180° F NOMINAL OPENING TEMPERATURE															
TURBOCHARGER A/R	T18A40 1.00 4MF-782 4.70 Sq. In	TV7101 1.39	TV7101 1.39	T18A40 1.50 4MF-782 6.54 Sq. In	TV8101 1.60	TV8101 1.39			T18A40 1.14	TV8102 1.23	TV8102 1.23	T18A90 1.50	TV8101 1.84	TV8101 1.84	TV8101 1.60	TV8101 1.60

TABLE 9 - 1977 Federal and California Engines

1978 CALIFORNIA CERTIFIED AUTOMOTIVE CONFIGURATIONS

ENGINE FAMILIES	4-53TC	6L-71NC	(c) 8V-71TAC		(d) 8V-71 TAC COACH	6V-92TAC		8V-92TAC	
			TAC	TTAC		TAC	TTAC	TAC	TTAC
INJECTORS (a)	5A55 5A60	71B5 B55 B60	7A65 7A70 7A75	7A75	7A50 7A55 7A60	9A80 9A85 9A90(g)	9A90(g)	9A80 9A85 9A90(g)	9A90(g)
APPROVED CONSTANT HORSEPOWER FOR TTAC ENGINES				305			240-270		335-365
MAXIMUM (b) FULL LOAD SPEED	2500	2300	2100	2100	2100	2100	2100	2100	2100
MINIMUM FULL LOAD SPEED	2500	1800	1950	1900	1800	1950	1900	1950	1800
CAMSHAFT LOBE POSITION	STD	STD	RET	RET	RET	RET	RET	RET	RET.
INJECTOR TIMING	5A55-1.496 5A60-1.508	1.500	1.460	1.460	7A50-1.466 7A55-1.466 7A[illegible]-1.460	1.484	1.484	1.484	1.484
THROTTLE DELAY YIELD LINK	Fuel Modulator	NOT REQ	(f) REQ.	(f) REQ.	(e) REQ.	(f) REQ.	(f) REQ.	(f) REQ	(f) REQ.
TURBOCHARGER A/R	T04B98 .96 3LM363 2.7 Sq. In		TV7101 1.23	TV7101 1.23	TV7101 1.23	TV8102 1.08	TV8102 1.08	TV8101 1.60	TV8101 1.60

1978 FEDERAL CERTIFIED AUTOMOTIVE CONFIGURATIONS

ENGINE FAMILIES	4L-53N	4-53T	6V-53N	(c) 6L-71N	(c) 6V-71N	(c) 8V-71N	(c) 12V-71N	(d) 6V-71N COACH	(d) 8V-71N COACH	6L-71T			8V-71T			8V-71TA	
										T	OTM	TT	T	OTM	TT	TA	TTA
INJECTORS (a)	C40 C45 C50	5A55 5A60	C40 C45 C50	71C5 C55 C60 C65 C70	71C5 C55 C60 C65 C70	71C5 C55 C60 C65 C70	71C5 C55 C60 C65	71C5 C55 C60	71C5 C55 C60	C65 N70 N75	C65 N70 N75	N75	C65 N70 N75	C65 N70 N75	N75	N65 7C70 7C75	7C75
APPROVED CONSTANT HORSEPOWER FOR TT & TTA ENGINES												220-230			305		305
MAXIMUM FULL LOAD SPEED (b)	2800	2500	2800	2300	2300	2300	2100	2100	2100	2100	2100	2100	2100	2100	2100	2100	1950
MINIMUM FULL LOAD SPEED	2400	2500	2400	71C5-1800 C55-1800 C60-1800 C65-1900 C70-1900	71C5-1800 C55-1800 C60-1800 C65-1900 C70-1900	71C5-1800 C55-1800 C60-1800 C65-1900 C70-1900	71C5-1800 C55-1800 C60-1800 C65-1900	1800	1800	1900	1900	1900	1900	1900	1900	1900	1900
CAMSHAFT LOBE POSITION	ADV.	STD	ADV.	71C5, C55, C60 – STD. C65 and C70 – ADV.				STD.	STD.	STD.	STD.	STD.	STD.	STD.	STD.	RET.	RET.
INJECTOR TIMING	1.470	1.496	1.470	71C5, C65, C70 - 1.484 C55 and C60 - 1.460				71C5-1.484 C55, C60 - 1.470		C65 – 1.460 N70 and N75 – 1.484						N65-1.484 7C70-1.466 7C75-1.460	1.460
THROTTLE DELAY YIELD LINK	(e) REQ	Fuel Modulator	(e) REQ.	NOT REQ	NOT REQ.	NOT REQ.	NOT REQ.	(e) REQ.	(e) REQ.	(f) REQ.	(f) REQ.	(f) REQ.	(f) REQ.	(f) REQ.	(f) REQ.	(f) REQ.	(f) REQ.
TURBOCHARGER A/R		T04B98 .96 3LM363 2.7 Sq. In								*T18A40 1.00 *4MF-782 4.70 Sq. In.	TV7101 1.39	TV7101 1.39	*T18A40 1.50 *4MF-782 6.54 Sq. In.	TV8101 1.60	TV8101 1.39	TV7101 1.23	TV7101 1.23

ENGINE FAMILIES	6V-92	8V-92	6V-92T			8V-92T			8V-92TA	
			T	OTM	TT	T	OTM	TT	TA	TTA
INJECTORS (a)	9270 9275 9280 9285	9270 9275 9280 9285	9280 9285 9290(g)	9280 9285 9290(g)	9290(g)	9280 9285 9290(g)	9280 9285 9290(g)	9290(g) 9A90(g)	9290(g)	9290(g)
APPROVED CONSTANT HORSEPOWER FOR TT & TTA ENGINES					240-270			9290-365 9A90 335-365		365
MAXIMUM FULL LOAD SPEED (b)	2100	2100	2100	2100	2100	2100	2100	2100	2100	2100
MINIMUM FULL LOAD SPEED	9270-1950 9275-1950 9280-1950 9285-2100	9270-1950 9275-1950 9280-1950 9285-2100	1900	1900	1800	1900	1900	9290-1900 9A90-1800**	1900	1900
CAMSHAFT LOBE POSITION	STD.	STD	STD.	STD.	STD.	STD.	STD.	STD.	STD.	STD.
INJECTOR TIMING	1.460	1.460	1.484	1.484	1.484	1.484	1.484	1.484	1.484	1.484
THROTTLE DELAY YIELD LINK	NOT REQ.	NOT REQ.	(f) REQ.	(f) REQ	(f) REQ	(f) REQ	(f) REQ.	(f) REQ.	(f) REQ	(f) REQ.
TURBOCHARGER A/R			*T18A40 1.14	TV8102 1.23	TV8102 1.23	*T18A90 1.50	TV8101 1.84	TV8101 1.84	TV8101 1.60	TV8101 1.60

*These turbocharger options to be cancelled effective 9/1/78.

**336 BHP 8V-92TT use 9A90 injectors only @ 1800 RPM.

TABLE 10 - 1978 Federal and California Engines

Families	4L-53T	* 6V-53T	*** 6L-71N	6L-71T	6L-71TT	6V-71N Coach	*** 8V-71N	8V-71N Coach	8V-71TA	8V-71TTA	6V-92TA Coach	6V-92TA	6V-92TTA	8V-92TA	8V-92TTA
Injectors	5A55 5A60	5A55	7E65, 7E60 7E55, 7E50	N65 7C70 7V75	7E75	7E50 7E55 7E60	7E65, 7E60 7E55, 7E50	7E50 7E55 7E60	N65 7C70 7C75	7C75	9B70 9B75 9B80	9B70, 9B75 9B80, 9B85 9B90	9B90	9A80 9A85 9A90	9A90
Maximum Full Load Speed	2500	2600	2300	2100	2100	2100	2300	2100	2100	2100	2100	2100	2100	2100	2100
Minimum Full Load Speed	2500	2500	1800 7E65-1900	1900	1800	1800	1800 7E65-1900	1800	1900	1900	1800	1800	1800	1900	1800
Minimum Idle Speed	500	500	500	500	500	400	500	400	500	500	500	500	500	500	500
Gear Train Timing	Std.	Std.	% Std.	Std.	Std.	Std.	Std. 7E65-Adv.	Std.	Std.	Std.	Std.	Std.	Std.	Std.	Std.
Injector Timing	1.496	1.496	1.484 7E55-1.496	N65-1.490 7C70-1.470 7C75-1.460	1.466	7E50-1.508 7E55-1.496 7E60-1.500	1.496 7E60-1.500	1.496 7E60-1.500	N65-1.484 7C70-1.466 7C75-1.460	1.460	1.470	1.470	1.470	1.480	1.480
Throttle Delay# Setting	# .365	# .404	DNA	%% .570	%% .594	.570**	DNA	.570**	%% .570	%% .570	.636(x)	%% .504 9B90-.570	%% .570	%% .570 9A90-.636	%% .636
Liner Port Height	.84	.84	1.05	.95	.95	1.05	1.05	1.05	.95	.95	.95	.95	.95	.95	.95
Liner Part Number	5132803	5132803	5113953	5102795	5102795	5113953	5113953	5113953	5102795	5102795	5107176	5107176	5107176	5107176	5107176
Turbocharger A/R	T04B98 .96 A/R##	TV6123 1.20 A/R	DNA	TV-7101 1.23 A/R	TV-6141 1.08 A/R	DNA	DNA	DNA	TV7101 1.23 A/R	TV7101 1.23 A/R	TV8102 1.23 A/R	TV8102 1.23 A/R	TV8102 1.23 A/R	TV8101$ 1.60 A/R	TV8101$ 1.60 A/R
Turbocharger Part Number	## 5103905	5104082	DNA	5107617	5107616	DNA	DNA	DNA	5101509	5101509	5102353	5102353	5102353	@@ 5101513	@@ 5101513
Blower Drive Ratio	2.49:1	2.49:1	2:1	1.65:1	1.51:1	2.05:1	2.05:1	2.05:1	1.95:1	1.95:1	2.05:1	2.05:1	2.05:1	1.95:1	1.95:1
Blower Part Number	5103563-LH 5103466-RH	5104298	5138554-LH 5138553-RH 5142017-Hor.	5107609 5108031-RH	5107608	5103589 5103532	5103494 5103588 5147152	5103588 5103494	5101484	5101484	5101528	5101528	5101528	5101483	5101483
Compression Ratio	18.7:1	18.7:1	18.7:1	17:1	17:1	18.7:1	18.7:1	18.7:1	17:1	17:1	17:1	17:1	17:1	17:1	17:1
Exhaust Valve Material	Nimonic 90	Nimonic 90	Inconel X Type 751	Nimonic 90 Aluminized	Nimonic 90 Aluminized	Inconel X Type 751	Inconel X Type 751	Inconel X Type 751	Nimonic 90 Aluminized	Nimonic 90 Aluminized	Stellite Fc. Inconel X	Stellite Fc. Inconel X	Stellite Fc. Inconel X	Stellite Fc. Inconel X	Stellite Fc. Inconel X
Exhaust Valve Part Number	5109925	5109925	5114288	5111336	5111336	5186381	5114288	5114288	5111336	5111336	@ 5100437	@ 5100437	@ 5100437	5100437	5100437
Certification Label Number	14B7-264	14B7-266	14B7-268	14B7-263	14B7-263	14B7-274	14B7-276	14B7-275	14B7-277	14B7-277	14B7-270	14B7-270	14B7-270	14B7-272	14B7-272

(x) Double Fill Hole (.250) .016 Diameter Discharge Orifice.
* Available late in 1979.
\# 53T Uses fuel modulator.
\## Optional 3LM-353, 2.7 Sq. in., 5104803.
@ 6V-92TA - Carpenter valve. Available.
@@ Double 0-92 (5107590).

% 7E65 - Built in advanced camshaft timing.
** Large fill hole (.250 dia.) .016 diameter discharge orifice.
%% Small fill hole (.078 dia.) .016 diameter discharge orifice.
*** Includes certain highway coach engines.
$ Optional 5LM-864, 6.5 sq. in., 5107687.
DNA Does not apply.

Table 11 - 1979 Federal Engines

FAMILIES	4L-53TC	6V-53TC*	6L-71NC	8V-71TAC	8V-71TAC	8V-71TTAC	6V-92TAC COACH	6V-92TAC	6V-92TTAC	8V-92TAC	8V-92TTAC
Injectors	5A55 5A60	5A55	71B5 B55 B60	7A50 7A55 7A60	7A65 7A70 7A75	7A75	9B70 9B75 9B80	9B70, 9B75 9B80, 9B85 9B90	9B90	9A80 9A85 9A90	9A90
Maximum Full Load Speed	2500	2600	2300	2100	2100	2100	2100	2100	2100	2100	2100
Minimum Full Load Speed	2500	2500	1800	1800	1900	1900	1800	1800	1800	1900	1800
Minimum Idle Speed	500	500	500	400①/ 500②	500	500	500	500	500	500	500
Gear Train Timing	Std.	Std.	Std.	Std.	Std.	Std.	Std.	Std.	Std.	Std.	Std.
Injector Timing	5A55-1.496 5A60-1.508	1.496	71B5-1.500 1.508	1.466 7A60-1.460	1.460	1.460	1.490	1.490	1.490	1.500	1.500
Throttle Delay Setting #	5A55-.365 5A60-.404#	.404#	DNA	.686①②	.586%%	.586%%	.636ⓧ	.570%% 9B90-.636	.636%%	.594%% 9A90-.660	.660%%
Liner Port Height	.84	.84	1.05	.95	.95	.95	.95	.95	.95	.95	.95
Liner Part Number	5132803	5132803	5113953	5102795	5102795	5102795	5107176	5107176	5107176	5107176	5107176
Turbocharger A/R	T04B98 .96 A/R##	TV6123 1.20 A/R	DNA	TV7101 1.23 A/R	TV7101 1.23 A/R	TV7101 1.23 A/R	TV8102 1.23 A/R	TV8102 1.23 A/R	TV8102 1.23 A/R	TV8101 $ 1.60 A/R	TV8101 $ 1.60 A/R
Turbocharger Part Number	5103905##	5104082	DNA	5101509	5101509	5101509	5102353	5102353	5102353	5101513 @@	5101513 @@
Blower Drive Ratio	2.49:1	2.49:1	2:1	1.95:1	1.95:1	1.95:1	2.05:1	2.05:1	2.05:1	1.95:1	1.95:1
Blower Part Number	5103563-L 5103466-R	5104298	5138554-LH 5138553-RH 5142017-Hort.	5101484	5101484	5101484	5101528	5101528	5101528	5101483	5101483
Compression Ratio	18.7:1	18.7:1	18.7:1	17:1	17:1	17:1	17:1	17:1	17:1	17:1	17:1
Exhaust Valve Material	Nimonic 90	Nimonic 90	Inconel X Type 751	Nimonic 90	Nimonic 90	Nimonic 90	Stellite Face Inconel X	Stellite Face Inconel X	Stellite Face Inconel X	Stellite Face Inconel X	Stellite Face Inconel X
Exhaust Valve Part Number	5109925	5109925	5114288	5111336	5111336	5111336	5100437	5100437	5100437	5100437	5100437
Certification Label Number	14B7-265	14B7-267	14B7-269	14B7-278	14B7-278	14B7-278	14B7-271	14B7-271	14B7-271	14B7-273	14B7-273

ⓧ Double Fill Hole (.250) .016 Diameter Discharge Orifice.
* Available late in 1979.
\# 53T Uses fuel modulator.
\## Optional 3LM-353, 2.7 Sq. in., 5104803.
① With application code No. 345. (**)
② Without application code No. 345. (%%)
** Large fill hole (.250 dia.) .016 diameter discharger orifice.
%% Small fill hole (.078 dia.) .016 diameter discharge orifice.
@@ Double "0" 92 - 5107590.
DNA Does not apply.
$ optional 5LM-864, 6.5 sq. in. 5107687.

Table 12 · 1979 California Engines

1980 FEDERAL CERTIFIED AUTOMOTIVE CONFIGURATIONS															
ENGINE FAMILIES	4L-53T	6V-53T	(c) 6L-71N	6L-71T	6L-71TT	(b) 6V-71N Coach	(b) 8V-71N Coach	(c) 8V-71N	8V-71TA	8V-71TTA	(b) 6V-92TA Coach	6V-92TA	6V-92TTA	8V-92TA	8V-92TTA
Injectors (a)	5A55 5A60	5A50	7E50 7E55 7E60 7E65	N65 7C70 7C75	7E75	7E50 7E55 7E60	7E50 7E55 7E60	7E50 7E55 7E60 7E65	7C75	7C75	9B70 9B75 9B80	9B90	9B90	9A90	9A90
Maximum Full Load Speed (a)	2500	2600	2300	2100	2100	2100	2100	2300	2100	2100	2100	2100	2100	2100	2100
Minimum Full Load Speed	2500	2500	1800 7E65-1900	1800	1800	1800	1800	1800 7E65-1900	1800	1800	1800	1800	1800	1800	1800
Minimum Idle Speed	500	600	500	500	500	400	400	500	(k) 500	(k) 500	500	500	500	500	500
Gear Train Timing	Std.	Std.	(d) Std.	Std.	Std.	Std.	Std.	Std. 7E65-Adv.	Std.	Std.	Std.	Std.	Std.	Std.	Std.
Injector Timing	1.496	1.490	1.484 7E55-1.496	N65-1.490 7C70-1.470 7C75-1.460	1.466	7E50-1.508 7E55-1.496 7E60-1.500	1.496 7E60-1.500	1.496 7E60-1.500	1.460	1.460	1.470	1.470	1.470	1.480	1.480
Throttle Delay Setting	(e) .365	(e) .404	DNA	(f) .570	(f) .594	(g) .570	(g) .570	DNA	(f) .570	(f) .570	(h) .636	(f) .570	(f) .570	(f) .636	(f) .636
Turbocharger A/R	T04B98 .96A/R 3LM-353 2.7 Sq. In.	TV6123 1.20 A/R	DNA	TV7101 1.23 A/R	TV6141 1.08 A/R	DNA	DNA	DNA	TV7101 1.23 A/R	TV7101 1.23 A/R	TV8102 1.23 A/R	TV8102 1.23 A/R	TV8102 1.23 A/R	TV8101 1.60 A/R 5LM-864 6.5 Sq. In.	TV8101 1.60 A/R 5LM-864 6.5 Sq. In.

1980 CALIFORNIA CERTIFIED AUTOMOTIVE CONFIGURATIONS							
ENGINE FAMILIES	6L-71TAC	6L-71TTAC	(b) 6V-92TAC Coach	6V-92TAC	6V-92TTAC	8V-92TAC	8V-92TTAC
Injectors (a)	7G75	7G75	9C70 9C75 9C80	9C90	9C90	9C90	9C90
Maximum Full Load Speed (a)	2100	2100	2100	2100	2100	2100	2100
Minimum Full Load speed	1800	1800	1900	1900	1900	1900	1900
Minimum Idle Speed	700	700	500	700	700	700	700
Gear Train Timing	Std.	Std.	Std.	Std.	Std.	Std.	Std.
Injector Timing	1.470	1.470	1.480	1.480	1.480	1.480	1.480
Throttle Delay Setting	(f) .586	(f) .586	(h) .636	(f) .660	(f) .660	(f) .660	(f) .660
Turbocharger A/R	TV-6141 1.39	TV-6141 1.39	TV-8102 1.08	TV-8102 1.08	TV-8102 1.08	TV-8101 1.39	TV-8101 1.39

DNA Does not apply
NA Not available at time of printing
(a) Refer to Engine Application Rating (Sales Tech Data Book I, Vol. 3) for specific application usage of injector size and full load speed combination. No load speed will vary with injector size and governor.
(b) Use No. 1 Diesel Fuel.
(c) Includes certain highway coach engines.
(d) 7E65 Injector has built-in advance camshaft timing.
(e) 53T uses fuel modulator.
(f) Small fill hole (.078 dia.) .016 dia discharge orifice.
(g) Large fill hole (.250 dia.) .016 dia. discharge orifice.
(h) Double fill hole (.250 dia.) .016 dia. discharge orifice.
(k) 700 rpm for 1800 rpm full load speed

Table 13 - 1980 Federal and California Engines

EXHAUST VALVE CLEARANCE ADJUSTMENT

The correct exhaust valve clearance at normal engine operating temperature is important for smooth, efficient operation of the engine.

Insufficient valve clearance can result in loss of compression, misfiring cylinders and, eventually, burned valve seats and valve seat inserts. Excessive valve clearance will result in noisy operation, especially in the low-speed range.

Whenever the cylinder head is overhauled, the exhaust valves are reconditioned or replaced, or the valve operating mechanism is replaced or disturbed in any way, the valve clearance must first be adjusted to the cold setting to allow for normal expansion of the engine parts during the engine warm-up period. This will insure a valve setting that is close enough to the specified clearance to prevent damage to the valves when the engine is started.

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Exhaust Valve Clearance Adjustment-Four Valve Cylinder Head (Cold Engine)

1. Place the governor speed control lever in the idle speed position. If a stop lever is provided, secure it in the stop position.

2. Remove the loose dirt from the valve rocker cover(s) and remove the rocker cover(s).

3. Rotate the crankshaft until the injector follower is fully depressed on the cylinder to be adjusted.

   NOTE: If a wrench is used on the crankshaft bolt, do not turn the engine in a left-hand direction of rotation as the bolt will be loosened.

4. Loosen the exhaust valve rocker arm push rod lock nut.

5. Place a .026 " feeler gage (J 9708-01) between the end of one valve stem and the rocker arm bridge (Fig. 1). Adjust the push rod to obtain a smooth pull on the feeler gage.

6. Remove the feeler gage. Hold the push rod with a 5/16 " wrench and tighten the lock nut with a 1/2 " wrench.

7. Recheck the clearance and adjust the push rod if necessary.

8. Adjust and check the remaining exhaust valves in the same manner as above.

Exhaust Valve Clearance Adjustment-Four Valve Cylinder Head (Hot Engine)

Maintaining normal engine operating temperature is particularly important when making the final exhaust valve clearance adjustment. If the engine is allowed to cool off before setting any of the valves, the clearance when running at full load may become insufficient.

1. With the engine at normal operating temperature (160-185 °F or 71-85 °C), recheck the exhaust valve clearance with feeler gage J 9708-01. At this time if the valve clearance is correct a .024 " feeler gage should pass freely between the end of one valve stem and the rocker arm bridge.

2. After the exhaust valve clearance has been adjusted, check the fuel injector timing.

Checking Exhaust Valve Clearance Adjustment

1. With the engine operating at 100 °F (38 °C) or less, check the valve clearance.

2. If a .026 " feeler gage J 9708-01, ± .006 " will pass between the valve stem and the rocker arm bridge, the valve clearance is satisfactory. If necessary, adjust the push rod.

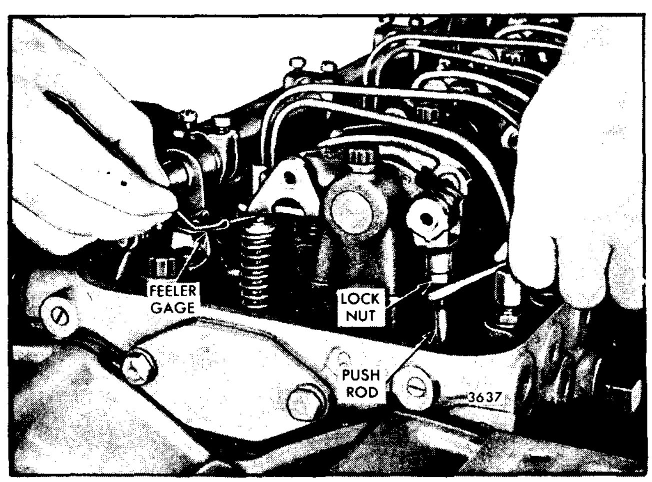

Fig. 1 - Adjusting Exhaust Valve Clearance

The exhaust valve bridges must be adjusted. The adjustment screws must be locked securely at the time the cylinder head is installed on the engine. Until wear occurs, or the cylinder head is reconditioned, no further adjustment is required on the valve bridges. A complete valve bridge adjustment is performed as follows:

Exhaust Valve Bridge Adjustment

1. Remove the loose dirt from the exterior of the engine and remove the valve rocker cover. Remove the injector fuel pipes and the rocker arm retaining bolts. Move the rocker arms away from the exhaust valve bridges.

2. Remove the exhaust valve bridge (Fig. 2).

3. Place the valve bridge in a vise or bridge holding fixture J 21772 and loosen the lock nut on the bridge adjusting screw.

> **NOTE:** Loosening or tightening the lock nut with the bridge in place may result in a bent bridge guide or bent rear valve stem.

4. Install the valve bridge on the valve bridge guide (without the spring if a spring-loaded bridge is used).

5. While firmly pressing straight down on the pallet surface of the valve bridge, turn the adjusting screw clockwise until it just touches the valve stem. Then turn the screw an additional 1/8 to 1/4 turn clockwise and tighten the lock nut finger tight (Fig. 2).

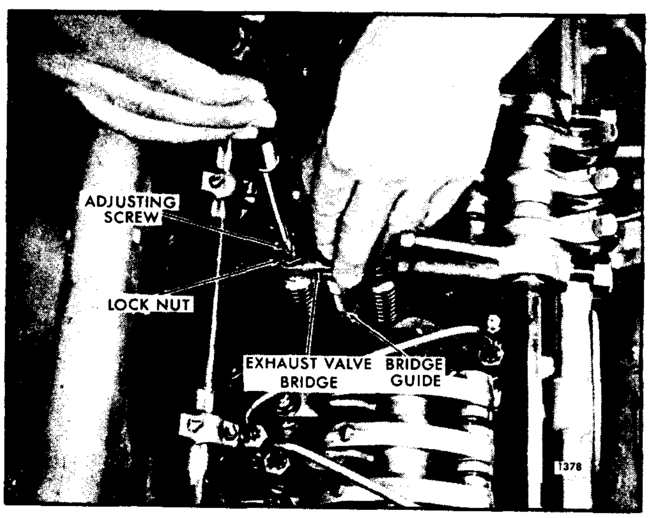

Fig. 2 - Exhaust Valve Bridge Adjustment (Four Valve Cylinder Head)

6. Remove the valve bridge and place it in a vise. Use a screw driver to hold the adjustment screw from turning and tighten the lock nut to 20-25 lb-ft (27-34 Nm) torque.

7. Lubricate the valve bridge guide and the valve bridge with engine oil.

8. Reinstall the valve bridge in its ORIGINAL position, without the spring (if a spring-loaded bridge is used).

9. Place a .0015 " feeler gage J 23185 under each end of the valve bridge or use a narrow strip cut from .0015 " feeler stock to fit in the bridge locating groove over the inner exhaust valve. While pressing down on the pallet surface of the valve bridge, both feeler gages must be tight. If both of the feeler gages are not tight, readjust the adjusting screw as outlined in Steps 5 and 6.

10. Remove the valve bridge and reinstall it in its ORIGINAL position (with the spring in place if a spring-loaded bridge is used).

11. Adjust the remaining valve bridges in the same manner.

12. Swing the rocker arm assembly into position, making sure the valve bridges are properly positioned on the rear valve stems. This precaution is necessary to prevent valve damage due to mislocated valve bridges. Tighten the rocker arm shaft bracket bolts to 90-100 lb-ft (112-136 Nm) torque.

13. Align the fuel pipes and connect them to the injectors and the fuel connectors. Use socket J 8932 to tighten the connectors to 12-15 lb-ft (16-20 Nm) torque.

> **NOTE:** Do not bend the fuel pipes and do not exceed the specified torque. Excessive tightening will twist or fracture the flared ends of the fuel pipes and result in leaks. Lubricating oil diluted by fuel oil can cause serious damage to the engine bearings.

Exhaust Valve Clearance Adjustment-Four Valve Cylinder Head (Cold Engine)

The exhaust valve clearance is always adjusted at the push rod. *Do not disturb the exhaust valve bridge adjusting screw.*

All of the exhaust valves may be adjusted in firing order sequence during one full revolution of the

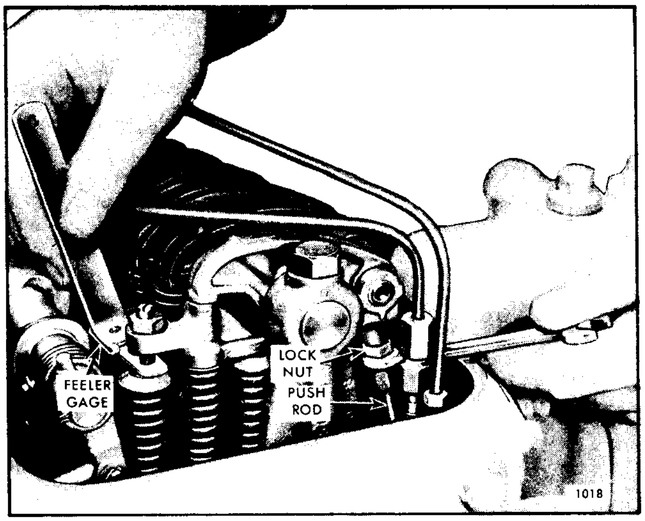

Fig. 3 - Adjusting Exhaust Valve Clearance (Spring-Loaded Valve Bridge)

crankshaft. Refer to Section 1 for the engine firing order.

1. Remove the loose dirt from the valve rocker cover(s) and remove the valve cover(s).

2. Place the governor speed control lever in the idle speed position. If a stop lever is provided, secure it in the stop position.

3. Rotate the crankshaft, with engine barring tool J 22582 or by using the engine starter until the injector follower is fully depressed on the particular cylinder to be adjusted.

NOTE: If a wrench or barring tool is used on the crankshaft bolt at the front of the engine, do not turn the crankshaft in a left-hand direction of rotation as the bolt will be loosened.

4. Loosen the exhaust valve rocker arm push rod lock nut.

5. Place a .016 " feeler gage (J 9708-01) between the end of the valve stem and the valve bridge adjustment screw (spring-loaded bridge only) or between the valve bridge and the valve rocker arm pallet (unloaded bridge only) -- see Figs. 3 and 4. Adjust the push rod to obtain a smooth pull on the feeler gage.

6. Remove the feeler gage. Hold the push rod with a 5/16 " wrench and tighten the lock nut with a 1/2 " wrench.

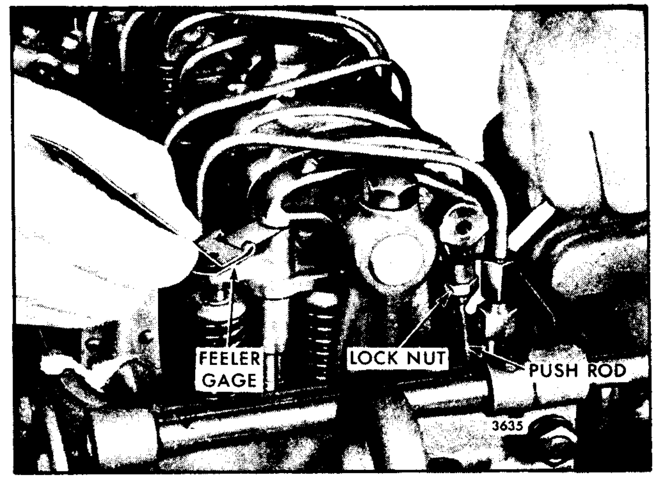

Fig. 4 - Adjusting Exhaust Valve Clearance (Unloaded Valve Bridge)

7. Recheck the clearance and adjust the push rod, if necessary.

8. Check and adjust the remaining valves in the same manner as above.

Exhaust Valve Clearance Adjustment-Four Valve Cylinder Head (Hot Engine)

Maintaining the normal engine operating temperature is particularly important when making the final valve clearance adjustment. If the engine is allowed to cool off before setting any of the valves, the clearance when running at full load may become insufficient.

1. With the engine at normal operating temperature (160-185 °F or 71-85 °C), recheck the exhaust valve clearance with feeler gage J 9708-01. At this time, if the valve clearance is correct, a .014 " feeler gage will pass freely between the valve stem and the valve bridge adjusting screw (spring-loaded bridge) or between the valve bridge and the rocker arm pallet (unloaded bridge).

2. After the exhaust valve clearance has been adjusted, check the fuel injector timing.

Checking Exhaust Valve Clearance Adjustment

1. With the engine operating at 100 °F (38 °C) or less, check the valve clearance.

2. If a .016 " feeler gage J 9708-01, ± .004 " will pass between the valve stem and the rocker arm bridge, the valve clearance is satisfactory. If necessary, adjust the push rod.

FUEL INJECTOR TIMING

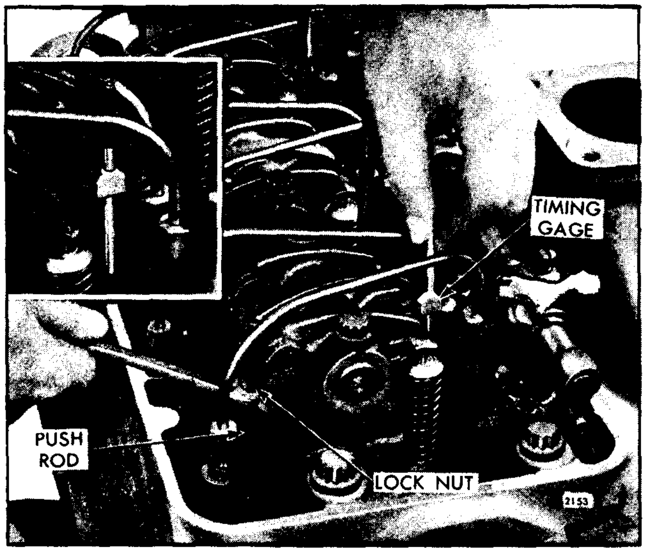

Fig. 5 - Timing Fuel Injector

To time an injector properly, the injector follower must be adjusted to a definite height in relation to the injector body.

All of the injectors can be timed, in firing order sequence, during one full revolution of the crankshaft. Refer to Section 1 for the engine firing order.

Time Fuel Injector

After the exhaust valve clearance has been adjusted, check the fuel injector timing.

1. Place the governor speed control lever in the idle speed position. If a stop lever is provided secure it in the stop position.

J-1853	For	1.460"
J-26888	For	1.466"
J-24236	For	1.470"
J-29065	For	1.480"
J-1242	For	1.484"
J-29066	For	1.490"
J-9595	For	1.496"
J-25454	For	1.500"
J-8909	For	1.508"
J-25502	For	1.520"

Timing Gages

2. Rotate the crankshaft until the exhaust valves are fully depressed on the particular cylinder to be timed.

3. Refer to Tables 1 through 13 and place the small end of the injector timing gage (see chart) in the hole provided in the top of the injector body, with the flat of the gage toward the injector follower (Fig. 5).

4. Loosen the exhaust valve rocker arm push rod lock nut.

5. Turn the push rod and adjust the injector rocker arm until the extended part of the gage will just pass over the top of the injector follower.

6. Hold the push rod and tighten the lock nut. Check the adjustment and, if necessary, readjust the push rod.

7. Time the remaining injectors in the same manner as outlined above.

8. If no further engine tune-up is required, install the valve rocker cover(s), using a new gasket.