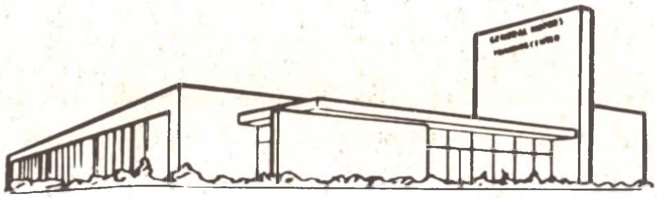
ADVANCED DIESEL



GM

Product
Service
Training

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FOREWORD

This booklet is supplied by GM Product Service Training to GM dealer service personnel upon their completion of the subject course conducted at GM Training Centers.

While this booklet will serve as an excellent review of the extensive program presented in the training center session, it is not intended to substitute for the various service manuals normally used on the job. The range of specifications and variation in procedures between carlines and models requires that the division service publications be referred to, as necessary, when performing these operations.

Portions of this manual were produced using information provided by Stanadyne Inc., Diesel Systems Group, manufacturer of the Roosa Master Injection Pump.

All information contained in this booklet is based on the latest data available at the time of publication approval. The right is reserved to make product or publication changes, at any time, without notice.

CONTENTS

INTRODUCTION

The intent of this manual is to study Diesel Fuel and its major properties as well as each component of the Diesel engine fuel system in sequence from the fuel tank filler cap right through to the nozzles.

The function of each component and its relation to adjacent components as well as how each stage of fuel processing is dependent on the preceeding stage to operate properly will be explained.

This program includes injection pump repairs which do not require test stand calibration as well as diagnosis studies for rough idle, excessive smoke and M.P.G.

Diesel engine stresses are most critical and by nature, the diesel engine is less forgiving. Accordingly, quality workmanship is most important with assembly procedures, torque specifications and cleanliness.

SECTION 1
DIESEL FUEL PROPERTIES

GENERAL DESCRIPTION

It is very important for the Diesel Technician to understand various properties of diesel fuel as they relate to vehicle design and engine performance. The following will include an explanation of the more critical properties as well as some other related facts.

Diesel engines are the most efficient reciprocating, internal combustion engines in use today. They are built in a wide variety of sizes and types for many different services, ranging from the large, slow-speed engines for shipboard installation to the relatively small, high-speed, automotive engines commonly used in trucks, buses, and small ships and boats.

Mechanically, diesel engines are quite similar to gasoline engines. However, there are some significant differences:

1. The diesel engine has a high compression ratio compared to a gasoline engine.
2. The diesel cylinder is charged only with air at the beginning of each cycle.
3. The air is compressed until very high pressures and temperatures are achieved.
4. Fuel is sprayed into the hot, compressed air near the end of the compression stroke where it ignites spontaneously to produce power.

The high compression ratio of the diesel engine and the higher heating value of diesel fuel accounts for its superior thermal efficiency over the gasoline engine.

Because the diesel engine burns liquid fuel, volatility is less significant in a diesel fuel than in a gasoline. Diesel engines can be operated on low volatility fuels ranging from kerosene to crude oil depending upon the engine design and the service in which it is used. The modern high-speed, automotive diesel engine, however, is usually operated on a middle distillate fuel of carefully controlled physical and chemical properties.

Middle distillate fuels are petroleum oils, heavier than gasolines, which are obtained from fractional distillation of crude oils. Like gasolines, distillate fuels will not burn unless they are mixed with air in the proper ratios.

Diesel fuel comes in three grades suitable for various types of engines and operating conditions.

The No. 1-D grade fuel is a kerosene-type designed essentially to meet the requirements of the General Motors Series 71 engine in city bus service.

The No. 2-D grade fuel is the one most generally used for all makes of engines.

The No. 4-D grade fuel is designed for low- and medium-speed engines operating under constant speed and high load conditions. It is not intended for use in automotive diesel engines, and will not be discussed further.

CRITICAL PROPERTIES

While various diesel fuels contain numerous properties, only the more critical properties which affect engine performance will be explained.

Pour Point and Cloud Point

Pour point and cloud point determine the minimum ambient temperature at which an engine can be operated on a waxy distillate fuel without the use of auxiliary heat.

The pour point defines the temperature at which the fuel stops flowing and cannot be pumped.

The cloud point defines the temperature at which parafin wax crystals separate from the fuel.

#2 Diesel fuel begins clouding approximately 20° ambient temperature and complete filter stoppage due to parafin wax crystal separation will begin below approximately 10° ambient temperature.

#1 Diesel Fuel has similar characteristics with the clouding process beginning approximately −20°.

Without the use of an auxiliary heater, #1 is recommended where ambient temperatures are anticipated to be below 20° even though complete stoppage occurs below 10°. This will allow for sudden drops in temperature, where wax crystals may form.

Some filling stations provide "winterized" "climatized" or "blended" fuel which is a combination of #1-D and #2-D. The Blend will vary depending on the amounts blended and fuel waxing will be reduced proportionately.

NOTE: Some dealer technical bulletins contain information on blending unleaded gasoline with #2 Diesel fuel to reduce fuel thickening and consequently, some owners are using this procedure. GM is no longer recommending gasoline blending with diesel fuel and therefore discourages use of gasoline mixtures. Never use gasohol.

Heating Value

The heat of combustion of a diesel fuel, expressed in British thermal units (Btu) per pound or per gallon, is a measure of the amount of energy available to produce work. In general, a diesel fuel having a higher volumetric heating value (Btu per gallon) will produce more power or provide better fuel economy than a fuel of lower heating value.

PROPERTIES	FUEL			
	GASOLINE	JP4	#1 DIESEL	#2 DIESEL
LB/GAL	5.9	6.5	6.9	7.2
BTU/LB	18,700	18,400	19,855	19,583
BTU/GAL	110,330	119,600	137,000	141,000
VISCOSCITY, CENTISTOKES	0.5	0.7	2.0	2.7
FLASH POINT	−40°	100°	100°	125°

Fig. 1-1 Typical Fuel Properties

Figure 1-1 shows that the heating value of #2-D is considerably higher than #1-D and therefore, #2-D provides the highest efficiency and M.P.G. "Blends" will reduce M.P.G. depending on the proportions used. Also #1-D is thinner by weight (viscosity) and becomes less compressable because of certain clearances with the fuel injection pump (which will be explained later). Considering the heating value and thinner weight starting the engine may require more cranking revs, both cold and warm. #2-D is recommended for best all around performance and economy.

Occasionally, diesel fuel will be sold as home heating oil from virtually the same pump at the filling station.

Usually this fuel will be diesel fuel and is not home heating oil. GM discourages use of home heating oil in diesel vehicles.

Viscosity

Viscosity is an important physical property of a diesel fuel affecting injection pump internal leakage and lubrication and injector lubrication and atomization.

The minimum viscosity is limited by the need for adequate injector and injection pump lubrication. Lower viscosity fuels are thinner and therefore will cause a higher rate of internal pump and injector leakage and injector dribblings which can lead to loss of power or smoke problems.

Since viscosity influences the size of the fuel droplets, it governs the degree of atomination and penetration of the fuel spray. These are major factors in obtaining sufficient mixing of fuel and air essential for proper combustion. If the viscosity is too high, the fuel droplets will be too large for proper mixing and poor combustion will result. Also, the droplets may strike the relatively cold cylinder wall and fail to burn. If the viscosity is too low, the fuel spray will not travel across the combustion chamber and the poor mixing will result in improper combustion. Poor combustion results in loss of power and excessive exhaust smoke.

Flash Point

Flash point does not affect engine performance. It is specified because it relates to the hazards in handling and storing diesel fuels, and governmental agencies have specified minimum safe values. A low flash point may indicate contamination with gasoline or other more volatile hydrocarbons.

Cetane Number

When fuel is injected into the combustion chamber of a diesel engine, ignition does not occur immediately. The interval between the beginning of injection and ignition of the fuel is called the ignition delay period or lag. The duration of the delay period is a function of engine design, operating conditions, and hydrocarbon composition of the fuel.

If the delay is too long, the engine may be hard to start, and when the accumulated fuel does ignite, the rate of energy release is so great that it causes engine roughness or diesel knock. If the delay is short, combustion is even and the engine runs smoothly.

The ignition quality of diesel fuels is expressed in terms of cetane rating. A high cetane number indicates good ignition quality (short delay period), and a low cetane number indicates poor ignition quality (long delay period).

The cetane requirement of an engine depends upon engine design and operating conditions. Cetane requirement increases as the compression temperature is reduced by such variables as low ambient temperatures, low water jacket temperature, low compression pressure, or light load operation. A high cetane number is desirable for low temperature starting.

Because this engine is equipped with glow plugs for cold starting aid, it is insensitive to cetane ratings.

In high-speed engines, a high cetane number fuel is generally desirable to prevent engine roughness and knock. However, in engines sensitive to cetane number, a high cetane number fuel may cause black smoke under high-load operation. The short delay causes raw fuel to be sprayed into an established flame which produces soot. Thus, cetane requirement, like octane requirement, cannot be sharply defined because of the differences in engine design and operating condition. The cetane numbers specified for diesel fuels are, therefore, a compromise to provide best overall performance for a wide variety of engines under varying operating conditions.

Additives

Most Diesel Fuel additives contain alcohol which has proven harmful to certain components of the Injection System and therefore, are not recommended. There are, however, some additives which are effective in reducing the pour point of certain Diesel fuels. It has been found that these depressants are not effective in all diesel fuels and therefore are not universal.

Starting Fluids

Use of starting fluids are absolutely not to be used. To inject anything other than air through intake can result in conditions such as hydro-static seizure, broken pistons, bent or broken connecting rods, broken starter or flywheel ring gear teeth etc. For example, up to a 50% overload can be obtained by injecting ether into the air intake.

Contamination

By law .05% (½ of 1%) of water sediment by volume is allowed to be present in diesel fuel. This small amount has little harm in itself however, larger amounts can be damaging. Normal engine operation will consume small amounts of water without problems. Larger amounts and particularly when allowed to remain inside the injection pump for extended periods can create severe corrosion damage to the pump and nozzles.

Water content in storage tanks can also be a problem when ideal conditions prevail for bacteria growth. The growth takes place at the fuel/water interface. Sometimes referred to as "slime", "Diesel goo" or "Critters". These microorganisms appear as gelatinous matter usually greenish black in color. Warm climates, humid conditions, water and extended storage periods of stagnant fuel reserves give the bacteria time and undisturbed conditions in which to breed. if moisture is eliminated, growth can't take place. Otherwise Diesel Fuel can be chemically treated with biocide to retard growth.

When "Diesel goo" gets into the fuel system, each component of the fuel system must be cleaned as thoroughly as possible and must be treated with biocide as this fungus is nearly impossible to destroy completely without this chemical. Biocides are available in small quantities at most large marinas.

SECTION 2

FUEL TANK COMPONENT, LINES, FILTERS AND FUEL PUMP

FUEL TANK COMPONENTS

The filler cap contains a 2-way check valve. This will allow air to escape during the day when the tank heats up. In the event of a rollover, the valve will prevent spillage. Under pressure, no greater than 2 psi will exist. The valve must also allow air to enter the tank to replace the fuel used by the engine. A vacuum of no more than about one inch of mercury can accumulate in the tank and a slight hissing sound when removing the cap is normal. The fuel system is calibrated with the cap in place and any alterations will effect performance. Diesel fuel tank caps are specific to Diesels. Gasoline tank caps may fit the diesel tank filler neck but should not be used.

The fuel pick up, commonly known as the "sock", has three functions:

1. Strain out large solids.
2. Act as a strainer to prevent entry of water.
3. Act as a wick to drain fuel down to the bottom of the tank since all pickup pipes do not reach the very bottom of the tank.

On 1978-79 models, the sock was short and laid on the bottom of the tank. It is made of saran and water will not enter until it becomes almost totally engulfed by water. This design kept back about one gallon of water.

By law in many states, water in fuel should be no more than ½ of 1%. That quantity of water will be absorbed by the fuel. Periodically, station operators check for water by putting a special gel on the dip stick. If it turns color, then water is present and it can be pumped out. Unfortunately, not all station operators are responsible and this prompted redesign of the sock in 1980 models to a longer style with attachment to the pickup tube entering at a point into the side of the sock.

With this design, the fuel pickup tube doesn't reach the bottom of the tank. However, since the sock acts as a "wick" the fuel level can actually be lower than the level of the tube and fuel will be drawn out right down to empty. Also, with this design, the level of water in the tank can be much higher before water enters the fuel system. This is about five gallons. Water that gets into the tank will eventually be absorbed by good fuel and will pass harmlessly through the fuel system. Water will be absorbed at a rate of about one gallon per 1000 miles.

Late in 1980 model production a water in fuel warning system became a mandatory option on diesels. Figure 2-1. This feature will detect the presence of water when it reaches the 1-1½ gallon level. The water is detected by a capacative probe. An electronic module provides a ground through a wire to a light in the instrument cluster that reads "water in fuel". On 1981 models the feature contains a bulb check. When the ignition is turned on, the bulb will glow from two to five seconds and then fade away. This feature was not available in the 1980 models or in the water and fuel retrofit kits which are available for 1978, 1979 and early 1980 model cars.

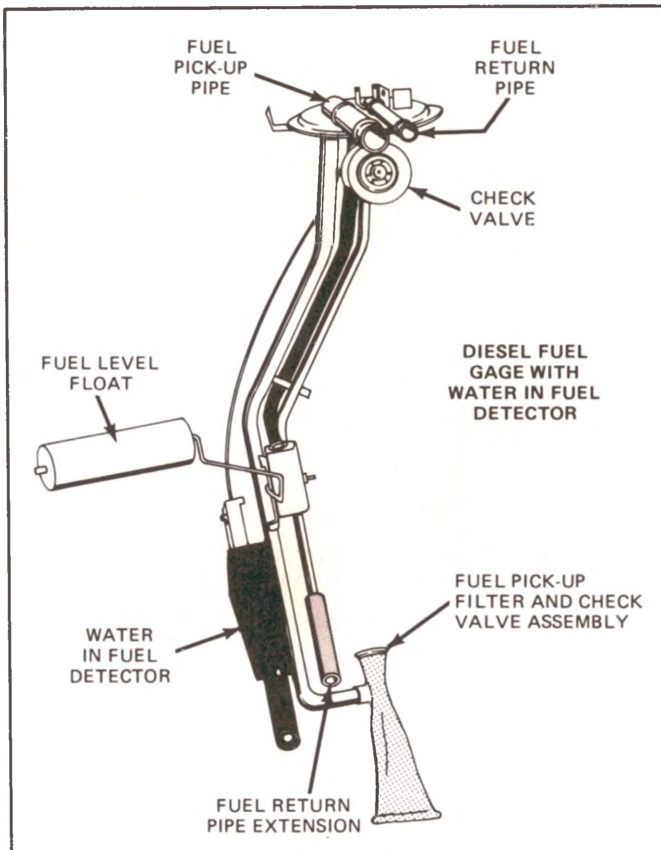


Fig. 2-1 Water in Fuel Tank Unit

Owners with water in fuel lights have been instructed to drain the water from the tank if the light comes on immediately after filling. There could be enough water in the system to get into the fuel system and shut the engine down after driving for a short distance. If however it comes on during a cornering or braking maneuver, there is less than a gallon and a shut down will not occur, however, the water should be removed within one or two days.

WATER IN FUEL DETECTOR DIAGNOSIS

THE DIESEL "WATER IN FUEL" SYSTEM USES AN ELECTRONIC WATER DETECTOR MOUNTED INSIDE THE FUEL TANK ON THE FUEL GAGE SENDER. THE DETECTOR WILL WARN THE DRIVER WHEN 1 - 2½ GALLONS OF WATER ARE PRESENT IN THE FUEL TANK BY LIGHTING A "WATER IN FUEL" LIGHT ON THE INSTRUMENT PANEL. THE LIGHT WILL ALSO COME ON FOR 2-5 SECONDS EACH TIME THE IGNITION IS TURNED ON. THIS BULB CHECK ASSURES THE DRIVER THE LIGHT IS WORKING. IF THERE IS WATER IN THE FUEL, THE LIGHT WILL COME BACK ON AFTER A 15-20 SECOND OFF DELAY, AND THEN REMAIN ON.

WHEN WATER IS DETECTED IT CAN BE DRAINED THROUGH THE FUEL RETURN LINE WITHOUT REMOVING THE FUEL TANK. SEE PURGE PROCEDURE BELOW.

WATER IN FUEL LIGHT ON AT ALL TIMES

With ignition on, disconnect 2 wire (yel/blk-pink) connector ("E" series has a single wire connector) at rear of fuel tank and check water in fuel light.

- **LIGHT ON** → Locate and repair short to ground in yel/blk wire from 2 wire connector to IP water in fuel lamp.
- **LIGHT OFF** → Purge fuel tank per purging instructions. Connect 2 wire connector and check water in fuel light.
  - **LIGHT ON** → Remove tank unit. Check wires for short circuits. If OK, replace detector.
  - **LIGHT OFF** → Normal - fuel had water in it.

WATER IN FUEL LIGHT DOES NOT COME ON DURING BULB CHECK

With ignition on, disconnect 2 wire (yel/blk-pink) connector ("E" series has a single connector) at rear of fuel tank and ground the yel/blk wire in the body harness. Check water in fuel light.

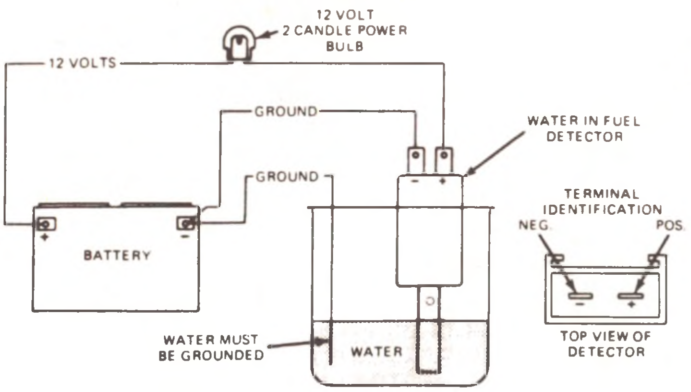
- **LIGHT ON** → Remove fuel gage tank unit and check yel/blk wire for opens. Check connections to water in fuel detector and mounting screw- must be tight. If OK, replace water in fuel detector.
- **LIGHT OFF** → Check water in fuel bulb. If OK, check for open circuit in yel/blk wire from 2 wire connector at rear of tank to IP water in fuel lamp socket.

FUEL TANK PURGE PROCEDURE

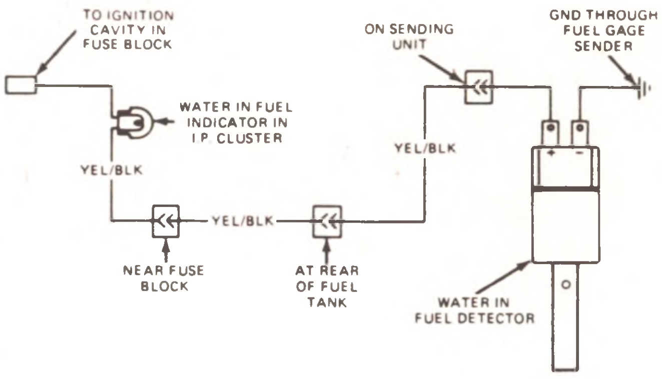
Cars which have a "Water in Fuel" light may have the water removed from the fuel tank with a pump or by siphoning. The pump or siphon hose should be hooked up to the 1/4 inch fuel return hose (smaller of the two fuel hoses) above the rear axle or under the hood near the fuel pump. Siphoning should continue until all water is removed from the fuel tank. Use a clear plastic line or observe filter bowl on draining equipment to determine when clear fuel begins to flow. Be sure to remove the cap on fuel tank while using this purge procedure. Replace the cap when finished. The same precautions for handling gasoline should be observed when purging diesel fuel tanks.

TESTING WATER IN FUEL DETECTOR

Connect water in fuel detector as shown using a 12 V 2 C. P. bulb. There must be a ground circuit to the water for the detector to work. The light will turn on for 2-5 seconds then dim out. It will then turn back on (after 15-20 second delay) when about 3/8" of the detector probe is in the water. Refer to illustration for test set-up.



TEST SET-UP



WATER IN FUEL DETECTOR CIRCUIT

Fig. 2-2 Water in Fuel Detector Diagnosis

To assist in doing this a return pipe extension which extends to the bottom of the tank allows an adequate amount of water accumulation to be siphoned out at a minimum cost without removing the tank. Use the fuel tank purge procedure shown in Figure 2-2.

The extended return pipe is included with all tank units that have the water in fuel feature. It was also phased into production on some 1980 model units that did not get the water in fuel unit. If the vehicle has a purple ground wire, it has the syphoning feature. A check valve is provided at the upper end of the return pipe to allow fuel to return in the event that frozen water plugs the end of the pipe.

All 1981 model vehicles using diesel engines have a sock with a relief valve in the top end. This relief valve is designed to open up in the event that high cloud point fuels are used in cold weather and the sock gets plugged with wax crystals.

The W.I.F. detector can be serviced separately from the tank unit assembly when it requires replacement. It can be bench checked by using the test setup shown in Figure 2-2.

The 1980 sensor module will turn the light on immediately when water contacts the probe and will stay on until the 12V signal is removed. This feature will indicate smaller amounts of water present as vehicle motions allow water to move about inside the tank. The 1981 module differs in that the detector probe must remain submerged in water for approximately a 15 to 20 second delay period. The indicator lamp will then come on and stay on until the 12V signal is removed. This feature will accommodate larger amounts of water.

DIESEL FUEL SYSTEM CLEANING PROCEDURE

Water in the Fuel System

Water entering the fuel system will not automatically damage the pump and nozzles. Water in sufficient quantity will simply shut the engine down because the engine will not run on water. If this happens, the water should be removed from the system as soon as possible because there are components in the pump that can rust.

To determine if the fuel system is contaminated with water first remove the engine fuel filter, pour the contents into a container and inspect the contents for the presence of water. Water will be indicated by separation of the fluid after it has been allowed to stand for several minutes. If water is found, do not remove the injection pump automatically.

Clean the entire fuel system using the following procedures:

1. Remove the negative cables from both batteries and have a carbon dioxide fire extinguisher near the work area. Remove fuel tank cap.

2. Some late production 1980 model vehicles contain a fuel sending unit that will allow water to be siphoned from the fuel tank. Removal of the fuel tank will not be required if water can be siphoned from the tank. Fuel tank gages with purple ground wires can be siphoned.

3. On late production 1980 model vehicles disconnect fuel return hose over the rear axle. Start a siphon through this hose. Continue siphoning until all the water is removed. Disconnect the main fuel hose and proceed to step 14.

4. On early production 1980 and prior years connect a drain hose to the main fuel pipe at the fuel pump or tank gage unit and drain.

5. A hand operated pump device should be used to drain the fuel tank. The manufacturer's instructions should be carefully followed for the particular equipment being used.

6. Disconnect tank unit wire from connector in rear compartment.

7. Remove ground wire retaining screw from underbody.

8. Disconnect hoses from tank unit.

9. Support fuel tank and disconnect the two fuel tank retaining straps.

10. Remove tank from car.

11. Remove fuel gage retaining cam, using Tool J-24187.

12. Remove fuel tank gage unit.

13. Remove any remaining fuel in the tank.

14. Disconnect main fuel hose at fuel pump. Using low air pressure, blow out line towards rear of car.

15. Disconnect the return fuel line at the injection pump, with low air pressure, blow out the line towards rear of car.

16. If fuel tank was removed, reintall sending unit and fuel tank then fill tank with diesel fuel and reinstall fuel tank cap.

17. Connect the main fuel and return line hoses at the tank.

18. Connect fuel hose to fuel pump. Reconnect battery cables.

19. Purge the fuel pump and pump to filter line by cranking the engine until uncontaminated fuel is pumped out catching the fuel in a closed metal container.

20. Install new filter. Leave the fitting going to the injection pump loose.

21. Install a hose from fuel return fitting on injection pump to a closed metal container with a capacity of at least two gallons.

22. Crack open high pressure lines at each nozzle.

23. With fitting at the filter outlet cracket open, crank the engine until fuel leaks out of the fitting. Tighten fitting.

24. With accelerator held to the floor, crank the engine until the water is purged from the system and uncontaminated fuel appears at each nozzle fitting. Do not crank for more than 30 seconds at one time. Repeat cranking if necessary, with a two minute interval between cranks. Stop cranking and tighten nozzle fittings.

25. Start engine and run at a idle for 15 minutes. Make sure fuel return line is installed in the metal container. Check the container so it doesn't overflow.

26. Remove hose from metal container. Connect the fuel return line to the injection pump.

Only in severe cases of damage caused by water contamination will it be necessary to remove the injection pump. If the engine fails to operate normally, proceed as follows:

1. Cut sealing wire.

2. Remove injection pump cover screws and cover.

3. Examine the interior of the pump for corrosion. Look for evidence of red rust on springs, aluminum corrosion or black gummy buildup on the parts.

4. Evidence of water contamination damage will require that the injection pump be returned to a Roosa-Master repair station for correction. Reassemble the cover.

5. To reinstall the cover: Hold the throttle lever in the idle position.

6. Position the cover about 1/4 inch forward (toward shaft end) and about 1/8 inch above the pump.

7. Move the cover rearward and downward into position, being careful not to cut the seal, and loosely reinstall the cover screws.

8. Remove and send the pump to a Roosa-Master dealer for repair after the cover has been installed.

Water in fuel has been a sensitive problem in many areas of the country. There have been a number of fuel systems that have been altered by removing the sock and installing an auxiliary water separator. Removing the sock will defeat the systems ability to handle large quantities of water. Because the pick up tube is not on the bottom of the tank, the engine could run out of fuel before the fuel gage reads empty. The addition of a separator will add very little to the system's capacity to handle water. If water exceeds the capacity of this current system, the water will still pass through the separator after it fills up.

If gasoline is inadvertently pumped into the tank, there will be no damage to the fuel system or the engine. The engine will not run on gasoline. Gasoline has a feature called Octane which defined is the ability of the fuel to resist ignition under high temperatures. Gasoline is a fuel that has high Octane and it resists ignition under high heat, it only will ignite by a spark. Gasoline in the fuel at small percentages, 0-30%, will not be noticeable to the driver. At greater percentages the engine noise will become louder. Gasoline at any percentage will make the engine hard to start hot. In the summer time, this could be a cause of a hot start problem.

Gasoline In Fuel System

1. Drain fuel tank and fill with diesel fuel.

2. Remove fuel line between fuel filter and injection pump.

3. Connect a short pipe and hose to the fuel filter outlet and run it to a closed metal container.

4. Crank the engine to purge gasoline out of the fuel pump and fuel filter. Do not crank engine more than 30 seconds.

5. Remove the short pipe and hose and install fuel line between fuel filter and injection pump.

6. Start engine and run at idle for 15 minutes. If engine does not start, continue with Step 7.

7. Purge the injection pump and lines by cracking each high pressure line at the nozzles. With accelerator held to the floor, crank engine until the gas is purged and clean fuel appears at fittings. (Do not crank for more than 30 seconds at one time. Repeat cranking if necessary, with a 2 minute interval between cranks.) Stop cranking and tighten nozzle fittings.

8. Start engine and run at idle for 15 minutes.

FUEL LINES & LIFT PUMP

Although the injection pump has capabilities to pull fuel from the tank, an engine mounted fuel pump is included in this system as an additional assist in the event of air in the lines such as running out of fuel, fuel line air leaks or air from occasional fuel tank service.

The fuel pump's main job is to supply 5½ lbs. to 6½ lbs. of pressure through the fuel filter to the Injection pump.

All 1981 models will be equipped with new "Fluro Elastomer" hoses which are made of "Viton" and contain a non-permeable tube inside.

The hoses will include a yellow stripe and the words "Fluro Elastomer" on the outside. Their purpose is to reduce emissions when hydro-carbons pass through the hose material.

An important function of all hoses, lines and fittings is to carry fuel with maximum absence of air.

When the fuel tank cap is in place and the injection pump and fuel pump are drawing fuel through the lines a low vacuum of 0-1 lb. mercury is created. This occurs because the fuel which the engine uses must be replaced by air. During this vacuum condition, the slightest leak, which may not leak fuel externally, could draw air into the system and depending on the volume of air, a wide variety of engine malfunctions are possible. These may show up as M.P.G. complaints, smoke complaints, performance complaints and hard starting or not start conditions.

For example, suppose the inlet fitting was slightly loose at the engine fuel filter. This would probably have an external leak and be a complaint of fuel leak or smell of diesel fuel accompanied by a "starts but then dies and can't re-start" complaint. It is possible that when the engine is shut down the fuel could syphon out of the lines and fuel pump and back into the tank. It is then replaced by air which entered at the loose fitting. The fuel system is now empty and as a result the engine must be cranked until the lines are full again.

Shop manual diagnosis charts should be referred to when diagnosing for air problems to determine the presence of air, first install a short clear plastic hose into the return line at the top of the injection pump. Start the engine and observe for air bubbles or foam in the line. If foam or bubbles are present, proceed as follows:

1. Raise vehicle and disconnect both fuel lines at the tank unit.
2. Plug the smaller disconnected return line.
3. Attach a low pressure (preferably hand operated pump) air pressure source to the larger ⅜ fuel hose and apply 8-12 P.S.I.

a. Diagnosing trucks equipped with dual tanks will require a check of the right fuel lines with the dash switch in the right tank position and a check of the left fuel lines with the dash switch in the left tank position. The switching valve could be a source.

4. Observe the pressure pump reading of 8-10 P.S.I. A decrease in pressure will indicate the presence of a leak. The pressure will push fuel out at the leak point indicating the location of the leak.
5. Repair as necessary.

In checking for air problems, the proper size clamps on all hoses should be checked. Also, a burr on the edge of a pipe could rip the inside of a line and create air ingestion. Particular attention should be given to improper installation or defective auxiliary filters or water separators.

Since operation of the hydraulic advance mechanism is dependent on transfer pump pressure and pump housing pressure, any deviation from pre-set tolerances can affect the advance mechanism and therefore, the injection timing. Fuel pump delivery less than 5½ lbs. to 6½ lbs. pressure, for example, will reduce total advance directly proportional to pressure loss. Leaks, plugged filters, air ingestion restricted lines etc. will all reduce pressure delivery. Return line restriction can raise housing pressure to as high as transfer pump pressure depending on the degree of restriction and eventually stall the engine by upsetting the balance of transfer pump and housing pressures.

DIESEL FUEL HEATER

For 1981, a Diesel cold weather package is available. This package consists of an in-line diesel fuel heater and the engine block heater. The purpose of the heater is to heat the fuel so that the filter does not plug with parafin wax crystals, thereby allowing use of the more efficient #2-Diesel fuel all the way down to its pour point. Figure 2-3.

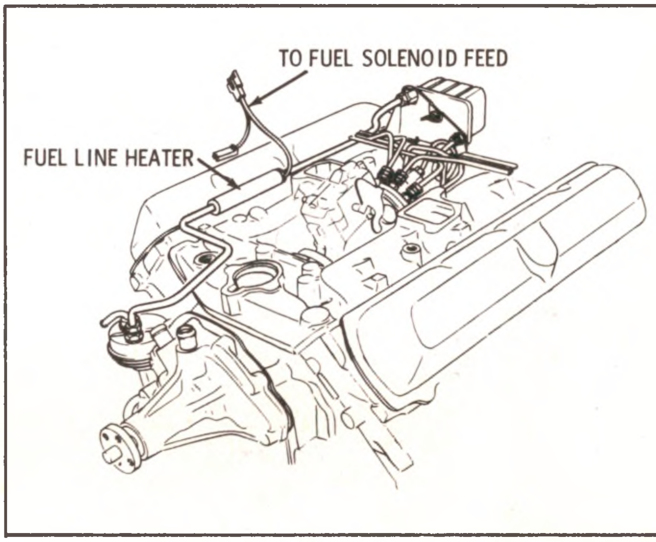


Fig. 2-3 Fuel Line Heater

The heater is electrically powered from the ignition circuit and is placed on the fuel filter inlet line a short distance up stream from the filter.

Following are some of the qualities designed into this system:

The heater is in-line, and in fact, a component of fuel pipe assembly between fuel lift pump and filter. It does not have any additional seals or joints that increase the possibility of fuel leaks.

The heater is thermostatically controlled to work when waxing of the fuel is expected. It is self-protected (by thermal fuse and break-away solder joint) against overheating resulting from dry fuel line, or lack of fuel flow.

The device can be divided into two major functional components, the heater and the power control assemblies. Figure 2-4.

The heater is ⅞ inches in diameter and approximately 5½ inches long and consists of an electric resistance strip spiral wound and bonded around the fuel pipe. To minimize the heat loss to the environment, heating element is surrounded by an insulating fiber.

The power control assembly senses fuel temperature and responds by closing an electrical circuit to the heater. The sensing element is a bimetal switch. The internal bimetal switch turns on at 20 degrees F. and shuts off at 50 degrees F. Power consumption is 100 watts. The heat will only be on until the under hood temperature gets hot enough to warm the fuel.

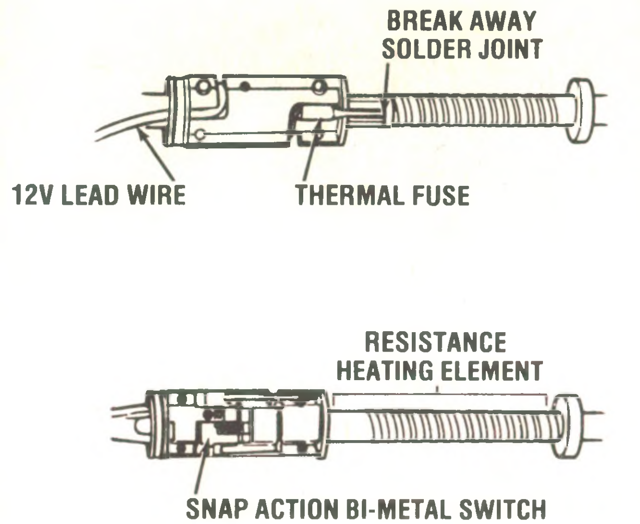


Fig. 2-4 Diesel Fuel Heater

The fuel tank filter sock has a bypass valve which opens when the filter is covered with wax allowing fuel to flow to the heater. Without this sock fuel line heater would be ineffective because the fuel would be trapped in the tank. Since the bypass valve is located at the upper end of the sock, fuel will only be drawn into the waxed sock if the tank contains more than approximately 4 gallons of fuel. Therefore it is important to maintain a minimum level of ¼ tank of fuel when temperatures are below 20°F.

In the event that this heater is installed as a retrofit, the filter sock with check valve must be included. Also since the connection for the fuel pipe is at a point in the side of the sock, the water in fuel tank unit must be used.

The heater cannot be serviced. However, it can be checked by using an ammeter connected in series. Checking must take place below 20° ambient temperature. Proper operation will draw approximately 7 amps.

FUEL FILTER

The engine fuel filter is a two-stage pleated paper type filter. Figure 2-5. The first stage consists of approximately 400 sq. inches of filtering area and will remove 94% of particles 10 microns and larger. The second stage is made of the same paper material and consists of approximately 200 sq. inches of filtering surface. The second stage is 98% effective in filtering the fuel already filtered by the first stage.

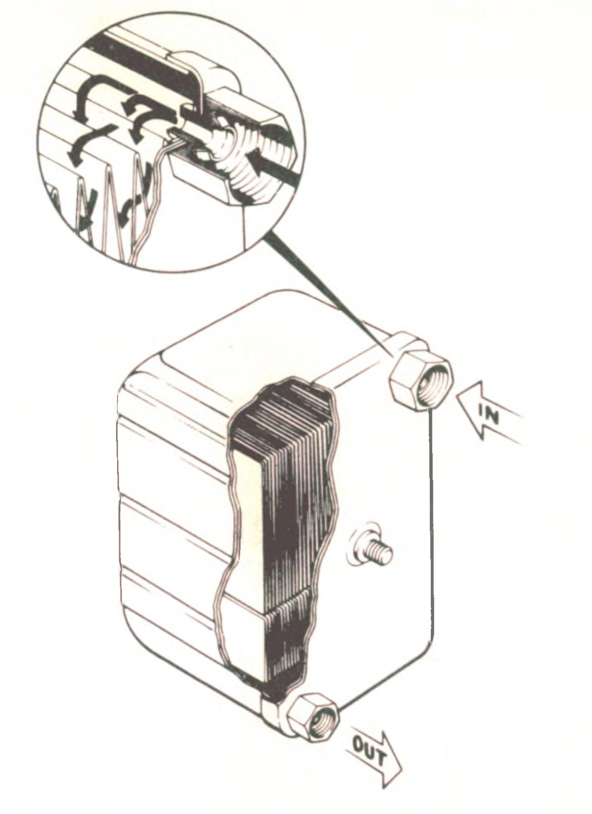


Fig. 2-5 Roosa Master Model 50 Filter

Particles which are larger than 10 microns may damage the pump's internal components. Figure 2-6 will compare various micron sizes and will ultimately show the filter's effectiveness.

The filter cannot be installed improperly as the inlet and outlet fittings are different sizes. Also, since the outlet is lower than the inlet any water which passes through will not remain trapped inside and cause damage by rust or freezing.

The entire fuel handling system is pre-calculated to supply 5½ to 6½ lbs. pressure to the injection pump and any deviation will affect pump operation. Each stage in which the fuel passes through in the injection pump is dependent upon the preceeding stage to operate properly.

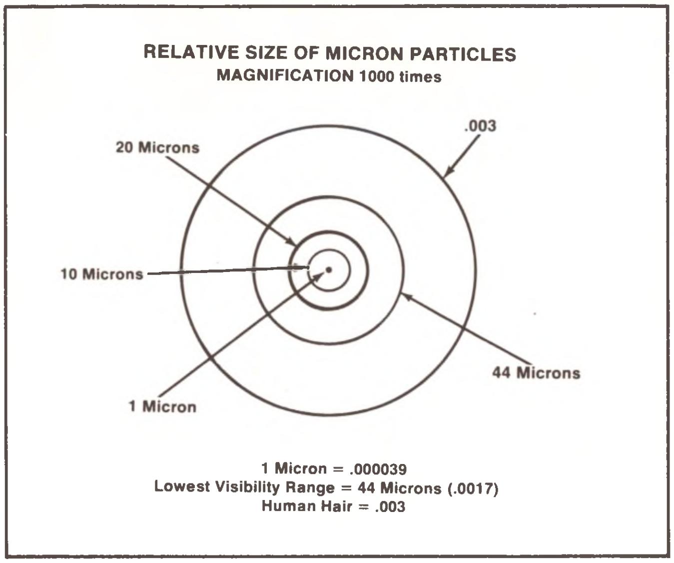


Fig. 2-6 Relative Size of Micron Particles

SECTION 3

ROOSA MASTER INJECTION PUMP

INJECTION PUMP OPERATION

It is necessary to become familiar with the function of the main components to understand the basic operating principles of the injection pump. Figures 3-1 and 3-2 will show the main components.

The main rotating components are the drive shaft (1), transfer pump blades (5), distributor rotor (2), and governor (12).

The drive shaft engages the distributor rotor in the hydraulic head. The drive end of the rotor incorporates two pumping plungers.

The plungers are actuated toward each other simultaneously by an internal cam ring through rollers and shoes which are carried in slots at the drive end of the rotor. The number of cam lobes equals the number of engine cylinders.

The hydraulic head contains the bore in which the rotor revolves, the metering valve bore, the charging ports and the head discharge fittings. The high pressure injection lines to the nozzles are fastened to these discharge fittings.

FUEL FLOW

The fuel flow schematic in figures 3-1 and 3-2 show the major components and their relationships.

Fuel is drawn through a strainer in the tank by the diaphragm-type fuel pump. Fuel at approximately 5½ to 6½ p.s.i. pressure flows through the fuel filter into the transfer pump and pressure regulator suction side.

Fuel under transfer pressure now splits into several directions. To the pressure side of the pressure regulator, to the head passage where three radial passages lead to the vent wire assembly, the pressure tap hole plug, the advance mechanism and to the metering valve.

The metering valve is the equivalent of throttle plates in a carburetor. It controls fuel flow to the pumping plungers.

The vent wire assembly is threaded into the top of the hydraulic head assembly next to the metering valve. It allows air and a controlled amount of fuel to escape to the housing where it will flow back to the fuel tank via the return oil circuit. The vent wire assembly is made up of a screw with a hole through it into which a wire is positioned.

The wire is free to vibrate and resists plugging by debris. Fuel, which flows through the vent wire assembly, circulates in the housing to cool and lubricate the internal pump components. A selection of screw assemblies containing different wire sizes is available to obtain the correct amount of return flow.

The housing pressure regulator is a ballcheck fitting in the governor cover which maintains even housing pressure and allows fuel to return to the fuel tank. This recirculation of fuel maintains normal operating temperature. At full load conditions, approximately half of the fuel which enters the pump is injected into the engine cylinders while the other half is returned to the fuel tank.

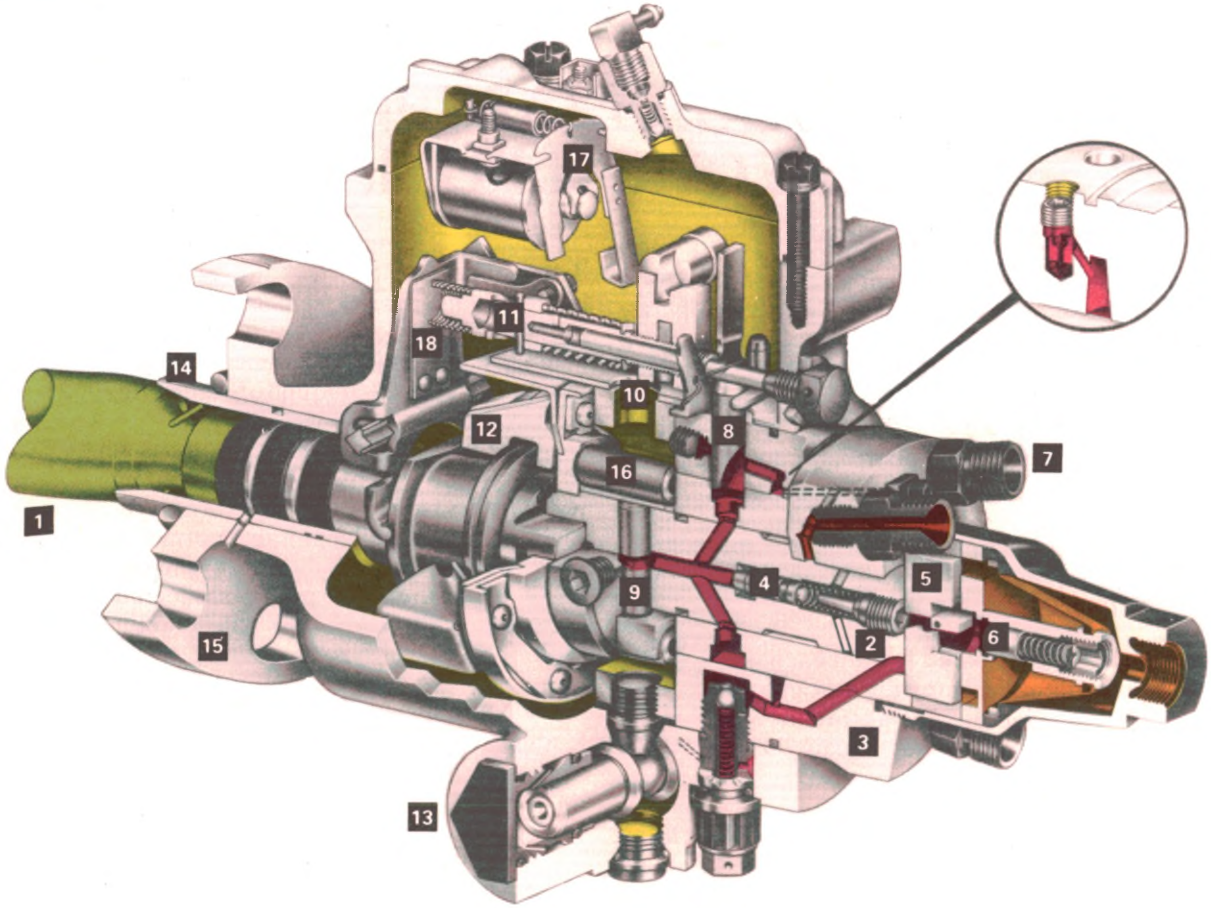
Fuel in the head passage also flows through a bore leading to the metering valve. The metering valve allows a varying amount of fuel to pass by, depending on its position, to charge the pumping plungers.

As the rotor revolves, the rotor inlet passage registers with the charging ports in the hydraulic head, allowing fuel to flow into the pumping chamber. With further rotation, the inlet passages move out of registry and the discharge port of the rotor registers with one of the head outlets. While the discharge port is opened, the rollers contact the cam lobes forcing the plungers together. Fuel trapped between the plungers is then pressurized and delivered by the nozzle to the combustion chamber.

Self-lubrication of the pump is an inherent feature of the pump.

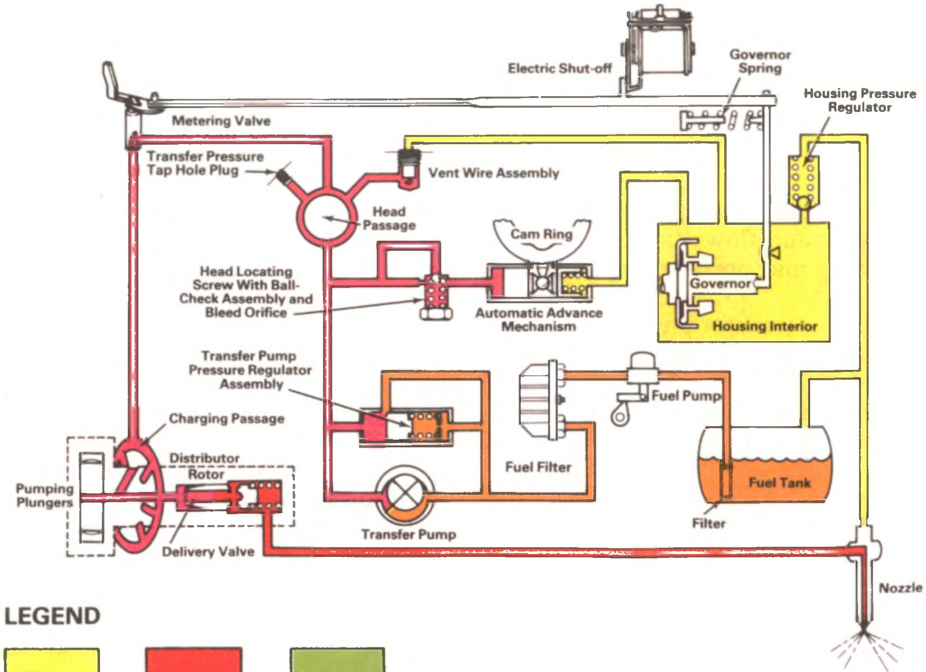
TRANSFER PUMP

The transfer pump at the rear of the rotor is of the positive displacement vane type and is enclosed in the end cap. The end cap also houses the fuel inlet strainer and transfer pump pressure regulator. The face of the regulator assembly is compressed against the liner and distributor rotor and forms an end seal for the transfer pump. The injection pump is designed so that end thrust is against the face of the transfer pump pressure regulator. The distributor rotor incorporates two charging ports and a single axial bore with one discharge port to service all head outlets to the injection lines. The transfer pump consists of a stationary liner and spring loaded blades which are carried in slots in the rotor. Since the inside diameter of the liner is eccentric to the rotor axis, rotation causes the blades to move in the rotor slots. This blade movement changes the volume between the blade segments.



COMPONENTS:

1 DRIVE SHAFT
2 DISTRIBUTOR ROTOR
3 HYDRAULIC HEAD
4 DELIVERY VALVE
5 TRANSFER PUMP
6 PRESSURE REGULATOR
7 DISCHARGE FITTING
8 METERING VALVE
9 PUMPING PLUNGERS
10 INTERNAL CAM RING
11 MIN-MAX GOVERNOR
12 GOVERNOR WEIGHTS
13 ADVANCE
14 DRIVE SHAFT BUSHING
15 HOUSING
16 ROLLERS
17 ELECTRIC SHUT-OFF
18 TEMPERATURE IDLE COMPENSATOR



LEGEND

INLET

TRANSFER PUMP PRESSURE

HOUSING PRESSURE

INJECTION LINE PRESSURE

ENGINE LUBE OIL

Fig. 3-1 Roosa Master DB2 Automotive Pump Typical 1978-79

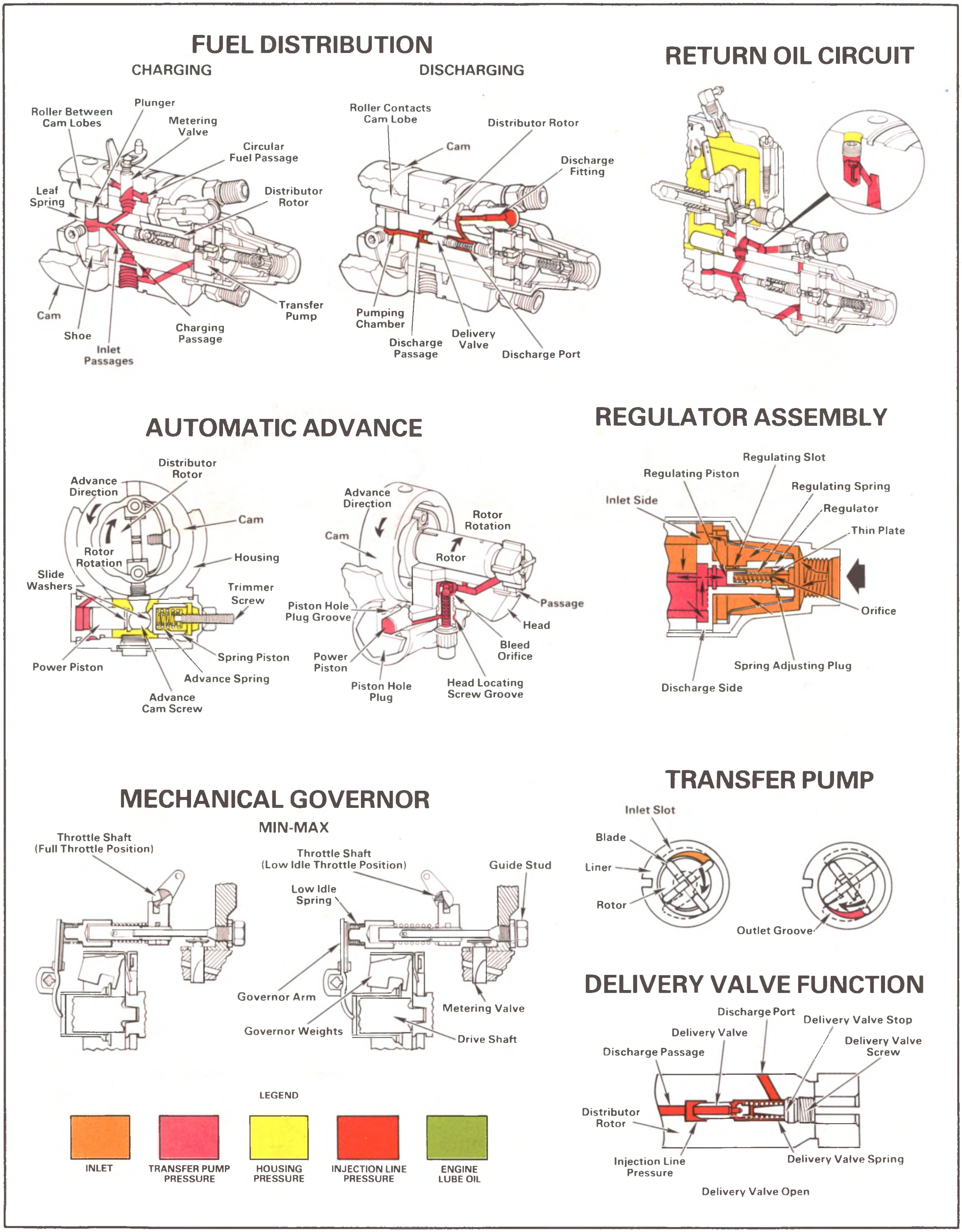
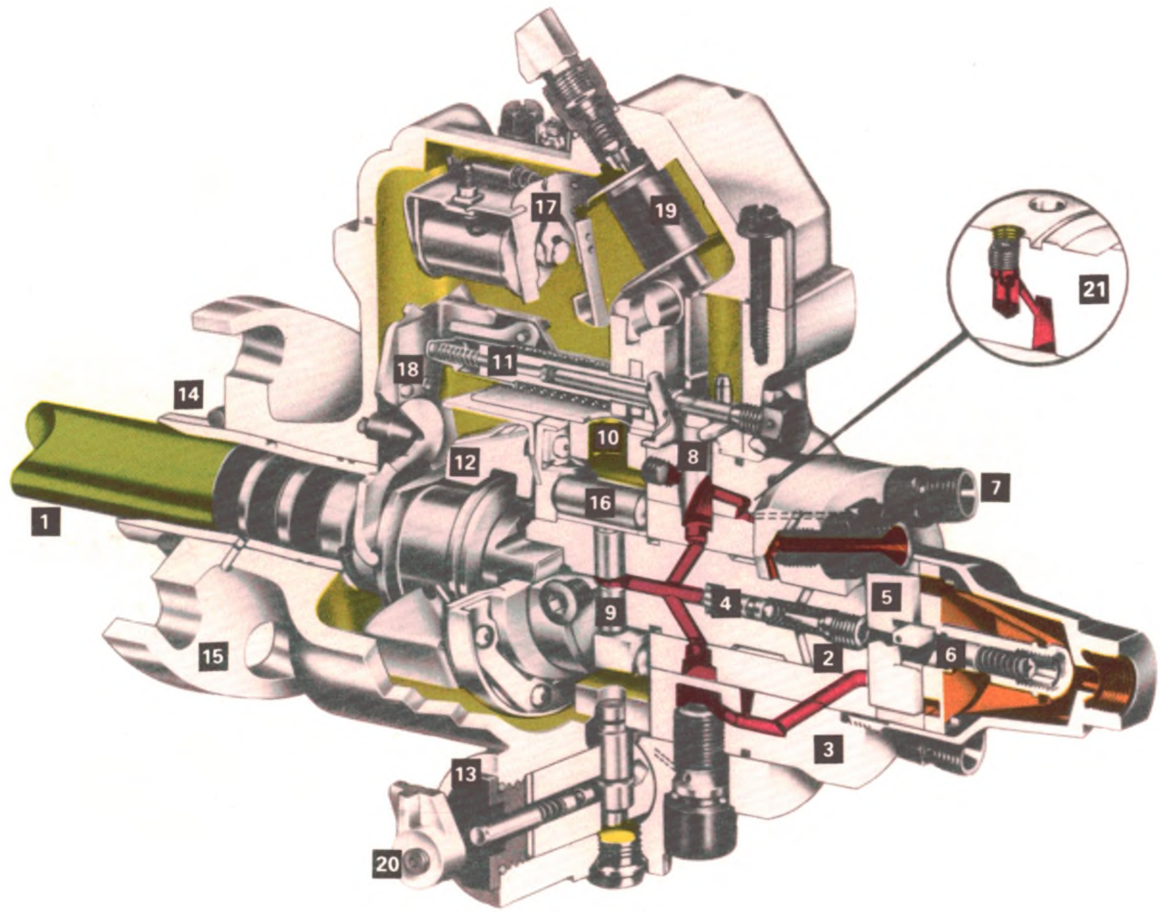
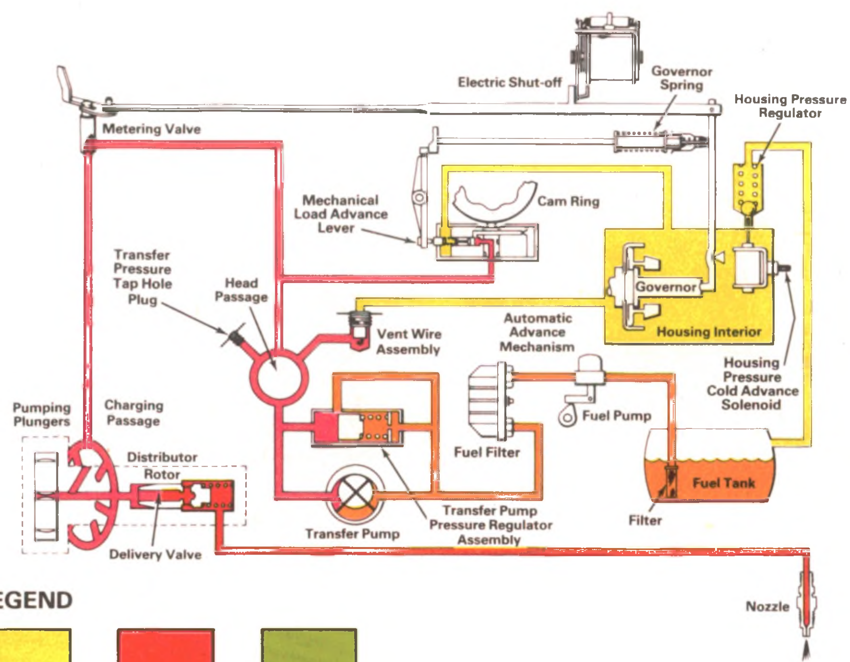


Fig. 3-1A Operating Principles Typical 1978-79



COMPONENTS:

1 DRIVE SHAFT
2 DISTRIBUTOR ROTOR
3 HYDRAULIC HEAD
4 DELIVERY VALVE
5 TRANSFER PUMP
6 PRESSURE REGULATOR
7 DISCHARGE FITTING
8 METERING VALVE
9 PUMPING PLUNGERS
10 INTERNAL CAM RING
11 MIN-MAX GOVERNOR
12 GOVERNOR WEIGHTS
13 ADVANCE
14 DRIVE SHAFT BUSHING
15 HOUSING
16 ROLLERS
17 ELECTRIC SHUT-OFF
18 TEMPERATURE IDLE COMPENSATOR
19 HOUSING PRESSURE COLD ADVANCE
20 MECHANICAL LIGHT LOAD ADVANCE LEVER
21 VENT WIRE ASSEMBLY



LEGEND

INLET	TRANSFER PUMP PRESSURE	HOUSING PRESSURE	INJECTION LINE PRESSURE	ENGINE LUBE OIL

Fig. 3-2 Roosa Master DB2 Automotive Pump with H.P.C.A. Typical 1981

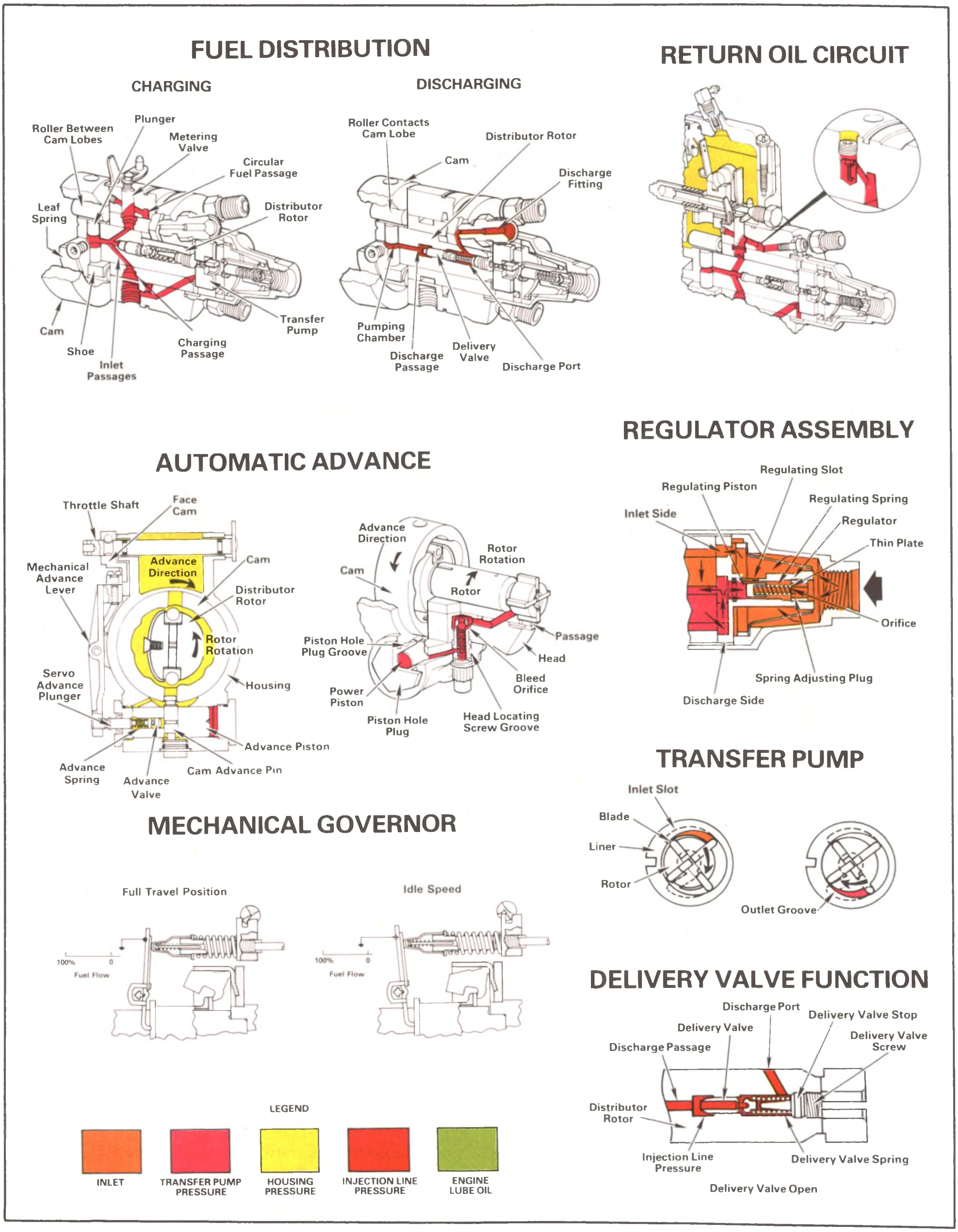


Fig. 3-2A Operating Principles Typical 1981

Transfer pump output volume and pressure increases as pump speed increases. Since displacement and pressure of the transfer pump can exceed injection requirements, some of the fuel is recirculated by means of the transfer pump regulator to the inlet side of the transfer pump.

The operation is shown under Operating Principles in Figures 3-1A and 3-2A. Radial movement causes fuel to be drawn into the kidney shaped inlet slot. As the blades rotate in the eccentric liner they move outward and the volume increases until the leading blade passes out of the registry with the slot. At this point, the rotor has reached a position where outward movement of the blades is negligible and volume is not changing, as the rotation continues. The fuel between the blades is carried to the bottom of the transfer pump liner and enters the outlet groove.

As the leading blade passes the opening of the kidney shaped outlet groove, the eccentric liner compresses the blades in an inward direction. As a result, the volume between the blades is reduced and pressurized fuel is delivered through the groove of the regulator assembly, through the transfer pump, through the rotor, past the rotor retainers and into a channel on the rotor leading to the hydraulic head passages. Volume between the blades continues to decrease, pressurizing the fuel in the quandrant, until the trailing blade passes the opening in the outlet groove.

PRESSURE REGULATOR ASSEMBLY

The Operating Principles Charts in Figures 3-1A and 3-2A show the operation of the pressure regulating piston. Fuel output from the discharge side of the transfer pump forces the piston in the regulator against the regulating spring. As flow increases, the regulating spring is compressed until the edge of the regulating piston starts to uncover the pressure regulating slot. Since fuel pressure on the piston is opposed by the regulating spring, the delivery pressure of the transfer pump is controlled by the spring rate and size of the regulating slot. Therefore, pressure increases with speed.

The transfer pump works equally well with different grades of diesel fuel and varying temperatures, both of which affect fuel viscosity. A unique and simple feature of the regulating system offsets pressure changes caused by viscosity difference.

Located in the spring adjusting plug is a thin plate incorporating a sharp-edged orifice. The orifice allows fuel leakage past the piston to return to the inlet side of the pump. Flow through a short orifice is virtually unaffected by viscosity changes. The biasing pressure exerted against the back side of the piston is determined by the leakage through the clearance between the piston and the regulator bore and the pressure drop through the sharp edged orifice. With cold or viscous fuels, very little leakage occurs past the piston. The additional force of the back side of the piston from the viscous fuel pressure is slight. With hot or light fuels, leakage past the piston increases, fuel pressure in the spring cavity increases also, since flow past the piston must equal flow through the orifice. Pressure rises due to increased piston leakage and pressure rises to force more fuel through the orifice. This variation in piston position compensates for the leakage which would occur with thin fuels and design pressures are maintained over a broad range of viscosity changes.

CHARGING AND DISCHARGING

Charging Cycle

As the rotor revolves, as shown in Figures 3-1A and 3-2A, the two inlet passages in the rotor register with ports of the circular charging passage. Fuel under pressure from the transfer pump, controlled by the opening of the metering valve, flows into the pumping chamber forcing the plungers apart.

The plungers move outward a distance proportionate to the amount of fuel required for injection of the following stroke. If only a small quantity of fuel is admitted into the pumping chamber, as at idling, the plungers move out a short distance. Maximum plunger travel and, consequently, maximum fuel delivery is limited by the leaf spring which contacts the edge of the roller shoes. Only when the engine is operating at full load will the plungers move to the most outward position. Note that while the angled inlet passages in the rotor are in the registry with the ports in the circular charging passage, the rotor discharge port is not in registry with a head outlet. Note also that the rollers are off the cam lobes. Compare their relative positions by observing the discharging diagram.

Discharge Cycle

As the rotor continues to revolve, the inlet passages move out of registry with the charging ports. The rotor discharge port opens to one of the head outlets. The rollers then contact the cam lobes forcing the shoes in against the plungers and high pressure pumping begins.

Beginning of injection varies according to load (volume of charging fuel), even though rollers may always strike the cam at the same position. Further rotation of the rotor moves the rollers up the cam lobe ramps pushing the plungers inward. During the discharge stroke the fuel trapped between the plungers flows through the axial passage of the rotor and discharge port to the injection line. Delivery to the injection line continues until the rollers pass the innermost point on the cam lobe and begin to move outward. The pressure in the axial passage is then reduced, allowing the nozzle to close. This is the end of delivery.

Delivery Valve

The delivery valve rapidly decreases injection line pressure after injection to a predetermined value lower than that of the nozzle closing pressure. This reduction in pressure permits the nozzle valve to return rapidly to its seat, achieving sharp delivery cut-off and preventing improperly atomized fuel from entering the combustion chamber.

The delivery valve operates in a bore in the center of the distributor rotor. The valve requires no seat — only a stop to limit travel. Sealing is accomplished by the close clearance between the valve and bore into which it fits. Since the same delivery valve performs the function of retraction for each injection line, the result is a smooth running engine at all loads and speeds.

When injection starts, fuel pressure moves the delivery valve slightly out of its bore and adds the volume of its displacement, to the delivery valve spring chamber. Since the discharge port is already opened to a head outlet, the retraction volume and plunger displacement volume are delivered under high pressure to the nozzle. Delivery ends when the pressure on the plunger side of the delivery valve is quickly reduced, due to the cam rollers passing the highest point on the cam lobe.

Following this, the rotor discharge port closes completely and a residual injection line pressure is maintained. Note that the delivery valve is only required to seal while the discharge port is opened. Once the port is closed, residual line pressures are maintained by the seal of the close fitting head and rotor. It is possible that the residual pressure may vary between injection lines. Because of this variance, a noticeable chuggle or feeling of slight engine misfire became apparent in vehicles equipped with standard transmissions and torque converter clutch equipped vehicles. This condition was dampened completely in the standard torque converters on earlier models.

As a result of chuggle, a vented rotor was designed and equipped on all 1979 models with standard transmission, all 1980 models and all 1981 models except "E" (which doesn't use TCC). The operation can be seen in Figure 3-3 which shows a series of vent ports, equal to the number of cylinders, simultaneously register with the head outlets after each injection period. During the vent cycle, all vent ports will align with all of the head outlets and therefore create equalized residual pressure in all cylinders resulting in smooth operation when the transmission went into direct drive.

As nozzles are cracked during some engine roughness diagnosis procedures, the engine may stall. This is due to the large release of residual pressure which actually starves remaining cylinders of fuel. Slight cracking may still provide adequate diagnosis without engine stall.

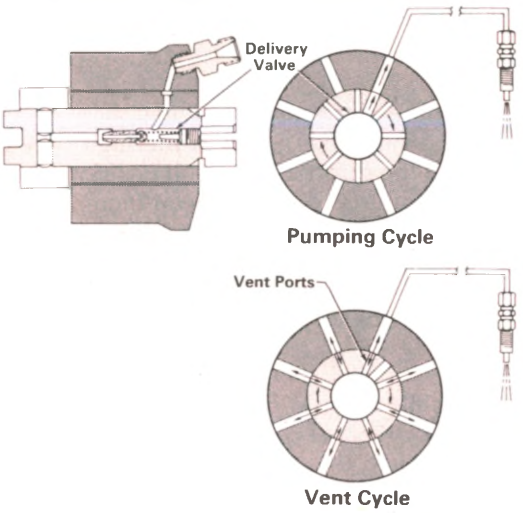


Fig. 3-3 Residual Pressure Balance Ports.

Return Oil Circuit

Fuel under transfer pump pressure is discharged into a vent passage in the hydraulic head. (Figure 3-1A and 3-2A). Flow through the passage is restricted by a vent wire assembly to prevent excessive return oil and undue pressure loss. The amount of return oil is controlled by the size of wire used in the vent wire assembly, i.e. the smaller the wire the greater the flow and vice versa. The vent wire assembly is available in several sizes in order to meet the return oil quantities called for on the specification. Note that this assembly is accessible by removing only the governor cover. The vent passage is located behind the metering valve bore and connects with a short vertical passage containing the vent wire assembly and leads to the governor compartment.

Should a small quantity of air enter the transfer pump, it immediately passes to the vent passage as shown. Air and a small quantity of fuel then flow from the housing to the fuel tank and via the return line.

Housing pressure is maintained by a spring loaded ballcheck return fitting in the governor cover of the pump.

Approximately 10 psi of fuel pressure is maintained to provide a bias for the transfer pump to provide the balance needed for proper timing.

Min-Max Governor

The governor mechanism consists of a cage with flyweights mounted on the rotor and a system of linkages which control engine speed at idle and provide complete and rapid governor cutoff to prevent engine overspeed. At all other loads and speeds, however, it acts as a solid link between the accelerator and the metering valve. To accomplish this, the governor spring is assembled to the governor under a pre-load. Deflection of the main governor spring will only occur at pump cutoff speed. Hence, it is called min-max, indicating governor spring control at minimum and maximum speeds only.

In the full throttle position view shown in Figure 3-1A and 3-2A the governor is in the high speed cutoff position. With the throttle in the full position, the engine (without load on it) and pump speed increases until the governor weights have generated enough force to deflect the main governor spring. Governor arm movement turns the metering valve to the shutoff position, restricting fuel delivery and preventing engine overspeed.

The low idle throttle position view shows the relationship of the governor parts when the pump is running at low idle. Notice that the throttle shaft is in the low idle position, the balance between the idle spring force and governor force positions the metering valve for low idle fuel delivery.

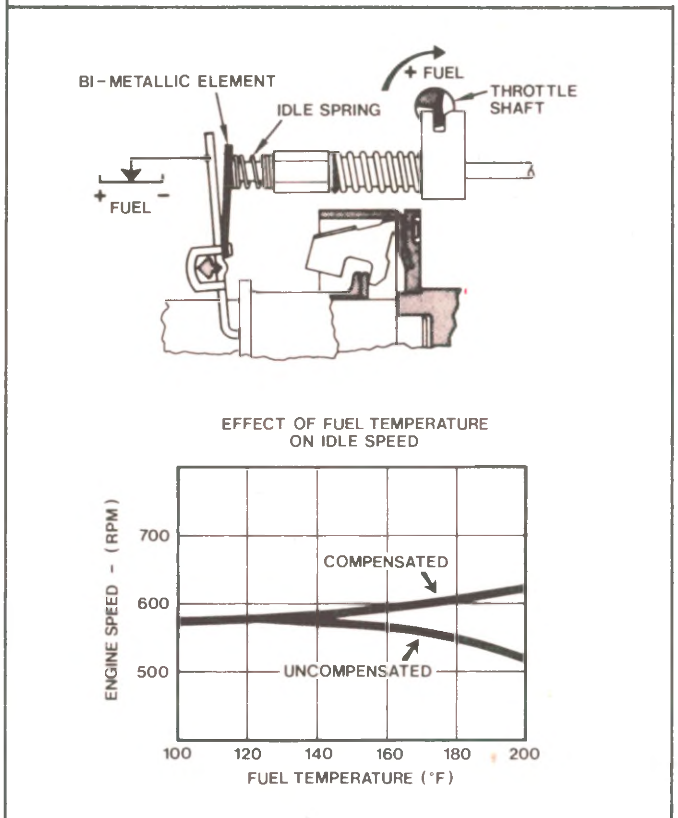


Fig. 3-4 Temperature Compensator for Engine Idle Speed.

Fuel Temperature Compensator for Idle Speed

Because the injection pump is located in the center of the "vee" retention of heat is a critical factor in fuel thinning particularly after a high ambient heat soak. As the hotter, thinner fuel passes through the pump, internal leakage increases and therefore reduces pump output. In order to prevent engine stalling from too small an output, a bimetal compensator strip Figure 3-4 is added to the governor arm to deflect relative to the governor arm. This motion increases the metering valve opening and provides a compensated idle speed curve.

Automatic Advance Mechanism

The automatic advance is a hydraulic mechanism which advances or retards the pumping cycle.

It is powered by fuel pressure from the transfer pump, to rotate the cam slightly and vary delivery timing. The advance mechanism advances or retards start of fuel delivery in response to engine speed changes.

Compensating inherent injection lag improves high speed performance. Starting delivery of fuel to the nozzle earlier when the engine is operating at higher speeds insures that combustion takes place when the piston is in its most effective position to produce optimum power with minimum specific fuel consumption and minimum smoke.

The advance pistons located in a bore in the housing engage the cam advance screw or pin and move the cam (when fuel pressure moves the power piston) opposite the direction of rotor rotation. Fuel under transfer pump pressure is fed through a drilled passaged in the hydraulic head which registers with the bore of the head locating screw. Fuel is then directed past the spring loaded ballcheck in the bore of the head locating screw. It then enters the groove on the outside diameter of the screw which registers with a drilled passage in the housing leading to the power piston side of the automatic advance assembly.

A groove around the power piston plug and a drilled passage allow the fuel to enter the advance piston bore. Fuel pressure against the piston must overcome the opposing spring force plus the dynamic injection loading on the cam in order to change the cam position. The spring loaded ballcheck in the bore of the head locating screw prevents the normal tendency of the cam to return to the retard position during injection by trapping the fuel in the piston chamber. When engine speed decreases, the hydraulic pressure is reduced and the spring returns the cam to a retarded position in proportion to the reduction in speed. The fuel in the piston chamber is allowed to bleed off through a control orifice located below the ballcheck valve in the head locating screw.

At low speeds, because transfer pump pressure is comparatively low, the cam remains in the retarded position. When engine speed increases, transfer pump pressure rises and moves the piston in the advanced direction. Advance piston movement is related to speed. Speed advance operation is shown in Fig. 3-5.

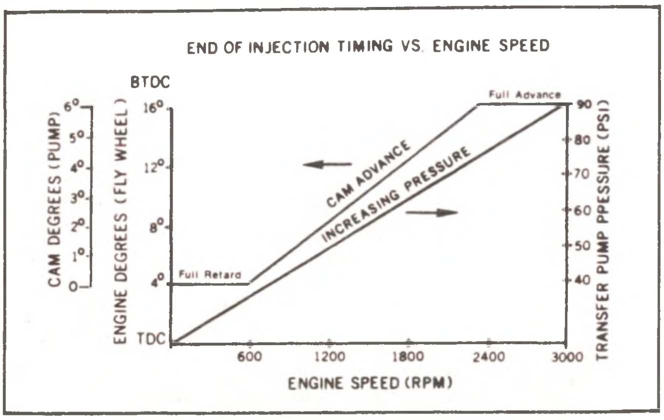


Fig. 3-5 Speed Advance Operation.

On all earlier models and some current models, a "trimmer screw" is provided to adjust advance spring preload which controls start of cam movement. It can only be adjusted on a test bench while running.

On many later models beginning with 1980, in addition to the normal speed advance, a mechanical light load advance is furnished as a function of throttle angle. (Figure 3-6). The mechanism consists of a face cam attached to the throttle shaft, an external pivot lever and a push rod which goes into the trimmer side of the timing advance bore. The purpose of this mechanism is to reduce emissions. It provides proper advance for light loads when the transfer pump pressure is low and cam ring is in the retard position.

Light load advance is provided by changing the reference point of the servo valve spring. A face cam, attached to the throttle shaft causes an external lever to pivot. The lower end of this lever contacts a push rod which is also the servo valve spring seat. This mechanism translates rotational motion of the throttle shaft into axial motion of the servo valve spring. Transfer pump pressure, applied to the inboard side of the servo valve and opposed by the servo valve spring, provides speed advance. As the servo valve moves in the advance direction, fuel flows through radial and axial passages to the power side of the advance piston. This action moves the advance piston until it reaches the servo valve and covers the radial supply passage. The advance curve obtained with the servo advance system is essentially independent of the pumping reaction.

H.P.C.A.

"Housing Pressure Cold Advance" or HPCA will be included with all 1981 vehicles except Canadian cars and trucks and Federal 49 state trucks.

The HPCA feature is designed to advance the injection timing about 3° during cold operation. The main purpose is the reduction of engine smoke, roughness, noise and emissions during cold start-up by advancing the fuel delivery system. Through the use of an engine mounted switch, the same switch that operates the fast idle solenoid below 125°, a solenoid located in the pump cover pushes the return fitting check ball away from its seat.

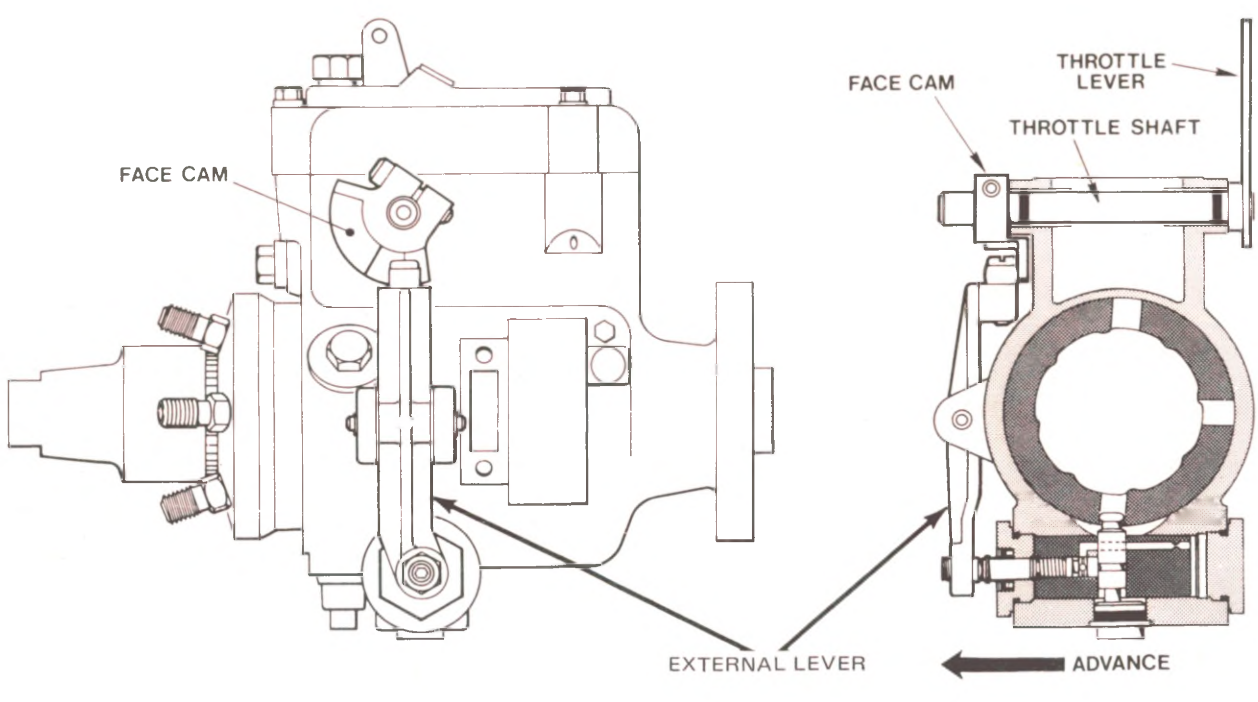


Fig. 3-6 Mechanical Light Load Advance.

Since approximately 10 psi housing pressure which accompanies advance spring pressure in the timing advance bore is relieved, transfer pump pressure will advance timing an additional 3° which initiates combustion sooner and results in a slower, more complete burning of the fuel. Above 125°, the switch opens, de-energizing the solenoid and housing pressure is returned back to 10 psi. The switch again closes when the temperature falls below 95°F. An improved cold idle and better cold starting also results.

HPCA operates from 2 to 10 minutes depending on engine temperature.

When changing the fuel filter or when the car has run out of fuel, disconnect the connector from the temperature switch and jumper connector terminals. This will aid in purging air from the pump. This procedure is necessary only on a hot engine, as the circuit will always be closed when the engine is cold.

Electric Shut Off

The pump is equipped with an electric shut off solenoid which through the governor linkage will push the metering valve into a closed position shutting off fuel for engine shut down when voltage is removed. When the solenoid is energized, internal spring pressure inside the solenoid is overcome and through the governor linkage the metering valve is allowed to operate freely throughout its throttle range.

Coil temperature has an effect on pull-in voltage required to operate the solenoid. Figure 3-7 will show the maximum production limits. This pull-in voltage requirement should always be considered when diagnosing no start conditions. Low battery voltage may be the cause. Pull-in voltage can be tested with Voltmeter at pump solenoid terminal during normal starting operation. Hold in is approximately 2 to 3 volts.

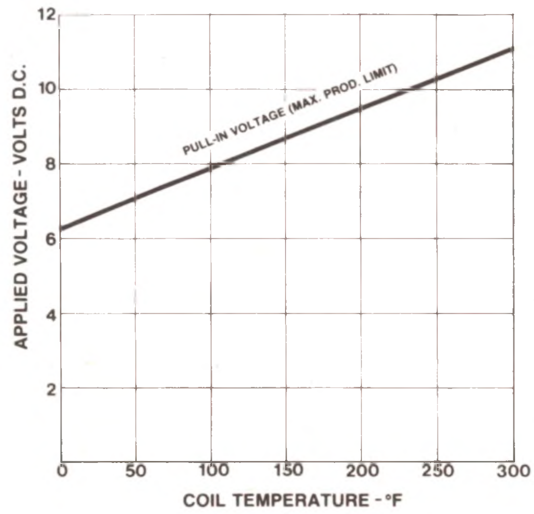


Fig. 3-7 Electric Solenoid Pull in Voltage.

INJECTION PUMP REPAIRS

The following procedure is not intended as a guide for complete overhaul. It does not include repairs which would involve calibration on a test stand. For operations which require re-calibration, the pump must be sent to an authorized Roosa Master agency.

Figure 3-8 shows a typical test stand installation. The test stand incorporates a 5 to 15 H.P. electric motor, depending on the particular model used, which drives the injection pump. The stand's motor simulates the automotive engine with the rpm controlled on the machine by the operator and not by the throttle opening. Various tests and adjustments are performed. Some are: Electric solenoid pull-in voltage, housing pressure cold advance solenoid operation, face cam position, min-max governor, return oil volume, housing pressure, transfer pump pressure and automatic advance adjustments. Actual calibration of fuel delivery is not adjustable within the head and rotor assembly but is affected directly by some of the above adjustments. Various rpm ranges and throttle openings are used to check output of the pump.

It should be understood that the injection pump is designed to deliver a metered amount of fuel at the proper time and is therefore incapable of delivering a rich or lean mixture. It should also be understood that other than a failure of the governor weight retainer ring or the correction of the min-max governor, the injection pump will have very little to do with a rough idle condition and therefore generally should not be sent to the local Roosa Master shop for rough idle.

Background information of failed governor weight retainer ring: diesel fuel that is contaminated with excessive water or the presence of alcohols found in some additives not normally present in recommended diesel fuels may accelerate failure of the elasticast governor weight retainer ring in the injection pump. Failure of the ring is heat related and will most likely result in a rough idle condition and, in some instances, the engine may not run. A failed ring will break apart into small black particles plugging the fuel return check valve. Remove the check valve if small particles are observed. Confirm

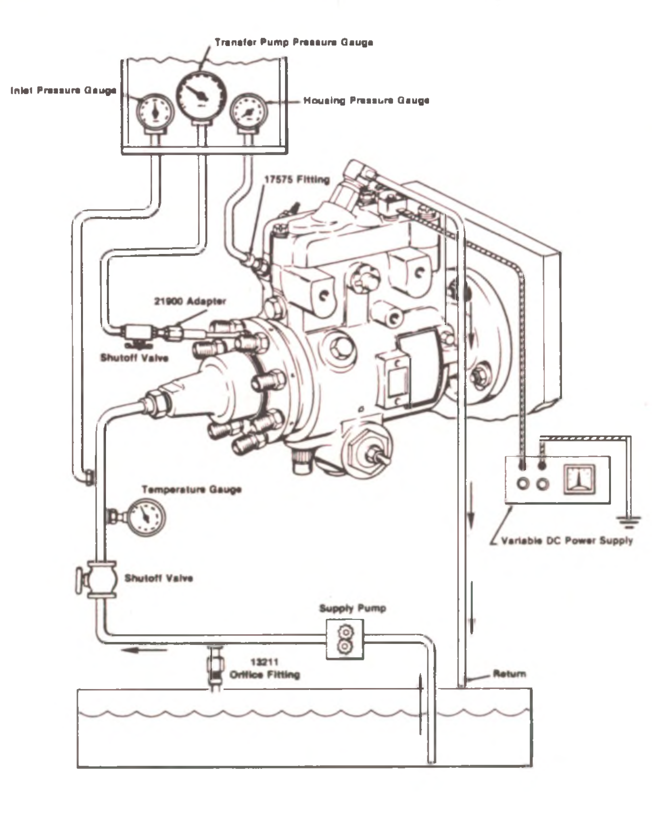


Fig. 3-8 Typical Test Stand Installation.

the findings by removing the pump cover and rotating the governor weight retainer in both directions (Figure 3-9) suitable tool or screwdriver. If the retainer moves more than 1/16″ and does not return, the retainer ring has failed. Normally a failed ring will allow ¼″ free movement.

If a failed ring is found, the pump will require removal from the engine. Follow the procedures listed in the shop manual.

A new Pellethane ring has been developed and is more resistant to heat, water and additives.

The procedure that follows include disassembly, various seal replacements, installation of the new pellethane governor weight retainer ring, and a bench leak test.

Operations which can be performed individually without removing the pump from the engine are as follows:

- Cover seal replacements
- Guide stud seal replacements
- Throttle shaft seal replacements
- Governor weight retainer ring checking procedure
- Min-Max governor service (will be covered in Section 5)

Each of these on-car operations are currently available in dealer technical bulletins.

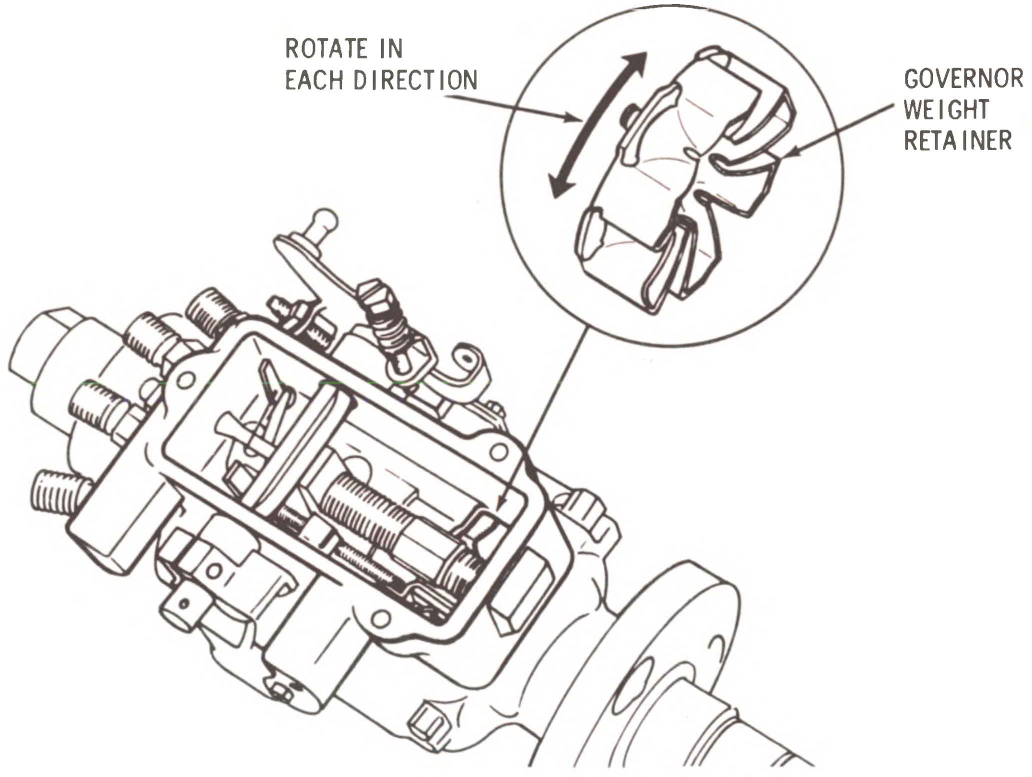


Fig. 3-9 Failed Governor Weight Retainer Ring Checking Procedure.

Disassembly

Special Roosa Master tools required to perform these repairs are as follows: 14490 Advance screw hole plug wrench, 15499 Bristol wrench, 15500 Advance screw plug hole bushing, 22727 driveshaft seal installer tool, 22998 mounting fixture and 22204 Synkut oil (or equivalent). Special Kent Moore Tools are: J-29601 face cam tool and J-29692 mounting fixture (same as 22998 above).

Refer to Figure 3-14 as necessary for various pump component locations.

1. With the cover installed, install plugs in the discharge ports, fuel inlet port and return line. Clean the pump thoroughly on the outside. Any cleaner that does not irritate the skin should be satisfactory. If nothing else, emerse in fuel oil and brush to clean, blow dry.
2. Install pump in holding fixture so that rear of pump is tilted downward.
3. Keep all gaskets with parts removed until reassembly. Some gaskets are similar, identification will be easier by comparing gaskets when reassembling.
4. Remove the timing line cover (side of pump).
5. Remove three (3) governor cover screws and governor cover (top of pump).
6. Remove guide stud and guide stud washer.
7. Remove min/max governor assembly. (Figure 3-10).

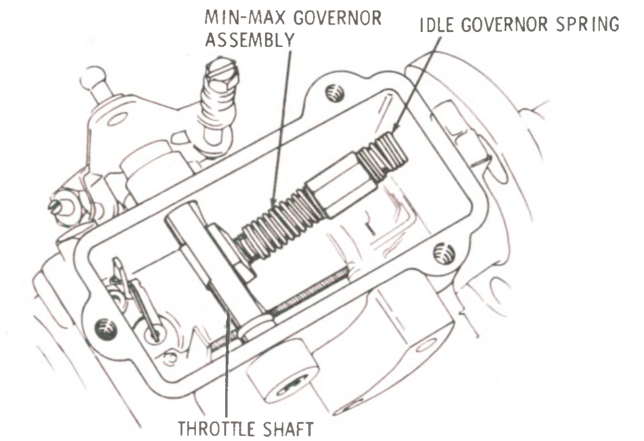


Fig. 3-10 Min-Max Governor Removal.

8. On all models without external advance lever, remove the vacuum drive pin, retaining ring and seal washer from the throttle shaft assembly.

9(A.) On all models with external advance lever, install the tool J29601 on the throttle shaft, tighten the thumb screw, and remove the tool and the vacuum switch drive pin (Figure 3-11).

(B.) Remove the face cam screw.

10. Remove the throttle shaft assembly.

11. Lift out the face cam and mylar washer on models so equipped.

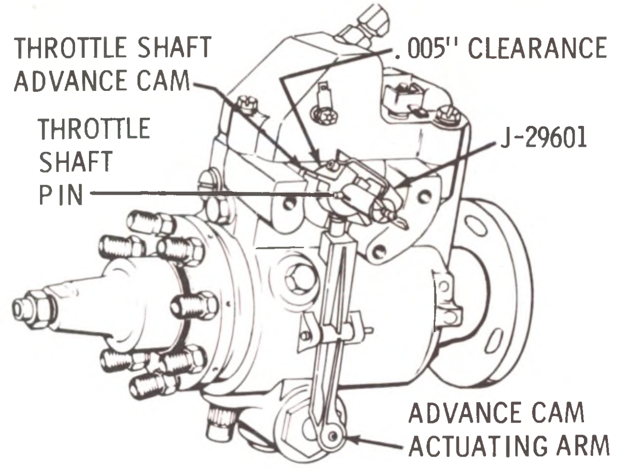


Fig. 3-11 Face Cam Tool, J-29601

12. Lift up the governor linkage hook assembly and remove the metering valve. (NOTICE: DO NOT DISTURB LINKAGE HOOK ADJUSTMENT.) (Figures 3-12 and 3-13).

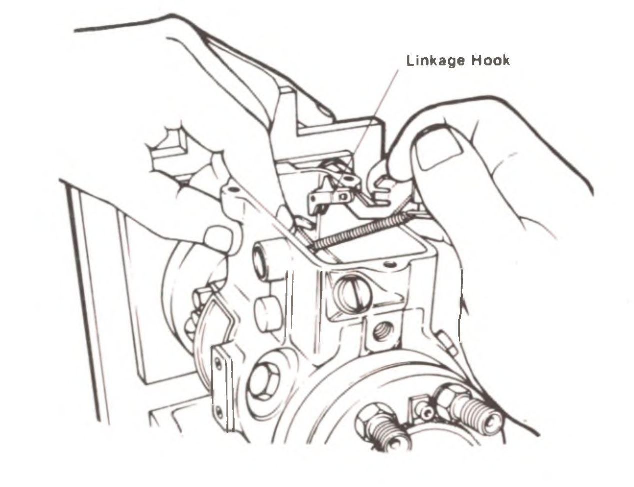


Fig. 3-12 Linkage Hook Assembly.

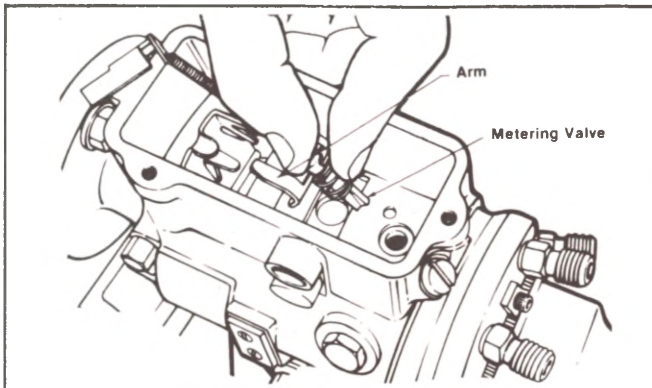


Fig. 3-13 Metering Valve.

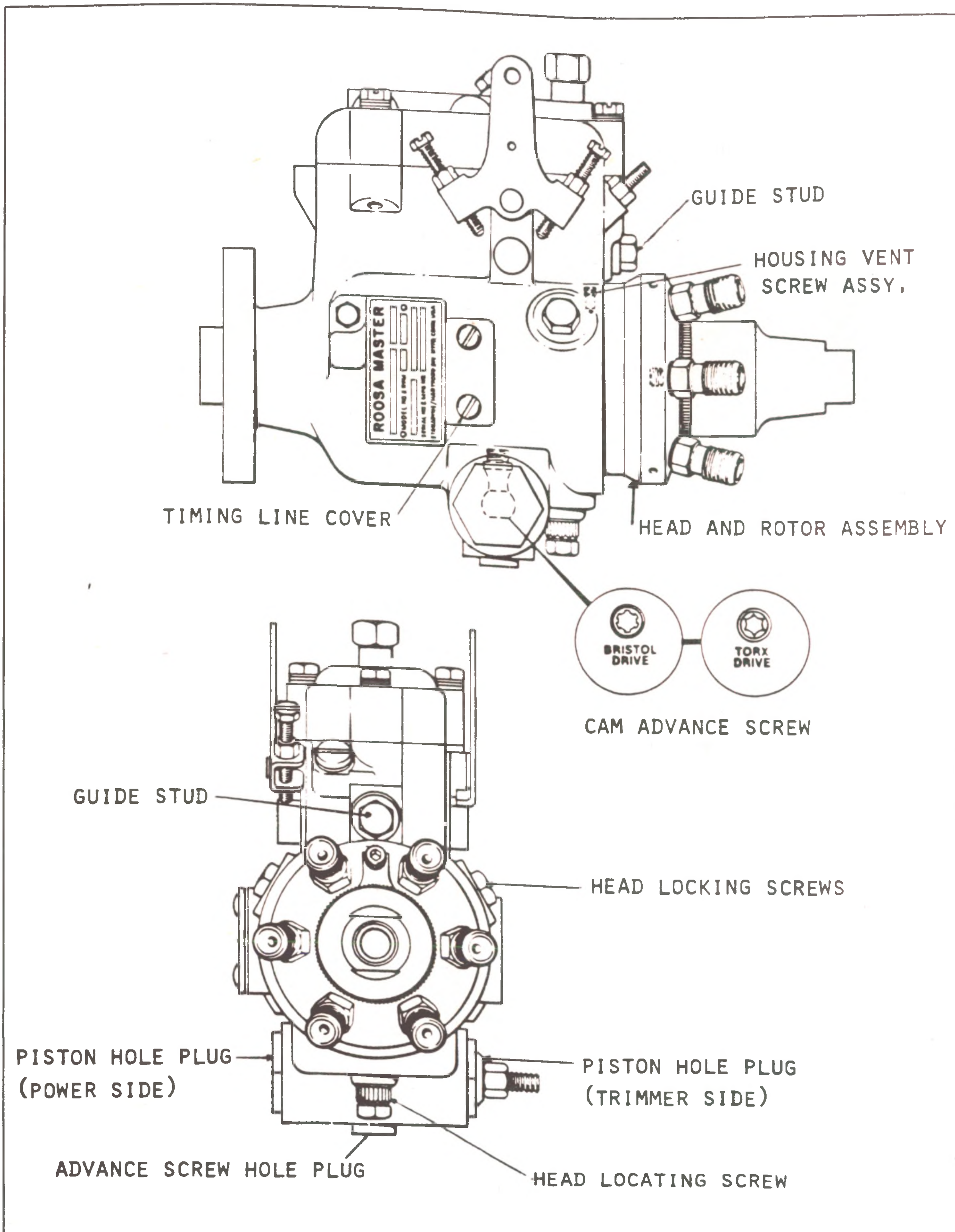


Fig. 3-14 Pump Components Locations.

13. Remove the housing vent screw assembly. Figure 3-15.

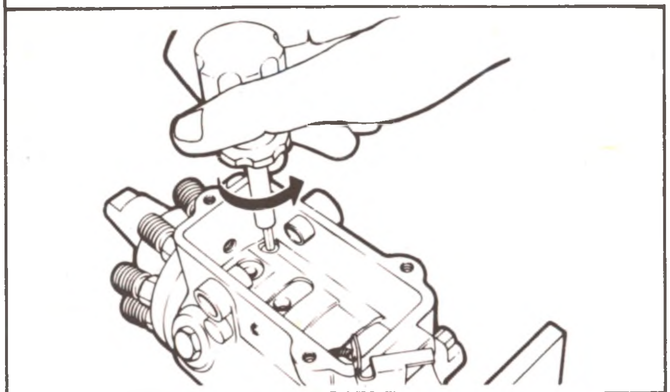


Fig. 3-15 Housing Vent Screw Assembly.

14. Remove one (1) head locking screw and loosen the other.

15. Turn pump upside down and remove head locating screw.

16. Remove advance screw hole plug, using 14490 wrench. Figure 3-16.

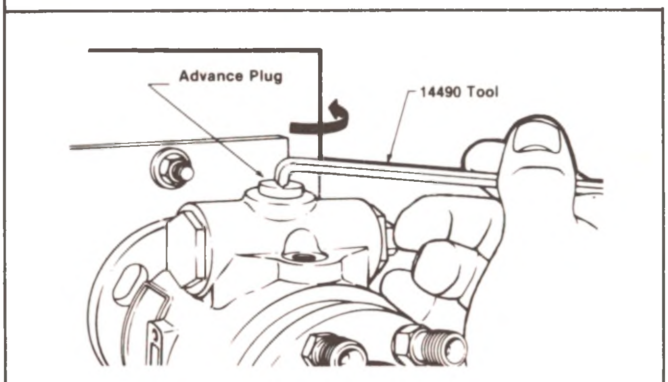


Fig. 3-16 Advance Screw Hole Plug.

17(A.) On all models without external advance, remove piston hole plug (trimmer side), slide washer, advance piston and outer spring.

(B.) Remove piston hole plug (power side), slide washer and power piston.

(C.) Install 15500 Bushing and Bristol tool and remove the cam advance screw. Be sure to fully seat tool into ball end to reduce the possibility of breakage. Figure 3-17. Some Bristol tools were manufactured with a 30° chamfer on the end of the tool. The life of the tool can be extended by grinding a 60° chamfer on the tool. All tools now have a 60° chamfer.

18. On External advance models, lift out cam advance pin.

19. Turn pump right side up.

20. Remove the remaining head locking screw.

21. Remove the head and rotor assembly, governor weights, thrust sleeve, and thrust washer. Figure 3-18. Take care that head and rotor assembly doesn't roll of workbench onto floor.

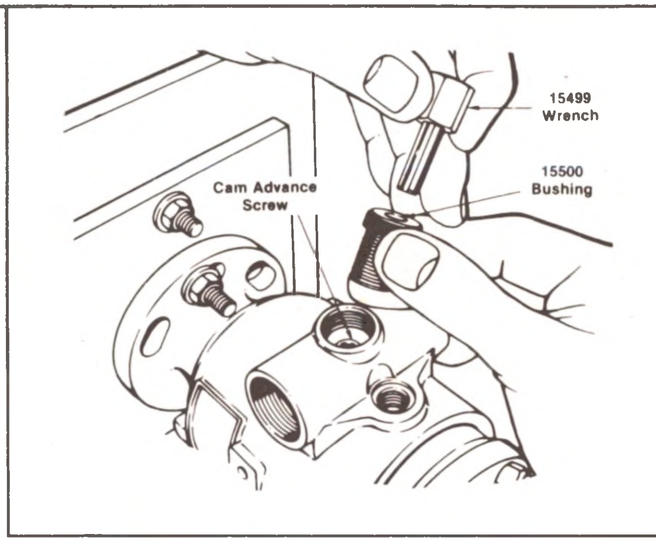


Fig. 3-17 Cam Advance Screw and Tools.

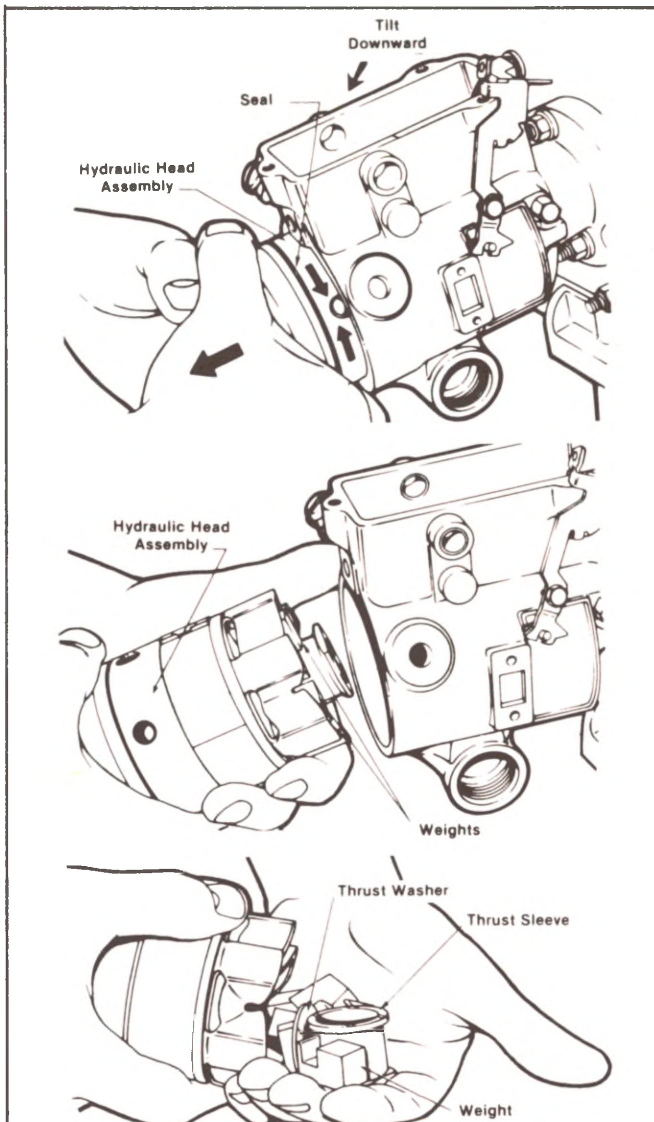


Fig. 3-18 Head, Rotor and Governor Weights.

22. Remove governor cage retaining snap ring. Figure 3-19.

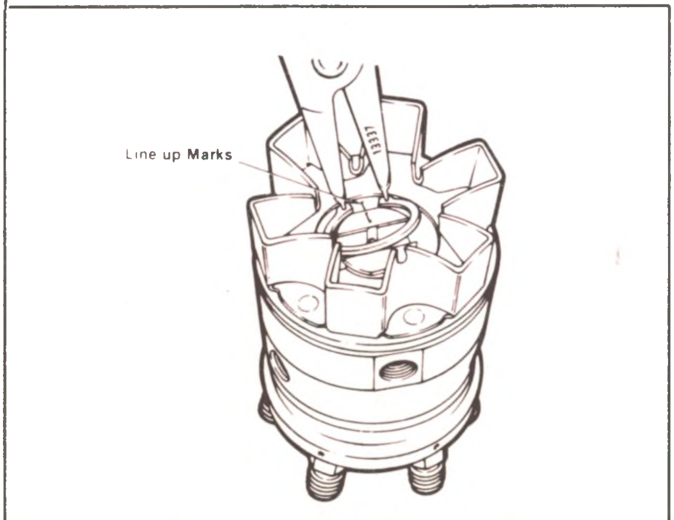


Fig. 3-19 Governor Cage Snap Ring.

23. Remove governor weight retainer assembly. Inspect the pins on the weight retainer for wear, pins can be worn by the slots in the drive plate after the ring has disintegrated. The base of the pin can have about .025″ worn away and still be satisfactory as long as there are no sharp edges to cut the ring. If the pins are worn excessively, bent, loose or sharp edges cannot be removed, the retainer should be replaced.

24. Remove elasticast ring by pulling ring off of pins. Slight forceable action will be required.

25. Flush and clean the pump and all parts — except the head assembly, examine the cam ring, shoes and rollers Figure 3-20 and remove particles. Do not disturb leaf spring attaching screw as this is a critical adjustment which is performed with special equipment. Also take care not to remove pumping plungers. Be sure they remain in their bore. Consider using an air syphon gun with a suitable solvent. Clean advance mechanism parts governor assembly parts, inside of pump housing and inside the check valve.

Absolute cleanliness is necessary.

ASSEMBLY

1. Install new pellethane governor weight retainer ring using #22 Truarc snap ring pliers or equivalent. This operation will take some practice. Stretch holes in pellethane ring over governor weight retainer cage pin and walk into place with circular motion.
2. Align timing marks on retainer assembly and rotor and install governor weight retainer assembly. Figure 3-19.
3. Install governor cage retainer ring (snap ring).
4. Install new hydraulic head seal and lubricate with Synkut oil.
5. Install governor weights, thrust washer (chamfered edge up) and thrust sleeve to the head and rotor assembly. Figure 3-21.

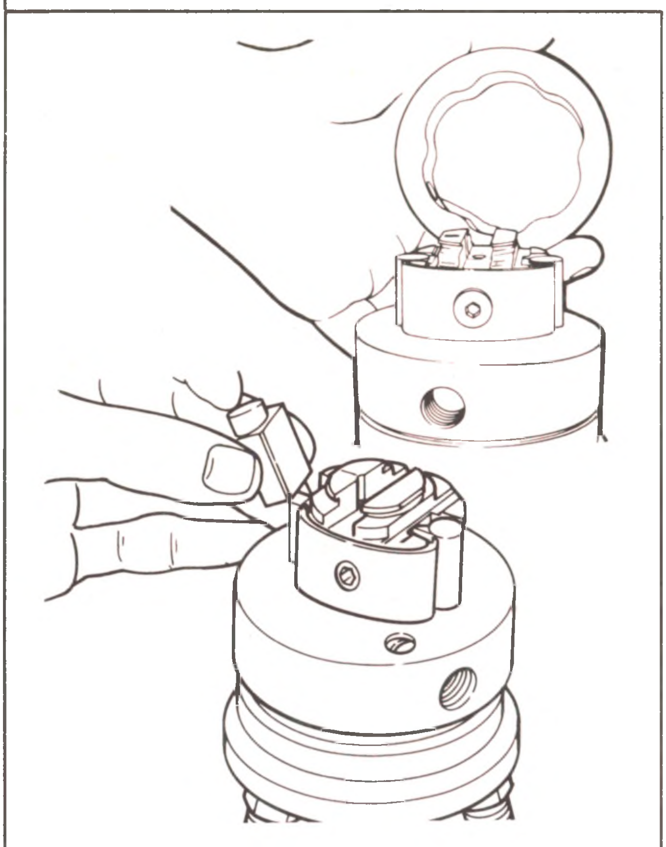


Fig. 3-20 Cam Ring, Shoes and Rollers.

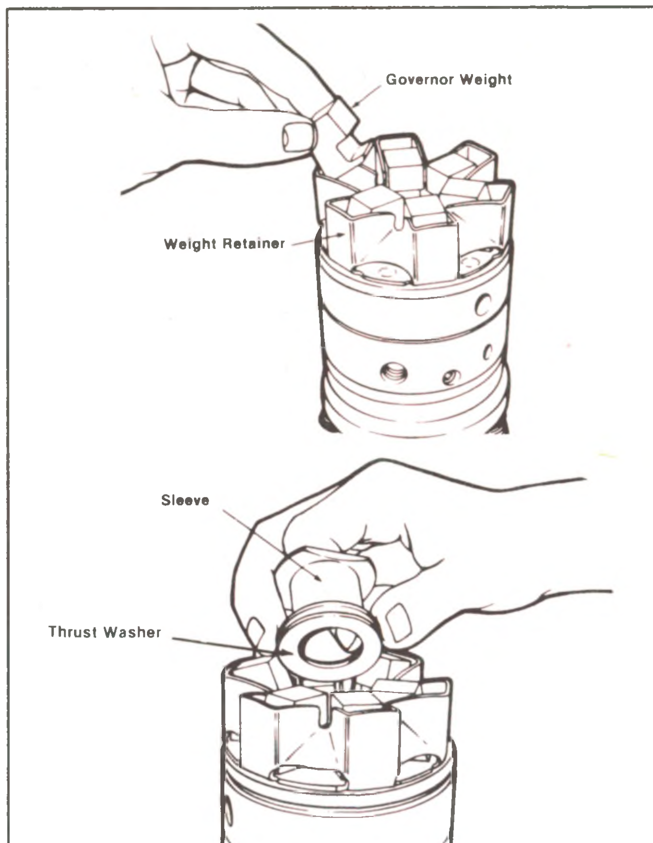


Fig. 3-21 Governor Weights, Thrust Washer and Sleeve.

6. Install the entire head and rotor assembly, making certain that the drive shaft is engaged properly (with "T" mark on drive shaft up, align dots on drive shaft tang and rotor slot). Reverse the action shown in Figure 3-18. Retain assembly with two (2) head locking screws (hand tight). NOTICE: Insertion of the head too far into the pump may cut the housing seal at the vent screw area. If the head goes in further than the locating screw holes, check the housing to see if seal is exposed, if it is, remove and replace the seal.

7. Turn pump upside down and install head locating screw using new head locating screw seals. Torque 15-18 ft. lbs. Then torque the two (2) head locking screws to 15-18 ft. lbs.

8. On all models without external advance, install the cam advance screw using the Bristol tool. Torque to 37-38 ft. lbs. Figure 3-17. Use grease to hold advance piston side washers in place and install the advance screw components, piston hole plug (power side) and piston hole plug (trimmer side), using new seals and lubricate. Torque plugs to 18-22 ft. lbs.

9. On models with external advance install cam pin.

10. Install advance screw hole plug using new seal and lubricate. Torque 75-100 in. lbs. or 6-8 ft. lbs. Reverse the action shown in Figure 3-16.

11. Rotate the drive shaft until timing lines come into alignment. While viewed through timing line opening, check drive shaft to be sure "T" mark is up.

12. Turn pump right side up and install housing vent screw assembly. Reverse the action shown in Figure 3-15.

13. Install metering valve. Figure 3-14.

14. Hook the governor linkage assembly to the metering valve. Figure 3-13. Check linkage for freedom.

15(A.) On external advance models, hold face cam and mylar washer in place and install the throttle shaft assembly, using new throttle shaft seals, and lubricate.

(B.) Install face cam screw and vacuum module drive pin.

16(A.) On all models without external advance, install the throttle shaft using new throttle shaft seals and lubricate.

(B.) Install a new throttle shaft seal washer and reinstall retainer ring.

(C.) Install new vacuum module drive pin.

(D.) On external advance models, install tool J29601 to position face cam and insert a .005" feeler gage between throttle shaft washer and housing. Figure 3-12. Push throttle shaft into housing to remove clearance and torque face cam screw to 17-21 in. lbs. and secure with Loc-tite 290.

17. Install the min/max governor assembly. Figure 3-11.

18. Install the guide stud using a new guide stud washer. Torque to 80-90 in. lbs. Be sure the wire spring on the metering valve assembly rests on the top of the guide stud shaft.

19. Examine check ball in return line fitting for approximately 1/16 inches movement when depressed. If check ball doesn't move, it may be seized by governor weight retainer ring particles and must be cleaned or replaced.

20. Install governor cover with new governor cover gasket using the action shown in Figure 3-22. Test solenoid with 12 volts, listening for audible click when energized. If no click can be heard, remove and reinstall cover and retest until click can be heard signifying proper shut off operation. Without the click the metering valve would be jammed open and if the engine were started, an instant runaway engine would result.

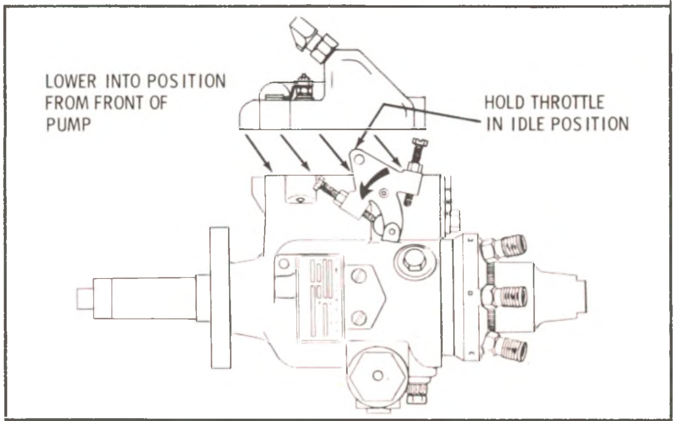


Fig. 3-22 Governor Cover Installation.

21. Install the timing line cover using new timing line cover gasket.

22. Install new pilot tube seal.

Figure 3-23 will show all torque values.

TESTING FOR LEAKS

1. Attach regulated air pressure to the fuel return fitting, use 10-15 psi (DO NOT EXCEED 15 psi) air pressure, emerse the pump in cleaning fluid or fuel oil and check for leaks. Slight leakage from discharge ports or fuel inlet is normal. (Consider plugging inlet port with a plug fitting). Therefore, it is recommended to submerge pump with drive shaft down in vertical position and maintain level just below discharge ports.

2. Install pump on vehicle and check housing pressure before installing air crossover. Incorrect housing pressure will require replacement of the ball check fitting.

DRIVE SHAFT SEAL REPLACEMENT

1. Drive the shaft retaining pin out of the pilot tube from the small hole through the large hole. 1981 model driveshafts are held in place by an "O" ring. Pull on the shaft with circular motion until shaft comes out.

2. Remove the shaft and remove the seals.

3. Clean the shaft.

4. Lubricate the seal installer tool. Polish seal tools with #400 grit paper before first use. This will aid installation of seals.

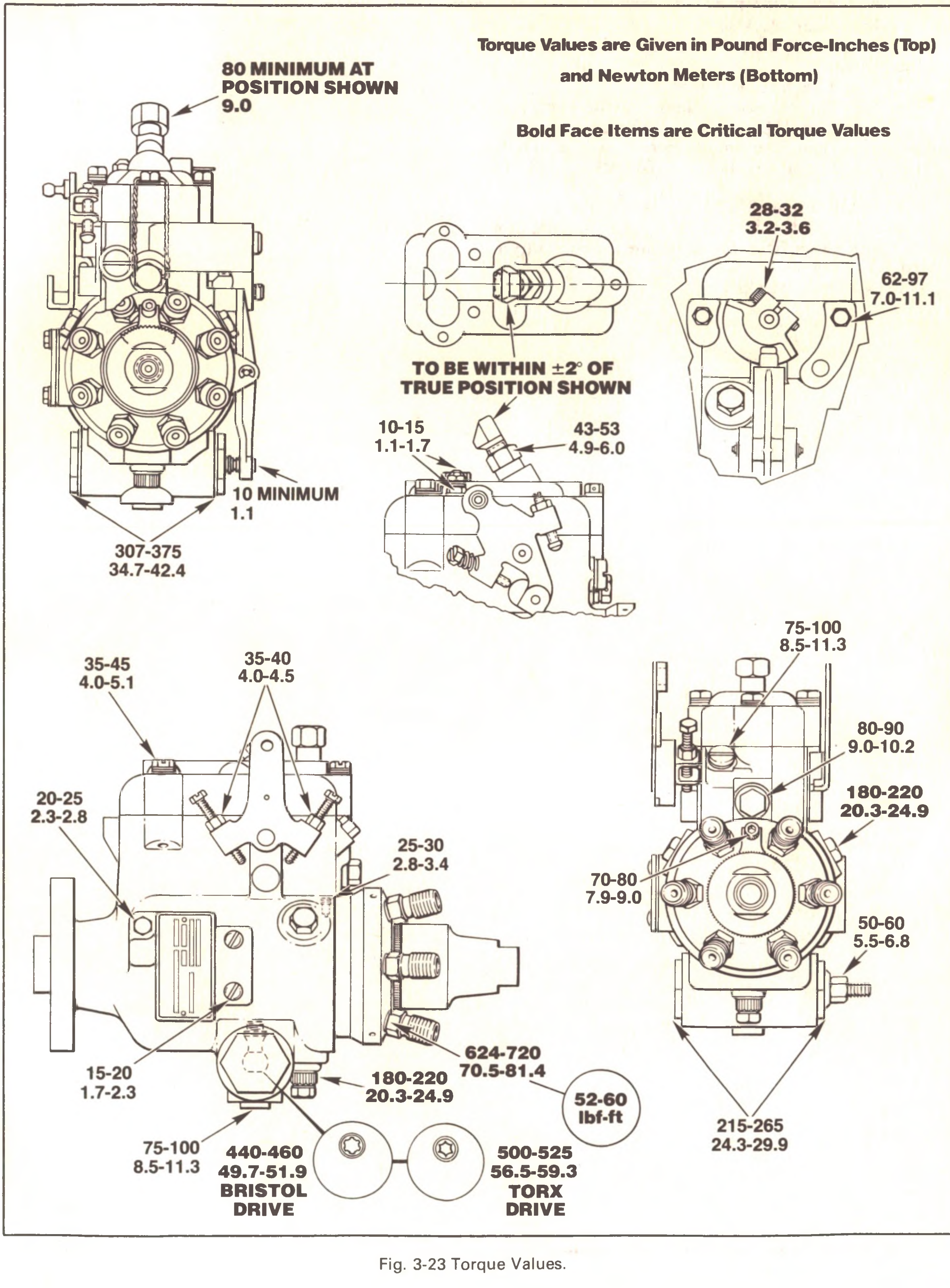


Fig. 3-23 Torque Values.

5. Install one black seal.

6. Relubricate the seal installation tool, and install the red seal.

7. Install the last black seal.

8. Lubricate the seals and reinstall the shaft, making sure that the drill points on the shaft end and the rotor are matched. Use circular motion while seals enter bore area and be sure seals don't fold backwards during installation.

9. Install new shaft retaining pin, driving it through the small hole to the big hole. The pin should not protrude out of either hole. Stone the area if necessary to remove any burrs.

10. Re-test for leaks.

SECTION 4

INJECTION LINES & NOZZLES

From the injection pump fuel is pumped into the high pressure fuel lines. It is essential that each line be nearly identical in length and inside diameter.

Only a small amount of fuel is forced into the line during each injection. This small amount of fuel pushes the fuel already in the line forward, forcing a small amount of fuel at the end of the line through the nozzle and into the combustion chamber. The nozzle restricts the fuel and acts as a shut off valve governed by its opening pressure. During this time, the high pressure has compressed the fuel somewhat and depending on the volume of the line, a greater or lesser compression inside the line occurs. The larger the volume of the line, the more compression takes place, therefore reducing the volume of fuel which passes through the nozzle. Also, the line expands slightly at higher pressures. The larger the diameter of the line the larger the expansion and consequently the less fuel is injected. Because of this, it can now be seen that larger lines will reduce the fuel going into the combustion chamber.

Therefore you can see the importance of each line being nearly identical in length and inside diameter.

Various facets of the nozzle's operation can also affect volume of fuel which enters the combustion chamber.

Two different types of nozzles are used — the pencil type and the poppet type.

The pencil type Figure 4-1 will be found on all 1978 and 1979 models and various 1980 and 1981 models. It is a closed end (nozzle valve does not project through an opening in the nozzle tip), differential pressure, hydraulically operated, hole-type nozzle. The nozzle body incorporates the inlet fitting, tip and valve guide. An edge filter is located in the inlet fitting, which is designed to be a final screening for debris which may have entered while line was open such as while on workbench. The inward opening valve is spring loaded and controlled by the pressure adjusting screw and lift adjusting screw which are secured by locknuts. These adjustments are very critical and can only be adjusted on a flow meter. No attempts should be made otherwise. A nylon seal beneath the inlet fitting "banjo" prevents leakage of engine compression while a Teflon carbon dam prevents carbon accumulation in the cylinder head bore.

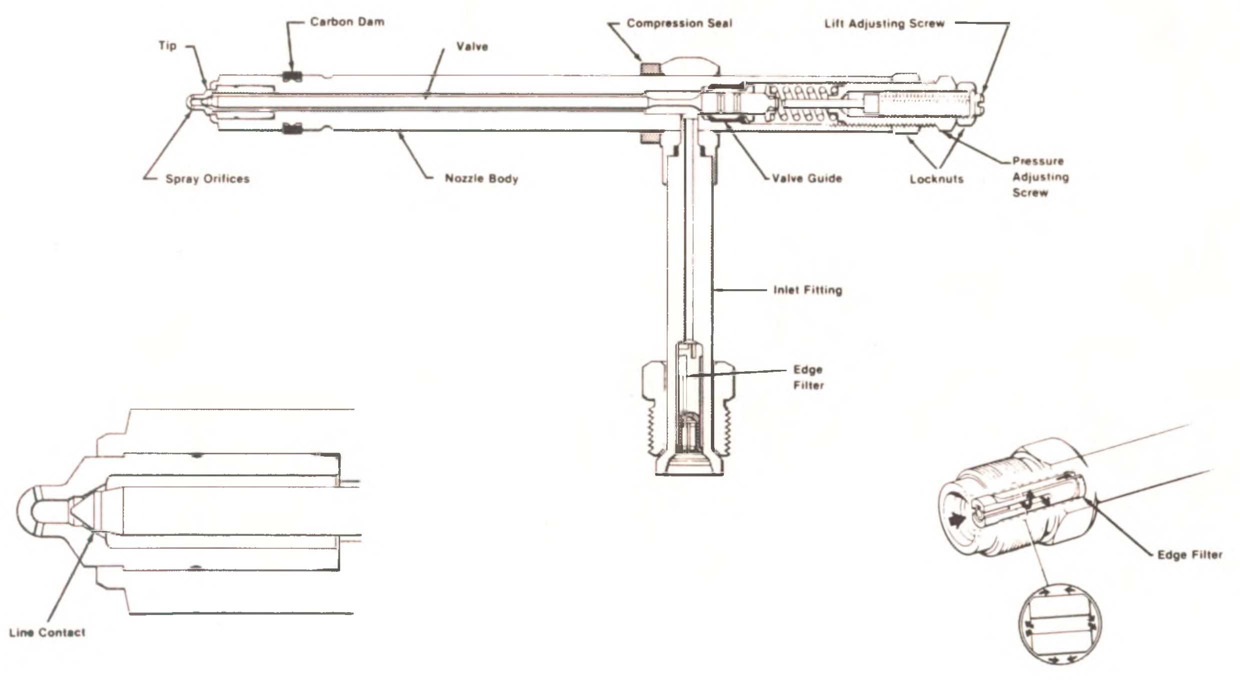


Fig. 4-1 Typical Roosa Master Pencil Type Nozzle

Metered fuel, under pressure from the injection pump, flows through the inlet, the edge filter, and around the valve, filling the nozzle body.

When fuel pressure enters the body of the nozzle and overcomes the spring force of the pressure adjusting spring, the nozzle valve lifts off its seat. As the valve raises to its predetermined lift height, high pressure fuel is allowed to flow through the spray orifices in the tip. When delivery to the nozzle ends and injection pressure drops below the preset nozzle opening pressure, the spring returns the valve to its seat.

Between injections, positive sealing is maintained by the interference angle, which results in line contact between the valve and its seat.

During injection, a small amount of fuel leaks through the clearance between the nozzle valve and its guide, lubricating and cooling all moving parts. The fuel flows through a leak-off boot at the top of the nozzle body and returns to the fuel tank.

The pencil type nozzle is installed into the cylinder head and held in place with a clamp and bolt.

The poppet style nozzle will be found on various 1980 and 1981 models. Figure 4-2. It is screwed directly into the cylinder head and is equipped with a nozzle having an outward opening, spring-loaded poppet valve in contrast with the inward opening valve of a conventional diesel fuel injector.

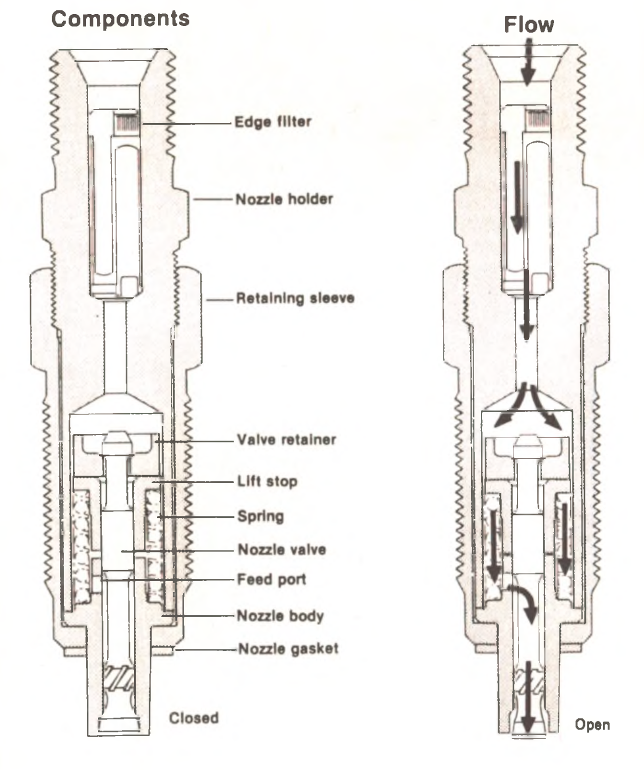


Fig. 4-2 Poppet Nozzle Cutaway

Since engine compression and combustion pressure forces on an outward opening valve are additive to that exerted by the nozzle spring, opening pressure settings of the poppet nozzle are correspondingly lower than those of conventional injectors. Furthermore, since the nozzle valve guide is not required to seal against injection pressure, this nozzle does not require a backleakage connection.

During injecting, a degree of swirl is imparted to the fuel before it emerges around the head of the valve, which forms a closely controlled annular orifice with the valve seat. The resultant high-velocity atomized spray forms a narrow cone for efficient burning of the fuel.

The assembly consists of a nozzle holder with integral edge filter, a preset nozzle assembly, a capnut and a cylinder head sealing washer.

For servicing purposes these four items, either singly or in combination, are the only replaceable parts, i.e. the component parts of the present nozzle assembly must not be adjusted or interchanged.

Fuel at injection pressure flows to the axial inlet on the nozzle holder and passes via the edge filter to the spring chamber. Feed ports in the nozzle body allow fuel to bypass the close-fitting valve guide diameter and reach the valve head via the swirl helices. The valve lifts at the opening pressure determined bye spring setting pre-load and continues to move until the stop fitted below the collar abuts the nozzle body. At the end of injection, the valve returns to its seat under spring action, the seating load being augmented by engine combustion pressure.

Poppet nozzles used in production will come from two sources; Diesel Equipment Division (of GM) and C.A.V. Lucas. Both are similar in design and construction and are interchangeable. The D.E.D. nozzle compression washer is staked in place and must be destroyed for removal whereas the C.A.V. Lucas compression washer is replaceable. Figure 4-3 shows identification and torque values.

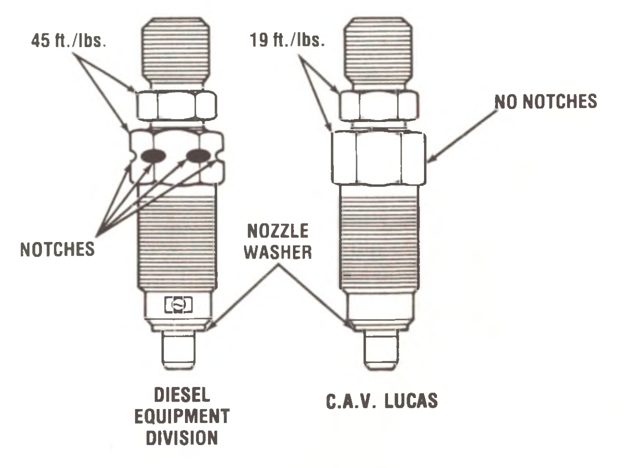


Fig. 4-3 Poppet Nozzle Identification

SECTION 5
ROUGH IDLE DIAGNOSIS

Rough idle is caused by variable power output between cylinders as they fire in sequence. The following can cause variable fuel flow to each cylinder and therefore, its relative power output.

- Air in fuel system
- Nozzle opening pressure
- Nozzle tip leakage (seat tightness)
- Injection line volume and internal diameter
- Line fitting leakage — normally this engine uses approximately .3 gal per hour at idle, and considering one wet nozzle out of eight cylinders, the amount of fuel being consumed is so small that even a damp, not yet dripping nozzle fitting can cause that cylinder not to fire
- Injection pump output
- Injection pump low speed governor sensitivity

Since the introduction of the vented rotor feature, the injection pump has become very sensitive to nozzle and injection line variables. Rough idle and/or coast down roughness may be caused by too great a sensitivity of the min-max governor. A kit has been developed to reduce this sensitivity for roughness up to 900 RPM. Coast down roughness can be verified as engine roughness or tire and wheel waddle by coasting down through the roughness period while in neutral and engine running at 1500 to 2000 RPM. If roughness is gone, install kit. During mid 1981, the new min-max governor has been phased into production. A blue daub of paint on the mounting flange will indicate the new style governor has already been installed at the factory.

The first step in correcting rough idle should be the installation of the min-max governor sensitivity kit. Dealer technical bulletins are available which also describe this procedure.

1. Remove min-max governor as described earlier in Section 3.
2. Discard idle spring and sleeve as shown in Figure 5-1.

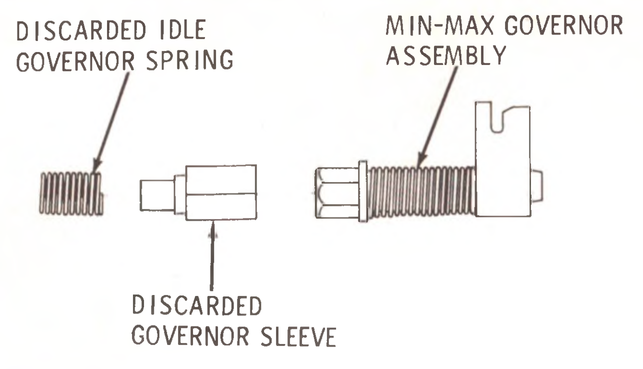


Fig. 5-1 Discarded Min-Max Governor Parts

3. Install plain colored idle spring insert (pin) through small end of the new spring. (The red idle spring insert has the head ground off approximately .017 in. is only to be used in the event that idle speeds can't be set to specifications. If idle still cannot be set to specifications with installation of red pin, pump will require recalibration on a test bench).
4. Install sleeve on to min-max governor as shown in Figure 5-2 and reinstall into pump.

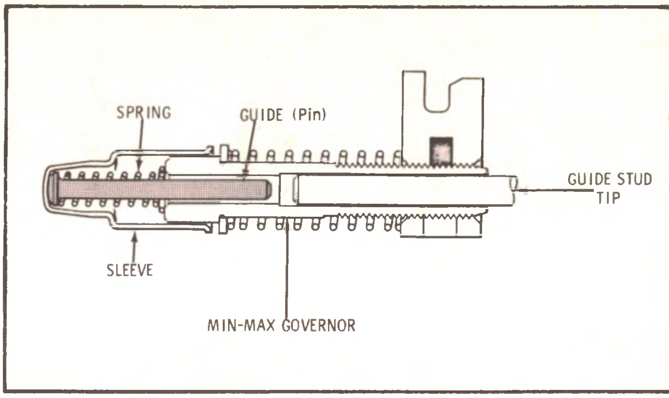


Fig. 5-2 Min-Max Governor Kit Installed

5. Apply blue daub of paint to mounting flange.

In the event that the kit installation does not completely correct the roughness condition, the following should be performed step by step.

- Brand new cars should have at least ¼ tank of fuel and it may be necessary to run engine at high RPM to purge air from system.
- Remove air cleaner and install magtach. Check slow and fast idle speed and correct as necessary. Adjust high vacuum switch if fast idle was adjusted.
- Check timing mark on injection pump for correct alignment and align if necessary. Never adjust timing while engine is running or serious personal injury could result.
- Disconnect vacuum hose from vacuum pump and observe idle quality. If idle improves, reinstall vacuum hose to pump. Loosen vacuum pump hold down clamp. Rotate pump in engine. If idle improves, clamp in that position. If idle does not improve, remove vacuum pump and reinstall with drive gear in different relationship to camshaft.
- Since the vacuum pump and the injection pump are both powered by the camshaft, it is possible that the power required for vacuum pump operation may coinside with injection pump pulses and set up a fore and aft action of the camshaft. This fore and aft camshaft movement can change the pump timing several degrees because the injection pump drive and camshaft gears

mesh with a beveled cut. If idle still has not improved after re-installing vacuum pump, remove the engine front cover and camshaft bolt. Install a revised bolt, camshaft bottom and spring. This will minimize on fore and aft camshaft movement. Figure 5-3. Refer to technical bulletins for part numbers.

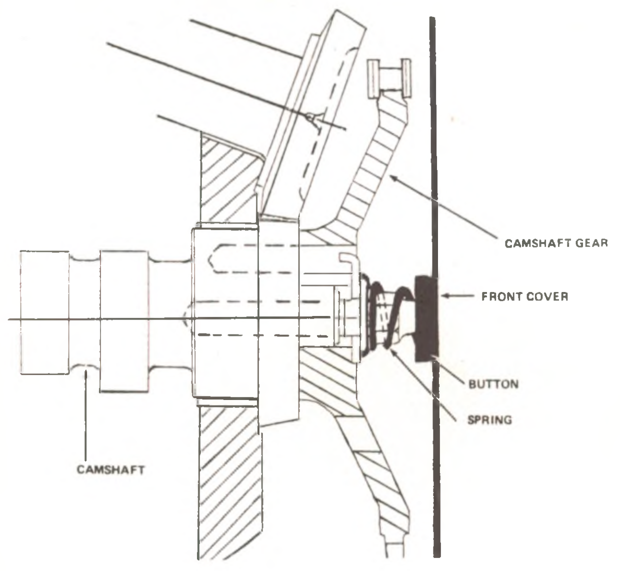


Fig. 5-3 Camshaft Thrust Button and Spring

This button and spring has been phased into production on mid year 1981 engines.

• Some fore and aft movement could also occur between the injection pump driven gear and driveshaft if the injection pump shaft spring is missing. The spring part #22502241 should be present in the driveshaft slot.

• With engine running, check for fuel pressure by cracking line at fitting between fuel filter and injection pump. If low pressure is evident, determine cause such as plugged filter or faulty fuel pump.

• Check for dampness or dripping of fuel at injection pump high pressure line connections (engine running) and correct if necessary.

• With engine running, examine nozzles for leaks at nozzle body or fuel line connection and correct if necessary.

Leakage between the nozzle inlet fitting and nozzle body may be corrected by loosening the inlet fitting nut and retorquing. The correct torque for a CAV Lucas nozzle inlet fitting nut is 19 ft. lbs. However, the Diesel Equipment Division nozzle inlet fitting nut must be torqued to 45 ft. lbs. Damage will result if nozzle inlet fittings are overtorqued.

• Remove fuel return line from top of pump. Install a short piece of clear plastic tube between return line and check for presence of bubbles or foam in tube with engine running. If bubbles are evident find cause and correct as necessary. Use the procedures found in Section 2.

• With engine running, loosen the line at the nozzles one at a time to bleed a small amount of fuel from the line. The engine may stall if the line is opened too far. If solid fuel appears, go on to the next nozzle. If foam appears shut the engine off and disconnect the line from the nozzle. Move the line so the inlet to the nozzle can be observed. Remove the pink wire to the pump and crank the engine and observe the nozzle inlet for bubbles.

Bubbles will indicate that the nozzle is leaking some engine compression. If bubbles are evident, replace the nozzle. Squirt some oil or fuel in the new nozzle inlet and recheck for bubbles. If bubbles are not evident, reconnect the line and go on to the next nozzle and repeat the process. Check any removed nozzle on a tester to determine if it is inoperative or if it is incompatible with the cylinder head. The nozzle may not be defective. Sometimes a nozzle in a certain head may leak but it can be OK in another head.

The compression washer on a 1980 model CAV Lucas nozzle is held in place by an interference fit. If lost or damaged, the washer can be purchased from a local Roosa-Master dealer, most of which are also CAV Lucas dealers.

The compression washer on a D.E.D. nozzle is staked into a groove in the tip. Parts are available from G.M.P.D. or use C.A.V. washer and pinch in place with pliers.

NOTE: It is essential that the fuel return and nozzles steps be performed prior to the ommeter test. The glow plug resistance checks will not show these conditions.

• Perform glow plug resistance test procedure as follows:

(This procedure is a means of determining the relative output of each cylinder. The greater the difference in output between cylinders the more likely the idle will be unacceptable. It provides a means of tailoring injection nozzles and lines to a particular engine/pump combination to provide uniform power output between cylinders and therefore, smoothing out the idle quality. The glow plug is actually used as a thermister to measure the heat in each cylinder and therefore the relative output.)

1. Use Kent-Moore high Impedance Digital Multimeter (Tool No. J-29125). It is important to use a strong

9V Alkaline Battery because of the low ohmmeter readings.

2. Select scales as follows: LH Switch to "OHMS," RH Switch to full counterclockwise. "200," center slide to the left "LO.DC."

3. Start engine, turn the heater on and allow engine to warm up. Remove all the feed wires from the glow plugs.

4. Adjust engine speed by turning the idle speed screw on the side of the injection pump. Adjust RPM to the worst engine idle roughness, but do not exceed 900 rpm (860 is the most likely speed to get roughest idle).

5. Allow engine to run at that speed for at least one minute. The thermostat must be open and the upper radiator hose hot.

6. Attach an alligator clip to the black test lead of multimeter. This clip must be grounded to the engine lift strap on the left-hand side of the intake manifold. It must remain grounded to this point until all tests are completed.

7. With engine still idling, probe each glow plug terminal and record the resistance values in firing sequence. Most readings will be between 1.8 and 3.4 OHMS. If these readings are not obtained, turn engine "OFF" for several minutes and check the glow plugs. The resistance should be .7 or .8 OHMS. If this reading is not obtained check meter for correct settings, use the specified battery in the meter and re-check the ground.

8. The resistance values are proportional to the temperature in each cylinder, and therefore proportional to the output of each cylinder.

9. If ohm reading on any cylinder is about 1.2 or 1.3 ohms, check to see if there is a mechanical condition. Make a compression check on the low cylinder and the cylinders which fire before and after lower cylinder. Correct the cause of the low compression before proceeding to the fuel system.

10. Examine the results, looking for differences between cylinders. Normally, rough engines will have a difference of .3 ohms or more between cylinders in firing order. It will be necessary to raise or lower the reading.

11. Remove the nozzle from the cylinder in which you wish to raise or lower the ohm reading. Determine the pop-off pressure of the nozzles with nozzle tester. Make certain that the tool used for injector removal is clean.

A. Opening pressure test —
The pressure gage valve should be opened approximately a turn or two. Raise the pressure to 200-300 p.s.i. below the opening pressure with the handle. Then close the gage valve. This will displace fluid gradually raising the pressure until the nozzle opens.

Caution: Test fuel spray is inflammable. Keep vapor away from open flames or personal injury could result.

When testing nozzles, do not place your hands or arms near the tip of the nozzle. The high pressure atomized fuel spray from a nozzle has sufficient penetrating power to puncture flesh and destroy tissue and may result in blood poisoning. The nozzle tip should always be enclosed in a receptacle, preferably transparent, to contain the spray. (Rags in the bottom of the container will reduce chances of splash.)

B. Seat Tightness —
Slightly open the line pressure gage for this test. The line pressure should first be allowed to fall at least 290 psi (2000kPa) below the actual opening pressure. Dry the nozzle tip with compressed air then increase the line pressure to 200 psi (1500kPa) below the actual opening pressure. Maintain this pressure for 5 seconds. After 5 second patterns 1, 2 and 3 are acceptable, patterns 4 and 5 are not acceptable. As shown in Figure 5-4.

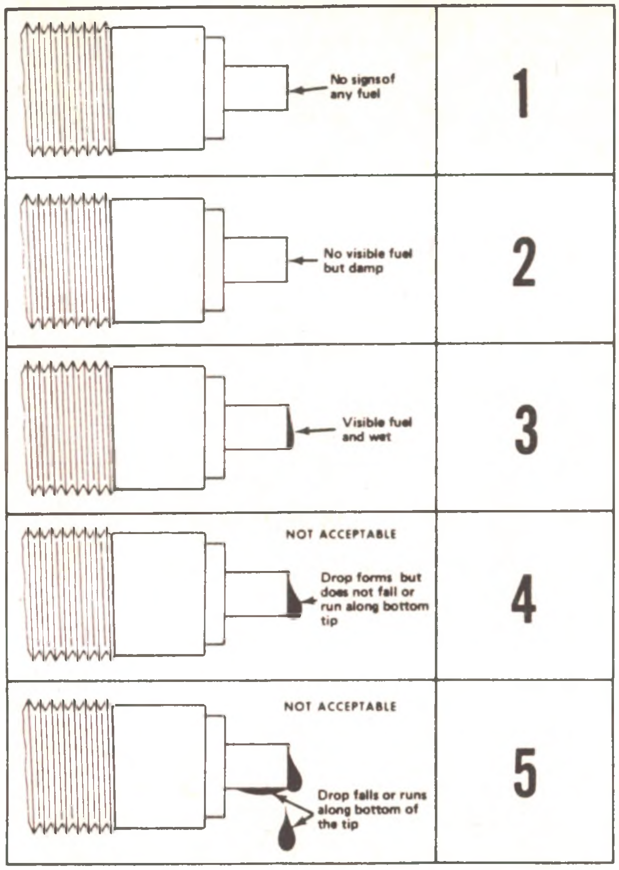


Fig. 5-4 Poppet Nozzle Seat Tightness Check

C. Spray Pattern —
Spray pattern should only be checked for atomization near the tip of the nozzle. Any small droplets or solid columns of fuel visible within approximately 1/2 inch of the nozzle tip are unacceptable. Operate the handle of the test equipment at a rate of 30 strokes per minute. Also, make sure the pressure gage valve is closed before checking the spray pattern or a bad spray pattern may be obtained.

Disregard the spray patterns shown in service manuals and other Technical Publications as they will no longer be used. Instead it is more important to check nozzles for seat tightness and for opening nozzle pressure. When a nozzle passes these two tests the spray pattern with the nozzle in the engine is nearly always satisfactory. As long as it chatters it is ok. If it does not, make sure it does atomize fuel.

D. Install nozzles with higher pop-off pressure to lower the ohm reading and nozzles with lower pop-off pressure to raise an ohm reading. Normally a change of about 30 psi in pressure will change the reading by .1 ohm. Nozzles normally will drop off in pop-off pressure with higher mileage.

E. Nozzle Cleaning —
On engines with poppet nozzles, opening pressure, seat tightness and spray pattern can all be affected by dirty nozzles. Rough idle, excessive noise and/or smoke may be the result of injection nozzles that require cleaning. If the injection nozzles are determined to be the cause of this condition, the following procedures should be used to clean the injection nozzle prior to testing:

- Remove the injection nozzle from the engine.
- Remove and discard old copper sealing washer from the tip of the injector.
- Disassemble the injection nozzle referring to Figure 5-5 as follows:

A. Unscrew the inlet fitting from the body and press the nozzle tip assembly out of the body.

B. Remove the retainer by sliding the retainer sideways to release the retainer from the valve.

C. Remove the spring seat, spring, and press the valve from the spray tip.

- Clean all of the disassembled pieces of the injection nozzle. Use a sonic bath cleaner or equivalent. Take care not to place nozzle valve and spray tip on metal workbench as it is absolutely essential that edges remain sharp.

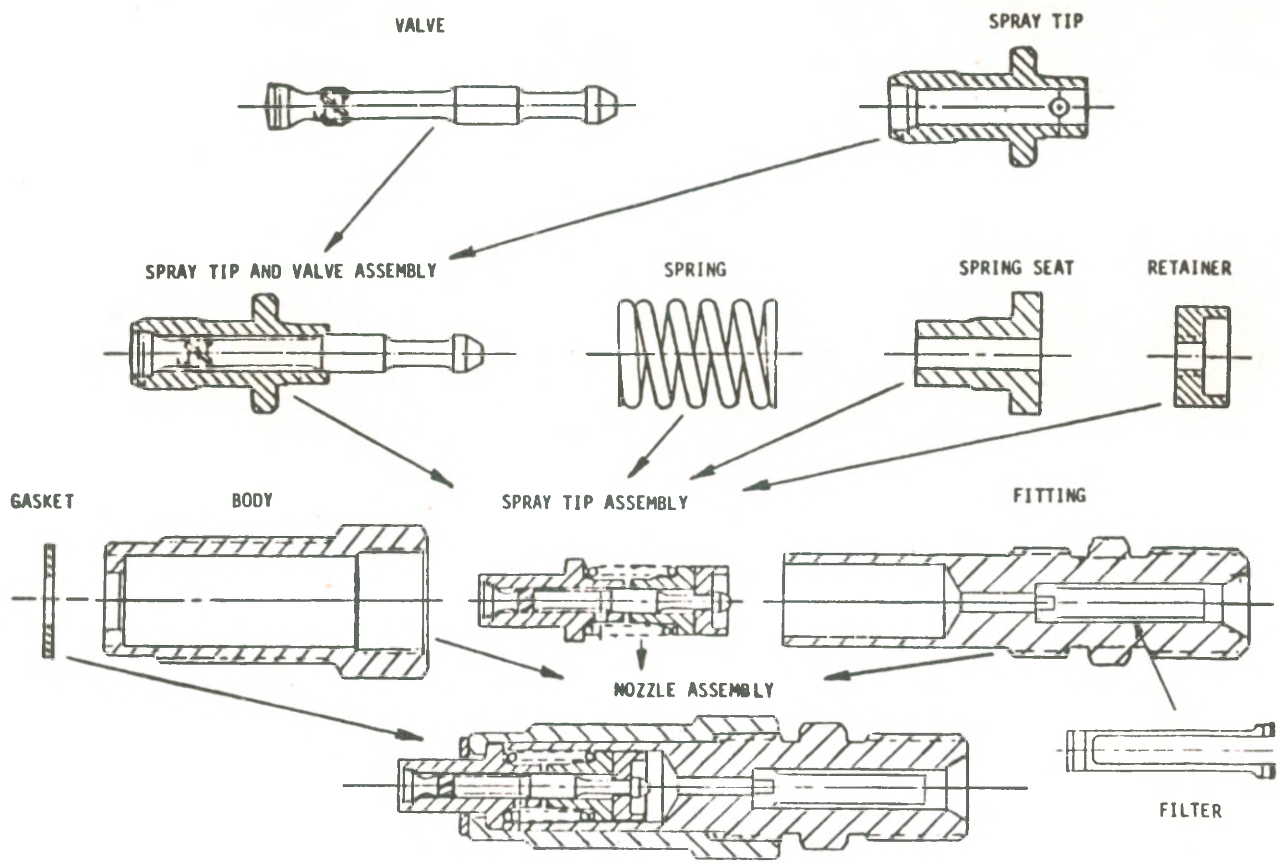


Fig. 5-5 Poppet Nozzle Assembly — Exploded View

• Visually inspect all of the components for cleanliness and damage. The tip of the valve and the interior of the spray tip must be examined very closely. These areas must be completely free of contamination to be satisfactory. The spray tip, valve, spring, spring seat and retainer (called the nozzle assembly), must never be intermixed with other nozzles as they are a matched assembly. However, the injector body and inlet fitting are not as critical and can be intermixed. Never lap nozzle parts.

• If the components are visually satisfactory, assemble the injector as follows:

A. Insert the valve into the spray tip.

B. Install the spring, spring seat and retainer.

C. Compress the spring and lock the retainer by pushing on the retainer and sliding the retainer to a center position after the spring has been compressed. After assembly, rotate the retainer with respect to the tip, by hand, to assure proper assembly.

• Install the nozzle tip assembly into the body. Screw the inlet fitting into the body assembly and tighten to (19 ft. lbs.) C.A.V. (45 ft. lbs.) D.E.D.

• Test the nozzle as outlined in the Service Manual.

• Install a new copper washer before assembling into the engine. Part #5233623 is the washer for D.E.D. nozzle. C.A.V. washers must be obtained at local Lucas (usually Roosa Master as well) service shop. C.A.V. washers can be re-used.

Pencil nozzles should not be disassembled for cleaning. Prior to cleaning, a quick check of the nozzles should be performed on the pop tester which may reveal any unusual conditions such as plugged holes. Remove carbon dam seal from the tip of the nozzle with sharp knife or razor blade. Do not damage groove. The only cleaning of pencil nozzles recommended is to brush loose carbon from the tip to the carbon dam seal groove with a "brass" wire brush. Do not use motorized equipment or steel wire brushes for this purpose, as they will destroy the orifices. See Figure 4-1.

Normally, the Teflon coating will stain in this area. Such staining is not detrimental. Carbon accumulation should be removed, but excessive brushing will remove the Teflon coating . If carbon removal by this method proves to be too difficult, a cleaning fluid formulated to soften carbon may be used.

12. If you are unsuccessful in correcting the rough idle with nozzle changes or the resistance values do not change when different nozzles are installed, the high pressure line needs to be checked. Generally it will not be necessary to check all lines. Only the suspected line or lines need be checked.

A. Remove injection line from engine and clean by blowing through with compressed air.

B. Each end of the tube should have a minimum diameter of .070 inches. (1980 engines with poppet nozzles only). Use the shank of a No. 50 drill. If it will not enter drill it out and blow the tube clean with compressed air. 1981 pipes are formed differently, consequently this operation is not required.

C. Prepare a 3cc Hypodermic syringe by installing a short piece of vacuum hose or rubber grommet or other suitable seal that will seal one end of the injection line when the syr nge is held tightly against the line.

D. Using windshield washer fluid, (do not use diesel fuel because it will swell the syringe seals) draw back into the syringe 3cc of fluid and eject ½cc back out to remove the air from the syringe.

E. Hold the line in as near vertical position es possible and press prepared syringe tightly against the lower end of the line fitting.

F. Slowly inject the fluid into the lower end of the line, when fluid appears out the other end, determine how much has been injected into the line by reading the syringe. Blow injection lines out with compressed air and recheck.

Low volume lines cause high ohm readings and high volume line cause low ohm readings.

Large lines can cause the nozzles to be ineffective. With large lines, nozzle changes may not change the cylinder readings.

Obtain and install larger volume lines or smaller volume lines based on findings.

13. An injection pump change may be necessary if the following occurs:
A. If the problem çylinder moves from cylinder to cylinder as changes in nozzles or lines are made.
B. If cylinder ohm readings do not change when nozzles and/or lines are changed.

NOTE: It is important to always recheck the cylinders at the same rpm.

Sometimes the cylinder readings do not indicate that an improvement had been made although the engine may in fact idle better.

SECTION 6
SMOKE DIAGNOSIS

Three different types of smoke will be reviewed in this section. Black, white end blue.

BLACK SMOKE

Black smoke is the most common smoking complaint. Diesels are usually rated according to the maximum horsepower developed at the "smoke limit." At a certain speed, a definite amount of air enters the cylinder. This amount of air is sufficient to produce complete combustion of a given quantity of fuel. If more fuel is injected, overloading the engine beyond the rated horsepower, there will not be sufficient air for complete combustion and black smoke will result. Under these conditions, the black smoke contains a large quantity of unburned carbon (soot) formed by thermal decomposition of the fuel in the over-rich mixuture in the cylinder.

The injection pump is incapable of delivering rich or lean mixtures. Therefore any variable that increases fuel or reduces the amount of air taken into the cylinder will increase the tendency to produce black exhaust smoke.

Some sources of black smoke directly related to improper burning of fuel are:

- Air into injection pump
- Fuel return restricted (both of the above will change automatic advance)
- Pump timing advanced (usually will be accompanied by excess combustion noise)
- Wrong fuel
- Excess fuel delivery from nozzles due to low opening pressure or struck nozzle.
- Less than 5½ lbs of fuel pump pressure

Although not directly fuel related some indirectly related sources of black smoke are:

- EGR stuck open (at w.o.t. only)
- Restricted exhaust
- Low compression
- Clogged air inlet
- Missing prechamber (causes black smoke when hot and white smoke when cold)

Presence of prechamber can be checked externally. To check, remove glow plug and insert a probe into the prechamber. If more than 2⅜" - 2¾" of the probe can be inserted, prechamber is missing

The fuel variables that can affect black smoke are gravity (an indirect measure of heating value), viscosity, and cetane number. An engine may smoke when a fuel of lower gravity is used. This is an overfueling problem that occurs because injectors meter fuel on a volume basis and low gravity fuels have more Btu's per gallon, and therefore, less fuel is required for equal power, equal air utilization, and equal smoke.

Increasing viscosity can also cause overfueling by reducing the leakage in the injection pump, thus allowing more fuel to be injected into the cylinder.

In engines which are sensitive to cetane number, the tendency toward black smoke is greater as cetane number increases. The short delay period of a high cetane number fuel assures that some raw fuel is sprayed into an established flame where the atmosphere is too lean for complete combustion.

WHITE SMOKE

At light loads, the average temperature in the combustion chamber may drop 500 degrees due to the decreased amount of fuel being burned. As a result of the lower temperature, the fuel ignites so late that combustion is incomplete at the time the exhaust valve opens and fuel goes into the exhaust in an unburned or partially burned condition producing the white smoke. Under these conditions, a higher cetane fuel or a more volatile fuel will tend to promote better combustion and reduce smoke. Any operating variable (jacket temperature, inlet air temperature, etc.) that increases compression temperature or reduces ignition delay will improve the white smoke problem. White smoke is considered normal when the car is first started but should stop as the car warms up. A continuing white smoke condition could indicate a loss of compression. Retarded timing and plugged fuel return can cause white smoke.

BLUE SMOKE

Blue smoke indicates that engine oil is burning in the cylinders and may be accompanied by excessive oil consumption.

Some mechanical conditions which should be considered are:

- Worn piston rings
- Failed valve seals
- Faulty crankcase vent valve

Some non-mechanical checks would include:

- Lube oil level too high
- Fuel oil in crankcase
- Wrong Dipstick

SECTION 7
M.P.G. DIAGNOSIS

The diesel, like any engine, is affected by driving habits. Speed is more critical on a diesel than a gas engine. On the highway, in the 50 to 75 mph range, the fuel economy will go down about 3 mph for each 10 mph increase in speed. A gasoline engine will lose about 1½ mpg for each 10 mph increase in speed. This condition is perhaps the most significant factor in obtaining good fuel economy. Fuel economy may vary as much as 5 mpg in a given vehicle with different drivers. M.P.G. will increase with use of a steady foot, easy acceleration and light braking. Most drivers are unaware of their "jerky" driving habits. If the owner either traded in or still has a higher performance vehicle, it may be a case of driving the diesel excessively hard trying to match this performance, but at the same time reducing fuel economy.

The type and condition of a trade-in, if there was one, could be a clue to the owner's driving habits. Another indication which would be very revealing would be a road test with the owner driving. Since most owners are unaware of their habits, it may be valuable to observe if the accelerator pedal is "pumped" excessively. Stop and go driving uses more fuel and hilly terrain will call for more accelerations, using more fuel.

Mechanical conditions of the vehicle both engine related and non-engine related, also effect mpg. In diagnosing poor fuel economy complaints, first determine if other conditions such as excessive smoke or poor performance or unusual noises are also present.

Some non-engine related items which play an important part in the fuel economy process are:

- Tires and inflation pressure — snow tires, radial types included, will drop fuel mileage by nearly two miles per gallon. Standard inch size tires used in place of metric size tires can generate as high as a 6% error in speedometer readings.
- Speedometer error
- Axle ratio
- Transmission malfunctions
- Weather — cold weather and increased viscosity of all lubricants in the power train (especially wheel bearing grease), stiffer tires, and driving through snow, slush, and ice require more power with a corresponding decrease in mileage.

Some engine related items which should be understood are:

- Engine compression — heat of compression is essential
- Missing or improperly installed prechambers can result in poor combustion
- Non-functioning glow plugs will result in poor combustion during engine warm-up
- A plugged air cleaner element or restrictions in the air intake system will cause a richer running condition.
- Plugged exhaust
- Worn camshaft or lifter will impair engine breathing
- Thermostatic fan — If the viscous drive in the thermostatic fan fails or locks up, the fan will be forced to operate at constant engine speed and will produce a very significant drop in mileage. Malfunction is easily recognized by continuous roar from the engine cooling fan.

Some fuel related items are:

- Fuel type and quality — The heating valve of No. 1 Diesel fuel is about 5% less than No. 2 diesel fuel. Gasoline mixed with diesel fuel will also reduce the heating value of the fuel and reduce fuel economy. Winterized blends usually fall somewhere between no. 1 and no. 2, depending on the blend and consumption decreases commensurately.
- Fuel line leaks
- Restricted fuel return line retards advance mechanism
- Pump timing — During factory calibration the pump dynamic timing mark is placed within one quarter degree electronically. Retarding the pump will result in quieter operation with less smoke. Advancing the pump will be noisier with some increase in smoke. "Right on" timing is best for maximum economy.
- Automatic advance malfunction usually demonstrates poor idle or poor part load performance with smoke and low power at higher speeds.
- Defective nozzles — (many possibilities here) opening pressure below spec., valve lift incorrect, excessive seat leakage, sticking or stuck-open valve.

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