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AUTOMOTIVE DIESEL MAINTENANCE 1. UNIT XIV, I--MAINTAINING THE AIR SYSTEM, CUMMINS DIESEL ENGINE, II--UNIT REMOVAL--TRANSMISSION.

HUMAN ENGINEERING INSTITUTE, CLEVELAND, OHIO

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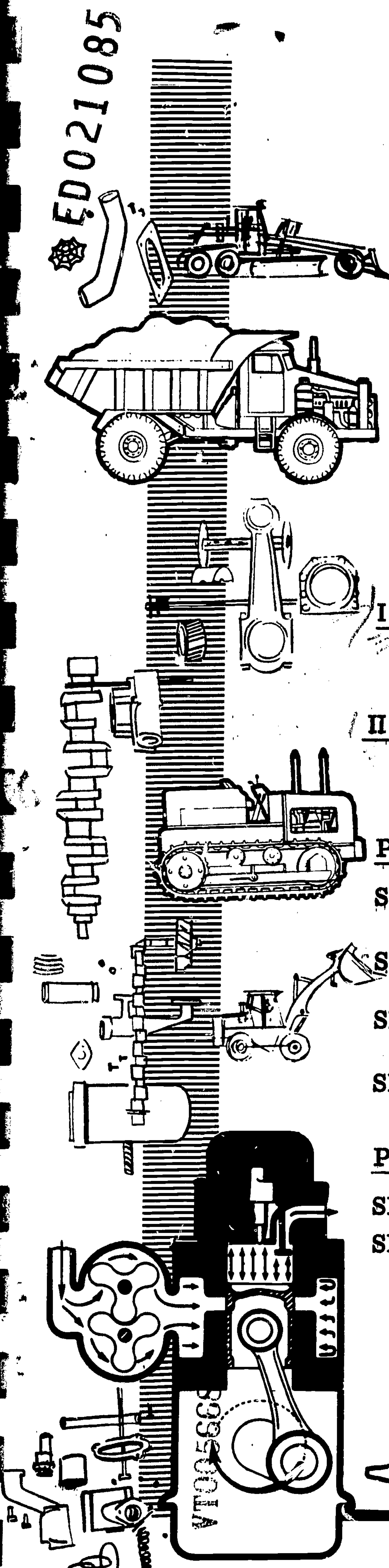
THIS MODULE OF A 30-MODULE COURSE IS DESIGNED TO DEVELOP AN UNDERSTANDING OF THE OPERATING PRINCIPLES AND MAINTENANCE OF THE DIESEL ENGINE AIR SYSTEM AND THE PROCEDURES FOR TRANSMISSION REMOVAL. TOPICS ARE (1) DEFINITION OF TERMS RELATED TO THE DIESEL AIR SYSTEM, (2) PRNCIPLES OF DIESEL AIR COMPRESSORS, (3) PRINCIPLES OF AIR STARTING MOTORS, (4) SERVICING CUMMINS AIR SYSTEM COMPONENTS, (5) PREPARATION FOR REMOVAL (TRANSMISSION), AND (6) UNIT REMOVAL. THE MODULE CONSISTS OF A SELF-INSTRUCTIONAL BRANCH PROGRAMED TRAINING FILM "UNDERSTANDING THE DIESEL AIR SYSTEM" AND OTHER MATERIALS. SEE VT 005 655 FOR FURTHER INFORMATION. MODULES IN THIS SERIES ARE AVAILABLE AS VT 005 655 - VT 005 684. MODULES FOR "AUTOMOTIVE DIESEL MAINTENANCE 2" ARE AVAILABLE AS VT 005 685 - VT 005 709. THE 2-YEAR PROGRAM OUTLINE FOR "AUTOMOTIVE DIESEL MAINTENANCE 1 AND 2" IS AVAILABLE AS VT 006 006. THE TEXT MATERIAL, TRANSPARENCIES, PROGRAMED TRAINING FILM, AND THE ELECTRONIC TUTOR MAY BE RENTED (FOR $1.75 PER WEEK) OR PURCHASED FROM THE HUMAN ENGINEERING INSTITUTE, HEADQUARTERS AND DEVELOPMENT CENTER, 2341 CARNEGIE AVENUE, CLEVELAND, OHIO 44115. (HC)

STUDY AND READING MATERIALS



AUTOMOTIVE DIESEL MAINTENANCE 1

I -- MAINTAINING THE AIR SYSTEM, CUMMINS DIESEL ENGINE, UNIT XIV

II -- UNIT REMOVAL -- TRANSMISSION.

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AM 1-14
4/19/66

HUMAN ENGINEERING INSTITUTE

This unit is presented in two parts. The first half covers the operation of the Cummins Diesel air system and its related components. The second half covers a brief discussion of removing number 5960 or 6061 Allison Transmissions from 14 or 15 FFD Euclid tractors or M 45 and LYSW Mack tractors.

I -- MAINTAINING THE AIR SYSTEM CUMMINS DIESEL ENGINE

SECTION A -- DEFINITION OF TERMS RELATED TO THE DIESEL AIR SYSTEM

Before going directly into the components of the Cummins diesel air system and how they operate, let's review a few terms related to properties of air.

VOLUMETRIC EFFICIENCY -- The volumetric efficiency of a 4 cycle engine, such as the Cummins, is the relationship between the quantity of intake air and the piston displacement. In other words, volumetric efficiency is the ratio between the charge of air that actually enters the cylinder and the amount that could enter the cylinder under ideal conditions. Piston displacement is used, since it is difficult to measure the amount of charge that would enter the cylinder under ideal conditions.

An engine would have 100 percent volumetric efficiency if, at atmospheric pressure and normal temperature, an amount of air exactly equal to piston displacement could be drawn into the cylinder. This is not possible, except by supercharging, because the passages through which the air must flow offer a resistance, causing the air to rise in temperature, and curtailing the flow. Therefore, volumetric efficiency is determined by measuring (with a orifice or venturi type meter) the amount of air taken in by the engine, converting the amount to volume, and comparing this volume to the piston displacement.

AIR REQUIREMENTS -- Volumetric efficiency varies with engines, but may be assumed to be between 75 and 85 percent for naturally aspirated 4 cycle engines. A NATURALLY ASPIRATED engine is one that has no means of forcing additional air into the cylinders other than air from atmospheric pressure (14.7 psi). An engine that is equipped with a turbocharger, or supercharger of some sort would not be a naturally aspirated engine.

When an engine is turbocharged, the volumetric efficiency may be as high as 100 percent. When calculating air required for 2 cycle engines, the volume supplied must be assumed to be 140 to 160 percent of the cylinder displacement, to allow for scavenging air. More will be said about scavenging later on.

The average air requirement of an engine in cubic feet per minute per brake horsepower (bhp), at 60F and 29.92 inches of mercury, atmospheric pressure, can be approximated from the following:

Naturally aspirated 4 cycle	2.2 to 2.75 cfm per bhp
Turbocharged 4 cycle	3.0 to 3.5 cfm per bhp
Two cycle	3.0 to 5.0 cfm per bhp

The required volume of air should be increased one percent for each five degrees above 60F, and three percent for each inch of mercury pressure below 29.92 inches.

SCAVENGING AND SUPERCHARGING -- We know from past units that SCAVENGING refers to supplying the cylinder with fresh air and at the same time clearing the cylinder area of all burnt gases. Not all diesel engines accomplish scavenging in the same manner. On Cummins 4 cycle engines that are not equipped with a turbocharger or supercharger, the air enters the cylinder area through the intake valves as a result of the pressure differential or suction created by the piston moving away from the combustion space. This is referred to as the "suction" type intake and is called a naturally aspirated engine. Flow of air into the cylinders in this type of engine is dependent solely on the atmospheric pressures. Naturally, less air would enter at 10,000 feet altitude than would enter at sea level, this would decrease the horsepower of the engine at higher altitudes.

On 4 cycle engines with turbochargers or superchargers, additional air under pressure is forced into the cylinders. This is accomplished by the blower (air pump driven either by exhaust gases or direct from gear train) compressing the air and forcing it into the intake manifold. Thus, an increased amount of air under constant pressure is available as required during the cycle of operation.

The increased amount of air available as a result of blower action is used to fill the cylinder with a fresh charge of air and, in the process, aids in clearing (scavenging) the cylinder of the gases of combustion.

The process of scavenging must be accomplished in a relatively short portion of the operating cycle; however, the duration of the process differs in 2 and 4 stroke cycle engines. In a 4 stroke cycle engine, scavenging takes place when the piston is nearing and passing TOP DEAD CENTER (TDC) during the latter part of the upstroke (exhaust) and the early part of the downstroke (intake). The intake and exhaust valve(s) are both open during this interval of time. The overlap of intake and exhaust permits the air from the blower to pass through the cylinder into the exhaust manifold, cleaning out the exhaust gases from the cylinder, and at the same time, cooling the hot engine parts.

Figure 1 shows how scavenging is accomplished in the 4 cycle engine as compared to the 2 stroke engine shown in Figure 2.

Supercharging a 4 stroke diesel engine requires the addition of a blower to the intake system, since the operations of exhaust and intake in an unsupercharged engine are performed by the action of the piston. The

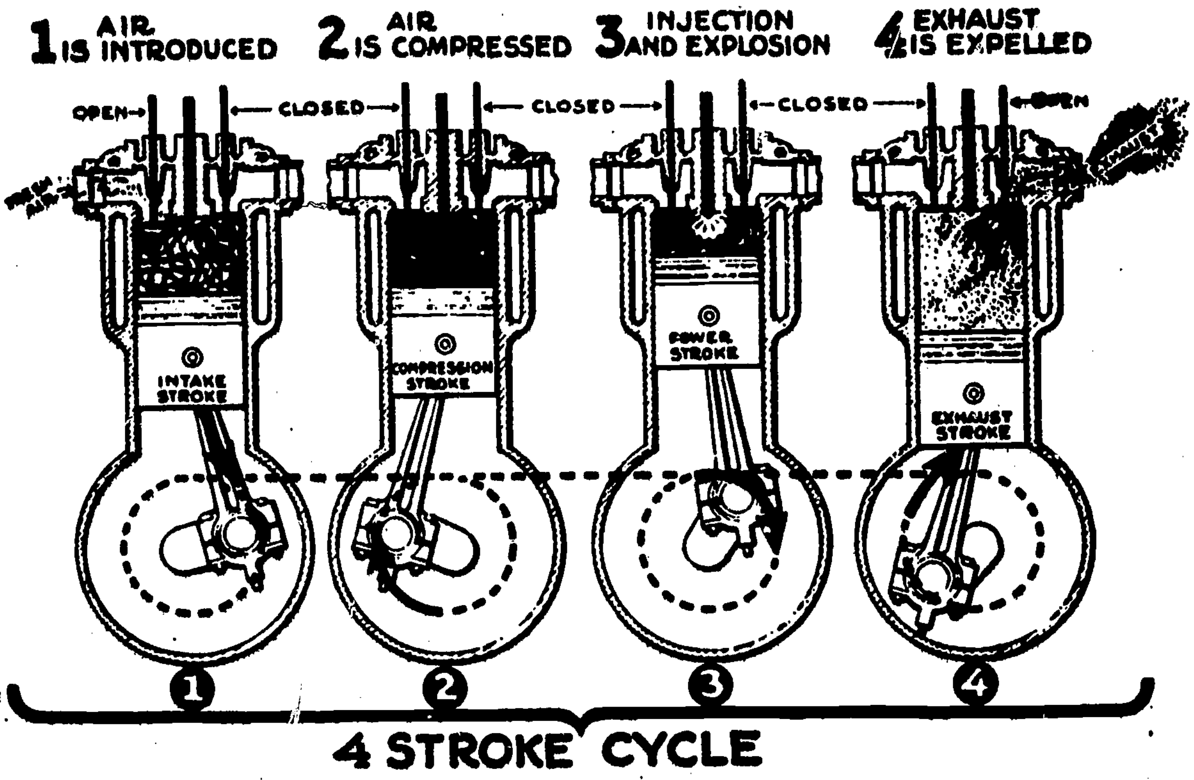

Fig. 1 Scavenging in a 4 cycle diesel.

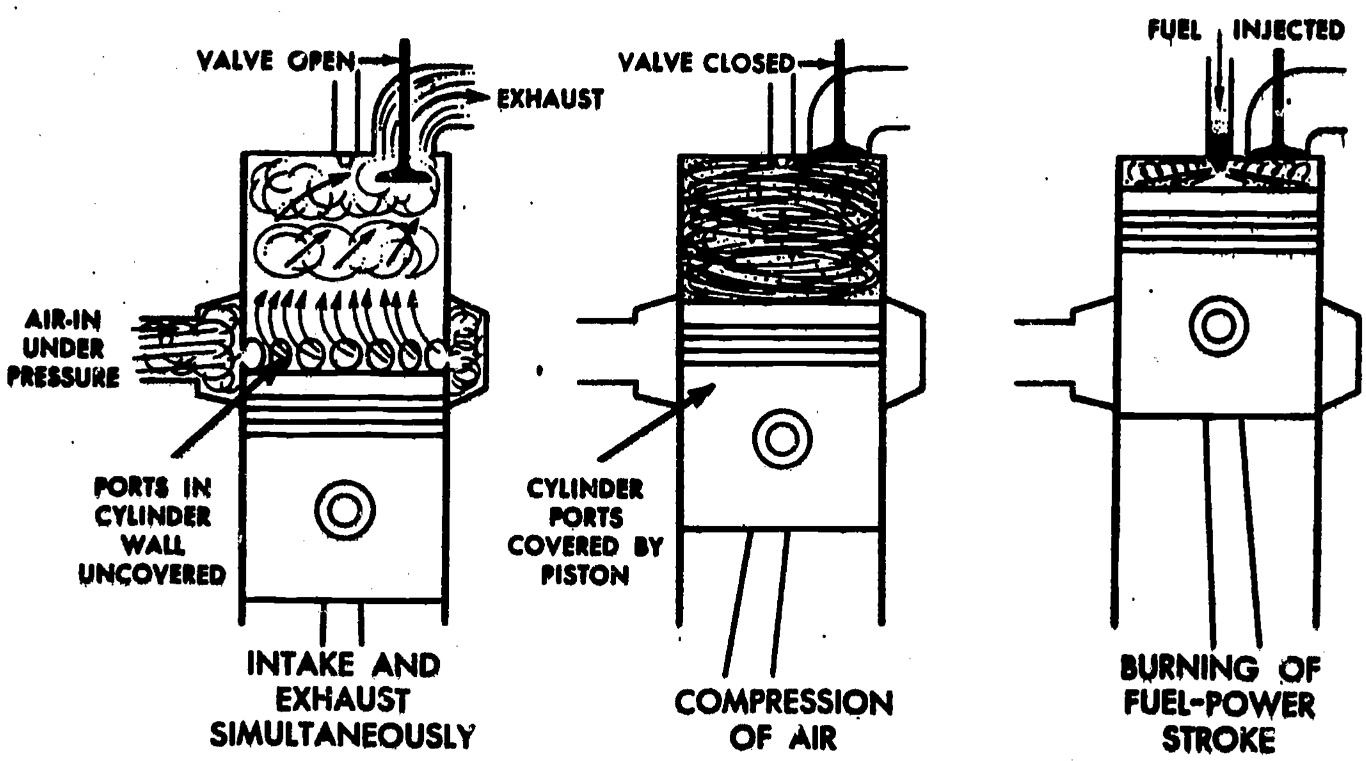

Fig. 2 Scavenging in a 2 cycle diesel.

timing of the valves in a supercharged 4 stroke cycle engine is also different from that in an engine which is not supercharged. In the supercharged engine, the intake valve opening is advanced and the exhaust valve opening is retarded, so that there is considerable overlap of the intake and exhaust events. This overlap increases power, the amount of the increase depending upon the supercharged 4 cycle engine also permits the air pressure created by the blower to be used in removing gases from the cylinder during the exhaust event.

In localities where extreme low temperatures prevail, the opening and closing of the intake and exhaust valves have to be adjusted. The reason for this is that at low temperatures the oxygen content of the atmosphere is increased, which allows more complete combustion. Remember, in the unit on combustion we said that the more oxygen particles that were available, the more complete would be the combustion process. When the oxygen content is too high the engine will overheat and eventually burn up. To protect against this situation, engine manufacturers, (on inline engines), provide a gasket (sometimes referred to as a shim pack) set which in effect shortens the push rods, forcing the intake and exhaust valves to be open a shorter period of time. For V engines, an offset key is inserted in the gear train, which changes the gear teeth position.

FOUR STROKE SCAVENGING AND SUPERCHARGING -- Figure 3 shows graphically how the opening and closing of intake and exhaust valves affect both scavenging and supercharging and the differences in these processes as they occur in supercharged 4 cycle engines.

In Figure 3, remember the crankshaft makes two complete revolutions in one cycle of operation.

In analyzing the diagram in Figure 3, at TDC (top dead center) peak compression has been reached, fuel injection is nearly complete, and combustion is in process. Power is delivered during the downstroke

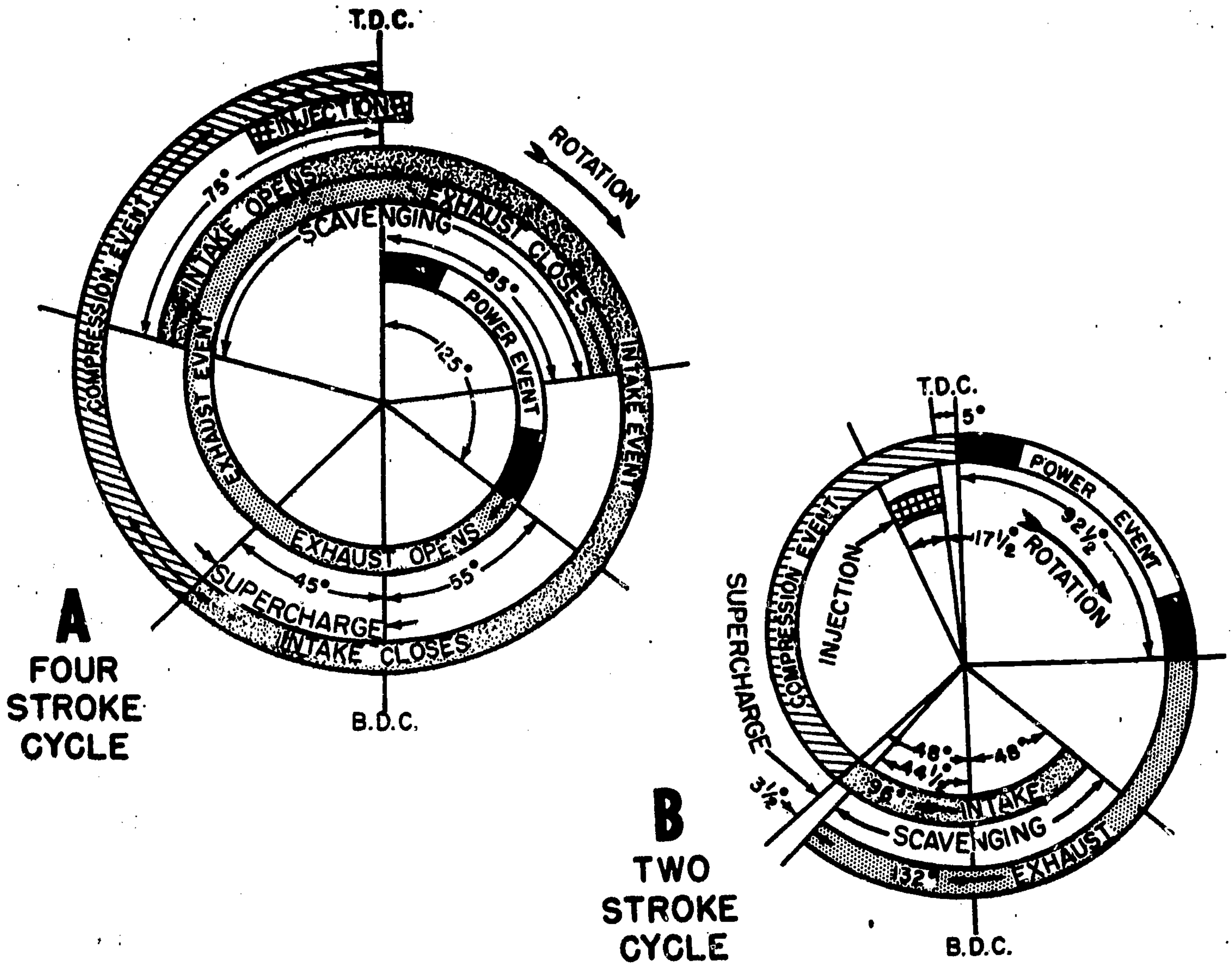

Fig. 3 Four cycle scavenging and supercharging.

of the piston for 125 degrees of the crankshaft rotation. At this point in the downstroke (55 degrees before BDC, bottom dead center), the power event ends and the exhaust valves open.

The exhaust valves remain open throughout the rest of the downstroke (55 degrees), throughout all of the next upstroke (180 degrees), and through 85 degrees of the next downstroke, a total of 320 degrees of shaft rotation. At a point 75 degrees before the piston reaches TDC the intake valves open and the supercharger begins forcing fresh air into the cylinder. For 160 degrees of shaft rotation, the air passes through the cylinder and out the exhaust valves, clearing the waste gases from the cylinder. The process of scavenging continues until the exhaust valves close at 85 degrees past TDC.

The intake valves remain open, after the exhaust valves close, for an additional 140 degrees of shaft rotation (45 degrees past BDC). From the time the exhaust valves close until the piston reaches approximately BDC, the cylinder is being filled with air, made available by the blower. During this interval, the increase in pressure is negligible because of the increasing volume of the cylinder space (the piston is on the downstroke). However, when the piston reaches BDC and starts the upstroke, the volume of the space begins to decrease as the blower continues to force air into the cylinder. The result is a supercharging effect, with the pressure reaching 3 to 5 psi by the time the intake valves close.

During the remainder of the upstroke (after the intake valves close) the supercharged air is compressed. Fuel injection begins several degrees before TDC and ends shortly after TDC. The actual length of the injection period in a specific engine depends on engine speed and load. When the piston reaches TDC, a cycle, involving two complete crankshaft revolutions and four strokes of the piston, has taken place; and the engine is ready to repeat the cycle.

SECTION B -- PRINCIPLES OF DIESEL AIR COMPRESSORS

As we have learned, air compression is universally associated with diesel engine operation as part of the fundamental working cycle of the engine. Compressed air is also required for other purposes, other than the engine, for off-highway equipment, such as air starting mechanisms, air braking systems, air horns, etc. Since this unit is basically concerned with the Cummins engine, the Cummins compressor will be discussed.

CUMMINS COMPRESSOR -- This unit is a single piston, reciprocating type air compressor that can be gear driven from the gear train, or have a belt and pulley arrangement drive, or be splined coupled.

The belt and coupling driven compressors have a two-piece connecting rod and a one-piece crankshaft, while the gear driven model uses a one-piece connecting rod and a two-piece crankshaft.

AIR INTAKE -- As the piston moves downward on the intake stroke, a partial vacuum occurs above the piston. The difference in cylinder pressure and atmospheric pressure forces the inlet valve down from its seat, allowing air to flow through the intake port into the cylinder. When the piston has reached the bottom of its stroke, spring pressure is sufficient to overcome the lesser pressure differential and forces the valve back up against the seat.

COMPRESSION -- When the piston starts its upward stroke, the increased pressure of the air in the cylinder and head forces the outlet valve away from its seat. The compressed air then flows through the outlet ports and into the air tank as the piston continues its upward stroke. When the piston reaches the top of its stroke, the air pressure in the head drops to a point where the spring forces the exhaust valve against its seat and closes off the outlet passage.

GOVERNOR -- Like most air compressors on diesel engine applications, the Cummins air compressor operates continuously while the engine is running. Therefore, there must be a way of stopping additional air pressure when pressure in the reserve or storage tank has reached its set pressure. This is accomplished by a pressure reducing valve, called the compressor governor. When the tank reaches the pre-determined pressure (90 to 120 psi) the governor cuts in and releases air pressure back to the top of the unloader cap. This pressure forces the cap down and prevents the intake valve from closing. Pressure in the delivery passage holds the exhaust valve in closed position. The pump is now in a no load condition because the intake passage also acts as the exhaust. When pressure in the air tank drops, the cap returns to its upper position and the intake and compression sequences repeat.

LUBRICATION -- The compressor is lubricated by the engine lubricating oil. Internal or external oil lines are used, depending on which application is used. Oil enters the compressor through drillings in the housing and lubricates the connecting rod bearings and crankshaft. The oil then flows to the compressor crankcase and returns to the engine through the oil drain located next to the oil inlet.

COOLING -- Water from the engine cylinder block cools the compressor. Water enters the upper part of the compressor crankcase and circulates around the crankcase and into the cylinder head. Flowing around the head, the water returns to the block through the water outlet port in the compressor cylinder head.

TROUBLESHOOTING THE AIR COMPRESSOR -- Chart I represents a list of abnormal operations of the Cummins air compressor and their probable causes.

ABNORMAL OPERATION	PROBABLE CAUSE
a. Compressor fails to maintain adequate pressure in the air brake system.	1. Excessive carbon in compressor cylinder head or discharge line. 2. Discharge valve leaking. 3. Excessive wear. 4. Intake valve stuck open. 5. Excessive leakage of intake valve.
b. Noisy operation.	1. Excessive carbon in compressor cylinder head or discharge line. 2. Worn or burned out bearings. 3. Excessive wear.
c. Compressor possess excessive oil.	1. Excessive wear. 2. Excessive oil pressure. 3. Back pressure from engine case. 4. Piston rings improperly installed.
d. Compressor does not unload.	1. Defective unloader or cap guide seal. 2. Unloading cavity plugged with carbon. 3. Unloading cap binding or stuck. 4. Unloader spring failure. 5. Unloader cap not seating properly on intake valve seat.

Chart I Cummins air compressor faults and causes.

SECTION C -- PRINCIPLES OF AIR STARTING MOTORS

One use of the compressed air generated by the air compressor is in starting the engine. Engines using the air starting motor have certain advantages over the ones using the electric starters. These are:

1. Freedom from sparks.
2. Lack of complicated relays.
3. Light weight.
4. Low cost.
5. Minimum maintenance.
6. Low voltage, 12 volts, instead of a 24 volt system.

The principle components of the air starting system are a multi-vane type air rotor (see Figure 4) a reduction gear assembly, and a Bendix friction clutch type drive. Figure 5 shows an exterior view of a typical heavy duty air starting assembly, used for cranking engines of 1100 cubic inches displacement and above.

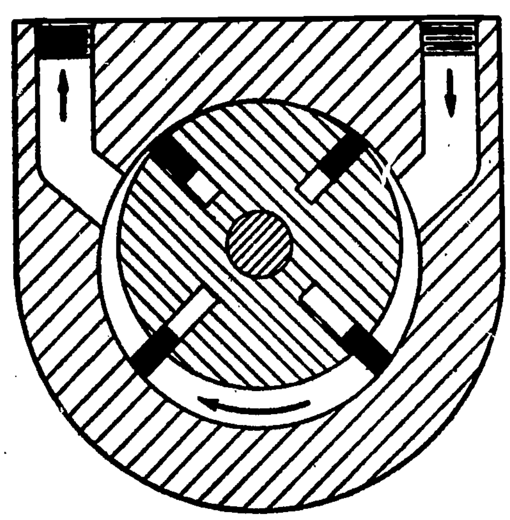

Fig. 4 Air rotary motor.

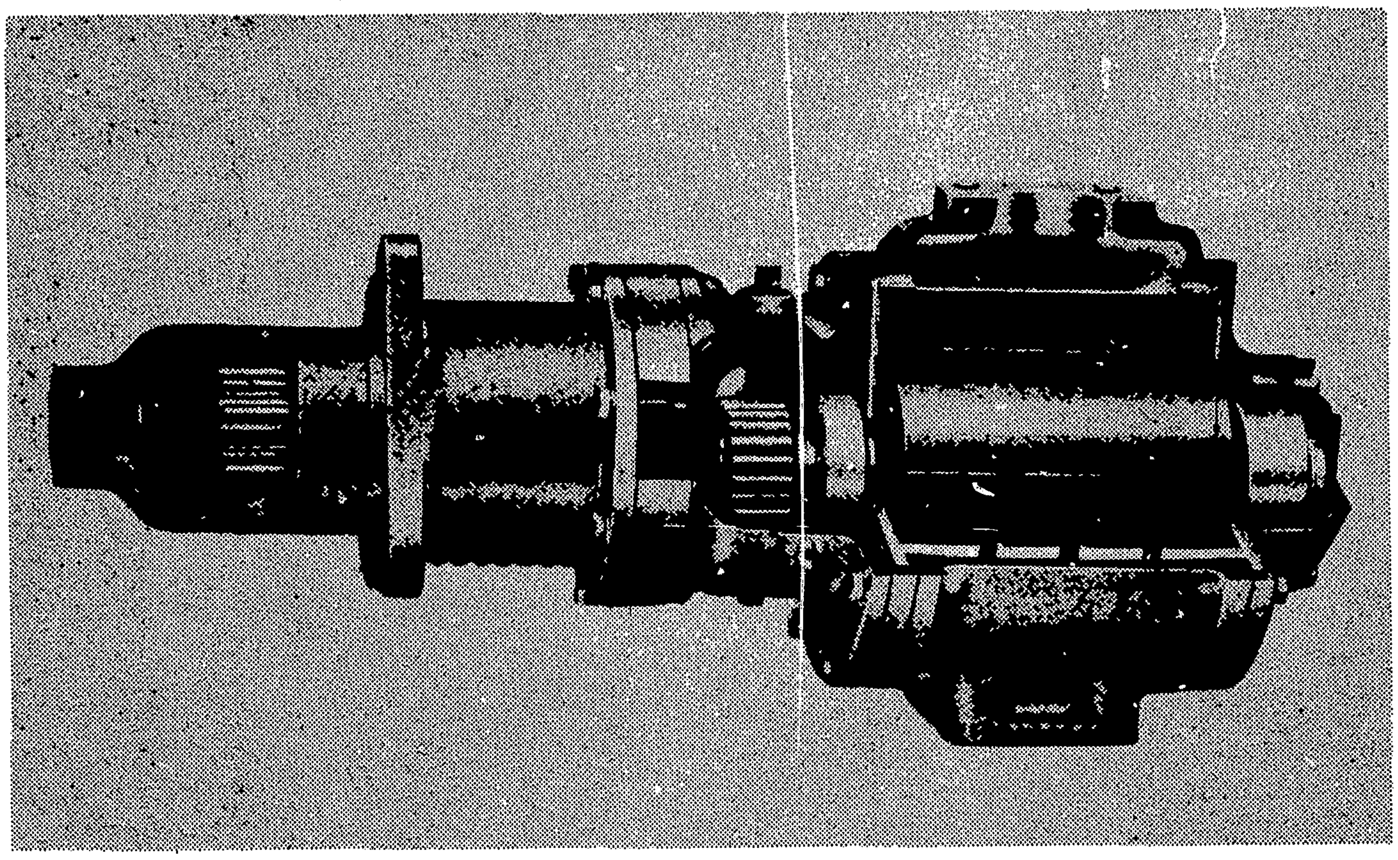

Fig. 5 View of heavy duty air starting motor.

In Figure 4 we can see that sliding vanes are fitted in a slotted rotor which is mounted eccentrically in the motor housing. Compressed air (approximately 100 psi) applied on one side causes rotation of the cylinder. Under constant load, these motors will run at constant speed. They are sensitive to changes in load and pressure, and will stall under excess load without damage.

Motor torque is proportional to air pressure. In this type motor, using 50 percent of the available pressure to handle the load allows 100 percent reserve starting torque.

Figure 6 shows the various components used in an air starting truck. Usually there are two reservoirs on large trucks, one for the air starter, and another for the brake system. In Figure 6, a pressure protection valve is used in the air supply line to protect the basic air system on a vehicle against complete loss of air during the starting operation. This

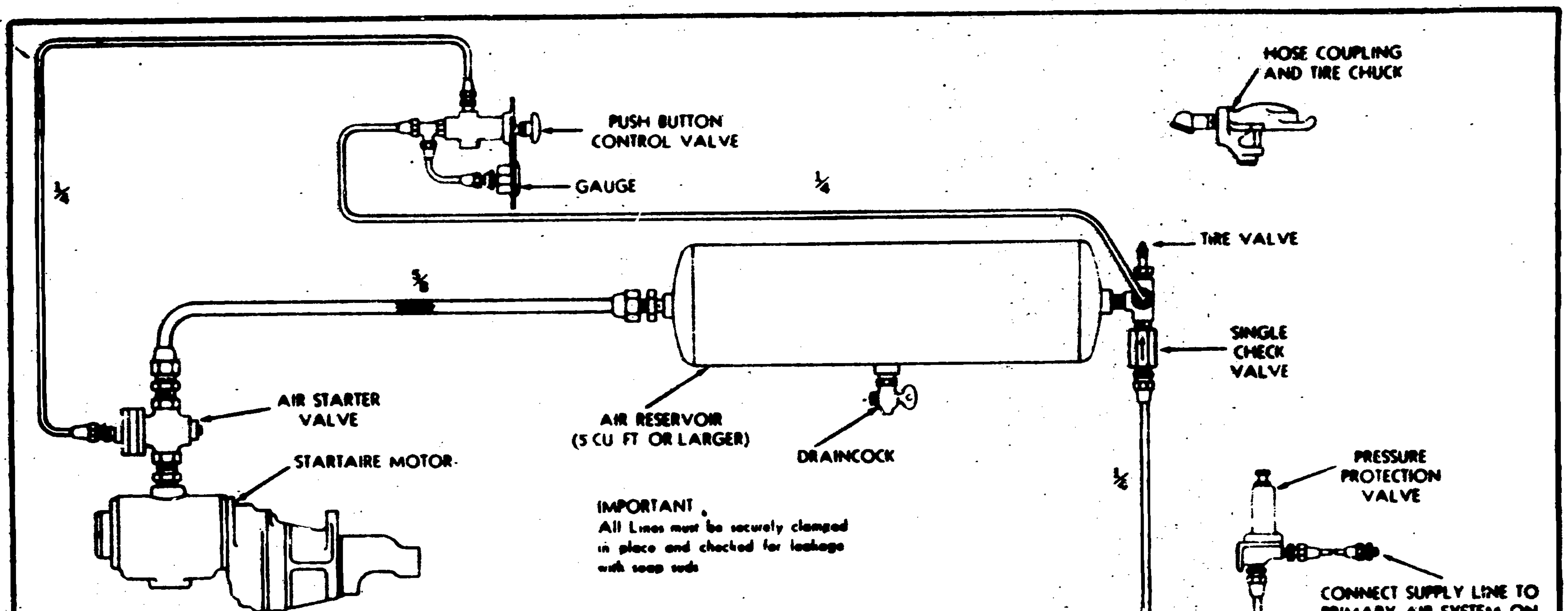

FIG. 1—Typical Startaire System Installation

Fig. 6 Typical air starter system.

system is somewhat self-contained in that the rubber seated single check valve permits easy maintenance and keeps leakage to a minimum.

A control valve, and an air pressure gauge registering air pressure in the air starting system, are mounted in the cab for easy accessibility. An air starting valve which opens or closes the air line between the starter reservoir and the motor, as controlled by the control valve, is mounted on or as close to the motor as possible, Figure 6. A quick coupling is provided to replenish the air system from an outside source if required.

OPERATING THE SYSTEM -- Before starting the engine, at least 100 psi should be registered on the gauge. Also all engine adjustements and prior starting procedures should be complete. When the push button is depressed, it should be kept depressed until the engine fires.

CAUTION: Be sure to release the button immediately upon engine firing, to allow the Bendix drive gear to disengage the flywheel.

BENDIX FRICTION CLUTCH TYPE DRIVE -- The Bendix drive is a device that accomplishes meshing and de-meshing of the drive pinion with the flywheel. It relies upon the principle of inertia to cause the pinion to mesh. Figure 7 shows the Bendix drive and housing of the heavy duty model.

When the air motor is not operating, the pinion is out of mesh and is entirely away from the flywheel gear. When the push button control valve is depressed by the operator the motor rotor immediately begins to revolve. The pinion, being weighted on one side and having internal screw threads, does not rotate immediately with the shaft but, because of inertia, runs forward on the revolving threaded sleeve until it meets or engages with the flywheel teeth.

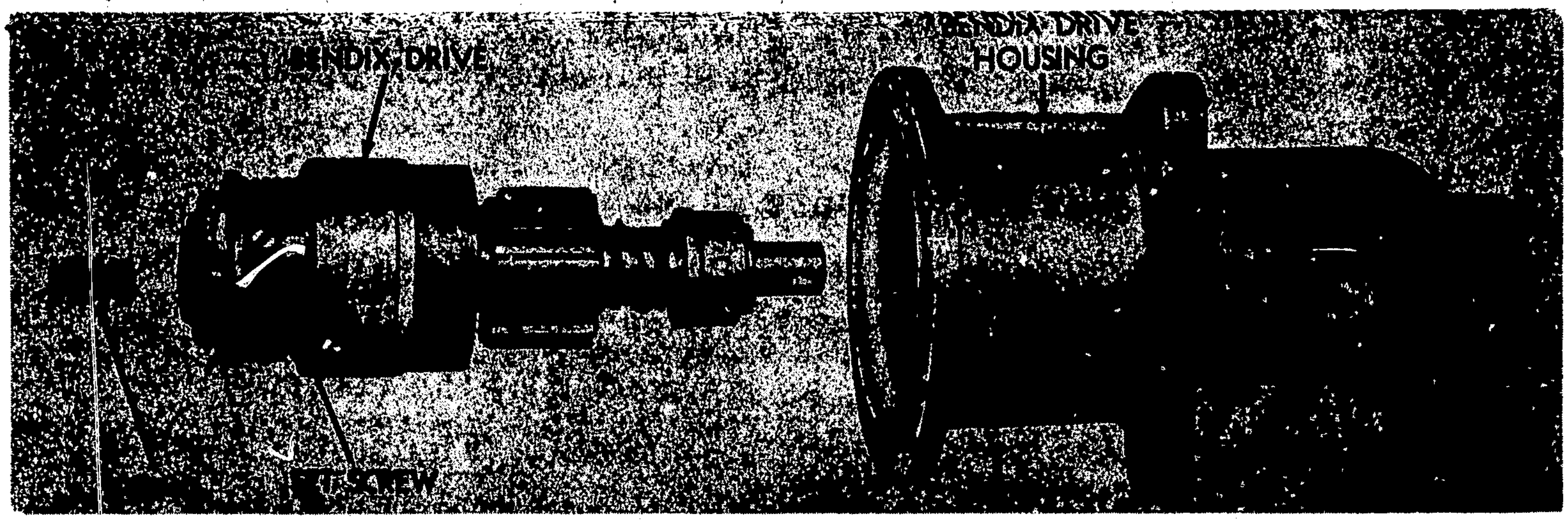

Fig. 7 Bendix drive and housing.

This type of Bendix drive has a series of spring loaded clutch plates which slip momentarily during the shock of engagement, to relieve the shock and prevent it from being carried back through the cranking motor. The slippage stops when engagement is completed, so that cranking torque is transmitted through the drive pinion to the flywheel ring gear.

When the engine begins to operate, the flywheel drives the pinion at a higher speed than the air motor is turning, causing the pinion to turn in the opposite direction on the threaded sleeve; this in turn disengages the pinion from the flywheel teeth.

TROUBLESHOOTING THE AIR STARTER SYSTEM -- For the air starter system to work effectively and to be trouble-free, it must be kept free of leaks. All connections should be checked monthly with soap suds while the system is at normal operating pressure, to be sure that leaks have not developed at connections or at any of the devices in the system.

Leakage at the system exhaust when it is not in use indicates that the air starter valve may be leaking. Possible leakage at the push button of the control valve and at the tire valve should also be checked with the system charged to normal operating pressure.

To check proper operation of the check valve, disconnect the air supply line to the check valve. There should be no measurable leakage at the inlet side of the check valve under such conditions. In making this test, the pressure protection valve is operating properly if it does not permit the basic air system pressure to be reduced below about 85 psi.

SECTION D -- SERVICING CUMMINS AIR SYSTEM COMPONENTS

Much has been said in past units about properly caring for air system components. The Cummins system is no exception. Many of the components are identical on different makes of diesel units, such as air cleaners, superchargers or turbochargers, air compressors, crankcase breathers, etc. However, let's briefly review some of the important procedures necessary for the mechanic to know when he is servicing the Cummins units.

COMPOSITE/DRY TYPE CLEANER -- The paper element in a dry type cleaner may be cleaned several times by using a compressed air jet to blow off the dirt. DO NOT hold air jet too close to paper element or the force could blow holes in it.

When installing the element, make sure it seats on the gasket at the air cleaner outlet end; Figure 8.

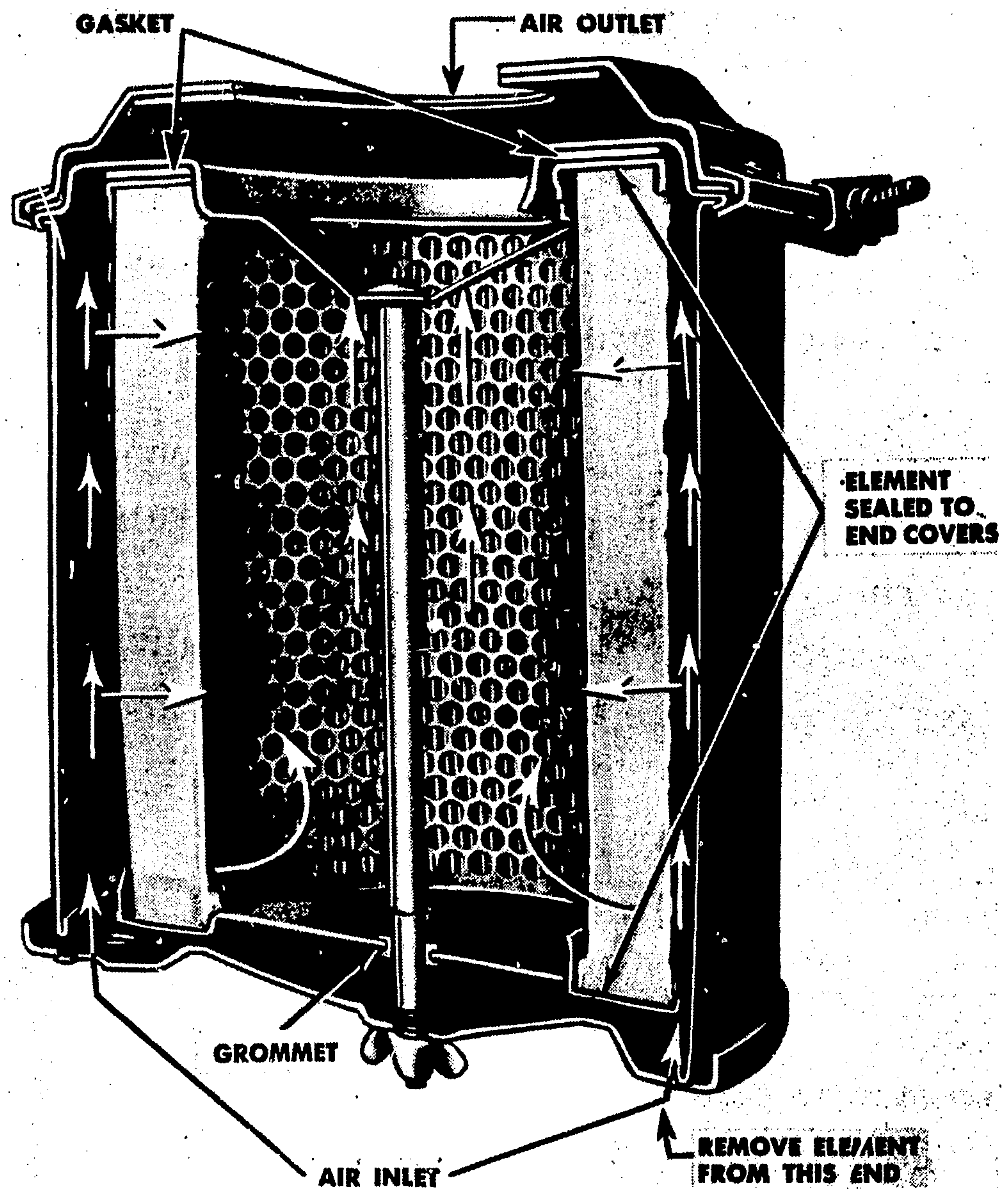

Fig. 8 Air cleaner, dry type.

When cleaning the vane portion of this type cleaner, use non-sudsing detergent and warm water, then dry with compressed air. Again, do not rupture cleaner with air jet.

OIL BATH TYPE AIR CLEANER -- This type of cleaner, like the dry type, requires constant attention to be sure no dirt gets into the engine.

The oil in this type cleaner must be checked often to be certain it is at the proper level and that it is not dirty. When changing the oil, it is a good practice to use an oil of the same grade as that used in the engine.

NOTE: Whenever the air cleaner(s) are serviced on a unit, always check air intake piping from air cleaner to intake manifold. Check for loose clamps or connections, cracks, punctures, or tears in hose or tubing, collapsing hose or other damage. If in doubt -- replace. Tighten all clamps and double clamp all connections. MAKE SURE all air goes through the air cleaner.

AIR AND VAPOR LINE CONNECTIONS -- Check all air and vapor lines and connections from compressor, supercharger, rocker housing cover, and cylinder head for leaks, breaks, stripped threads etc. Correct as required.

NOTE: In cold weather, condensed moisture in air tanks and lines may freeze and make brakes useless. Drain air tanks periodically to keep water out of the brake system. In some localities, alcohol is added to the tanks. In addition, alcohol feeders are used which permit a continuous flow of alcohol, to prevent freezing of air lines.

CHECKING INLET AIR RESTRICTION -- On naturally aspirated engines, attach a vacuum gauge or water manometer in the middle of the intake manifold or on the air intake piping. When located in the air piping, the adapter must be perpendicular to the air flow and not more than six inches from the air intake manifold connection.

On turbocharged or supercharged engines, attach the checking fixture one pipe diameter upstream from the supercharger or turbocharger in a straight section of tubing.

Idle the engine until normal operating temperature is reached. Speed engine up to rated speed, full-load, and take reading from vacuum gauge or manometer. Air restriction must not exceed 20 inches of water or 1.8 inches of mercury. It is a good practice to change fitters when the reading is between 16 inches and 20 inches of water.

NOTE: See maintenance manual if these limits are exceeded.

II -- UNIT REMOVAL -- TRANSMISSION

SECTION A -- PREPARATION FOR REMOVAL

This part of the unit presents a step-by-step procedure necessary to follow when removing a No. 5960 or 6061 Allison transmission from Euclid 14 or 15 FFD trucks or Mack LYSD and M 45 trucks. Many of these procedures apply to other types of vehicles; check your maintenance manuals for differences. Some maintenance and safety precautions will be inserted throughout this section.

STEAM CLEANING -- The first step in removing a transmission from a truck is to move the truck to the steam cleaning area. Then remove the hood and side panels and place all parts on the rear of the truck. Next steam clean the whole front of the truck, cleaning the engine and transmission. The time spent in doing a thorough cleaning job will be made up quickly during disassembly. In addition to actual time saved by transmission cleaning, the quality of work will be improved. A note of caution -- USE A FACE SHIELD whenever possible while steam cleaning, to avoid accidents.

Next move the truck into the shop or working area. Be sure there is enough room to do the job and that the following tools are available:

1. Floor jack with transmission adapter plate.
2. Miscellaneous hand tools.
3. Oil drain pan.

GOOD SHOP PRACTICE -- You will recall in text Unit AM 1-11, when we were removing an engine, we listed some good shop practices. Keep these in mind when removing the transmission.

Next drain the oil from the transmission into an oil sump or drain pan. NOTE: Clean up any spilled oil around the area, to maintain cleanliness and prevent accidents.

The following procedural steps are to be done in sequence:

1. Disconnect oil cooler inlet and outlet lines from the brake control valve mounted on the left side of the converter housing. Also, if remote mounted oil filters are used, disconnect the two lines from the filter base mounted to the top of the converter housing. Be sure to drain all disconnected oil lines and plug them, to prevent the entrance of dirt.

2. Disconnect the speedometer cable from the rear of the transmission and also at the two hold-down clamps. Remove the converter oil temperature gauge connection from the top left side of the converter housing. Also the adapter housing (remote mounted filters).

3. Disconnect the linkage from the transmission selector valve plunger and from the brake control valve plunger.

4. Remove the driveline from the transmission outlet flange and differential flange.

5. Disconnect parking brake linkage on left side of transmission.

SECTION B -- UNIT REMOVAL

6. Support the transmission with the floor jack and transmission adapter plate.

7. Support the engine with either a floor jack or blocking.

8. Remove twelve capscrews holding the flexplate to the flywheel through the opening in front of the engine flywheel housing. NOTE: The opening is found on the opposite side of the engine starter. On GM engines the opening is closed with a large plug. On Cummins engines the opening is covered by a plate with two capscrews. The engine must be turned part of a revolution for each capscrew.

CAUTION: Do not drop any capscrews inside the flywheel housing, as it may jam the ring gear, preventing the engine from turning.

9. Remove floor plate from cab over the transmission. Also remove top cover plate on converter housing, mounted by eight capscrews.

10. Through the top opening in the converter housing, remove the three capscrews mounting the converter housing to engine flywheel housing. Remove the remaining capscrews around the outside of the converter housing.

CAUTION: Be sure that transmission floor jack is supporting the transmission before removing the mounting bolts.

11. Remove capscrews from rear cradle supports, right and left side.

12. Lower transmission with floor jack and take to steam cleaning room for a more thorough cleaning.

13. Flush and clean oil lines and oil cooler.

14. Inspect shift linkage and repair as necessary.

This has been a very brief discussion on how to remove a transmission from a truck. Later on more will be said about this operation.

DIDACTOR PLATES FOR AM 1-14D

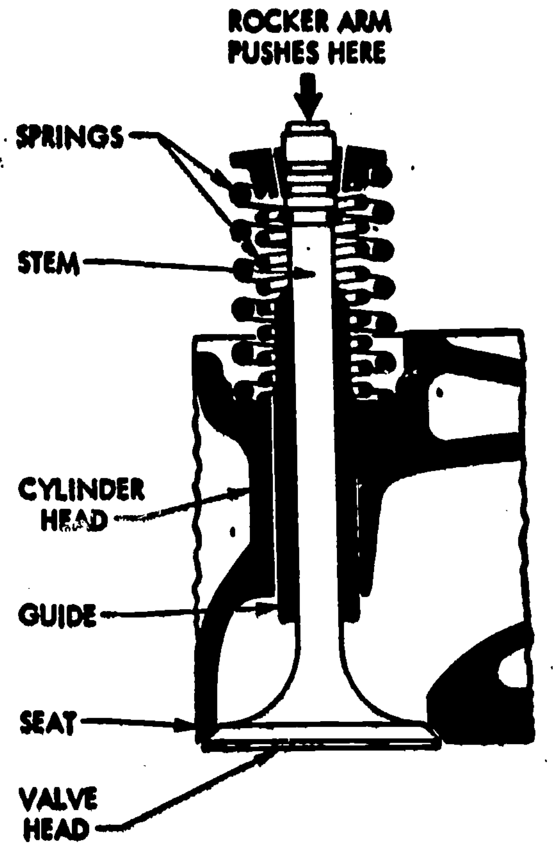

Plate I One-piece valve arrangement.

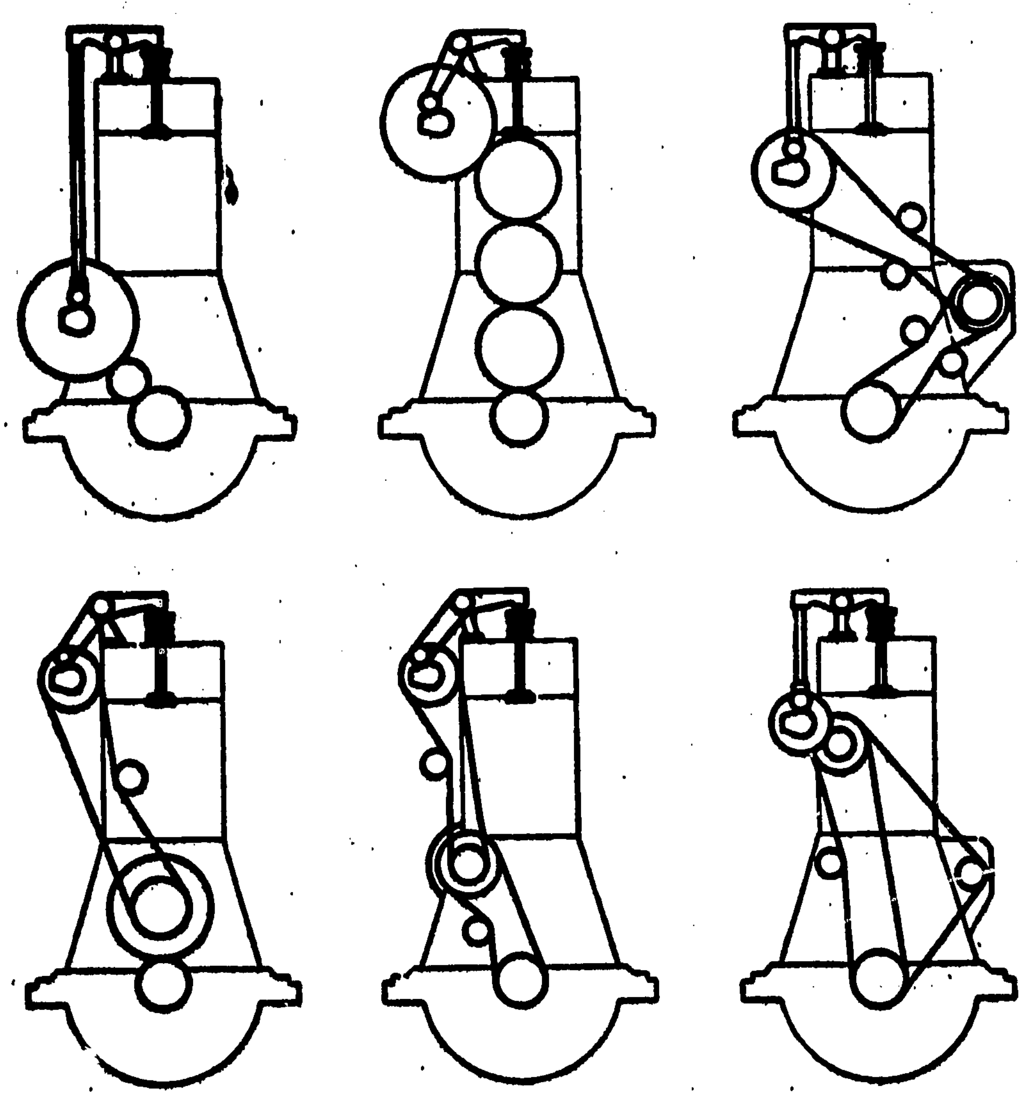

Plate II Typical camshaft drives.

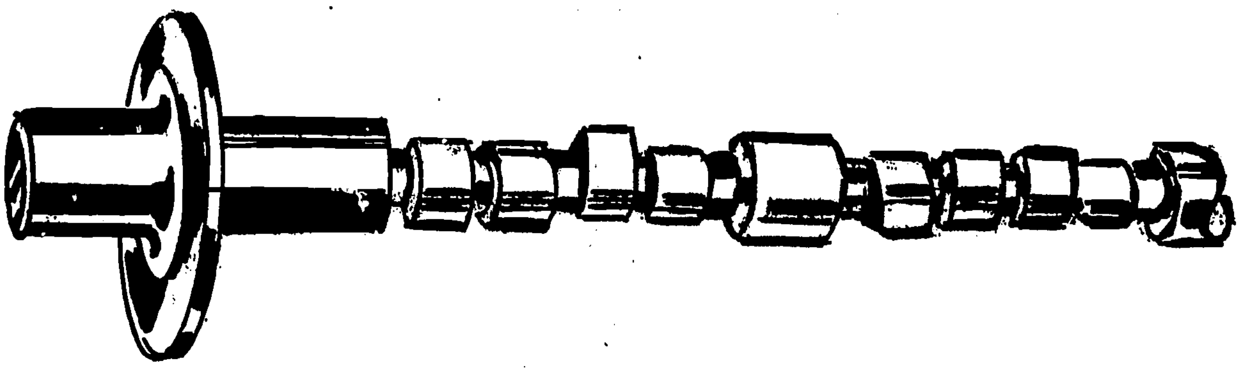

Plate III Camshaft for a V-12 diesel engine.

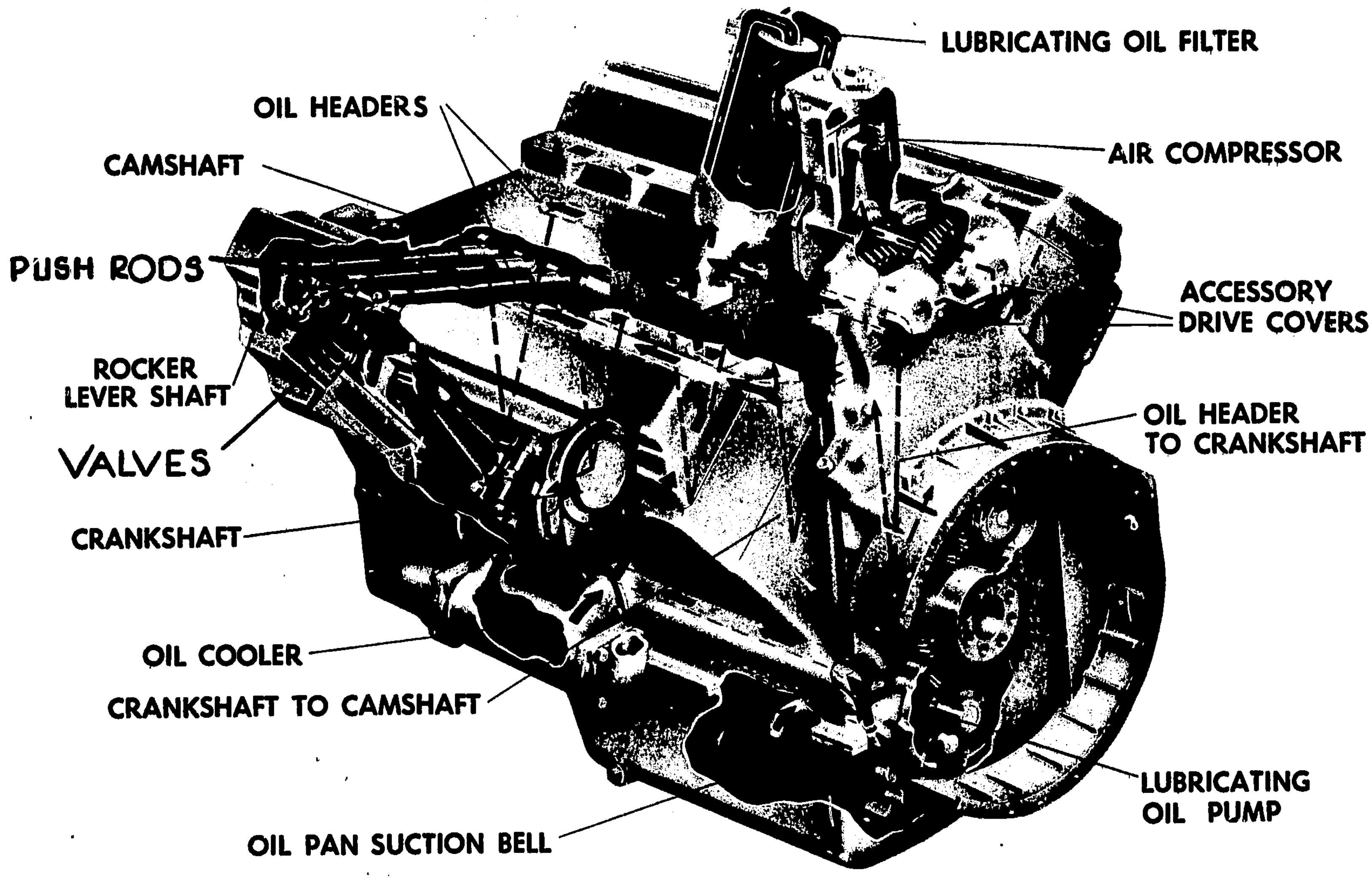

Plate IV V-8-350 Cummins camshaft/crankshaft.

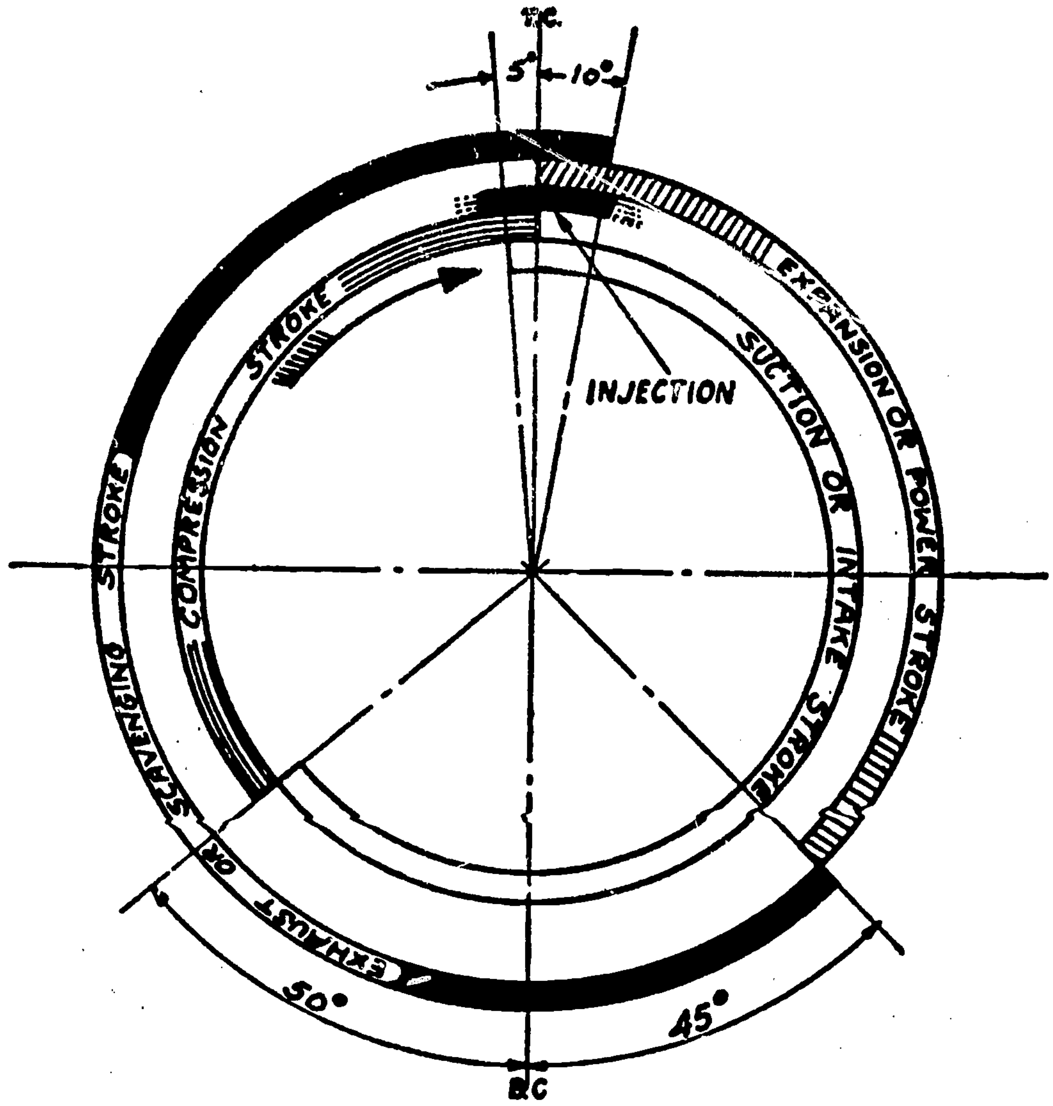

Plate V Typical crank circle timing diagram for a 4-cycle engine.

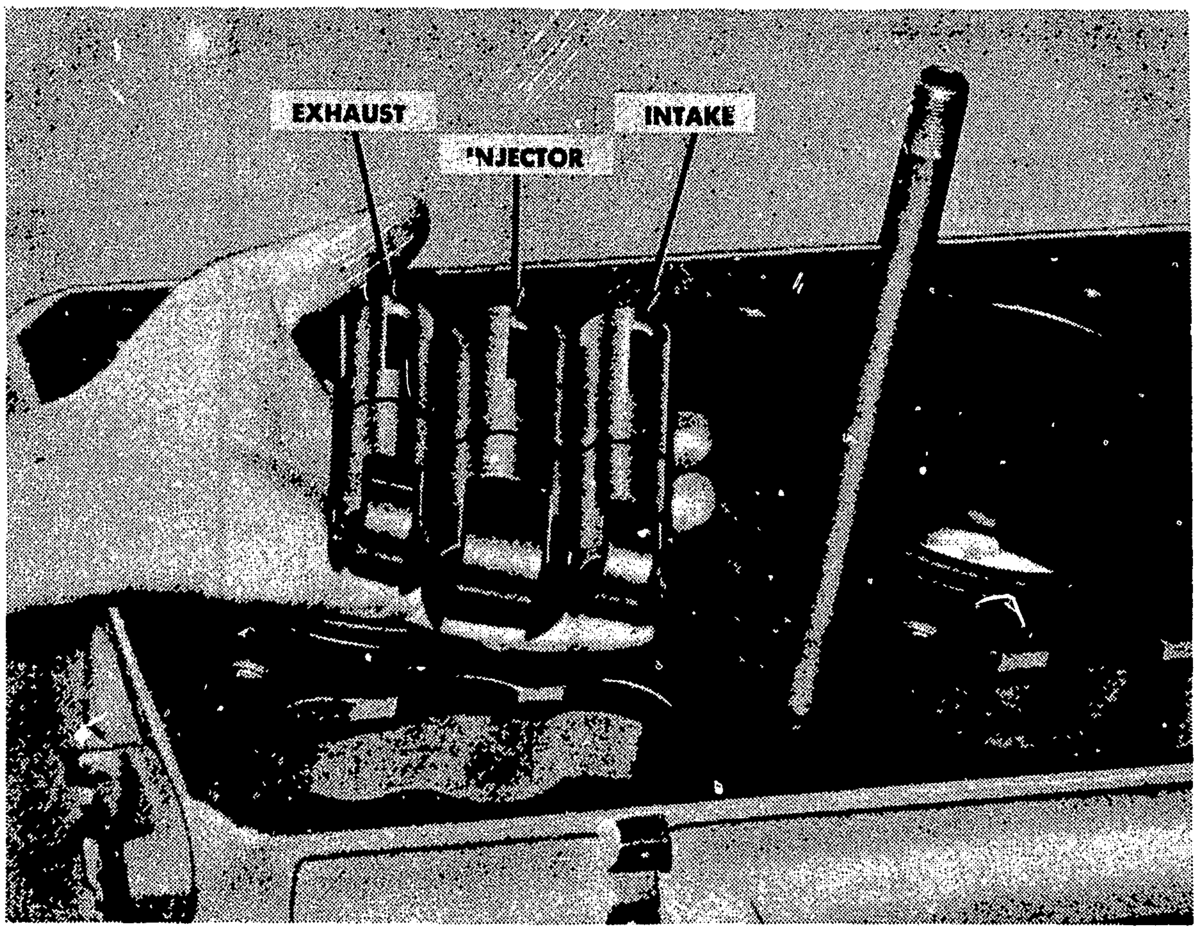

Plate VI Cam follower tappets.

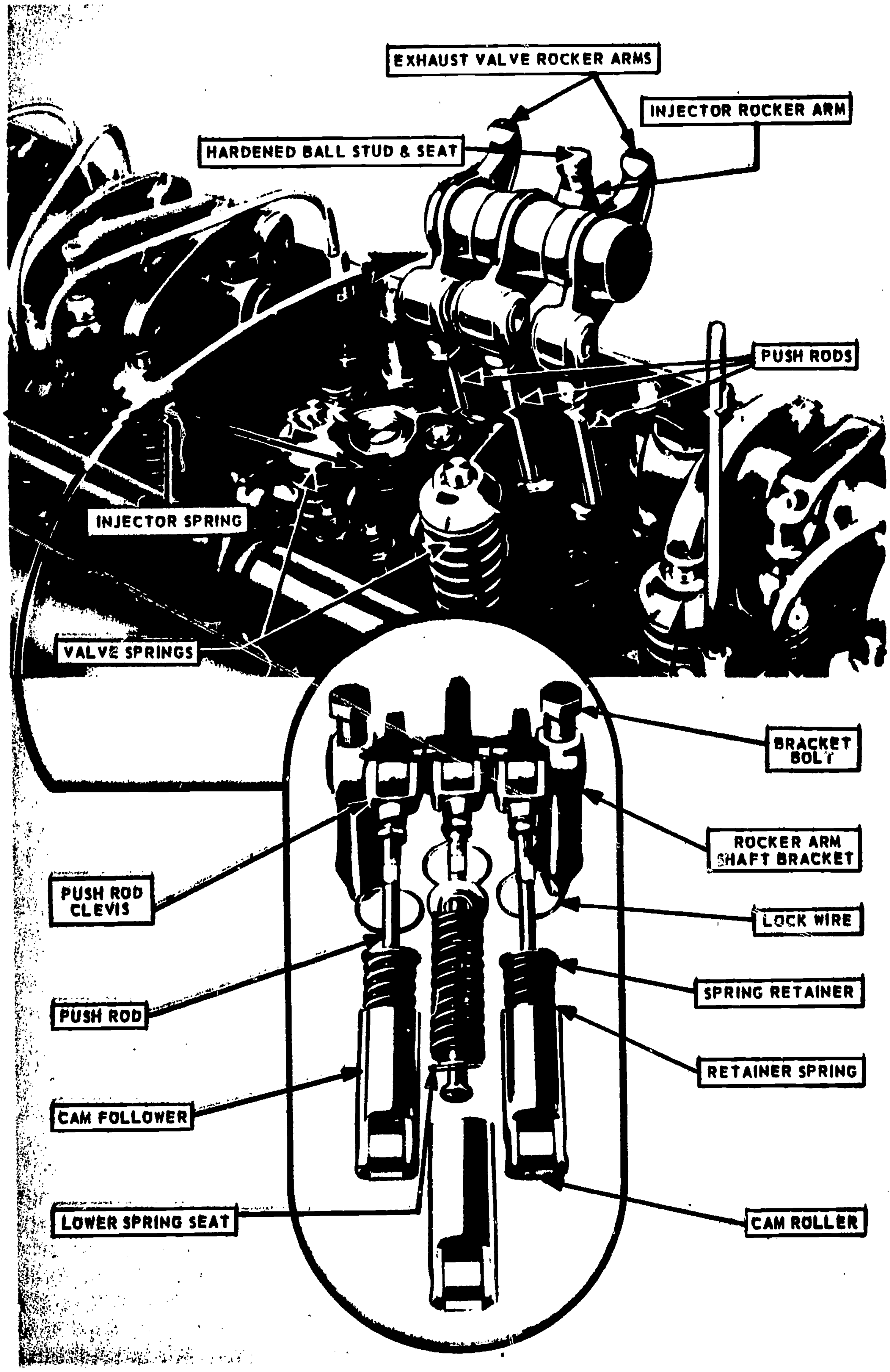

Plate VII Valve actuating mechanism.

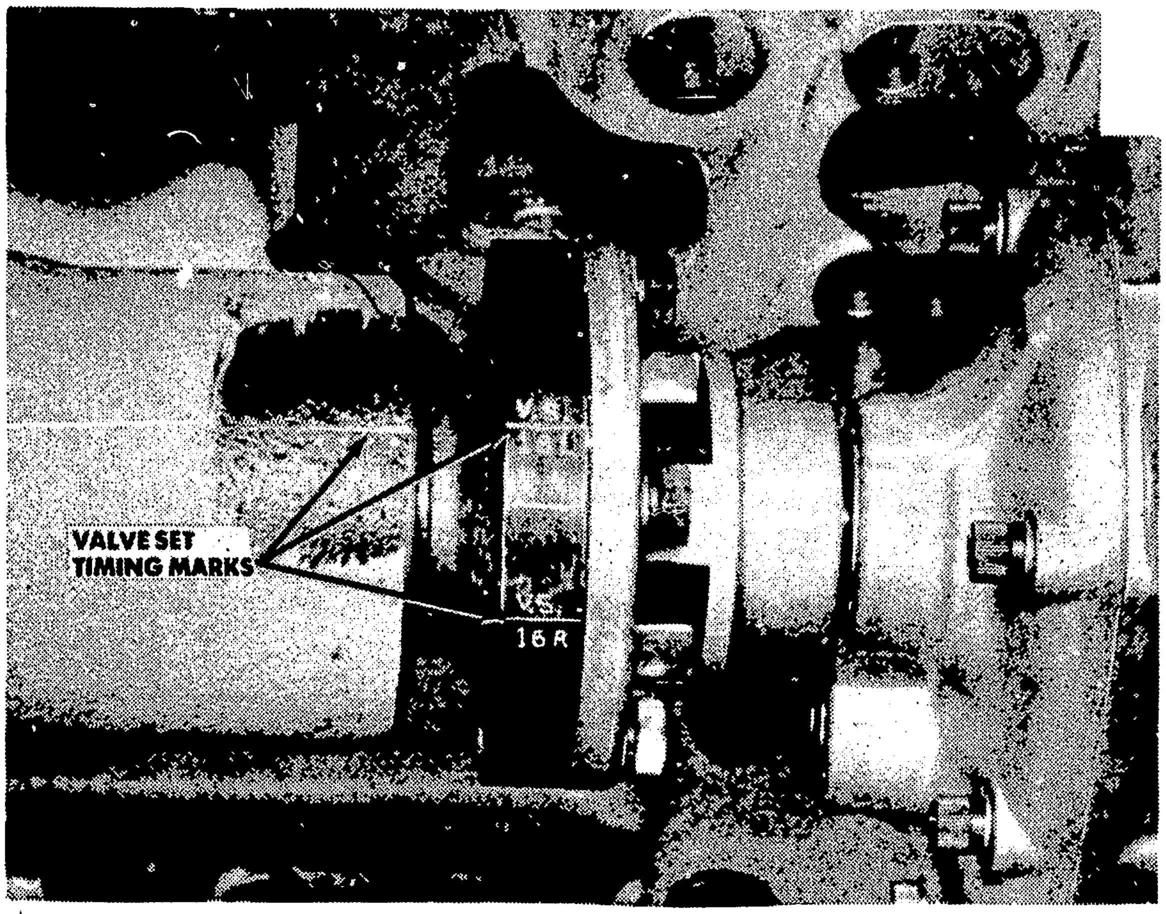

Plate VIII Valve set timing marks on jack shaft.

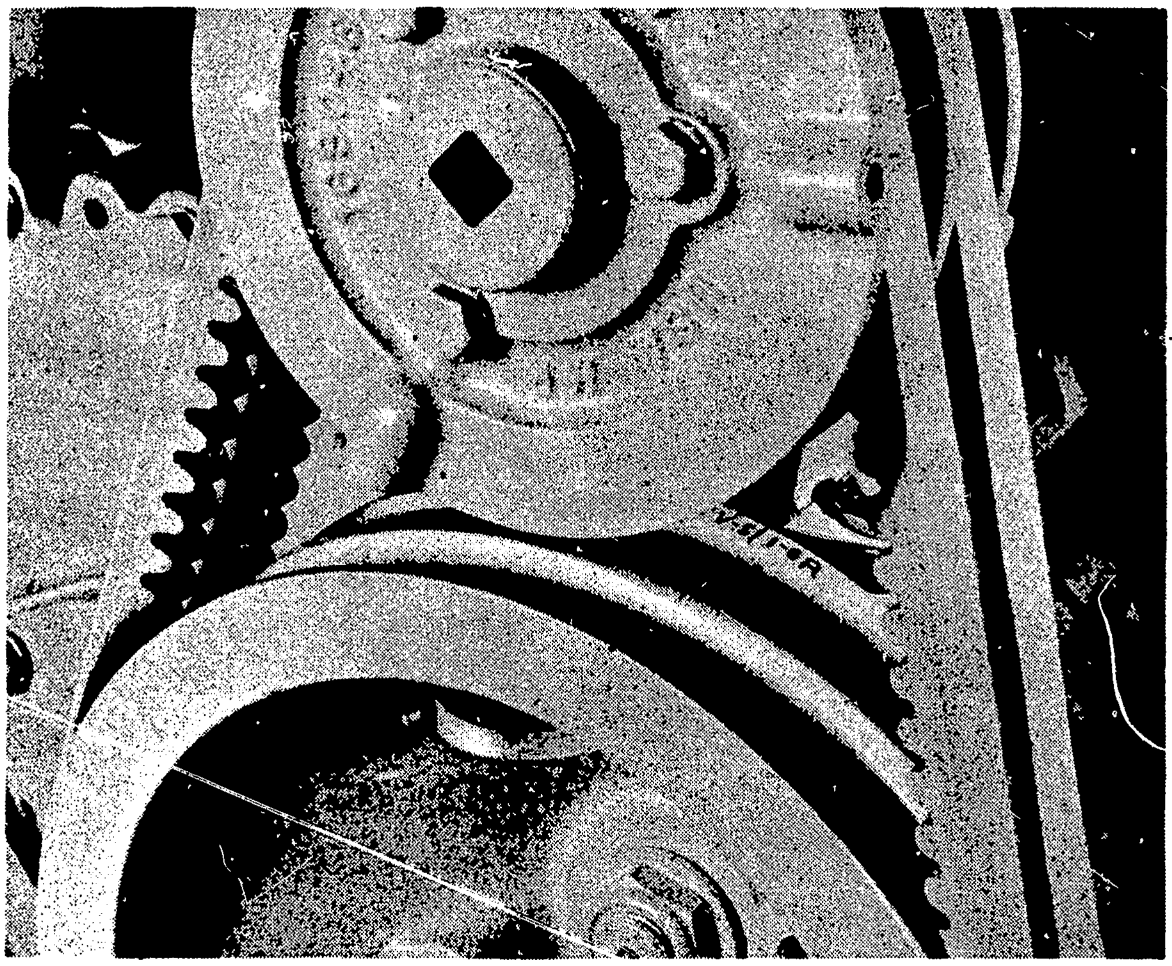

Plate IX Valve set timing marks, water pump drive pulley.

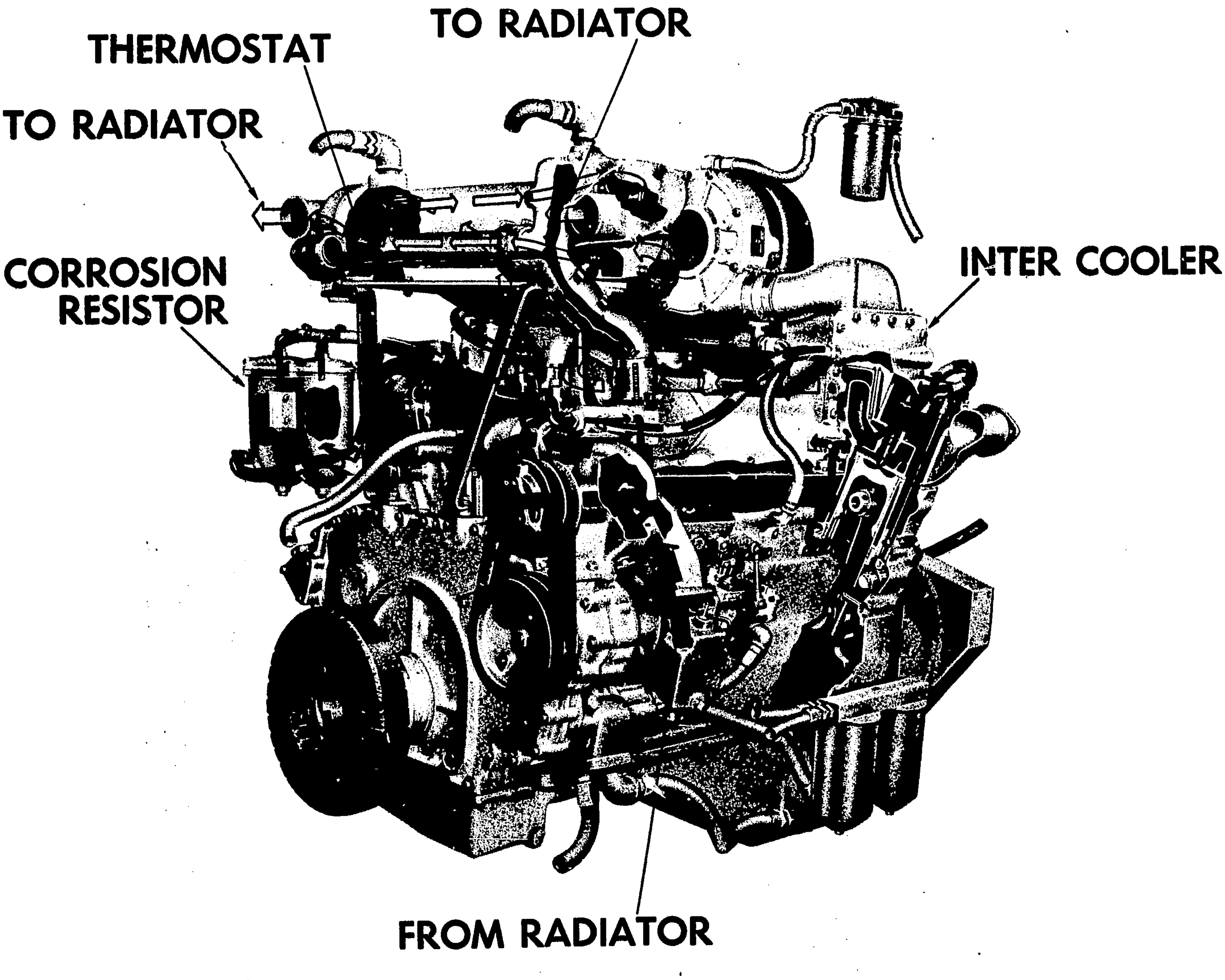

Plate X VT-12-700 coolant flow.

DIDACTOR

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AM 1-14D
4/21/66

UNDERSTANDING THE DIESEL AIR SYSTEM

Human Engineering Institute

+ MINN. STATE DEPT. OF ED. VOCATIONAL EDUCATION

Press A — 1 Check to see that timer is OFF

1

1

This film has been designed to supplement class text AM 1-14, Maintaining the Air System -- Cummins Diesel Engine, covering basic engine characteristics and technologies as related to the air intake and exhaust systems.

The main subject covered will be valves and actuating gear needed in a diesel to control the flow of air and exhaust gases. Also, valve timing, air cooling and air heating by heat exchanger on turbocharged engines will be covered.

Press A — 2

1

2

ENGINE CYCLES -- Diesel engines, the same as other types of engines, usually are built with a number of working cylinders, because the use of multiple cylinders increases the frequency, and reduces the amount of impact, of individual impulses on the crankshaft. This allows the engine to run smoother. This also makes it easier to balance the inertia forces on reciprocating parts, thereby reducing engine vibration.

In a naturally aspirated diesel engine, air is drawn into the cylinder through the intake valves as the piston moves on the down stroke. Atmospheric pressure is greater than the pressure inside the cylinder during this stroke.

Press A — 3

1

3

On the compression stroke the air is compressed to a fraction of its original volume, usually 14 to 1. This is called the Compression Ratio. When the air in the cylinder is compressed close to its maximum, fuel is injected under great pressure into the cylinder head. Because of the high temperature (1000F) attained by compressing the air, the fuel ignites immediately and releases large amounts of heat, most of which is imparted to the gases of combustion, increasing their pressure. Gases usually reach their maximum pressure shortly after the end of the compression stroke.

What we have just described means that the crankshaft has made ________ revolution(s) in a 4 cycle engine.

A. one — 5
B. two ⟩ 4
C. four

1

4

No. You are wrong. Only one revolution of the crankshaft has occurred. There have been two piston strokes, but only one complete turning of the crankshaft. Take another look at what we've said so far.

Press A — 2

1

5

OK. One revolution of the crankshaft has occurred. As the gases expand through combustion, the piston is pushed down in the cylinder; this is the power stroke. After the gases have been fully expanded, they are expelled from the cylinder by the piston moving on the second upstroke. When the piston has completed the exhaust stroke, there have been two complete revolutions of the crankshaft and four piston strokes. It is obvious to us now that the opening and closing of the valves must be exactly in mesh with the turning of the crankshaft; this is called valve timing.

Press A — 6

1

6

We can say that an engine cycle covers the ________
________.

A. time between intake and compression. — 7
B. time between intake and exhaust. — 8
C. time between ignition and compression. — 7

1

7

No. You are confused. An engine cycle refers to the time lapse between intake and exhaust. Read this explanation again and take your time.

Press A — 2

1

8

OK. An engine cycle takes place in the time between the intake valve's opening and the exhaust valve's closing.

VALVE DESIGN - When we consider the general design of the valve, we should remember that the exhaust valve particularly is subjected to the high-temperature gases, and that the heat absorbed must be carried away through one of two paths (a) from the valve face to the seat in the head, or (b) from the valve stem to the valve guide.

The valve stem *needs a large area to transmit heat to the* guide, but it should be somewhat flexible between the guide and the head. Plate I shows a design for good cooling, with a reduced diameter for flexibility.

Press A — 9

1

9

This flexibility, along with a flexible valve head, will allow the valve to seat on a slightly distorted cylinder head seat. However, if the stem is made too small, or the head too thin, valve temperature will be increased.

On the other hand, the head should not be beefed up for increased strength, which can better be obtained with a material having high hot-strength to withstand the thermal shock and mechanical load. The fillet between the stem and head should *have a generous radius*, and all heated edges should be well rounded.

Press A — 10

1

10

Exhaust valves are likely to burn out faster than intake valves on four cycle engines because ______________.

A. the entire area of the exhaust valve is exposed to heat. — 11

B. exhaust valves are closed during combustion. — 12

C. exhaust valves are not cooled by incoming air. — 13

1

11

No. Even though the entire area (including the top surface) of the exhaust is exposed to the hot gases and the top surface of the intake valve is not, this is not the reason they burn out faster.

The answer we wanted here is that the exhaust valves are not cooled by the incoming air like the intake valves are.

Press A — 13

1

12

No. You are entirely incorrect. Both valves are closed during combustion; if they weren't no pressure would be exerted on the piston. Read this material again and read carefully.

Press A — 2

1

13

OK. Intake valves are cooled by the incoming fresh air.

On 4 cycle engines, the exhaust valve size is not so critical as on a 2 cycle because the exhaust gases are forced out by the piston during an entire stroke. The inlet valve openings (4 cycle engine) are more important, since all the intake air enters the cylinder through these openings. Restrictions to the air flow not only increase the pumping loss but also reduce the volumetric efficiency. Most high speed 4 cycle engines today have two inlet and two exhaust valves per cylinder with the inlet valves being of a larger diameter.

Press A — 14

1

14

Air-flow restriction becomes more critical when engine speeds are increased, due to the high velocity of gas flow. For this reason the power of every high speed engine reaches a maximum or peak at a certain speed, beyond which an increase in speed results in a drop in power output.

Because of these conditions, intake valves of high speed 4 cycle engines are made as large as possible and are sometimes as much as 25 to 35 percent larger than the exhaust valves.

Press A — 15

1

15

Before moving on, let's review what's been covered so far. To increase the number of individual impulses, and reduce their impact, on the crankshaft, manufacturers have built ______________________________.

A. engines with a reduced number of reciprocating parts. — 16

B. engines with turbochargers. — 17

C. engines of a multiple cylinder design. — 18

1

16

No. You are not reading very carefully. The reciprocating parts in an engine have to do with the forces of inertia and engine vibration.

They do not affect the number of individual impulses, or their impact, on the crankshaft.

Go back and look for a better answer to this question.

Press A -15

1

17

No. Engines with turbochargers have little to do with individual impulses on the crankshaft. Turbochargers only increase the volumetric efficiency of an engine by forcing more air into the cylinder.

Try this question again.

Press A - 15

1

18

OK.

A naturally aspirated engine is one that operates on

________________.

A. the difference between pressure in the cylinder and atmospheric pressure. -21
B. the principle of mechanically forcing large quantities of air into the cylinders. - 19
C. a much lower compression ratio than other engines. -20

1

19

No. You are not reading as carefully as you should. A naturally aspirated engine is one that uses the difference in pressure principle. Atmospheric air pressure is greater than pressure inside the cylinder when the piston is on the down stroke, thus air rushes from where the pressure is high (outside) to where it is low (in the cylinder) until the two pressures are equalized.

Press A - 21

1

20

No. Naturally aspirated engines have as high a compression ratio as do other types. Compression ratios in modern high speed diesel engines are usually from 14 to 18 to 1, or more.

Try this question once more.

Press A - 18

1

21

OK. Naturally aspirated engines depend solely on the difference in pressure principle between atmospheric pressure and pressure in the cylinder at the time the piston is on the down stroke. It would seem logical then that at high altitudes the ________________.

A. intake valves should be open longer for each cycle than at lower altitudes. -22
B. horsepower of an engine would decrease as compared to lower altitudes. -24
C. naturally aspirated engines have an advantage over the turbocharged engine. - 23

1

22

No. The pressure is lower at high altitudes, and it wouldn't matter if the intake valves were open longer; not enough to make any difference.

The fact is that the engine would develop less horsepower at higher altitudes because it would be starving for air.

Press A - 24

1

23

No. At higher altitudes the turbocharged engine would have an advantage over the naturally aspirated engine. The blower would force air into the cylinders whereas with naturally aspirated engines the pressure ratio between the atmosphere and cylinder would decrease considerably at higher altitudes. These engines would be starving for air.

Press A - 24

1

24

OK. At higher altitudes the atmospheric pressure is low. This would allow less air to enter the cylinders, thus reducing the horsepower of the engine.

VALVE ACTUATING GEAR -- The basic job of the valve actuating gear is to cause and to control the opening and closing of the inlet and exhaust valves. In most engines, this gear consists of rocker arms which actuate the valves, push rods which connect the rocker arms, cams on the camshaft and a drive connecting the camshaft to the crankshaft.

Press A — 26

X (C) → 25

2

25

You have answered one or more of the questions in this section incorrectly. Let's review this again before moving on to new material. Read carefully and take your time in answering the questions.

Press A → 2

2

26

CAMSHAFT DRIVES -- In 4 cycle engines, the camshaft speed must be exactly one-half the crankshaft speed, so that the camshaft makes one complete revolution while the crankshaft makes two. We know from the earlier part of this lesson that two complete revolutions of the crankshaft in a 4 cycle engine means there have been ________ piston strokes.

A. two ⟩ 27
B. one ⟩ 27
C. four — 28

2

27

No. Two revolutions of the crankshaft means there have been four strokes of the piston; intake, compression power and exhaust.

Let's move on.

Press A — 28

2

28

OK. Four piston strokes have occurred.

In a 2 cycle engine we know the camshaft speed must be exactly the same as the crankshaft speed. Because these speed relations must be exact and there is no room for lag, the connecting drives must be positive; this requires the use of gears or chains.

Many drive arrangements are used, as shown in Plate II. The camshaft may be located low, near the crankshaft, using long push rods, typical of the Cummins' in-line diesel; or it may be located on the cylinder block, using short push rods typical of a Cummins V-type engine; or at the cylinder head level, without push rods.

Press A — 29

2

29

A camshaft for diesel engines is generally made as an integral forging. Plate III shows a camshaft forging for a V-12 engine. One intake and one exhaust cam are provided for each cylinder, along with seven camshaft bearing journals. The journal diameters are large to permit endwise removal of the shaft from the bearing sleeves.

Integral camshafts are made of a low-carbon alloy steel with the cam and journal surfaces carburized before finish grinding. Carburizing means the surfaces are impregnated with carbon and heat treated for hard surfacing purposes.

Press A — 30

2

30

Arrangement of the cams on the shaft determines the firing order of the cylinders, while the contour of each cam controls the time and rate of opening and closing of the valves.

Shape and contour of the cam surface depend upon the desired valve timing, valve lift, type of cam follower and the engine speed.

Before moving on, let's review what has been said about valves and valve gears. The length of time that the intake and exhaust valves are open depends on ________________.

A. the number of cylinders in the engine. — 31
B. the location of the camshaft and length of the push rods. — 31
C. the speed of the engine. — 32

2

31

No. You are confused. We said the camshaft actuates the push rods, which in turn open and close the valves. Think, if there is no lag allowable between movement of the crankshaft and the camshaft, what would determine the length of time that the valves are open and closed?

Try this question again.

Press B — 30

2

32

OK. The speed of the engine determines length of time the valves are open.

To control the stresses in the valve mechanism, valves are opened and closed gradually by a ramp on the cam. In high speed engines, where forces involved increase with the square of the speed, it becomes very important that the cams are designed perfectly.

There are many types of camshaft arrangements in diesel engines. All Cummins diesels ____________

A. use short push rods with the camshaft close to the head. — 33

B. use a chain drive camshaft with a sprocket arrangement. — 33

C. use the push rods arrangement (short on V engines, long on in-line engines). — 34

2

33

No. We said all Cummins engines use a push rod arrangement. We also said the camshaft turns at one-half the speed of the crankshaft. Try this question again.

Press A → 32

2

34

OK. The push rods are long on the in-line engines and shorter on the V engines; see Plate IV. Notice that the push rod between the intake valve rod and the exhaust valve rod operates the injector for that cylinder. In Plate V we can see exactly at what instant the fuel is injected into the cycle. Study this diagram; can you tell when the intake and exhaust valves are open, when they are closed?

Improper timing of the exhaust valves, whether early or late, will result in increased heat losses in the engine. If early, the valve releases the pressure in the cylinder before all the work can be obtained. If late, the necessary amount of air for the next charge cannot be obtained.

Press A — 35

2

35

The ramps on a camshaft allow the valves on a diesel engine to ____________.

A. seat tightly against the valve seat inserts. — 36

B. open and close rapidly with no chance of the valves sticking. — 37

C. open and close gradually in accordance with the firing of the cylinders. — 38

2

36

No. Seating tightly against the valve seat has nothing to do with the ramp on the camshaft. The answer we wanted here was that the ramp allows a gradual opening and closing of the valves, which is critical in high speed engines.

Press A — 38

2

37

No. The ramp allows gradual opening and closing of the valves. As far as the ramp having anything to do with valve sticking, this is false. Usually valve sticking is the result of weak or broken springs, or burnt valves.

Press A — 38

2

38

OK. Let's move on to other parts of the valve actuating mechanism.

CAM FOLLOWERS -- Followers which contact each cam on the camshaft may be flat, or the roller type as shown in Plate VI, typical of the Cummins engine. The follower is commonly made of low carbon steel, carburized, and ground to provide a long-wearing surface against the cam.

Press A — 40

X (C) → 39

3

39

You have answered one or more of the questions in this section incorrectly. It will be best if you review this material again, to establish it in your mind before moving on. Read carefully and take your time in answering. Get them all right on the first try, and then you will be able to move along to the next section.

Press A → 26

3

40

ROCKER ARMS -- Most engines use a push rod to transmit cam motion to a rocker arm; see Plate VII. This rocker arm then opens the valve. In the case where two exhaust or two intake valves are operating, both valves may be operated by a bridge.

Rocker arms swing on a steel fulcrum pin or pivot, resting in a bronze bushing. The rocker arm may contact the end of the valve stem by means of a roller, but some form of set screw or "tappet" is more usual.

Press A — 41

3

41

The set screw is not only simpler and lighter than the roller but also permits adjusting the tappet clearance or lash so that the valve closes firmly on its seat. The other way to adjust valve timing on a Cummins engine is by shortening the push rods through insertion of gasket or shim sets, or by using an offset key (V types) to change the camshaft.

VALVE SPRINGS -- The required spring force depends upon weight of reciprocating parts of the valve mechanism, cam contour and maximum engine speed. This force is greatest when the valve is near its wide-open position. Of course the main purpose of the valve springs is to keep the valves ___(1)___ when they are not forced ___(2)___ by the camshaft and push rods.

A. (1) closed; (2) open — 43
B. (1) open; (2) closed — 42
C. (1) seated; (2) closed — 42

3

42

No. The push rods are actuated by the turning of the camshaft, and force the valves open gradually as the roller rolls up the ramp on the camshaft. The valve is closed by the spring force.

Press A — 43

3

43

OK. Valve springs are made of highly tempered round steel wire, wound in a spiral coil. Only a small portion of the spring force is needed to keep the valve tight on its seat. The principal duty of the spring is to provide sufficient force, while the valve is being lifted, to overcome the inertia forces of the valve gear caused by the rapid motion. By overcoming these inertia forces, the spring keeps the push rod in contact with the cam and thus prevents the bouncing that would otherwise occur. In order to give the spring sufficient force for this purpose, it is always compressed when it is installed. It is further compressed when the valve is ________.

A. open. — 45
B. closed. — 44
C. Neither A or B. — 44

3

44

No. Remember the valve spring works against the valve being opened by the push rod. The springs in other words, are constantly trying to keep the valves closed.

Let's take another look at that last paragraph.

Press A — 43

3

45

OK. Now, let's talk about valve timing. In a 4 cycle engine, such as Cummins, the dividing points between the four main events (suction, compression, expansion, and exhaust) do not come at the very beginning and end of the corresponding strokes. The differences are smaller in low speed engines and increase as the engine speed increases.

As mentioned earlier, valves must be opened gradually, to avoid excessive inertia forces, and must be lifted well off their seats before they open effectively.

Press A — 46

3

46

Also, the gases themselves have inertia, which means that it takes time to start them moving, and once started moving, they tend to keep moving. All these conditions must be allowed for in the valve timing of an engine.

Consequently, the intake valve is opened before TCD (top dead center) by 10 to 25 degrees of the crankangle; it is closed from 25 to 45 degrees after BDC (bottom dead center). In order to release the exhaust gases in time, the exhaust valve begins to open 30 to 60 degrees before BDC (on the expansion stroke) and closed 10 to 20 degrees after TDC.

Press A — 47

3

47

Note: When the piston is near TDC at the end of the exhaust stroke (and at the beginning of the suction stroke), both valves are open during a considerable period. The period that the valves are open together is called the valve overlap period; its purpose is to get more burned gases out and more fresh air in.

Both exhaust valves and intake valves are opened and closed prior to and after the four strokes of a piston because of ________.

A. the time it takes to actuate them. — 48
B. the inertia forces involved. — 50
C. the engine camshaft design. — 49

3

48

True, there is a certain amount of time involved to actuate the valves, but it could be done quicker if the cam was designed differently. The answer we wanted here is: because of the inertia forces involved.

Press A — 50

3

49

No. This is why the valves are actuated early and late, but the reason we wanted here is: because of the inertia forces involved.

Press A — 50

3

50

OK. The inertia forces are the reason why the valves are actuated early, and closed after the TDC and BDC, of each stroke in a four cylinder engine.

The period called "valve overlap" refers to the ______ ______.

A. exhaust valve(s) being open through two strokes. — 51
B. exhaust and intake valves being open during the compression and part of the combustion stroke. — 52
C. intake and exhaust valve(s) being open at the end of the exhaust stroke and at the beginning of the suction stroke. — 53

3

51

No. The valve overlap refers to both valves being open during one of the strokes of the piston. In this case, it is during the end of the exhaust stroke and at the beginning of the suction stroke.

Press A — 53

3

52

No. Remember we said neither valve could be open during the compression stroke, or there would be no compression. The answer we wanted here is: both valves are open during the last part of the exhaust stroke and the beginning of the suction stroke.

Press A — 53

3

53

OK. Valve overlap during this portion of the piston strokes is necessary to ______.

A. allow the proper scavenging of the cylinder. — 56
B. cool the exhaust valves with incoming air. — 54
C. satisfy the contour of the camshaft. — 55

3

54

No. Remember, we said the exhaust valves are hotter than the intake valves because nothing but exhaust gases escape from them. Think and then try this question again.

Press A — 53

3

55

True, but the engine is designed this way. The reason we wanted here is: (llow complete scavenging of the cylinder with incoming air crowding out the exhaust gases.

Press A — 56

3

56

OK. Scavenging of the cylinder is the reason why the valves are both open during this time. Now let's discuss the procedure required for adjusting the injector plungers and valves on a V-12 Cummins engine.

INJECTOR AND VALVE ADJUSTMENTS -- Injector and valve adjustments should be made when:

1. A new or rebuilt engine is installed.
2. A new or rebuilt engine has run for 100 hours.
3. Performance is unsatisfactory.
4. An engine has been overhauled.
5. The cylinder head assembly has been serviced.

Press A — 58

4

x(c) → 57

57

You have answered one or more of the questions in this section incorrectly. It will be better to review it now instead of going further with new material. Read carefully during the review, and take your time in answering.

Press A →40

4

58

TIMING MARKS -- Injector plungers and valves are adjusted on engines 90° after top center firing position. The right bank (V-12) accessory drive, spider (see Plate VIII) or the water pump drive pulley (see Plate IX), or the flywheel, is marked to show injector and valve set positions.

On engines with compression release levers, pull lever back to bar engine over. This lifts all intake valves, making it possible to turn the engine without working against compression.

4

Press A — 59

59

To relieve compression on engines without a compression release, turn each intake valve adjusting screw down one turn from the adjusted position.

Next bar the engine in direction of rotation to No. 1 top center firing position for left bank, in this position both intake and exhaust will be closed for No. 1 cylinder, left bank.

NOTE: There are holes provided in the flywheel and slots provided in the flywheel housing for a cranking bar.

4

Press A — 60

60

Continue to rotate the crankshaft one-quarter turn until the "1-6LVS" mark on the water pump drive pulley or accessory drive spider lines up with the timing mark on the gear case cover, or the accessory drive housing, respectively. The engine is now in position to adjust the injector plunger and valves for No. 1 left bank cylinder.

Adjust the injector plunger and valves as outlined in the maintenance manual for No. 1 cylinder.

Injector plungers and valves must be adjusted on engines __(1)__ degrees after __(2)__ center firing position.

A. (1) 80 (2) bottom — 61
B. (1) 90 (2) bottom — 61
C. (1) 90 (2) top — 62

4

61

No. You are not reading as carefully as you should! We said the adjustment must be made 90° after top center firing position.

Press A — 62

4

62

OK. We also said on the Cummins V-12, there are three places that have timing marks for adjusting the injector plungers and valves. These are ___(1)___, ___(2)___, and ___(3)___.

A. (1) accessory drive spider, (2) fuel pump, and (3) flywheel. — 63
B. (1) water pump drive pulley, (2) fuel pump, and (3) flywheel. — 63
C. (1) accessory drive spider, (2) pump drive pulley, and (3) flywheel. — 64

4

63

No. Read this information over carefully and answer this question again. Feel free to look at Plates VIII and IX while you are reading.

Press A — 58

4

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64

OK. You are correct.

On Cummins engines without compression release levers, to release the compression, it is necessary to ________

________.

A. bar the engine in direction of rotation to No. 1 top center firing position. — 65

B. loosen the valve adjusting locknut and back off the adjusting screw. — 66

C. turn each intake valve adjusting screw down one turn from the adjusted position. — 67

4

65

No. The compression should be released before barring the engine over. The answer we wanted here was: to turn each intake valve adjustment screw down one turn from the adjusted position.

Press A — 67

4

66

No. You have chosen a step necessary when adjusting the valves. Try this question again, and think before you answer it.

Press A — 64

4

67

OK. You are correct. Let's move on.

After adjusting the injector plunger and valves for No. 1 cylinder, rotate the crankshaft to the next "VS" mark according to the firing order of the engine.

NOTE: Check the maintenance manual for firing order of the engine.

Continue until all injectors and valves have been correctly adjusted.

CAUTION: Two complete revolutions of the crankshaft are needed to set all injector plungers and valves. Also, injector and valves can be adjusted for only one cylinder at any one position.

Press A — 69

x (c) → 68

5

68

You have answered one or more of the questions incorrectly in this section. It will be best if you review it again before moving on to new material. Read carefully and think before you answer the questions.

Press A → 58

5

69

AIR COOLING/HEATING AND DENSITY OF AIR CHARGE -- Incoming air into a turbocharged engine, such as the Cummins VT 12-700 (see Plate X), is increased in temperature due to compression. This results in a reduction of air density in the air charge going to the cylinders.

When air is compressed to 5 psi, its temperature will be increased about 55 to 60 F, which corresponds to a 10% reduction in air density. If the air is compressed to 10 psig, the resultant increase in temperature will be over 100 F, with a reduction in air density of near 17%.

To combat this, the VT 12-700 employs a heat exchanger (inter cooler) mounted between the turbocharger and the air intake manifold; see Plate X.

Press A — 70

5

70

Cooling the air in hot weather, and heating it in cold weather, by this method increases air density and also reduces exhaust temperatures for a given power output. This reduction in exhaust temperature is one of the factors which enable turbocharged engines to develop more horsepower than naturally aspirated engines can develop.

Most turbocharged engines utilize a heat exchanger because ________.

A. air under pressure has a high density. — 71

B. cool air is desirable for the engine's power output. — 73

C. hot air increases the exhaust temperatures, hence more power. — 72

5

71

No. Remember it this way: high air pressure means high temperature, with low air density or oxygen content. Cooling this air then, by using a heat exchanger, lowers the temperature and increases the air density. Hence, engine exhaust temperatures are lower; result: more power and better performance.

Press A — 73

5

72

No. High exhaust temperatures do not mean more power. It is just the opposite. The exhaust temperatures must be kept at normal operating ranges. The purpose of the heat exchanger then, is to lower the air temperature. This increases the density, or oxygen content, hence more power and better engine performance.

Press A — 70

5

73

OK. You are correct. Cool air is desirable for an engine (summer operation) from the standpoint of mass flow of air, power output, temperature of engine parts, and fuel economy.

A heat exchanger consists of an enclosed fin-and-tube, or cellular radiator type structure. Cool water circulates through the tubes or cells and absorbs heat from the air passing through the enclosure. A thermostat controls the air temperature for summer/winter operation. Heat exchangers are used commonly between a turbocharger and the air intake manifold, to reduce the air temperature after being heated by the turbocharger.

Press A — 74

5

74

PROPERTIES OF AIR as they relate to cooling and heating by the heat exchanger, can be summarized this way: When air is compressed, as it is by the turbocharger, or when the outside air is hot (say 90°), the density or concentration of air particles is low (by volume). This condition increases the exhaust temperatures in the engine, which in turn lowers engine performance. Remember, low density, less oxygen and incomplete combustion, result in low engine performance and high exhaust temperature.

On the other hand, high air density (extreme cold weather) means too much oxygen for the amount of fuel injected. Result: overheating again - you might say over-combustion.

Press A — 75

5

75

We can see then that air temperature must be kept constant to obtain maximum engine performance. Let's review.

Low engine performance (in summer) can be caused by ______________________.

A. low air density. — 78
B. high air density. — 76
C. too much oxygen in the air by volume. — 77

5

76

No. In the summer we said the air was hot and the air density is low; this means the particles of air (nitrogen and oxygen) are scattered farther apart than when the density is high. This low density condition actually starves the engine for oxygen; therefore the need for cooler air. Remember it this way: low air density = high temperature = low engine performance and high exhaust temperatures.

Press A — 78

5

77

No. We said in the summer, the air had low density. This means there are fewer oxygen particles per volume of air to mix with the fuel particles. The result is incomplete combustion, high exhaust temperature and low engine performance.

Try this question again.

Press A — 75

5

78

OK. Remember, low air density means fewer oxygen particles per volume of air to mix with the fuel particles. This results in incomplete combustion, high exhaust temperatures and low engine performance.

The inter/after cooler on a Cummins turbocharged engine is always located between the ______________.

A. air filters and the turbochargers. — 79
B. intake valves and the intake manifold. — 80
C. turbocharger and the intake manifold. — 81

5

79

No. The purpose of the cooler or heater is to reduce the air temperature after it has been compressed by the turbocharger. Think and try this question again.

Press A — 78

5

80

No. There is nothing between the intake manifold and the intake valves. The manifold covers the intake valves and serves as a storage place or reservoir for the incoming air. Think, and try this question again.

Press A — 78

5

81

OK. The cooler/heater is located between the turbocharger and the intake manifold.

This cooler/heater is thermostatically controlled. Which of the two mediums passing through this piece of equipment do you think is stopped when the air reaches the correct temperature?

A. Air. — 82
B. Water. — 83
C. Both air and water. — 82

5

82

No. You are not thinking. If the air were stopped the engine would shut down, because there would be no mixture in the cylinder. Try this question again.

Press A — 81

5

83

OK. The only medium that could be stopped is the water. Cut off the air and the engine will shut down.

In extremely cold weather (20 to 40° below zero) when the air density is high, a heater is required for the incoming air because ____________________.

A. there is incomplete combustion in the cylinder. — 84
B. there is over-combustion in the cylinders. — 86
C. there is too much nitrogen in the air for maximum engine performance. — 85

5

84

No. There would be over-combustion. Remember, we said when the air is extremely cold, the air has high density. This means there are more oxygen particles to mix with the fuel practices, hence, better combustion.

Press A — 86

5

85

No. The only particles that are in abundance when the air is extremely cold are oxygen particles. We said the air density is high during this condition. This means there are more oxygen particles to mix with the fuel particles, hence, better combustion.

Press A — 86

5

86

OK. There is over-combustion in the cylinders due to the excess of oxygen in the air. In some cases it is necessary to retard the opening of the intake valves due to this condition.

Another method used to force more air into the cylinders to increase the horsepower of a diesel is by the use of superchargers. The supercharger used on a Cummins engine is the roots type blower (similar to the GM type). On the VT 12-700, two blowers of this type (one on each side) are used for each bank of cylinders. They are gear driven air pumps.

Press A — 87

5

87

Although superchargers are effective on 4 cycle engines, the turbocharger is becoming more widely used. The reason for this is because superchargers require 15 to 20% of the available engine horsepower to drive them, and are limited to lower speeds, since they are gear driven. As we know, the turbocharger is driven by exhaust gases which are wasted to the atmosphere anyway.

Press A — 88

5

88

A naturally aspirated engine is one that depends on ________________ to force air into the cylinders.

A. turbochargers > 89
B. superchargers
C. atmospheric air — 90

5

89

No. Both turbochargers and superchargers are mechanical means of forcing more air into the cylinders than would be delivered by using atmospheric air. An engine that depends on atmospheric air pressure for operation is called a naturally aspirated engine.

Press A — 90

5

90

OK. That completes this lesson on the principles of air for diesel engines.

PRESS REWIND

X (C) → 91

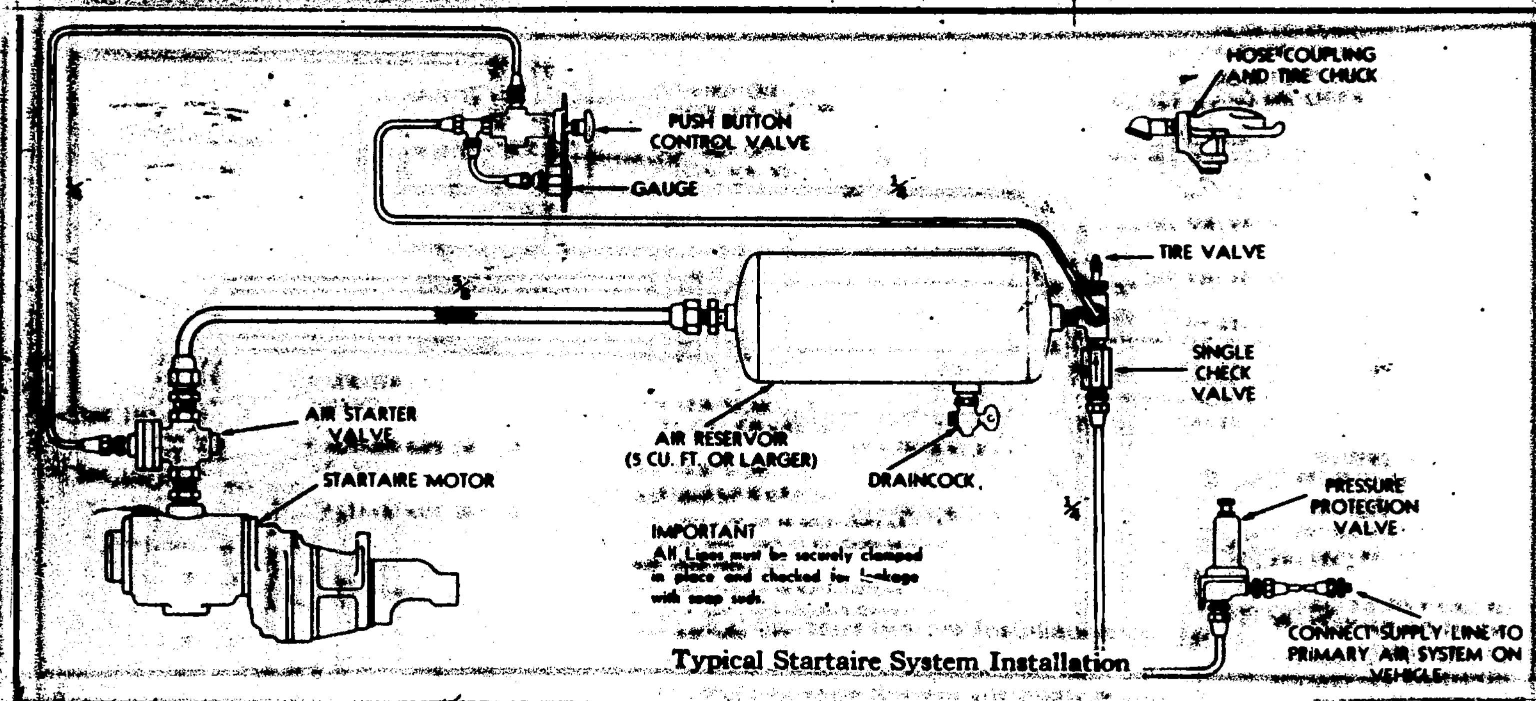
5

91

You have answered one or more of the questions in this last section incorrectly. Read this portion over and think as you read; then answer the questions carefully.

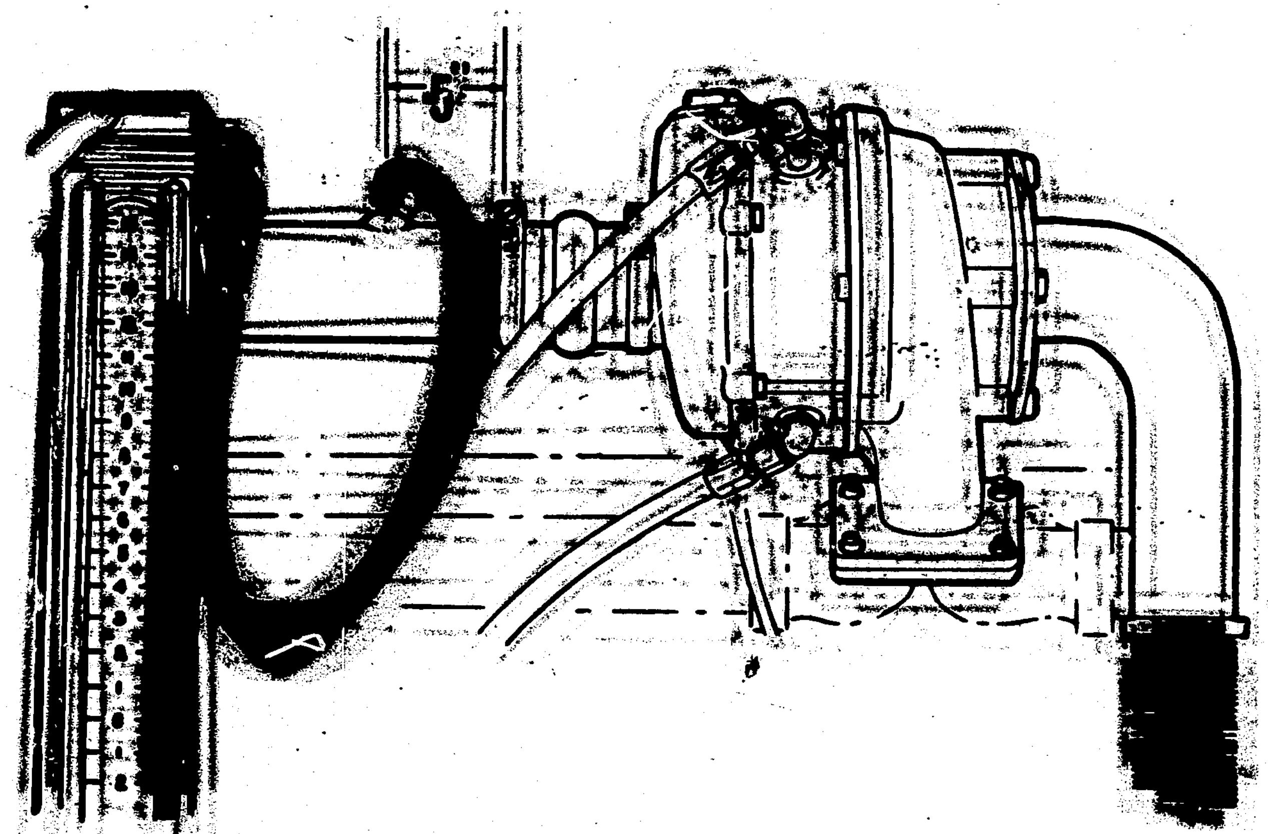
Press A → 69

5



Typical Startaire System Installation

AM-1-14-5



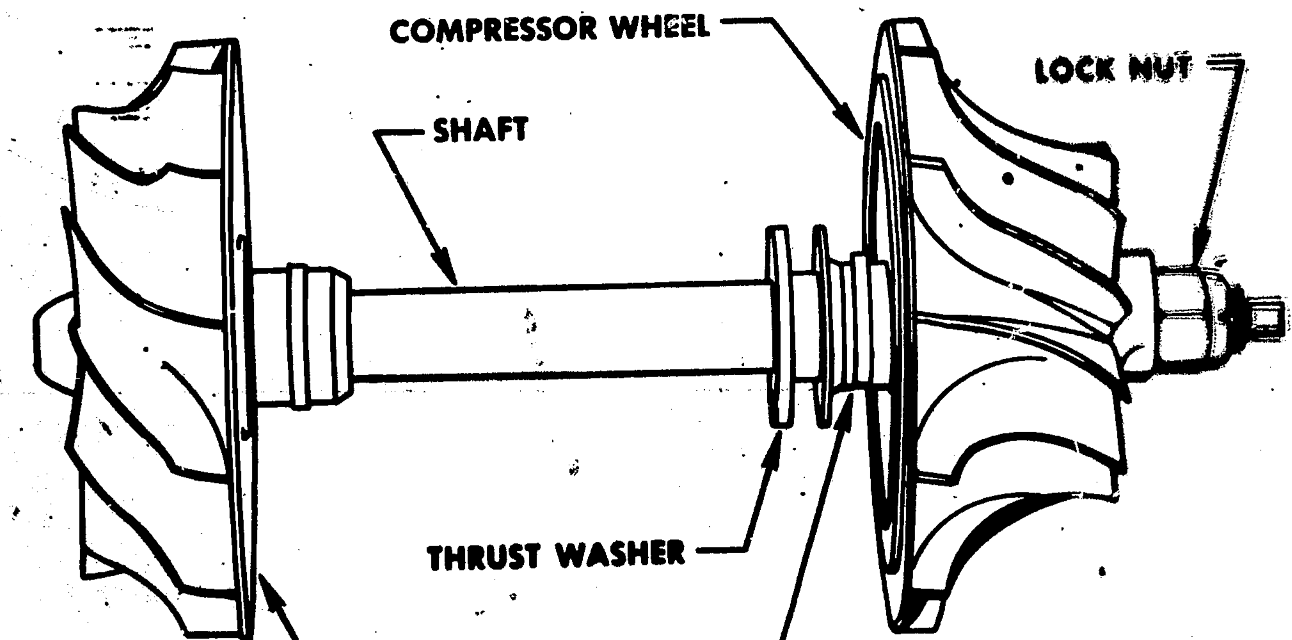
6209121

Check inlet air restriction

AW-1-14-4

HU[illegible]
ENGINEERIN[illegible]
INSTITUTE

2341 Carnegie Ave
Cleveland, Ohio 44115



Turbocharger rotor assembly

AM 1-14-1

INSTRUCTOR'S GUIDE

Title of Unit: I Maintaining the Air System - Cummins Diesel Engine — AM 1-14
II Unit Removal - Transmission — 4/19/66

FIRST: Be sure all questions have been answered that students might have on home study units.

OBJECTIVES:

1. To introduce the Cummins air system by discussing some technical terms related to air system requirements.

2. Exposing the student to terms such as naturally aspirated, scavenging and supercharging, volumetric efficiency, TDC and BDC as they are related to the four cycle engine.

3. Explaining the various uses of compressed air on diesel powered trucks. Also the technical principles behind air compressors and air starter systems.

LEARNING AIDS suggested:

WALL CHARTS: Bulletin No. 983418, Title: CUMMINS TURBOCHARGER

VUE CELLS:
AM 1-1 (1) (2 cycle vs. 4 cycle)
AM 1-1 (2) (4 cycle)
AM 1-2 (2) (Air Cleaner - Oil Bath)
AM 1-2 (3) (Air Cleaner - Dry)
AM 1-2 (4) (Air Cleaner - Two Stage Dry)
AM 1-2 (5) (Air Filter - Dry)
AM 1-14 (1) (Turbocharger rotor assembly)
AM 1-14 (2) (Turbocharger exhaust gas and air flow)
AM 1-14 (3) (Cummins air compressor)
AM 1-14 (4) (Checking inlet air restriction)
AM 1-14 (5) (Typical "Startaire" system installation)

MODELS: Any models of air system components you can locate around the shop will be helpful in class. Things such as a turbocharger, a blower, different types of air cleaners etc.

QUESTIONS FOR DISCUSSION AND GROUP PARTICIPATION:

1. What is "Volumetric efficiency" and how can it be increased?

2. When can an amount of air exactly equal to the piston displacement be drawn into the cylinder?

3. What is meant by a "naturally aspirated" engine?

4. How is scavenging accomplished by a naturally aspirated 4 cycle engine?

5. Does the same amount of air enter the cylinders on a 4 cycle engine, no matter what the altitude is? Explain.

6. Explain what is meant by TDC and BDC.

7. What is the difference between a Cummins turbocharged engine and a Cummins supercharged engine?

8. What happens when the oxygen content is too high?

9. For what purposes is compressed air used on diesel powered trucks?

10. How is the Cummins air compressor similar to the engine?

11. What is the purpose of the unloader cap on the Cummins air compressor?

12. How is the Cummins air compressor lubricated and cooled?

13. What is the minimum air pressure that should be available before an attempt is made to use the air starter system?

14. What basic mechanical principle allows the Bendix drive to operate?

15. How is air inlet restriction normally checked?