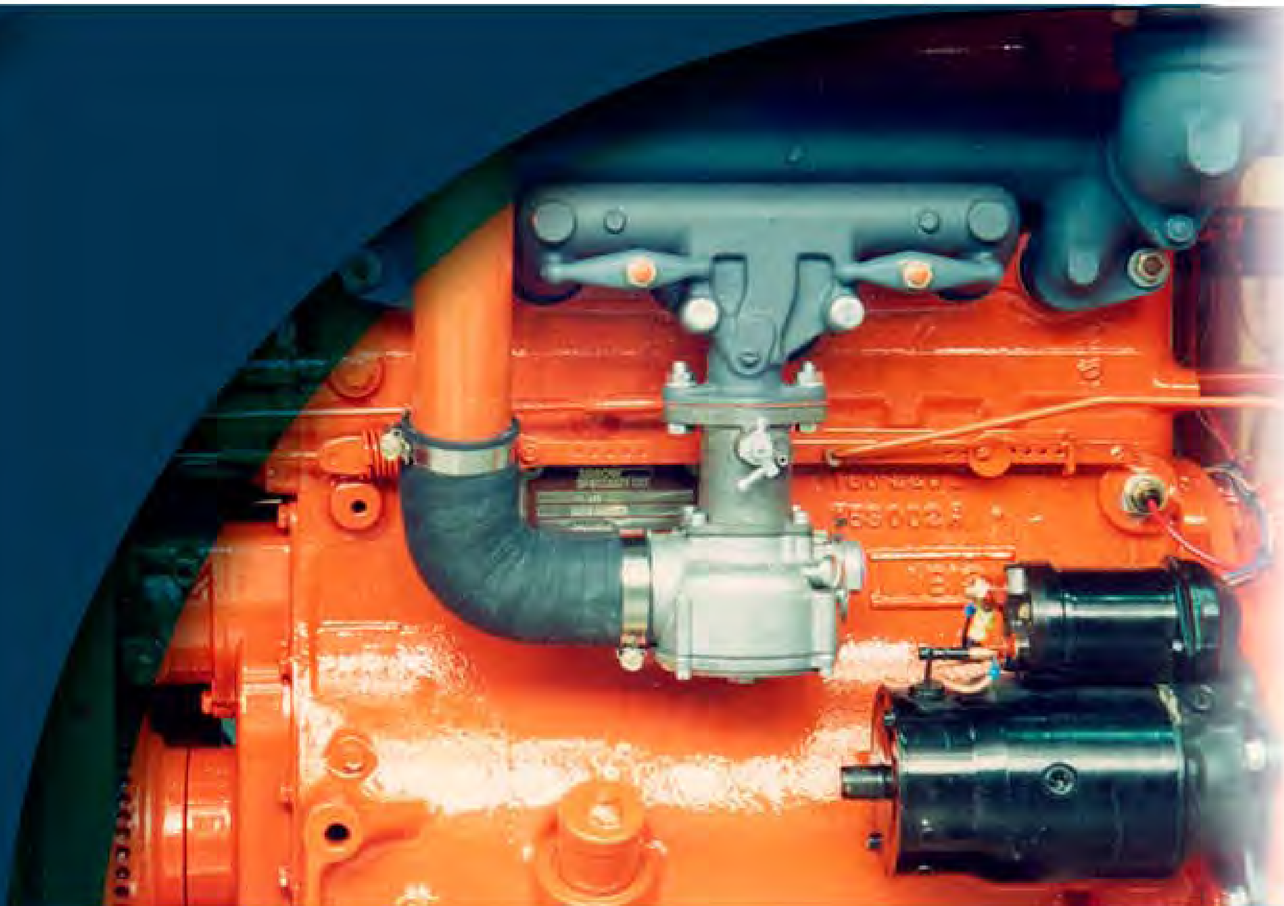

VR 155 232 265 283 310
OPERATION & MAINTANANCE

ARROW ENGINE COMPANY
a TRIMAS company
5608 January 2006

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ARROW ENGINE COMPANY

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SAFETY PRECAUTIONS

For details on safety rules and regulations in the United States, contact your local Occupational Safety and Health Administration (OSHA).

These safety precautions are published for your information. Arrow Specialty Company does not, by the publication of these precautions, imply or in any way represent that these published precautions are the sum of all dangers present near industrial engines. If you are operating industrial engines, it is your responsibility to ensure that such operation is in full accordance with all applicable safety requirements and codes. All requirements of the United States Federal Occupational Safety and Health Administration Act must be met when Arrow engines are operated in areas that are under the jurisdiction of that United States department. Engines operated in countries other than the United States of America must be installed, operated and serviced in accordance and compliance with any and all safety requirements of that country which may be applicable.

BODILY PROTECTION

Wear OSHA approved bodily, sight, hearing and respiratory system protections. Never wear loose clothing, jewelry or long hair around an engine.

EXHAUST GASES

Engine exhaust products are toxic and may cause injury or death if inhaled. All engine installations must have an exhaust discharge pipe so that exhaust gases are delivered into the outside air. A closed building or shelter must be adequately vented to provide a steady supply of fresh air.

ENGINE FUELS

Engine fuels are highly combustible and may ignite or explode. Fuels must be conducted to the engine with proper piping, free from leaks, and designed to resist breakage from vibration. When filling fuel tanks, never smoke or use open flame in the immediate area. Fuel tanks should be grounded to prevent buildup of static electricity. If a gas engine has been cranked excessively without starting, shut off the gas fuel supply and ignition. Then crank the engine to purge the cylinders and exhaust system of accumulated, unburned gas. If you fail to do this, a spark plug could ignite the gas and cause an explosion.

POSITIVE FUEL SHUT-OFF

Some means of positive fuel shut-off should be provided for emergency use. Pressurized fuels (natural gas, liquified petroleum gas, etc.) should have another positive shut-off valve, preferably automatic, other than those in carburetor or gas pressure regulation equipment. It is the final responsibility of the engine owner to ensure that the installation is free from fuel or exhaust leakage, and such installation meets all applicable codes.

GAS USED TO ENERGIZE STARTERS

Gas used to energize starters must be discharged away from the engine into a harmless area. Ignition connections and electrical equipment on engines exposed to a potentially explosive atmosphere should be equipped to eliminate spark hazard. It is the responsibility of the engine owner to specify or provide such connections and equipment.

SAFETY GUARDS

Engines must be provided with guards to protect persons or structures from rotating or heated parts. It is the responsibility of the engine owner to specify or provide such protection.

CRANKCASE ANTI-EXPLOSION VALVES

These valves must be kept in proper working condition to relieve crankcase pressure.

IGNITION SYSTEMS

Ignition systems can cause electrical shocks. Avoid contacting ignition units and wiring.

A spark plug will fire if the storage capacitor in a breakerless magneto has been charged by hand-turning the magneto. This happens even though the ignition system harness is disconnected at the magneto. When the harness is reconnected, and the ignition switch is in the "on" position, the capacitor will discharge and fire a spark plug. The plug will ignite any gas that has accumulated in that cylinder. The crankshaft and driven equipment may rotate, possibly causing personal injury or damage to equipment. Gas that has accumulated in the exhaust system may also be ignited.

Before reconnecting the ignition harness to a breakerless magneto, discharge the storage capacitor to ground. Do this by clipping one end of a wire lead to the magneto housing. Then touch the other end to the harness connector pins on the magneto. You will hear a snap when a capacitor discharges.

If the ignition switch is in the "off" position, the capacitor is immediately discharged to ground when the ignition harness is reconnected to the magneto.

As a safety measure, ground all pins. Some breakerless ignition systems have more than one storage capacitor.

WARNING

If a gas engine has been cranked excessively without starting, shut off the gas fuel supply and ignition. Then crank the engine to purge the cylinders and exhaust system of accumulated, unburned gas. If you fail to do this, a spark plug could ignite the gas and cause an explosion.

COOLING SYSTEM PRESSURE CAPS AND CONNECTIONS

Do not remove the pressure caps while the engine is operating or while coolant is hot. The cooling system is under pressure and severe burns could result from the hot coolant spewing out when the cap is removed. Wait until the engine and coolant have cooled down before removing the radiator or surge tank caps. Always replace weak hoses, lines, and fittings.

FUEL INJECTORS

Never allow an injector to spray against the skin. The fuel oil will penetrate the skin and may cause serious infection and injury.

GENERATOR SETS

The voltage produced by generator sets is dangerous. Severe, possibly fatal, shock may result from contact. Make sure the generator set is grounded before operation. Be extremely careful when the unit or surrounding area is damp or wet.

When servicing any part of the electrical system or making any connections, make sure main power switch is OFF. Clean or service generator set only when engine is shut down.

In case of an accident from electrical shock, shut down the generator set at once. If it cannot be shut down, free the victim from the live conductor. Avoid direct contact with the victim. Use a dry board, dry rope, or any nonconducting implement to free the victim. If the victim is unconscious, apply artificial respiration and get medical help.

Do not operate the generator set with the ammeter circuit open. Voltage, dangerous to both equipment and personnel, can be generated in an open secondary circuit of a current transformer.

If the generator set is stopped by operation of safety devices, do not attempt to operate it until the cause has been eliminated.

When the generator set is shut down after operation, disconnect all line switches to all external power load and parallel circuits.

ENGINE AND EQUIPMENT, REPAIR AND SERVICE

Always stop the engine before cleaning, servicing, or repairing the engine or driven equipment. Place all controls in OFF position to prevent accidental restarting. If possible, lock all controls in the OFF position and take the key. Put a sign on the instrument panel warning that the engine is being serviced. Before restarting, make sure that all tools and other material are removed from the engine and equipment.

Proper service and repair are important to the safe, reliable operation of engines and related equipment . The procedures recommended by Arrow in this manual are effective methods for performing service and repair operations. Some of these procedures require the use of specially designed tools. The special tools should be used when and as recommended. Anyone who uses a service, repair, or installation procedure not recommended by Arrow must first satisfy themselves thoroughly that their safety will not be jeopardized by the service methods they select.

HOUSEKEEPING

Good housekeeping results in a clean, safe work area. An orderly work area with clean walkways and neatly arranged tools and equipment is a major factor in accident prevention.

ENGINE FAN BLADES

1. Do not operate the engine with a fan which has been bent, mutilated, modified or in any way damaged.
2. Do not operate the engine if the fan contacts or strikes any engine accessory or the radiator shroud or core.
3. Do not rebalance the fan. Contact the fan supplier if rebalancing is required.
4. Ensure that all bolts attaching the fan are securely installed to a torque specified by the engine or vehicle manufacturer.
5. Install the fan so the word "front" stamped on the fan faces the radiator.
6. Perform all required maintenance on the subassembly to which the fan is attached (water pump, fan drive, etc.) (See operator/service manual.)
7. Do not modify or substitute any parts of the engine without the approval of Arrow Specialty Company. Take special care not to make modifications which will increase the operating speed of the fan.
8. Install the fan only if the engine has been approved for fan installation. Likewise, install a subassembly to which the fan is attached (water pump, fan drive, etc.), only if approved or specified for use on the engine.
9. If the fan or fan drive contains any plastic or rubber component, have the fan and drive inspected by a qualified mechanic after operation at or exposure to excessively high temperatures [above 250° F. (120° C.) air temperature].
10. Replace the fan if indications of excessive corrosion or erosion appear in the fan.
11. For reversible or adjustable pitch fans, make sure the blades are correctly locked in the proper position prior to operation. Also, inspect the fan prior to operation to ensure that ice and dirt have not accumulated on the fan to cause potential unbalance of the fan.
12. Be sure all fans, fan drives and belts are properly shielded.

TURBOCHARGERS

Turbochargers are specifically designed for each application. Nozzle rings must not be changed without consulting the engine manufacturer since they limit turbocharger rpm. Excessive rpm may result in turbocharger failure with resultant personal safety hazards. Turbochargers operate at high temperatures. Therefore, all flammable material must be kept away from them. Engines must be shut down and at room temperature before working on turbochargers or burns will result. Keep all foreign material away from turbocharger openings.

ENGINE STORAGE CHEMICALS

Preservative oil contains a petroleum distillate which is harmful or fatal if swallowed. Avoid contact with skin. Vapor is harmful and causes irritation of eyes, nose, throat and skin. Use only with adequate ventilation. Avoid prolonged or repeated breathing of vapor. Avoid contact with eyes, and clothing. Do not take internally. Keep container closed and away from heat. Always read and observe the "CAUTION" labels on the containers. Do not destroy the labels on the containers.

Generally, heating of preservative compounds is confined to 200° F. (93° C.) or less. These temperatures are easily reached by placing the preservative container in heated water. If this is done, the container must be vented or opened to reduce the danger of explosion. Direct heating presents a dangerous and unnecessary fire hazard.

FIRE PROTECTION

Locate fire extinguishers so that they are easily accessible if a fire starts. Carefully maintain records of extinguisher inspection and recharging to ensure the fire extinguishing capabilities when required. Consult your fire extinguisher supplier or insurance engineer for recommendations on the type, size, and quantity of fire extinguishers required. Select and post alternate routes of escape from any engine installation. Design installation to meet all applicable fire codes.

CLEANING SOLVENTS

Use approved cleaning solvents in a well ventilated area. Avoid breathing fumes; some vapors can be fatal. Keep away from open flames or sparks. Do not use gasoline or paint thinners or other highly volatile fluids for cleaning. Always read and observe the "CAUTION" labels on containers. Do not destroy the labels on the containers. Cleaning solvents can cause various types of skin irritations.

WELDING EQUIPMENT

Welding gas cylinders can explode if damaged. Cylinders must be stored in accordance with manufacturer's specifications and applicable safety requirements.

When using acetylene, check valves should be installed between the regulators and hoses to prevent flashback into the regulators and supply tanks. Flashback could cause the regulators and supply tanks to explode.

Oily and greasy materials must be kept away from oxygen valves, hoses, etc. Oxygen may combine with such materials and explosive reaction could result.

Always wear protective eye shields when welding, cutting or watching a welding operation. Protective clothing and face shields must be worn. Do not weld or cut near combustible materials.

GROUNDING PRECAUTIONS WHEN WELDING

When using an electric welder on an engine, clip the ground lead as close to the welding site as possible. Putting the ground lead too far from the welding site may result in arcing across the main bearings, and fusing them to the crankshaft.

ELECTRIC POWER TOOLS

Be certain the electric tool is properly grounded. Wear proper eye protection. Do not work in wet or damp conditions. Be sure the tool is in good condition and safety guards are in position. An electric trouble light must also be grounded. Do not carry electric power tools by the cord. Do not yank the cord when removing from an outlet; instead, grasp the plug to remove it from an outlet.

LEAD ACID BATTERIES

Always disconnect the battery ground connection from batteries before performing any work on the engine or equipment. This will prevent sparks or burns when accidently shorting an electrical connection.

Never expose batteries to open flame or electric spark. Battery action generates a flammable, explosive gas. Do not allow battery fluid to contact skin, eyes, fabrics, or painted surfaces. Battery fluid is a sulfuric acid solution which could cause serious personal injury or property damage. Wear eye protection when working with batteries.

Precautions When Using Booster Batteries and Cables

Do not attempt to jump start an engine having a frozen battery. The battery may rupture or explode. Before starting, examine all fill vents on the battery. If ice can be seen, or if the electrolyte fluid cannot be seen, do not attempt to start with jumper cables.

Batteries should be treated carefully when using jumper cables. The following procedures assist in reducing sparks and explosion hazards always present in both batteries when connecting charged batteries to discharged batteries.

Turn off all electrical loads. Remove vent caps and lay a damp cloth over open vent wells of each battery. The charged booster battery or batteries must have the same voltage capacity as the discharged battery or batteries.

The positive post is identified by a "+", pos. and red color and is larger in diameter than the negative post.

The negative post is identified by a "-", neg. and gray color.

Negative Grounded Battery or Batteries

First, connect one jumper cable from the positive post on the charged battery or batteries to the positive post on the discharged battery or batteries. If more than on battery is connected in "series" or "series parallel", connect the jumper cable to the positive post that has the cable leading to the starting motor.

Second, connect the other jumper cable from the negative post on the charged battery or batteries to a good ground on the engine.

When removing jumper cables, always disconnect the ground jumper cable from the engine before disconnecting the other jumper cable.

Positive Grounded Battery or Batteries

This is the same procedure as for negative grounded battery or batteries, except the negative post will have the cable leading to the starting motor and the positive post will be grounded.

COMPRESSED AIR

Compressed air or gases should never be used to clean clothing or the body. Compressed air can pierce the skin and cause severe and very painful injury. Never use your hand to check air, gas, or liquid flow rates. Do not engage in "horseplay" with air, gas, or liquid hoses. Observe all applicable regulations as related to compressed gases.

SODIUM FILLED VALVES

When handling sodium filled valves always wear approved safety goggles, a hat or cap, long sleeves, and gloves. If refacing of sodium filled valves is required, do not exert undue force at the grinding wheel as this could crack the hollow valve stem and allow the sodium to escape.

Do not handle broken sodium filled valves with bare hands. Sodium or sodium residue can cause severe burns. Sodium burns are of the same nature as caustic burns. Wash burns with large volumes of cold water, then neutralize with vinegar. The affected parts should then be treated as a burn and medical attention sought.

If a broken valve should ignite, smother the flames in dry soda ash or dry sand. Water, carbon dioxide in any form, or carbon tetrachloride should never be used on sodium fires since these materials react violently with hot sodium. The smoke and fumes are irritating; adequate ventilation should be provided and inhalation or contact with the smoke and fumes avoided.

Broken sodium filled valves may be stored prior to disposal in moisture free clean oil or kerosene. Unserviceable sodium filled valves must be disposed of in accordance with local, state, and/or federal regulations as applicable.

INTOXICANTS AND NARCOTICS

Workers under the influence of intoxicants and/or narcotics are unsafe workers and are a hazard to themselves and other employees.

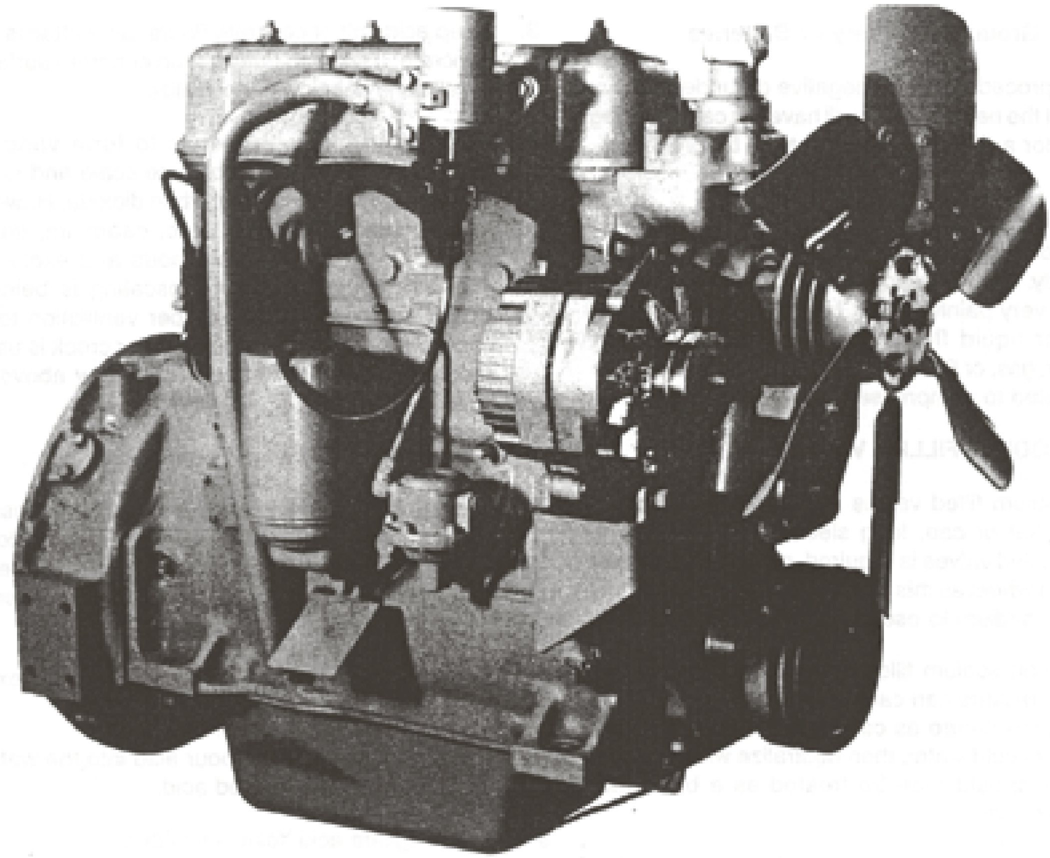
SAFETY PRACTICES FOR HANDLING ACIDS.

Throughout this manual, acid cleaning procedures are recommended for certain castings or pieces of equipment.

WARNING

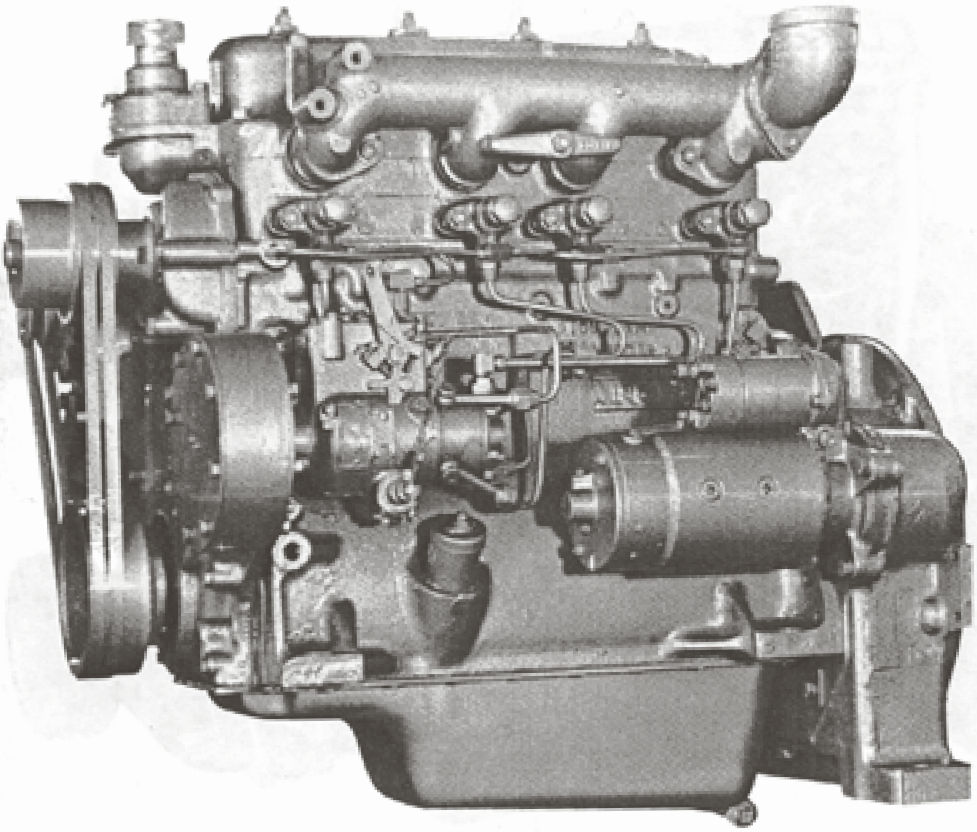
Always add the acid to the water - never add water to acid when mixing solution.

1. Avoid contact with skin, clothing, and eyes.
2. Descaling operations should be performed away from all fire, sparks or other ignition sources.
3. Keep acids off of concrete floors, as it attacks lime in the concrete. If solution does get on concrete surfaces, apply an alkaline solution to neutralize.
4. Acids can react with metals to form various gases. Generally, acid solutions on lime scale and rust result in the formation of harmless carbon dioxide. However, when acids contact aluminum, zinc, cadmium, tin, sulfides, arsenic and cyanides, poisonous and explosive gases may be generated. When descaling is being done in closed equipment, install proper ventilation to carry the gases away. When an open tank or crock is used, gases should be diluted by adequate air flow above the open tank.
5. Always fill closed vessels from bottom up.
6. Be sure that there are no leaks in the vessel being descaled which will permit solution to leak into opposite side of equipment. Good practice is to fill the opposite side of the equipment being descaled with water to a level higher than the acid solution.
7. Use an acid-proof pump, or an inexpensive, expendable one.
8. When mixing with water, pour acid into the water, do not pour water in concentrated acid.
9. Do not agitate acid solutions with air.
10. Applications of acid should be followed by thorough rinsing, then neutralizing with an alkaline solution to remove all acidic residue, to prevent further action.
11. Store acid solutions in either an acid-proof wooden or synthetic rubber lined steel container should be used.
12. Check steel equipment to be treated with acid solution for copper or brass fittings or fusible metal plugs. If possible, dissimilar metals should be removed prior to descaling to prevent electrolytic action which might interfere with the inhibiting action of acid solution. Do not use acid to descale equipment constructed of aluminum.



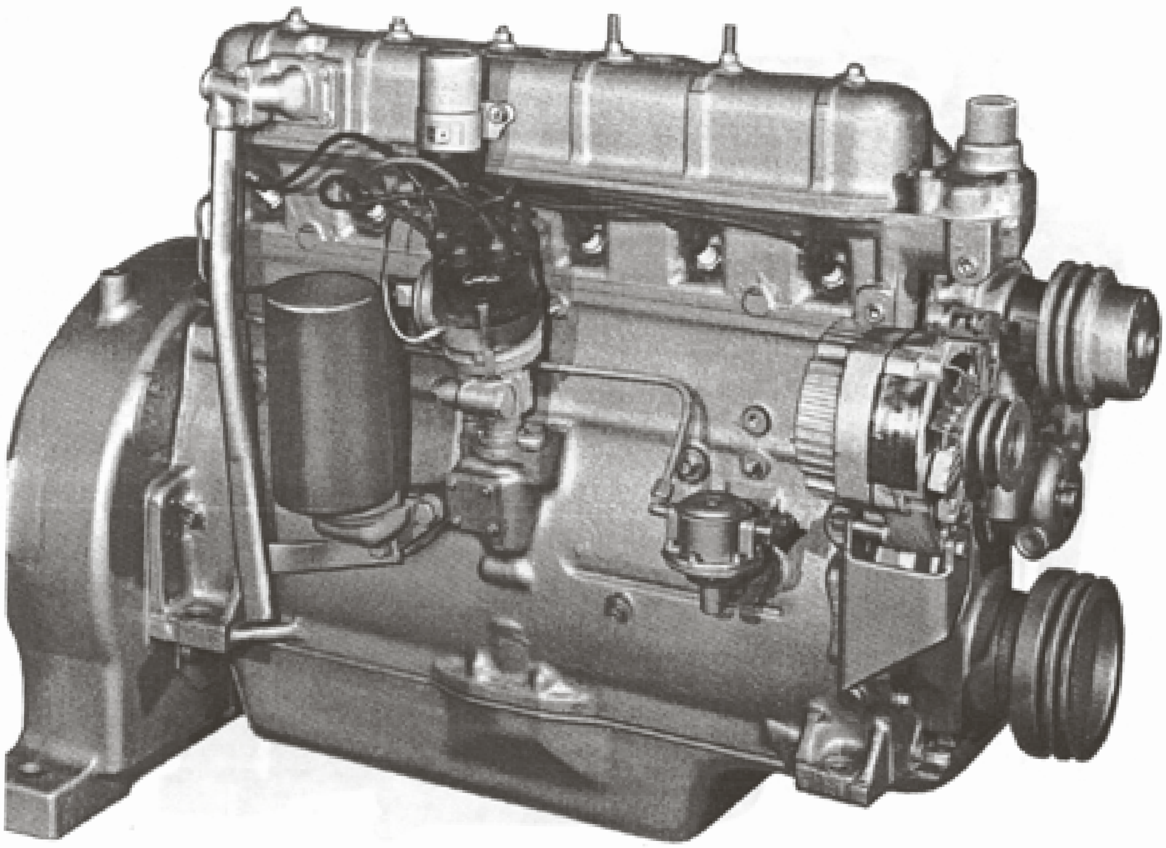
VRG 155 GASOLINE ENGINE - RIGHT FRONT VIEW

ENGINE MODEL		VRG 155
Displacement	cu. in. liters	155 2,54
Bore	inches mm	3 5/8" 92,0
Stroke	inches mm	3 3/4 95,0
Speed Range	rpm	1200-2200
Maximum Continuous Horsepower	Gasoline Nat. Gas	37 HP @ 2000 rpm 29 HP @ 2000 rpm
Normal Oil Pressure	psi	25-35 (avg.) @ 1500 rpm 12 (min) @ 800 rpm
Oil Temperature	°F °C	200 - 220 93,3 - 104,4
Normal Coolant Temperature	°F °C	180 - 200 82,2 - 93,3
Spark Plug Gap		.025 in. .636 mm
Weight (Dry)	lbs. kg.	520 236



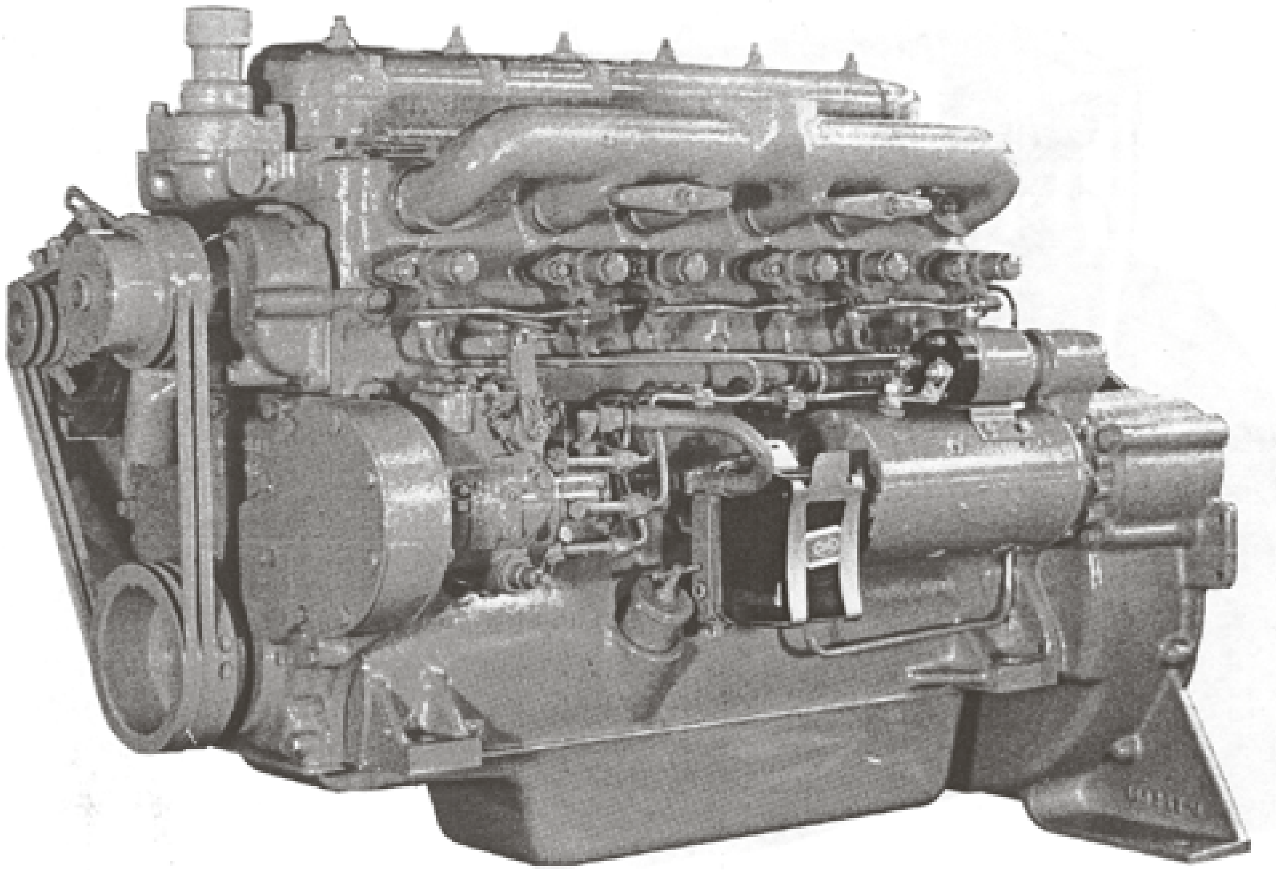
VRD 155 DIESEL ENGINE - LEFT SIDE VIEW

ENGINE MODEL		VRD 155
Displacement	cu. in. liters	155 2,54
Bore	inches mm	3 5/8" 92,0
Stroke	inches mm	3 3/4 95,0
Speed Range	rpm	1200-2200
Maximum Continuous Horsepower		36 @ 2000 rpm
Normal Oil Pressure	psi	25-35 (avg.) @ 1500 rpm 12 (min) @ 800 rpm
Oil Temperature	°F °C	200 - 220 93,3 - 104,4
Normal Coolant Temperature	°F °C	180 - 200 82,2 - 93,3
Weight (Dry)	lbs. kg.	565 257



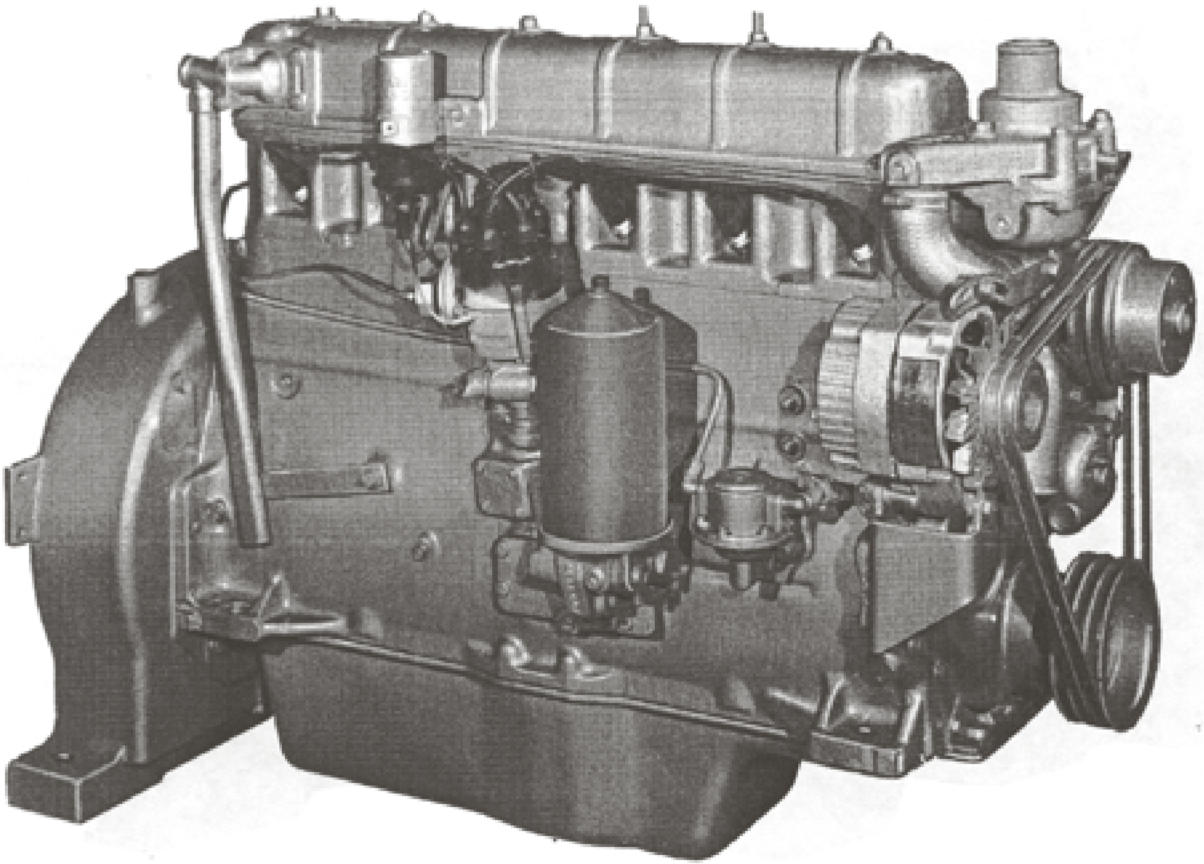
VRG 232 GASOLINE ENGINE - RIGHT FRONT VIEW

ENGINE MODEL		VRG 232
Displacement	cu. in. liters	232 3,8
Bore	inches mm	3 5/8" 92,0
Stroke	inches mm	3 3/4 95,0
Speed Range	rpm	1200-2200
Maximum Continuous Horsepower	Gasoline Nat. Gas	53 HP @ 2000 rpm 46 HP @ 2000 rpm
Normal Oil Pressure	psi	25-35 (avg.) @ 1500 rpm 12 (min) @ 800 rpm
Oil Temperature	°F °C	200 - 220 93,3 - 104,4
Normal Coolant Temperature	°F °C	180 - 200 82,2 - 93,3
Spark Plug Gap		.025 in. .636 mm
Weight (Dry)	lbs. kg.	607 305



VRD 232 DIESEL ENGINE - LEFT FRONT VIEW

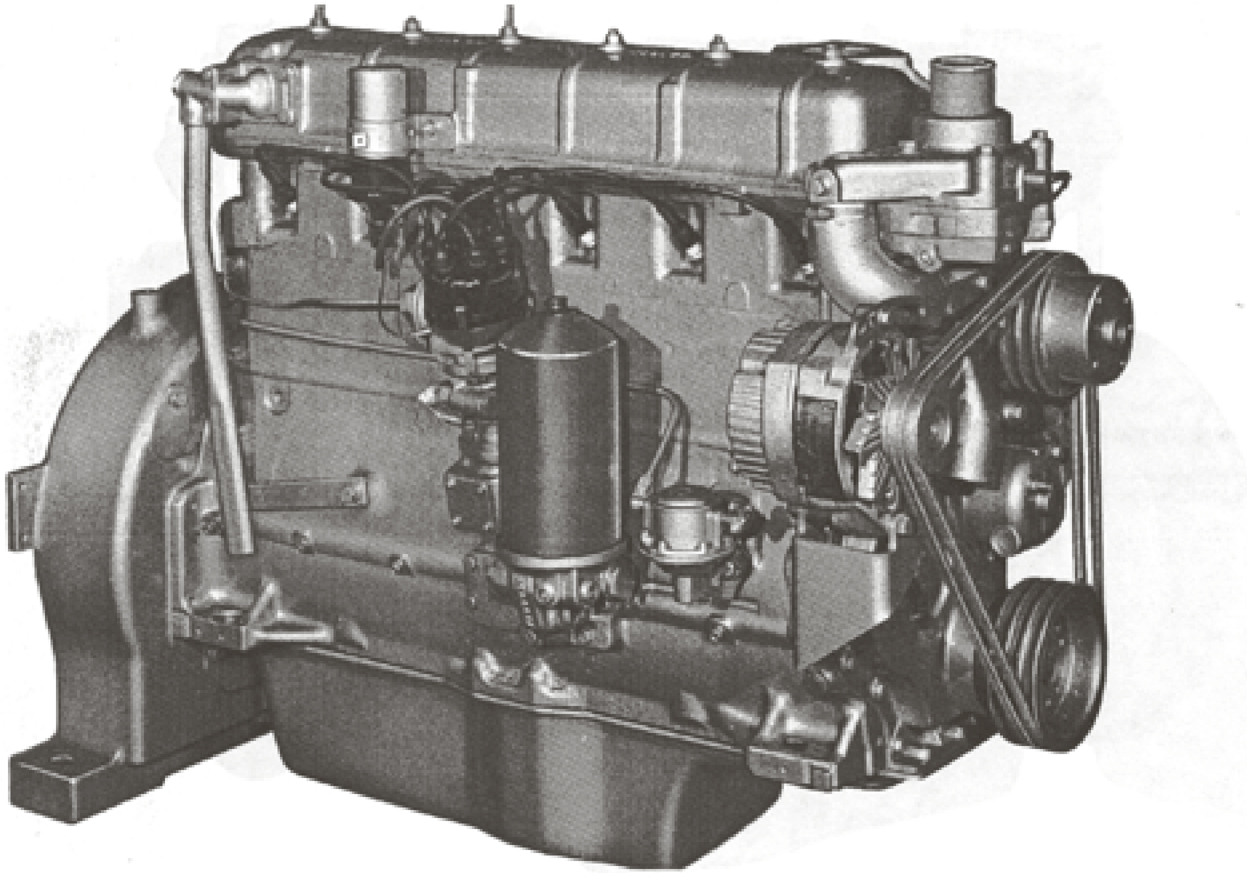
ENGINE MODEL		VRD 232
Displacement	cu. in. liters	155 3,8
Bore	inches mm	3 5/8" 92,0
Stroke	inches mm	3 3/4 95,0
Speed Range	rpm	1200-2200
Maximum Continuous Horsepower		55 @ 2000 rpm
Normal Oil Pressure	psi	25-35 (avg.) @ 1500 rpm 12 (min) @ 800 rpm
Oil Temperature	°F °C	200 - 220 93,3 - 104,4
Normal Coolant Temperature	°F °C	180 - 200 82,2 - 93,3
Weight (Dry)	lbs. kg.	870 395



VRG 265 GASOLINE ENGINE - RIGHT FRONT VIEW

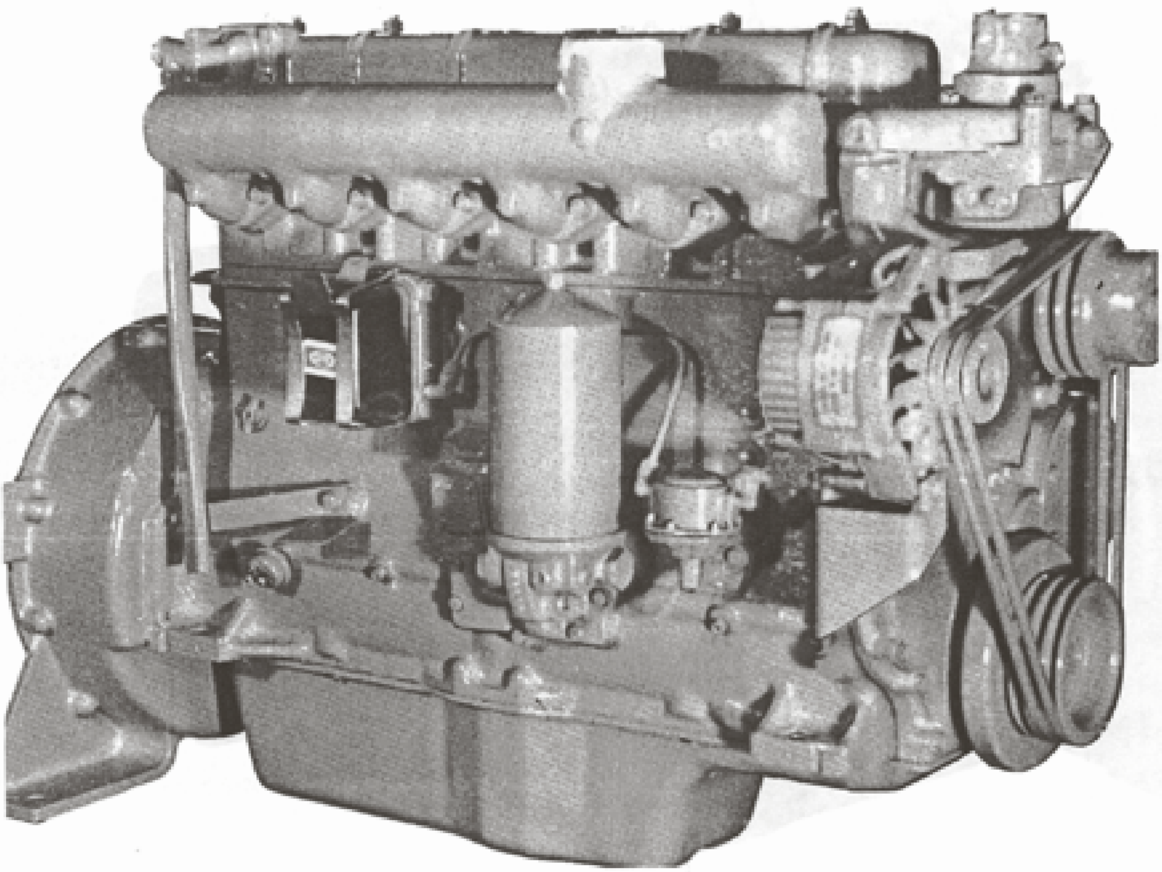
ENGINE MODEL		VRG 232
Displacement	cu. in. liters	265 4,3
Bore	inches mm	3 3/4" 95,0
Stroke	inches mm	4" 102,0
Speed Range	rpm	1200-2200
Maximum Continuous Horsepower	Gasoline Nat. Gas	72 HP @ 2000 rpm 58 HP @ 2000 rpm
Normal Oil Pressure	psi	25-50 (avg.) @ 1500 rpm 12 (min) @ 800 rpm
Oil Temperature	°F °C	200 - 220 93,3 - 104,4
Normal Coolant Temperature	°F °C	170 - 190 76,6 - 87,7
Spark Plug Gap		.025 in. .636 mm
Weight (Dry)	lbs. kg.	745 339

ARROW ENGINE COMPANY



VRG 283, VRG 310 GASOLINE ENGINE - RIGHT FRONT VIEW

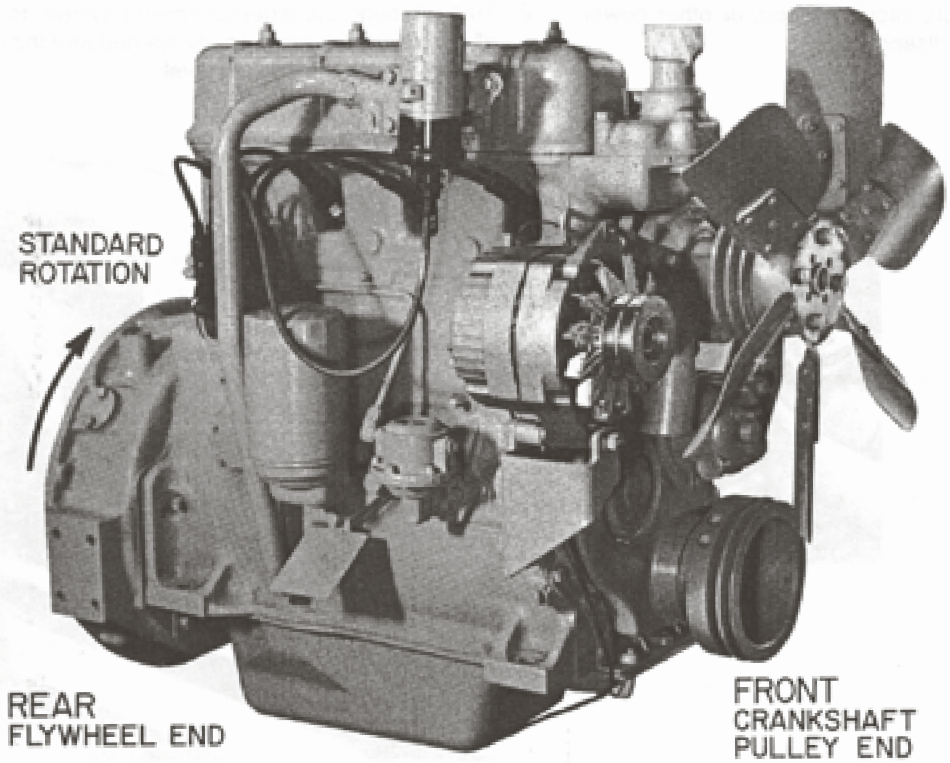
ENGINE MODEL		VRG 283	VRG 310
Displacement liters	cu. in. 4,6	283 5,1	310
inches Bore	3 7/8 mm	3 7/8 98,0	98,0
inches Stroke	4 mm	4 3/8 102,0	111,0
Speed Range	rpm	1200-2400	1200 - 2400
Maximum Continuous Horsepower Nat. Gas	Gasoline 66 @ 2000 rpm	83 @ 2000 rpm 73 @ 2000 rpm	91 @ 2000 rpm
Normal Oil Pressure	psi	25-50 (avg.) @ 1500 rpm 12 (min) @ 800 rpm	25-50 (avg.) @ 1500 rpm 12 (min) @ 800 rpm
°F Oil Temperature	200 - 220 °C	200 - 220 93,3 - 104,4	93,3 - 104,4
Normal Coolant Temperature °C	°F 76,6 - 87,7	170 - 190 76,6 - 87,7	170 - 190
Spark Plug Gap		.025 in. .636 mm	.025in. .636 mm
Weight (Dry) kg.	lbs. 376	825 382	840



VRD283, VRD310, VRD310S DIESEL ENGINES - RIGHT FRONT VIEW

ENGINE MODEL		VRD 283	VRD 310	VRD310S
Displacement	cu. in. liters	283 4,6	310 5,1	310 5,1
Bore	inches mm	3 7/8 98,0	3 7/8 98,0	3 7/8 98,0
Stroke	inches mm	4" 102,0	4 3/8 111,0	4 3/8 111,0
Speed Range	rpm	1500 - 2200	1500- 2400	1200 - 2200
Maximum Continuous Horsepower		61 @ 2000 rpm	79 @ 2000 rpm	122 @ 2400 rpm
Normal Oil Pressure	psi	25-50 (avg.) @ 1500 rpm 12 (min) @ 800 rpm	25-50 (avg.) @ 1500 rpm 12 (min) @ 800 rpm	25-50 (avg.) @ 1500 rpm 12(min) @ 800 rpm
Oil Temperature	°F °C	200 - 220 93,3 - 104,4	200 - 220 93,3 - 104,4	200 - 220 93,3 - 104,4
Normal Coolant Temperature	°F °C	170 - 190 76,6 - 87,7	170 - 190 76,6 - 87,7	170 - 190 76,6 - 87,7
Weight (Dry)	lbs. kg.	870 395	925 420	1020 463

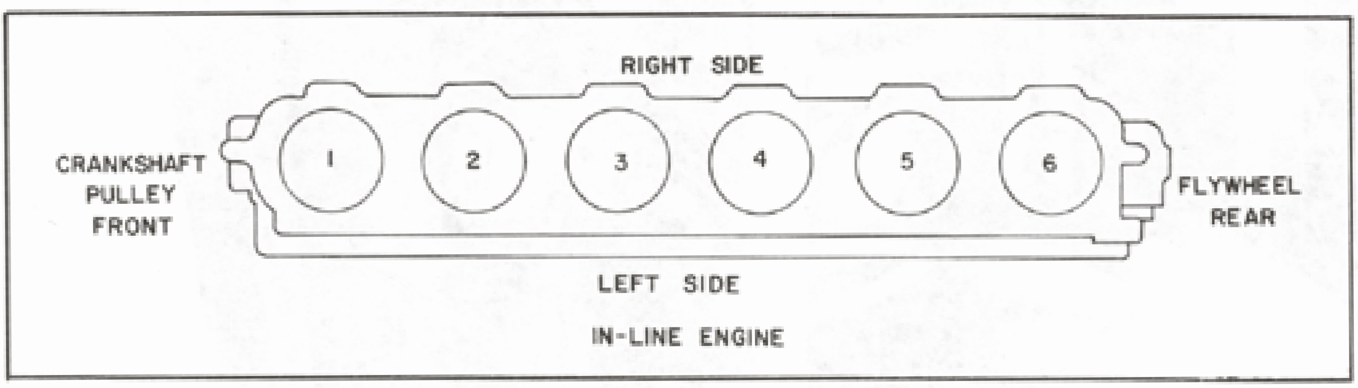
ENGINE REFERENCE POINTS



FIRING ORDER

Six Cylinders - 1-5-3-6-2-4

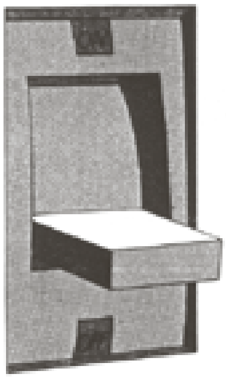
Four Cylinders - 1-2-4-3

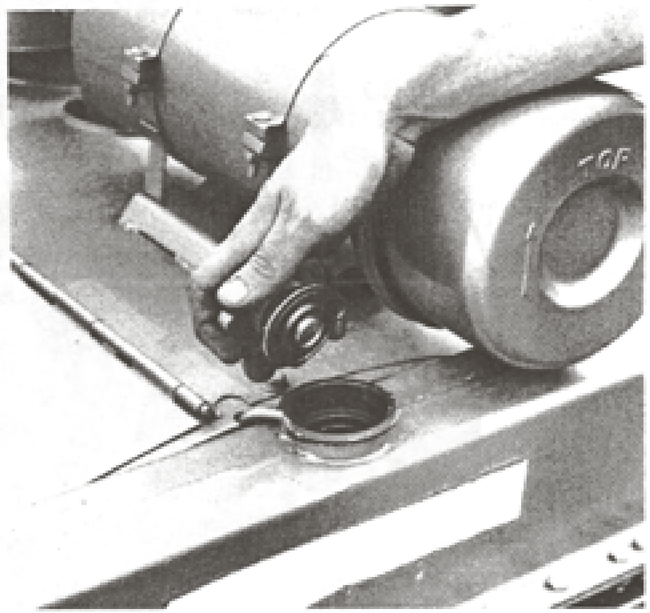


BEFORE STARTING

1. Be sure the main clutch, circuit breaker, or other power transmission device is disengaged.

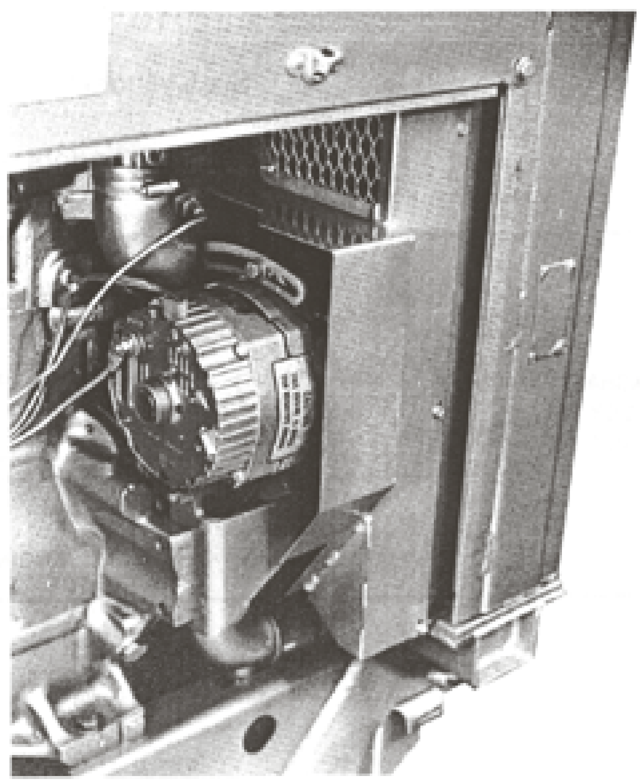
2. Trace through the external cooling system to make sure all control valves are properly opened and the drain cocks closed. Check the coolant level.





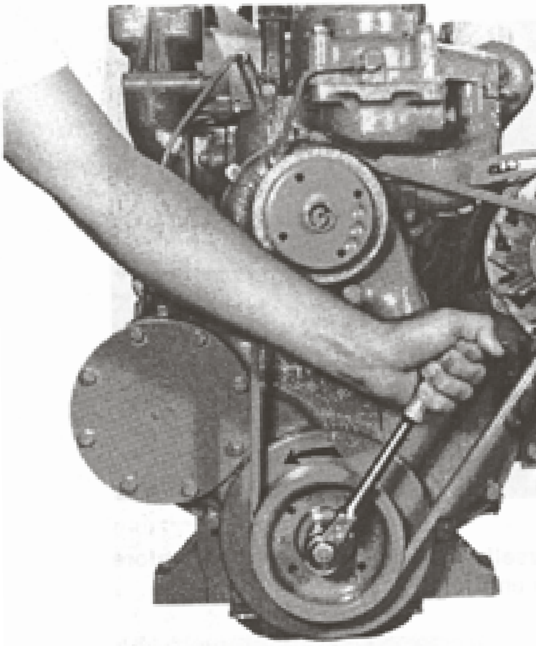
3. Inspect drive belts (water pump, alternator, and other equipment). Examine for good condition and correct tension.

4. Make certain all guards are secure on engine and driven equipment.

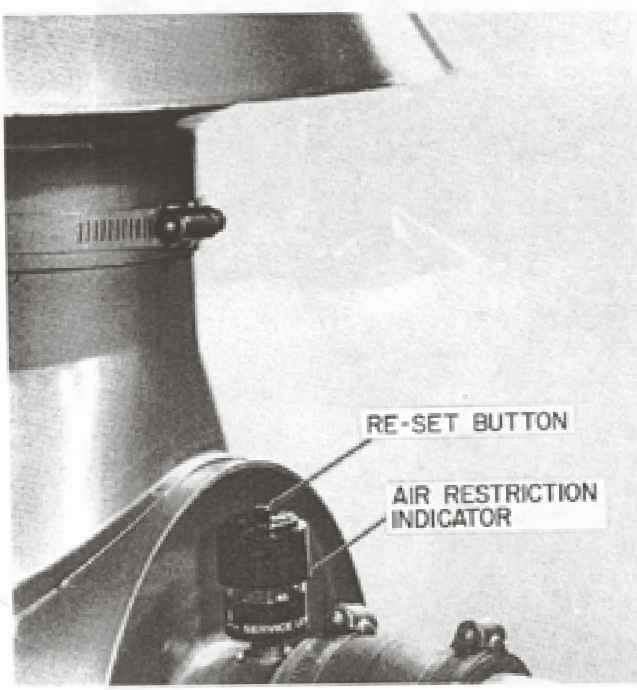


BEFORE STARTING (CONTINUED)

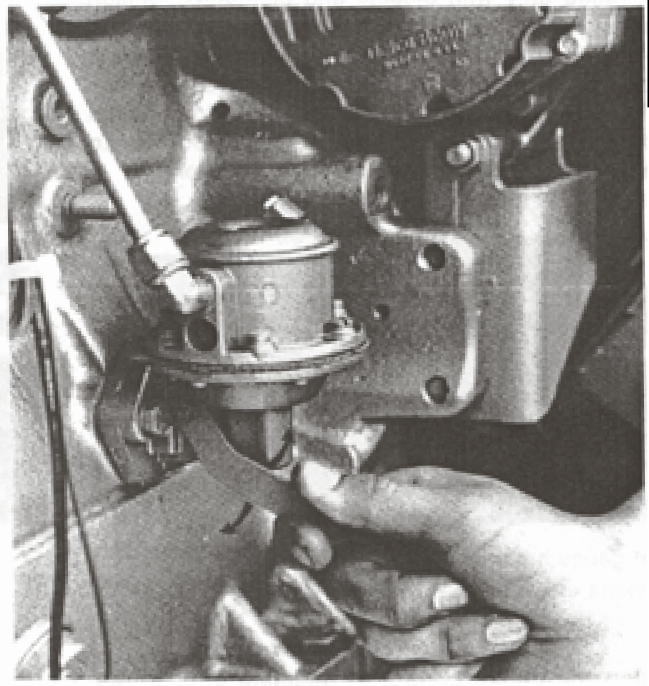
5. Check the air restriction indicator, if engine is so equipped. Clean air filter element and dust cap if indicator shows red. Check oil bath type air cleaner daily.



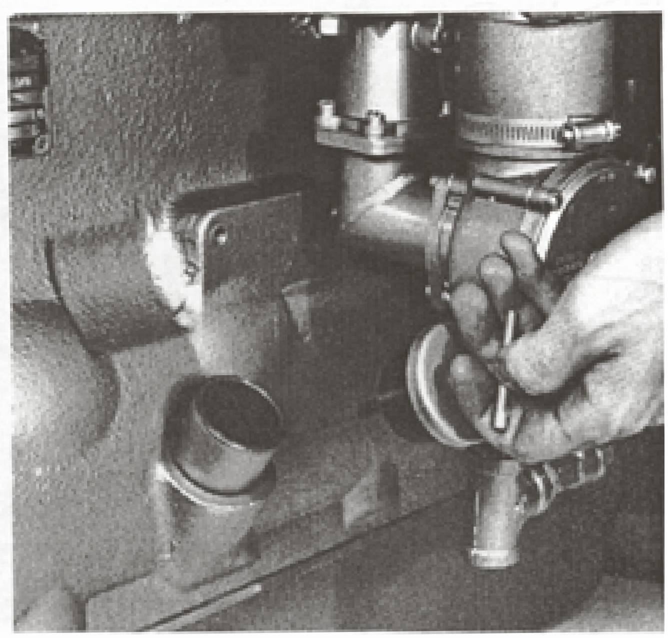
7. If the engine has been standing idle for some time, bar it over by hand to be sure it is free.



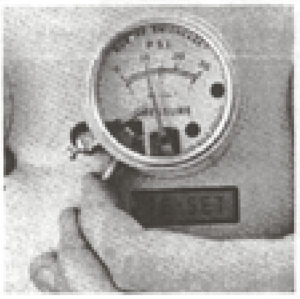
6. Check the oil level as indicated on the dipstick prior to starting engine. Stop engine and recheck oil level after 5 to 10 minutes operation at low idle. Add oil as required to bring level to "full" mark.



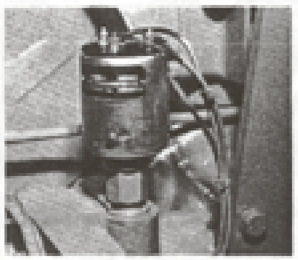
8. Fill engine fuel tank and drain enough fuel from outlet sump trap to remove water or sediment accumulations. If diesel main fuel supply is gravity fed, allow a quantity of fuel to flow into a disposal bucket to clear up any air locks in the line and wash out scale and sediment. Use the hand primer to purge diesel fuel lines and filter units of air.



9. Reset the safety shutdown controls. Diesel and gasoline engines which utilize the oil pressure Murphy Swichgage® must have the Swichgage® reset button depressed until the lockout latches. Depress the reset button of the Murphy magnetic switch in the instrument panel (used only with diesels and distributor ignition engines which utilize Murphy Swichgages®). Diesel and gasoline engines which utilize an overspeed switch (Synchro-Start) with a reset button, must have the switch reset before restarting after an overspeed shutdown. Some Synchro-Start overspeed switches incorporate an automatic reset and do not include a reset button.



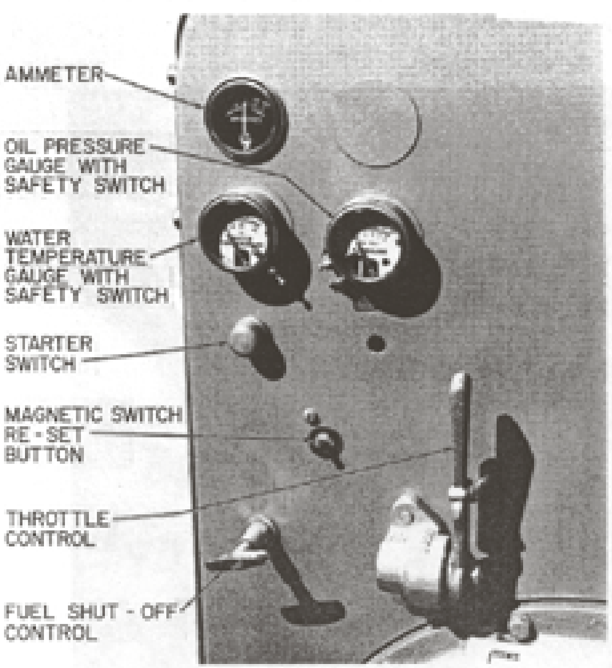
Push in gauge button until lockout engages.



Re-set everspeed switch (Synchro-Start) if engine shut down on overspeed.

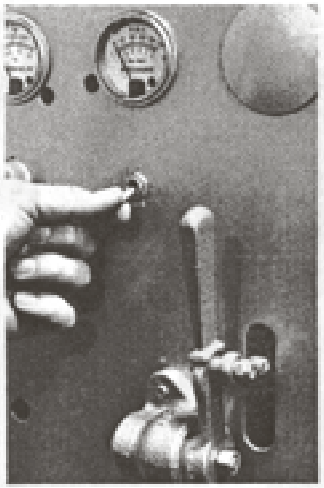
11. Position the choke control of gasoline engines as required for cold engine starting.

    Be sure the fuel shutoff valve is opened prior to attempting to start the engine.

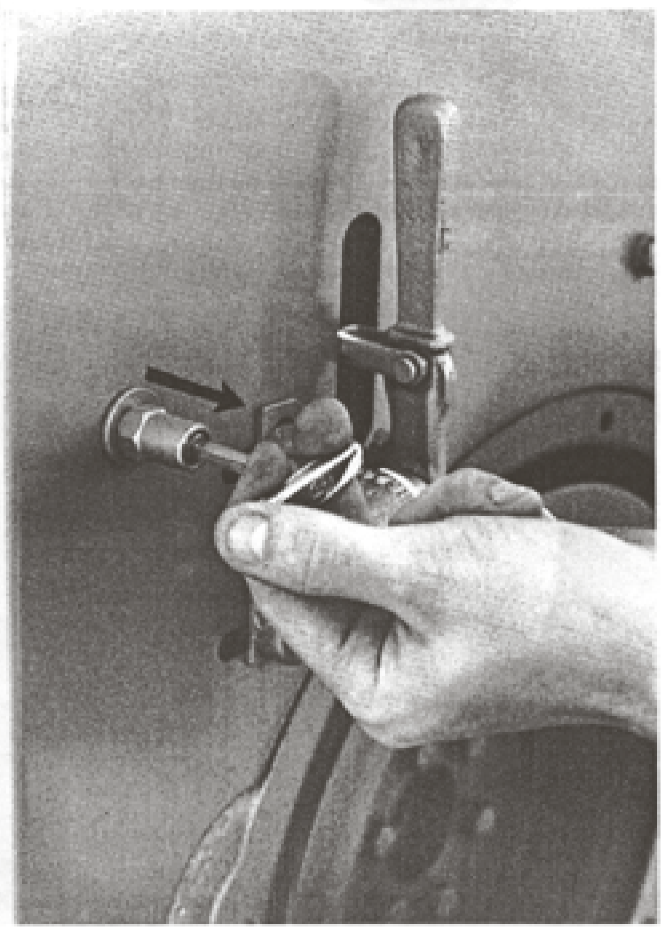


10. Gasoline engines must have the ignition switch placed in the "ON" position.

    Diesel engines must have the fuel shutoff control lever pushed towards the engine.

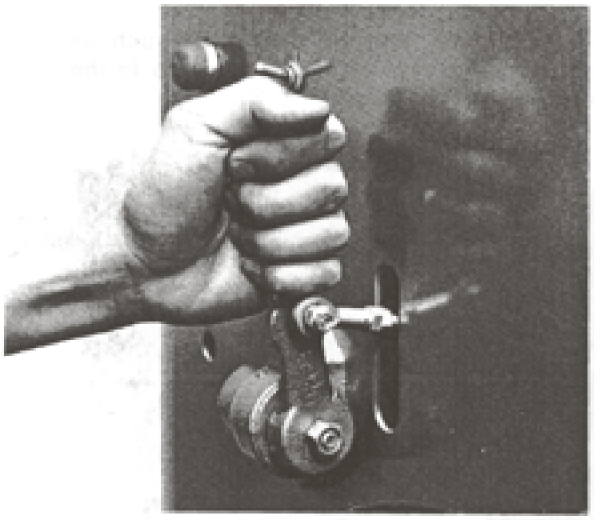


12. Familiarize yourself with all engine controls before attempting to run engine.



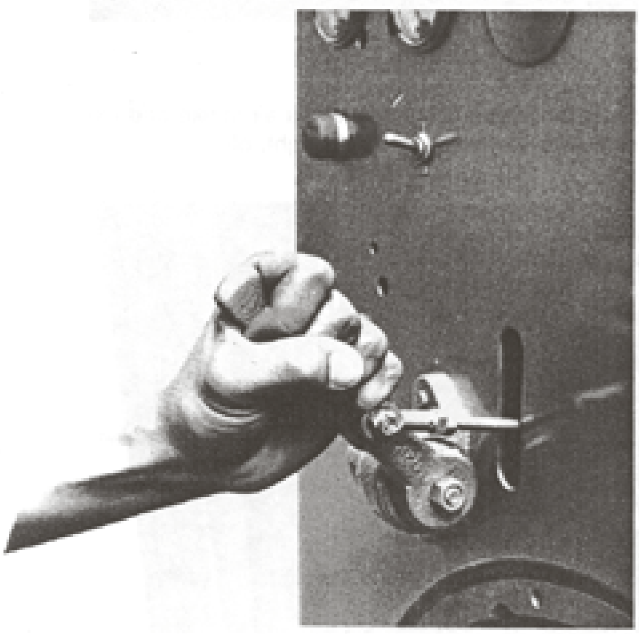
STARTING ENGINE

1. Place throttle control lever in "low-speed" position.



2. Actuate starter control to crank engine.

3. After engine starts, check for adequate oil pressure indications and place throttle control lever in medium idle speed position with no load for engine warm-up. Check that the Murphy Swichgage® safety control (when applicable) has released so that the engine cannot operate with low or no oil pressure. The Switchgage must be released by oil pressure before the oil safety control is effective.



4. Warm up engine until oil pressure stabilizes and coolant temperature reaches at least 100 ° - 120° F.

5. Place choke control of gasoline engines in "full-in" position.

   Engine speed for applying load will vary depending upon engine application. Generally, load should be applied gradually with engine speed set high enough to carry the load.

CAUTION

If adequate oil pressure is not indicated within 25 to 30 seconds, shut the engine down at once and correct the cause. Never operate without an adequate oil pressure indication in the hope that a faulty gauge or cold oil is responsible.

NOTE

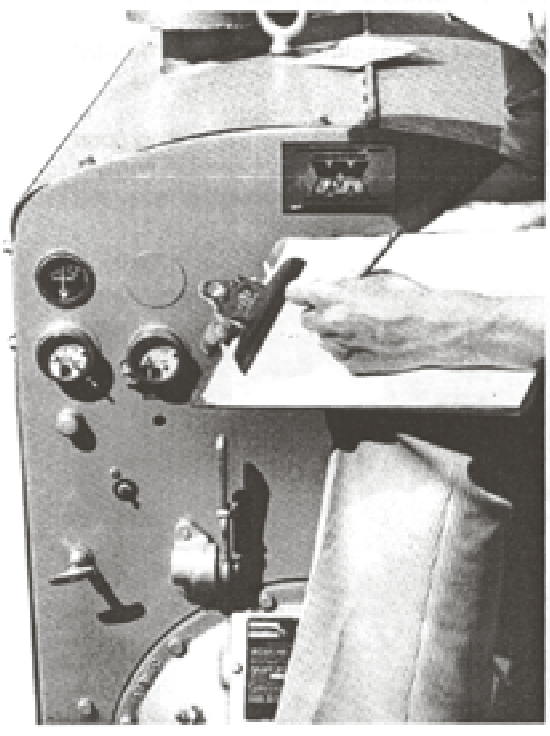
Be sure white smoke in diesel engine exhaust has "cleaned-up" before applying maximum load. Experience and observation of exhaust for minimum smoking will enable operator to determine when diesel engine is warmed up. Use of partial load after start-up will shorten time required to warm-up engine.

OPERATING

There are a number of important things to check while the engine is running.

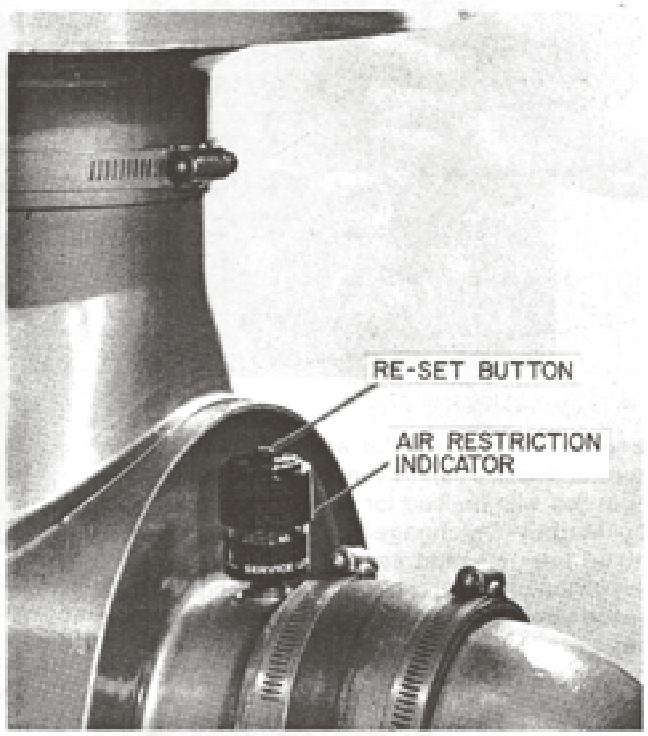
1. Learn and record the normal operating readings. Lube oil pressure should read 25-35 psi for all VR series 155 and 232 gas and diesel engine. The other VR series engines run at 25-50 psi. These are high idle readings, 1500 rpm.

   All operating temperatures range from 180-195°F (182.2-90.6°C). Changes from normal may be signs of developing trouble.



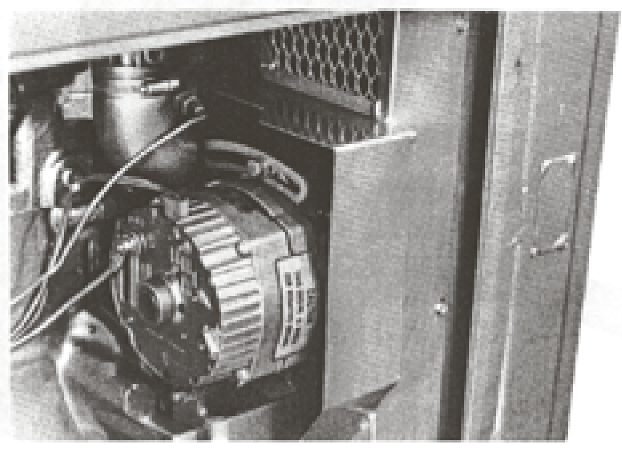
2. Check the air intake restriction indicator, if engine is so equipped.

   Listen to the engine. Certain problems, such as occasional misfiring, may first be noticeable in the engine sound.



3. Check for oil or coolant leaks.

4. Check general engine security such as air intake and exhaust connections, belt, guard bolts tight, etc.

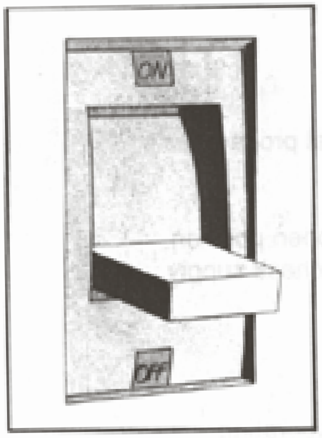


CAUTION

Avoid prolonged idling - in excess of 20 to 30 minutes at a time without bringing the engine up to normal operating temperatures near full- load. Excessive idling periods tend to cause cylinder, energy cell, and turbocharger problems by creating excessive coke and deposits.

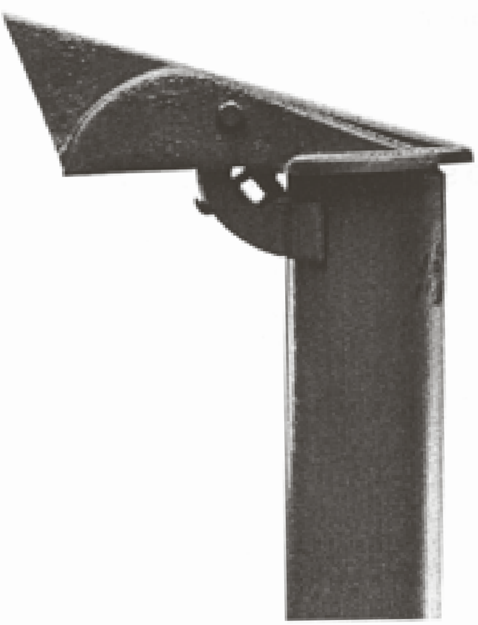
STOPPING

1. Remove load by disengaging clutch control lever, opening main circuit breaker, etc.



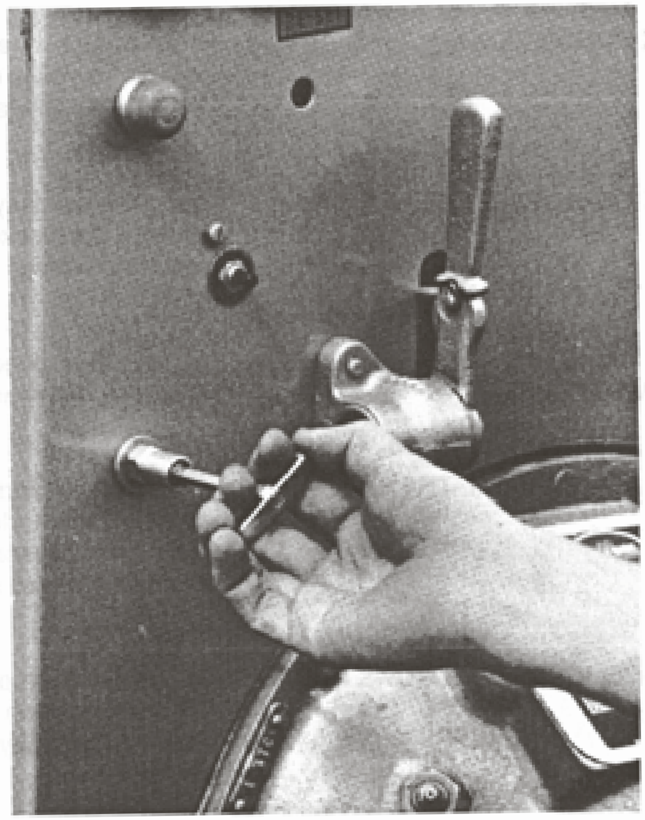
2. Place throttle control lever in medium idle speed position, and allow engine to idle for a few minutes to reduce and normalize engine temperatures. It is advisable, if the engine has overheated due to either excessive load or through some malfunction of the cooling system, to operate the engine at idle speed for a few minutes to bring temperatures back to normal before stopping it.

3. Stop engine when it has cooled sufficiently. Depending upon the engine installation, it can be stopped in a number of ways.



A. Gas engines should normally be stopped by shutting off the fuel supply. Gasoline engines should be stopped by placing the ignition switch in OFF position. If gasoline engine "diesels" (after run-in), it may be necessary to install an antidieseling device to the carburetor.

B. Diesel engines should be stopped by pulling the fuel shut-off control lever away from the engine.



4. Unless otherwise protected, the exhaust pipe should be capped upon shutting down the engine to prevent condensation, rain, or snow from getting into the engine. A pail or bucket inverted over the exhaust pipe will be sufficient.

5. Test the coolant solution for adequate antifreeze to protect the engine from freezing during shutdown periods. The Immediate and anticipated air temperature will govern the amount of antifreeze needed.

QUICK TROUBLE CHECK CHART FOR OPERATORS

CHECK CONTROLS	follow starting steps, re-setting safety controls remote or automatic operation engines have special procedures
CHECK FUEL SYSTEM	be sure fuel is getting to engine; check valves for open position, check possibility of water, rust, pipe scale: diesel - check supply lines for air lock and fuel filters for plugging
CHECK COOLING SYSTEM	coolant level okay and system not air locked radiator not blocked (trash), shutter open, and fan operating raw water valves open to heat exchanger
CHECK AIR INTAKE AND EXHAUST SYSTEMS FOR BLOCKS	air filter dirty, check air restriction indicator air intake or exhaust outlet capped
CHECK MECHANICAL THINGS	check throttle and governor control linkage for freedom from sticking and interference examine accessory drive belts for condition and tension if cranking speed seems low, check battery condition
CHECKING IGNITION ON GAS ENGINE	water on ignition parts and wires signs of corrosion at wire terminals or broken wires spark plugs poorly gapped or worn out

IF THESE CHECKS DO NOT SOLVE THE PROBLEM, REFER TO SERVICE MANUAL TROUBLE SHOOTING

COLD WEATHER STARTING

An engine jacket coolant heater, lubricating oil heater, and/or other approved starting aid should be utilized as required for cold weather starting.

When ambient temperatures dictate the need for cold weather ether starting aids on VRD Series Engines, the following quantities should be used: VRD155 and VRD232 engines - 2 to 2.5 cc measured quantity; VRD283, VRD310, and VRD310S engines - 3 to 3.5 cc measured quantity.

CAUTION

Careless use of ether starting aids can result in serious damage to an engine, such as broken rings, pistons, or cylinder heads. Only one measured quantity, as outlined above, is to be used per 20 second cranking interval. If engine fails to start after second injection of ether and 20 second cranking interval, refer to troubleshooting procedures as other engine deficiencies are indicated. Do not attach starting aid to engine. Engine vibration can cause seal failure in the ether container. This could allow ether to discharge onto the engine, creating a fire hazard. Mount starting aids on vehicle or equipment frame and connect it to engine intake manifold by a flexible hose.

BREAK-IN PROCEDURE

New or overhauled engines should receive a break-in run. NOTE: All new Class A diesel engines receive a break-in run before shipment from Arrow Specialty Company. This operation can be performed with the lube oil specified under LUBRICATING OILS. After warm-up of approximately 30 minutes, proceed with a load and unload cycle. Repeated loading (minimum of half load, maximum full load), with equal idle periods in 5 minute intervals for a period of two hours, results in rapid break-in and quick seating of piston rings. Never idle for more than 15 minutes during the break-in or for the first 100 hours of operation. NOTE: Stand-by generator engines should follow this procedure using a load bank.

EXERCISE OF STAND-BY UNITS

It is recommended that a generator set or other stand-by unit be exercised once each week. A record should be maintained of performance, incidental servicing, and output of both the engine and driven equipment.

Always operate the engine long enough to stabilize oil and water temperatures at the normal operating level expected under load. Do not operate under no load conditions for other than very brief periods. Loads of at least one-third up to the normal rated capacity are recommended. Ordinarily, an exercise run of one to one and one half hours will be needed to stabilize temperatures. If the engine cannot be loaded, it should not be exercised for more than 10 minutes each exercise period.

It is recognized that some types of driven equipment cannot be operated without fairly extensive procedures to "put them in line". Examples are hospital generators in some types of switching configuration; air-conditioning compressors which can only be loaded by changing over to chilled water from heating water circulation; and pumps which are not set up for waste discharge or recirculation. In such cases, weekly exercise periods may have to be reduced, where possible, to operational periods long enough only to prove the engine's ability to crank and start, or, checkout of starting circuitry and safety equipment with the starter disabled. In this event, special attention must be taken to prevent internal corrosion, sticking and gumming of fuel controls, and deteriorated starting batteries. In all cases, arrangements should be made to run the engine and driven equipment under load at least every 90 days.

LIGHT LOAD OPERATION

We recommend the following maintenance schedule for all VR Series engines that are consistently run at 25% or less of the continuous duty rating. This schedule is to be followed in addition to standard maintenance procedures.

1. Maintain engine jacket coolant temperature between 180° and 190°F.
2. Air cleaner elements should be checked daily. Clean and replace as required.
3. At 50 operating-hour intervals, run engine at 50% load or better to clean carbon off engine components.
4. Fuel filter elements should be changed after each 100 hours of operation.
5. Inspection and overhaul schedule of cylinder heads should be updated to allow for a 25% reduction in hours between servicings.
6. Our experience indicates that lightly loaded gas engines will have more stable operation when equipped with single electrode spark plugs. However, for heavily loaded gas engines, we recommend the use of multi-electrode spark plugs as they provide better performance and longer service life.
7. Change lube oil according to fuel type:
   Gasoline - every 50 hours
   Nat. Gas - every 500 hours
   Diesel - every 125 hours
8. Service injectors at 1,000 to 1,500 hour intervals.

When operating above 25% of continuous duty rating, follow normal maintenance schedule.

When applicable, we suggest running fewer engines per site to increase the load on each engine.

ENGINE PERFORMANCE RECORD

Engine operating information, recorded during regular inspections, is necessary to apply proper Preventive Maintenance schedules. Accurate records help control costs by avoiding unnecessary servicing, ensuring needed servicing, and provide "trend" information on the general engine condition. We recommend keeping a record of the following information, selecting items applying to your engine.

HOUR METER READING_______________

TACHOMETER(RPM)_______________

FUEL METER READING_______________

ENGINE OIL PRESSURE_______________

ENGINE OIL TEMP_______________

COOLANT TEMPERATURE_______________

GAS PRESSURE @ CARBURETOR INTAKE_______________

MANIFOLD VACUUM_______________

CRANKCASE PRESSURE pos/neg_______________

UNUSUAL NOISE(S) VIBRATION_______________

OIL LEAKS_______________

COOLANT LEAKS_______________

ALTERNATOR OUTPUT_______________

OPERATIONAL INSPECTION

Examine fuel, water, and lubricant lines for signs of leaks, damage, or corrosion.

Inspect the coolant level and condition. Rust, foaming, or oil in the coolant shows need for cooling system servicing.

Air cleaners and breathers should be checked daily for cleanliness and tightness.

Examine engine foundation for condition of grout, tightness of hold down bolts, and general alignment of driven equipment.

ENGINE WARM-UP

Proper engine warm-up is important for long engine life. A warm-up period allows for an even thermal expansion of engine components. Also, the lubricant warms up and attains normal viscosity during warm-up. Oil pressure is also built up, assuring proper oil distribution and lubrication of vital engine parts.

(Stand-by units that require immediate full load pick-up can be equipped to maintain a constant oil pressure and engine temperature. Consult your Arrow distributor for further information.)

To warm the engine up, run the engine at a medium engine speed with no load. Warm up engine until oil pressure stabilizes and coolant temperature reaches at least 100 - 120°F.

CAUTION

If adequate oil pressure is not indicated within 25 to 30 seconds, shut the engine down at once and determine the cause. Never operate an engine without adequate oil pressure readings in the hope that a faulty gauge or cold oil is responsible. The problem could be something else, and serious engine damage would result.

FUELS

NATURAL GAS - Arrow VR gas engines are designed to burn natural gas. Natural gas is normally considered as having an anti-knock (octane) rating equivalent to 120.

GASOLINE - It is important to use gasoline with an octane rating high enough to avoid serious detonation (knocking). 85 octane is suitable for VRG Series Engines, if the gasoline is of good quality.

DIESEL - The VR diesel engines will operate on any good domestic commercial No. 2 Diesel fuel oil of 40 Cetane or above (see accompanying table). The fuel must be free from water, foreign material, and contaminants due to storage deterioration. Storage periods of one year should be considered maximum, after which fuel tanks should be drained, inspected, and filled with fresh fuel. When fuel oil from sources other than the usual reputable refiners is considered, the Engineering Department of the Arrow Specialty Company should be consulted.

Jet "A" fuel is generally a satisfactory fuel for VR diesel engines from the standpoint of cetane rating and operational satisfaction with the following exceptions:

1. There may be Jet "A" from some refineries which does not meet our minimum cetane value of 40. In cases of doubt, a cetane rating should be obtained.

2. Jet "A" fuel may have a lighter specific gravity than No. 2 diesel fuel, which averages around 0.83. If the Jet "A" is substantially lighter, engine maximum power will be reduced because of the lower BTU content per specific injected volume of fuel. This reduction will be approximately the same percentage by which the Jet "A" is lighter than No.2 diesel fuel.

PREVENTIVE MAINTENANCE

FUEL OIL SPECIFICATIONS

Fuel Oil Physical Properties	Limits	ASTM Test Method
API Gravity	30 min.	D-287
Cetane Number	40 min. (Note 1)	D-613
Sulphur%	0.7 Max.	D-129
SSU Viscosity-Sec @ 100°F.	30-50	D-88
Water and Sediment - %	0.1	D-96
Pour Point °F. Min.	10°F. Below Amb.Air	D-97
Conradson Carbon	0.25%	D-189
Ash % Max.	0.02	D-482
Alkali or Mineral Acid	Neutral	D-974
Distillation °F.		D-158
10% Min.	450	
50%	475 to 550	
90% Max.	675	
End Point Max.	725	
Cloud Point	Note 2	D-97

Note 1. For automatic starting units, a fuel with 50 cetane minimum is recommended.
Note 2. Cloud Point should not be more than 10°F. above Pour Point.

LUBRICATION GUIDE

Lubrication intervals listed in the Service Schedule and Procedures are for normal operation and should coincide with other preventive maintenance services; however, under unusual conditions, intervals should be shortened if there is evidence of dirt, sludge or breakdown of lubricant.

The following precautions should be observed when lubricating the engine:

1. Keep all lubricants in closed containers and store them in a clean, dry place away from heat. Always protect the lubricants from dust, dirt or moisture. Keep lubrication equipment clean and ready for use at all times.
2. Before lubricating, wipe surrounding areas clean to prevent dirt or other foreign matter from entering the lubrication system. Use a cloth moistened with solvent to remove any old or hardened lubricants. After lubricating, remove any excess lubricant and wipe any spilled lubricant from parts not requiring lubrication.

LUBRICATING OILS

The performance of a lubricant, like that of any manufactured product, is the responsibility of the refiner and producer. Also, the engine operator, to a large degree, controls the oil's performance, for the operator is the one who must make decisions on oil changes, filter changes, loads, general maintenance, and operating conditions.

Oil is designated several ways; including the API, which is usually stamped on the container; the military, and the engine manufacturers.

For Class A engines operating on diesel fuel, Arrow Specialty Company recommends lubricating oils designated by the API as CE, by the military as MIL-L-45199B or MIL-L-2104C, and by the manufacturer as S-3

For Class A engines operating on gasoline or gas, Arrow Specialty Company recommends lubricating oil designated by the API as CC, SD, or SE, and by the military as MIL-L-2104B or MIL-L-46152.

Synthetic lubricating oils are not recommended by Arrow, as we do not have sufficient experience with them.

SELECTING OIL VISCOSITY

The correct lubricating oil viscosity (often referred to as "weight") must be determined with the engine operating under its normal loaded speed and temperature, using SAE 30 oil.

1. Start and load engine as described under "STARTING"
2. After oil and coolant temperatures stabilize, note the temperature of the oil in the oil pan. Use an accurate temperature gauge. Compare this temperature with the following chart. The correct oil viscosity will be found in the right hand column.

CLASS "A" ENGINES
OIL TEMPERATURES METHOD

Oil Pan Operating Temperatures	SAE Viscosity Numbers
210° - 250°F.	40
160° - 210°F.	30
130° - 160°	20

Engines operating with low oil temperatures (below 160°F.(71°C.)) can be expected to show excessive sludging and wear. Engines operating with high oil temperatures (above 230°F. (110°C.)) may experience lacquering and ring sticking due to oil oxidation. If, for any reason, oil temperatures cannot be corrected to the normal operating range, more frequent oil changes may help in extending engine life.

When the actual operating oil temperature is not known, an estimate of the SAE oil grade to use can be made by assuming the oil pan operating temperature of Class A engines will be 120 degrees above the air temperature in heavy-duty service. For example: At an air temperature of 70°F., estimated oil pan operating temperature would be 190°F. Use SAE 30 as indicated in the above table. NOTE: This is only an estimate, since the type of installation determines the amount of air circulation for cooling around the oil pan. Actual oil pan operating temperatures should be measured whenever possible.

Multi-viscosity oils (10W-30, for example) should be used only when cold starting conditions make it absolutely necessary. Oil change periods should be reduced by 50% for VR Series engines using multi-viscosity oil, because multi-viscosity oils may rapidly lose their highest viscosity rating in industrial service.

OIL CONSUMPTION

Oil consumption should range from 0.0005 to 0.004 pounds per horsepower hour as determined by the following formula:

$$\text{LBS/HP-HR} = \frac{1.82 \times \text{quarts of oil used}}{\text{Operating HP} \times \text{total hours of operation}}$$

OIL CHANGES

The crankcase level should be checked prior to each day's engine operation and at the same time the condition of the oil as revealed on the bayonet gauge should be observed carefully. Replace oil at any time it is plainly diluted, broken down, thickened by sludge, or otherwise deteriorated. Remember that some modern oils cannot be judged on the basis of color alone because the additives are intended to hold carbon particles in suspension The standard filters supplied will not remove these particles. The dark appearance of the oil is not necessarily an indication that the oil should be changed. Whenever oil is changed, the filters must be serviced. Oil performance will reflect engine load, temperature, fuel quality, atmospheric dirt, moisture nd maintenance. Where oil performance problems arise or are anticipated, the oil supplier should be consulted.

For VR series engines, recommended oil change intervals for engines receiving normal maintenance are as follows:

Gasoline	Gas	Diesel	
100	500	250	For continuous duty operation at continuous duty rating. Clean environment with oil sump temperature of 230°F. (110°C.)
75	200	200	For engines operated in excess of continuous duty rating
50	500	125	For engines operated consistently at 25% or less of continuous duty rating (light load operation).
100	300	200	For engines in stand-by service.*

*If stand-by service is less annually than hourly intervals listed, change oil annually.

.xtended oil change intervals should be utilized with caution on any engine using highly dispersant oils. The dispersants function by absorption of particles of contaminants; however, when dispersant saturation is reached, these oils tend to "dump out" all of the suspended contaminants in a relatively short period of time. Laboratory analysis will not predict the "dump out" point precisely. Consequently, close attention to engine conditions by the operator is required when establishing an extended oil change interval.

When using an engine oil with which you have no previous operating experience, a well monitored maintenance program should be conducted to observe the engine's performance and interval condition for the first year's usage. This procedure will help in determining if the new oil is compatible to your type of operation.

CAUTION

The use of some types of oil, as well as dusty environment, marginal installation, internal engine condition and/or operating the engine with malfunctioning carburetion or injection equipment ,may require more frequent oil changes. We suggest the lubricating oil be monitored with a good oil analysis program. Contact your local Arrow Distributor for periodic engine maintenance.

OIL CHANGE PROCEDURE

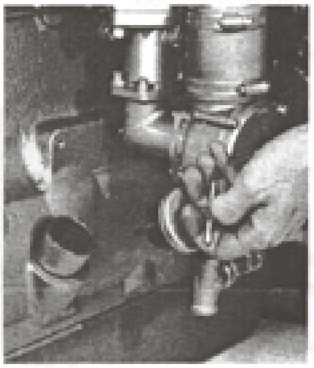
1. Remove crankcase oil drain plug, drain oil and securely replace plug.
2. Replace filter element.
3. Fill the crankcase with ten quarts of oil (only seven quarts for VRG and VRD232 and six quarts for VRG and VRD 155).
4. Operate the engine for a few minutes in order to circulate oil through system
5. Stop engine and check for additional oil requirement. Bring level to "full" mark.

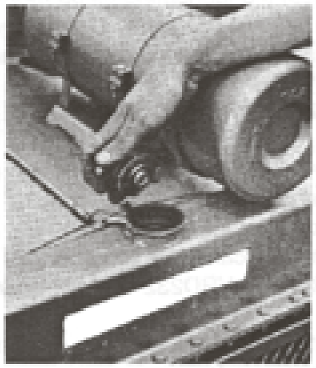
Not all oils in every type of engine will give maximum service. Therefore, be careful to examine the oil after the first draining to determine whether it is standing up in service. Trial periods of 10 hours are suggested. At the end of such periods, make a careful inspection of the oil depth gauge for sludging, frothing and emulsification. Such conditions call for more frequent changes or a different oil. In winter operation, low oil temperatures (below 160°F.) are particularly likely to cause sludge formation. Temperature-control devices - curtains, shutters, etc. - should be used if needed in order to hold the oil temperature around 180°F.

SERVICE SCHEDULE AND PROCEDURES

OIL AND COOLANT LEVEL

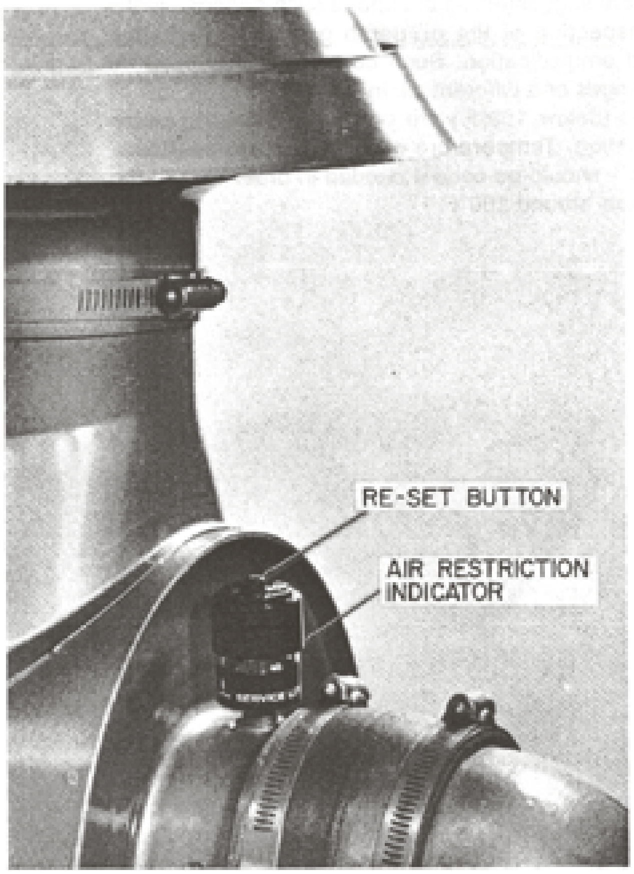
Check levels daily and fill as required. Change oil and filters as recommended.





AIR FILTERS

Check restriction indicator daily and clean filter if indicator shows red.

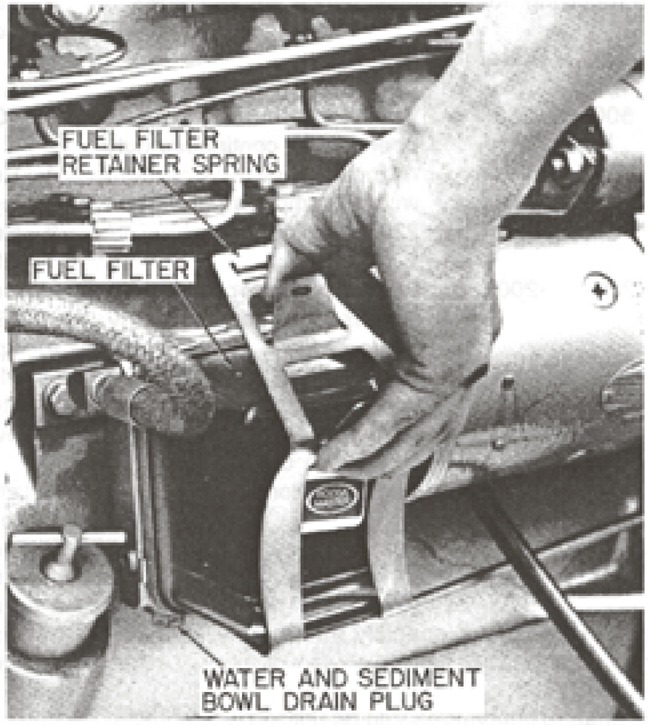


VALVE ADJUSTMENT

Adjust valve clearance every 500 hours.

FUEL FILTER (Diesel Only)

Check sediment bowl daily for accumulations and drain if necessary. Replace fuel filter element when lube oil and filter are changed.

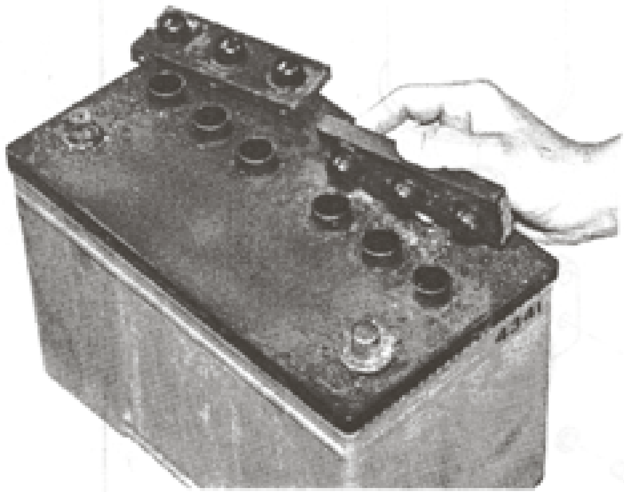


FAN BELTS

Check belts weekly for proper tension and material condition. Make sure guards are secure.

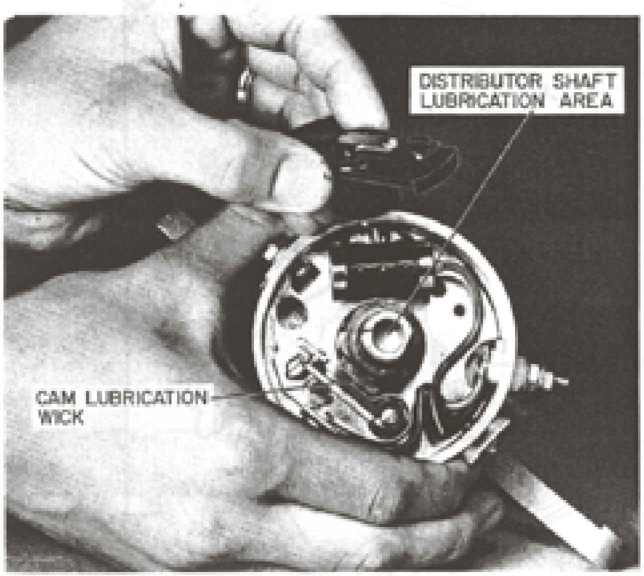
BATTERY

Check electrolyte level weekly and fill as required. Inspect terminals for corrosion periodically. A specific gravity of between 1.250 - 1.285 with all cells within 0.010 and 0.015 of each other indicates a well charted battery.



DISTRIBUTOR (Gasoline only)

Lubricate the cam lubrication wick every 500 hours (may be prelubricated). Lubricate shaft every 1000 hours.



SPARK PLUGS

Inspect every 250 hours and replace every 500 hours.

Spark plug gap .025" - Gasoline and Gas

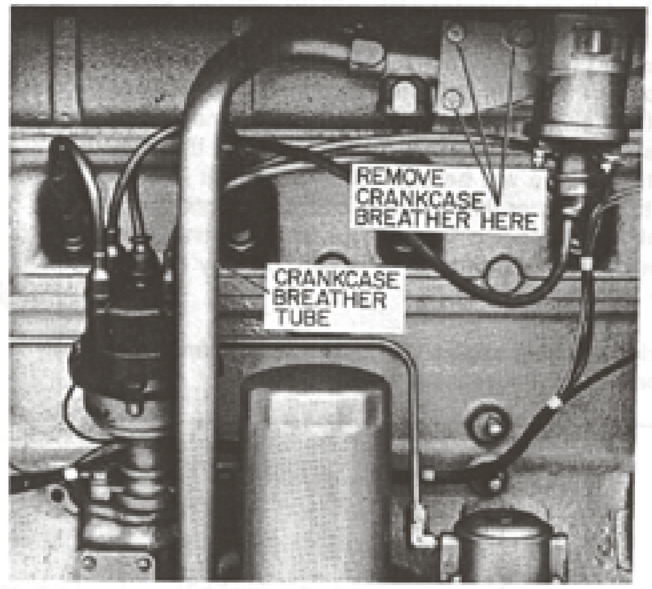
Spark Plug Size 155 + 232 Models - 18 mm
265, 283, + 310 Models - 14 mm

GAS CARBURETOR

Inspect diaphragm annually and replace if cracked or deteriorated.

CRANKCASE BREATHER

Clean every 100 hours



IGNITION POINTS

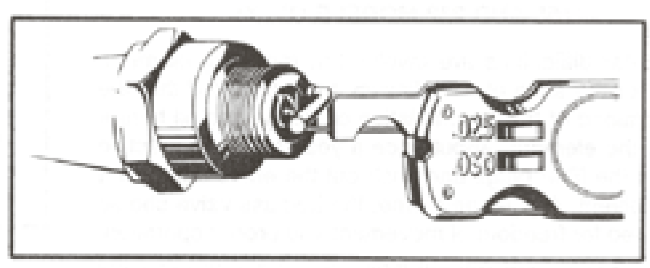
Adjust point clearance every 500 hours. Replace points and condenser if necessary. After adjusting points, be sure to check and adjust engine timing.

POWER TAKE-OFF

Lubricate at intervals according to instructions of manufacturer.

FUEL STRAINERS (If Applicable)

Disassemble, clean, and wash strainer elements at 150 hour intervals.

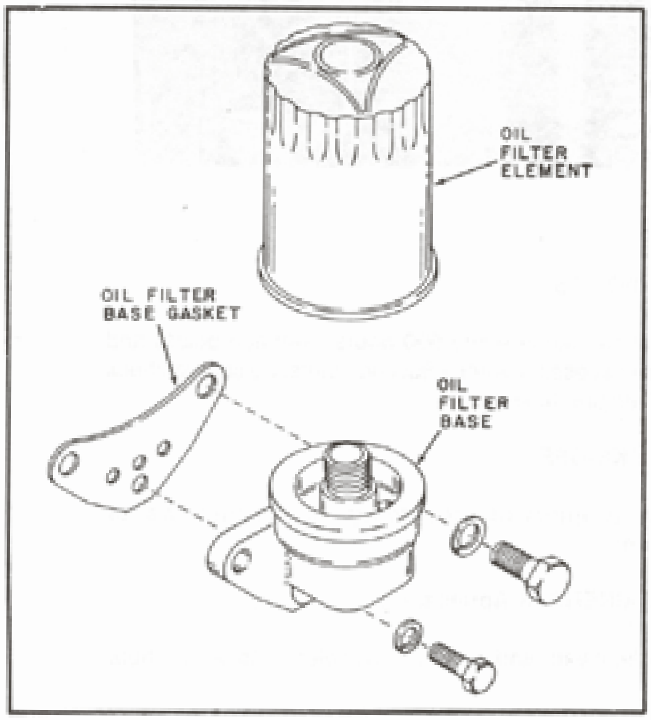


OIL FILTERS

Although some variations may appear in the oil filter installations used on the VR Series engines, the same general principles of maintenance apply to most of them. In all cases the manufacturer's recommendations accompanying the filter, or the instruction label applied to the side of the filter, should be followed carefully.

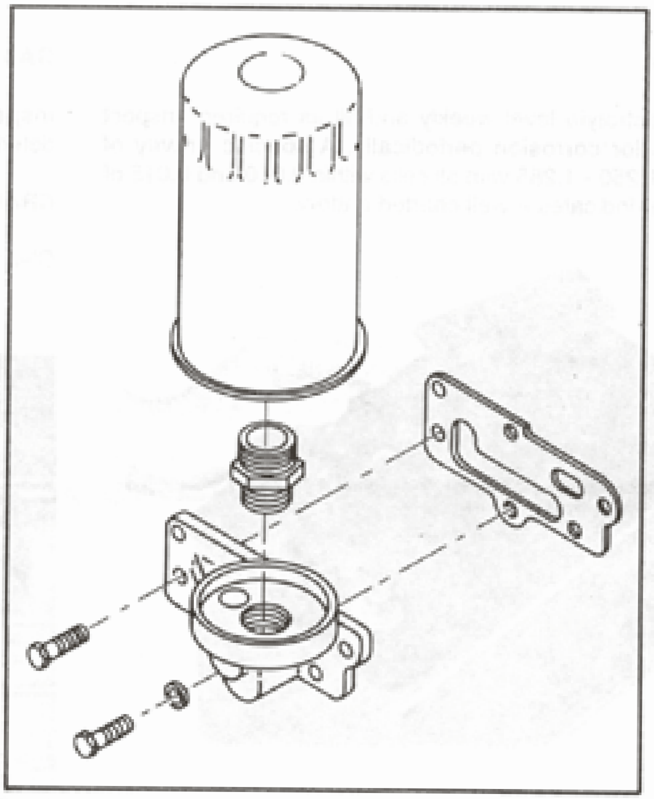
Full-flow filters are an integral part of the lubrication system. Never block off the filter, even temporarily, when running the engine. ALL OIL GOING TO THE ENGINE MUST PASS THROUGH THE FILTER. For this reason it is doubly important when changing oil that the element be changed and the filter parts thoroughly washed to prevent clogging or blocking of the oil flow to the engine. Where filter neglect or an unusually rapid accumulation of sludge clogs the filter element, the engine will be starved of oil. But it is very important to remember that the dirty oil that brought about the filter element clogging is now bypassing the filter and going through the engine itself. This dirty oil may reduce engine life materially.

All VR Series engines, except VRG and VRD 155 and 232, are equipped with full-flow filters.

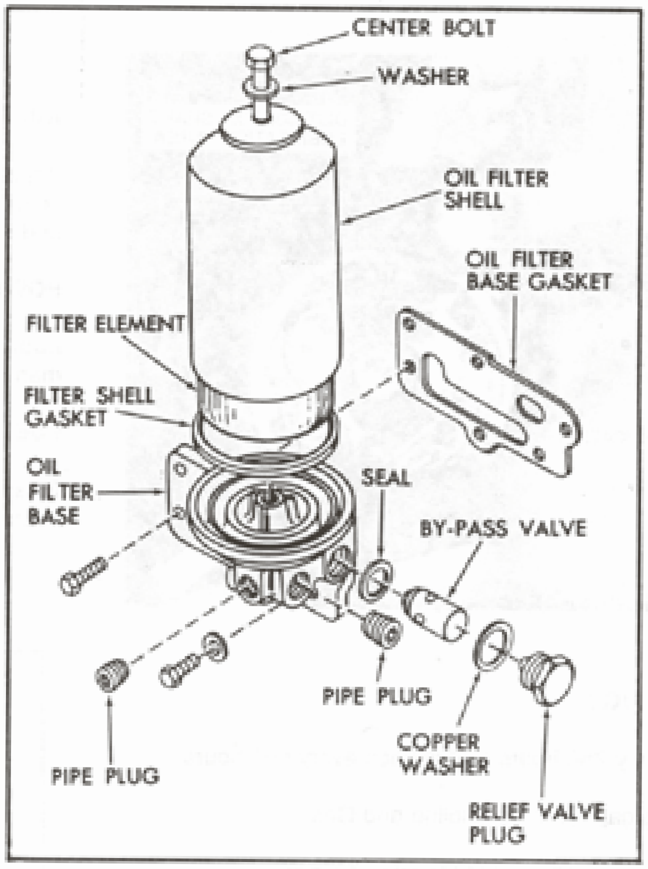


TYPICAL SHUNT TYPE OIL FILTER
(155 AND 232 MODELS ONLY)

No particular difficulties are involved in replacing element, although for the sake of cleanliness, it is suggested that the filter be drained of the accumulation of sludge and oil before removing the element. About once a year it is good practice to remove the filter plugs and flush out the entire unit with a suitable solvent. At the same time, the by-pass valve should be examined for freedom of movement and proper operation. To ensure a clean job without leaks, it is important that the filter seal gasket be handled carefully and replaced at the same time as the element.



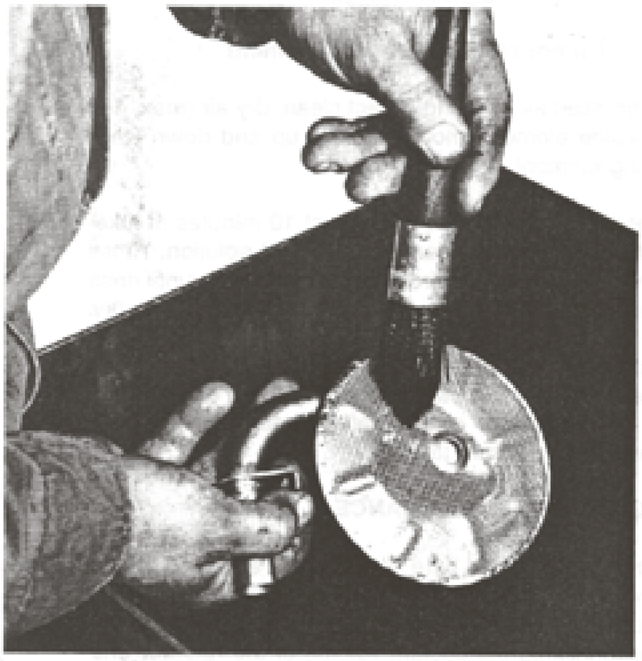
TYPICAL FULL-FLOW OIL FILTER
(CURRENT 283 AND 310 MODELS ONLY)



TYPICAL FULL-FLOW OIL FILTER
(PREVIOUS 283, 310 MODELS AND CURRENT 265 MODELS ONLY)

OIL PUMP INLET SCREEN

The inlet of the oil pump is protected by a wire screen designed to protect the pump and engine from the introduction of foreign material. If any indications of low or fluctuating oil pressure appear, it is recommended that the pump screen be very thoroughly washed in a suitable solvent.



CLEANING OIL PUMP INLET SCREEN

FUEL FILTER

The element of the standard diesel engine fuel filter is removed by pressing inwards and towards engine block on upper tab of spring clip. Clip will unsnap when pulled and bowl and filter may be removed. Clean filter base with solvent not harmful to aluminum. Replacement is in reverse order. The fuel filter housing has a vent plug at the top and a water and sediment drain plug on the bottom.

CAUTION

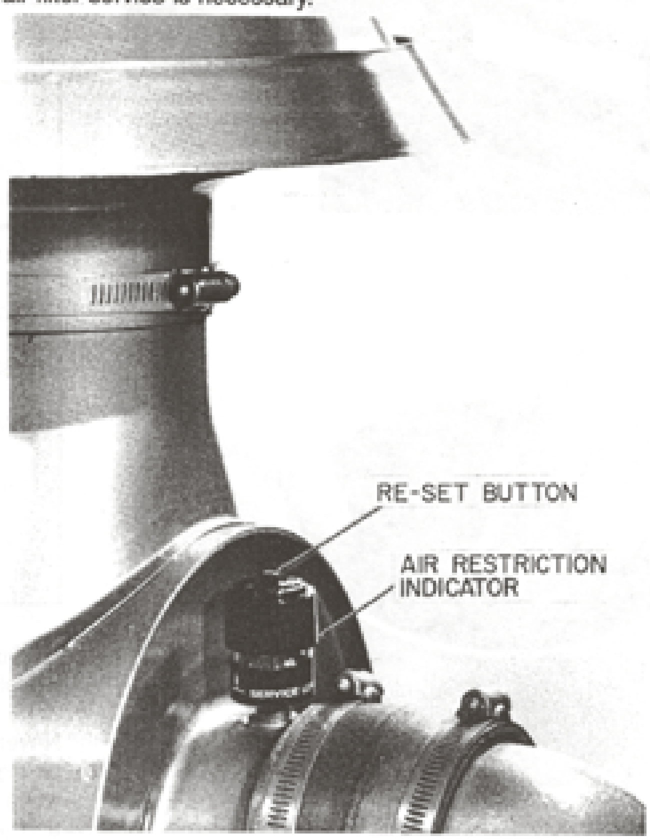
To avoid damaging fuel oil filter assembly during overhaul torque all fuel fittings, elbows and connections to 150 + 50 inch lbs. At this force, one extra turn is permissible to position fitting. Use non-hardening gasket adhesive on threads for sealing.

REMOVING FUEL FILTER

AIR CLEANERS

Follow the directions attached to the cleaner if any are present. If no directions are visible, examine the cleaner to determine whether it is an oil bath type or dry type. Oil bath cleaners have an oil reservoir which traps the dirt as a thick sludge. Wipe or wash out such accumulations and replenish the reservoir to the indicated level with clean engine oil. Oil in cleaner should be changed at each engine oil change. Both oil bath and screen type cleaners have a metal mesh or wool through which the air passes. Ordinarily the unit containing this material should be washed clean in non-volatile cleaning solvent, allowed to drain; then dipped in light oil and allowed to drain again at each cleaning.

An air restriction indicator device mounted in the piping from the circular style air filter serves as positive evidence when air filter service is necessary.



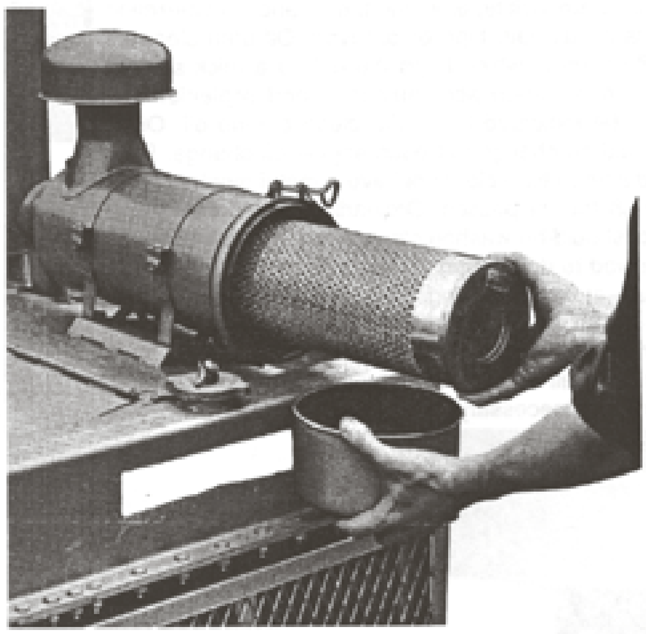
CHECKING AIR RESTRICTION INDICATOR

PREVENTIVE MAINTENANCE

CAUTION

Unless the signal is locked in view, indicating a clogged air cleaner, it will return to a normal setting upon engine shut-down. Normally the element is serviced long before the gauge indicates a need, but the operator is cautioned to check the gauge every day while the engine is running. After the element has been serviced the reset button on the restriction indicator should be depressed to re-set it.

Two styles of dry type air cleaners are available for VR Series engines. Open units are equipped with an upright hat style cleaner. The second type available is the circular style air cleaner supplied with VR closed units. This style cleaner is has a pre-cleaner built into each assembly.



CLEANING AIR CLEANER

Dirt trapped by this pre-cleaner will be collected in a dust cup or the end of the filter. When removing dust cup and filter element be careful not to spill any dirt on the engine. (This cleaner is also available as an option for the VR open units.)

To clean the dry type elements, proceed as follows:

CAUTION

Do not rap, beat or drop element.

1. Compressed air cleaning. Direct clean, dry air (max. 100 psi) inside element, moving nozzle up and down while rotating element.

2. Water wash cleaning. Soak element 10 minutes in luke-warm water and non-foaming detergent solution. Rinse with water (max.40 psi) from inside of element until rinse water is clean. Air dry - do not use compressed air to dry.

Inspect after cleaning by placing a light inside the element. Replace element if it is ruptured, has pin holes, or damaged gaskets. Always replace element after three cleanings or 6 months, whichever occurs first.

COOLING SYSTEM MAINTENANCE

The cooling system of the bare engine holds about 10 quarts of water without provision for radiators or other equipment. When adding antifreeze compounds on a percentage basis, remember to include the coolant volume of the radiator and other external parts of the cooling system. The following table may be used as a guide:

Ethylene Glycol "Prestone"	Radiator Glycerine (G.P.A.)	Freezing Points °F	°C.
16%	37%	20	- 7
25%	55%	10	- 12
33%	70%	0	- 18
39%	81%	-10	-23
44%	92%	- 20	- 29
48%	100%	- 30	-35

To prevent rust when using water alone, add one ounce of soluble oil for every gallon of coolant in the cooling system.

Never fill the cooling system with only water if the engine is to be exposed to sub freezing temperatures. This applies even when warm water is used because the water in the radiator and jacket passages cools rapidly and is likely to freeze before the engine can be started. If it is planned to leave the coolant in the engine at the next shutdown, mix the proper proportion of antifreeze and water before filling the engine.

· drain cooling system, drain external components and .emove drain plug from left rear side of engine.

Under normal conditions, the heat-sensitive thermostat in the water outlet will maintain temperatures within the desired limits.

By way of caution, it must be remembered that if the engine is to be operated with the thermostat removed - and this is not recommended except in case of emergency - provision must be made to block off the by-pass passage or water will continue to recirculate without passing through the radiator or other external cooling system. Shutters or other means will be required to maintain the temperature at the desired level.

Thermostat Removal and Testing

Ordinarily, thermostats will seldom need replacement in the field. They should be checked from time to time, however, and are quickly accessible by removing the thermostat housing at the forward end of the cylinder head. The steps necessary to accomplish this are simply the removal of the water outlet connection hose, and the cap screws securing the housing. Thermostats damaged by corrosion or other causes are not repairable and must be replaced.

Thermostats should be tested in hot water for proper opening. A bucket or other container should be filled with ·fficient water to cover the thermostats and fitted with a good .ality thermometer suspended in the water so that the sensitive bulb portion does not rest directly on the bucket bottom or side. A stove or torch is used to bring the water to a heat range of 170° F., while the thermostat is submerged in the water. Stir the water for even heating. As the temperature passes the 165° - 170° F. range, the thermostat should start to open and should be completely open when the temperature has risen to 185° - 190° F. VRG and VRD 232 thermostats start to open at about 180°F. and are fully open at 202°F. VRG and VRD 155 thermostats start to open near 192° - 199°F., and should be fully open at 219° F. Lifting the thermostat into the colder temperature of the surrounding air should cause a pronounced closing action and the unit should close entirely within a short time. A large thermostat is used in order to ensure adequate reserve circulation for heavy operation and to pass large volumes of cooling water. Use care to seat the thermostat squarely and concentrically to avoid interference with the thermostatic action. Be certain the thermostat housing seal is in place.

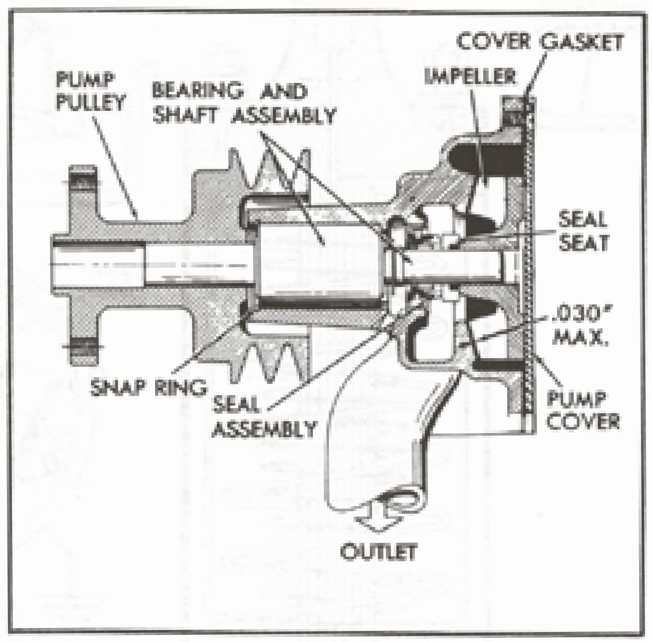
Cleaning The Cooling System

When clean, soft water is used as a coolant, and when the proper inhibitors or antifreeze solutions are used, radiator and cooling passage accumulations will not be excessive. About once each year, however, the engine will benefit if the cooling system is cleaned of sludge and sediment.

It is recognized that a number of excellent commercial cooling system cleaners are available. ARROW SPECIALTY COMPANY SUGGESTS, HOWEVER, THAT AN OPERATOR CONSIDERING THE USE OF SUCH A CLEANER FIRST INVESTIGATE ITS POSSIBLE REACTION WITH THE COPPER AND BRONZE PARTS IN THE ENGINE. If such a cleaner is used, follow the manufacturer's recommendations carefully.

Water Pump

REMOVING THERMOSTAT



WATER PUMP - SECTIONAL VIEW

PREVENTIVE MAINTENANCE

The belt driven water pump requires no special packing or attention during its service life. An internal seal, used in combination with a permanently lubricated integral ball bearing and pump shaft, provides a durable, ruggedly constructed water pump.

For service purposes the entire shaft, bearing, and seal must be disassembled from the pump body and new parts installed. Since an arbor press is required for this purpose, field repairs are not recommended unless such equipment is readily available.

The sealing member of the pump consists of a smooth carbon washer riding against a polished surface.

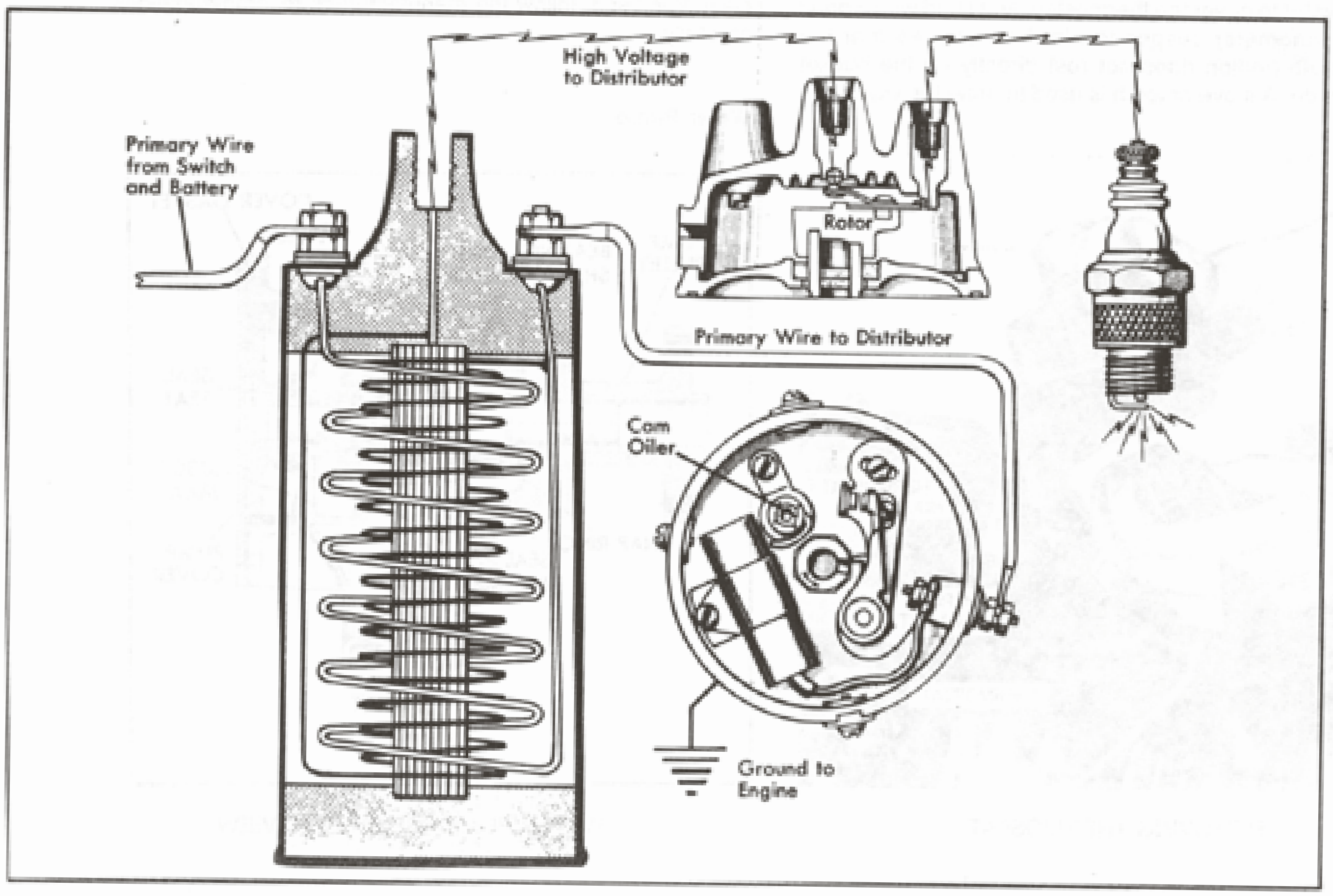
DISTRIBUTOR ADJUSTMENTS

Distributor point clearances may be adjusted with the distributor installed in the engine. In some cases, however, it will be found much more convenient to loosen the cap screws holding the distributor clamps, disconnect the vacuum advance tube (if applicable) and carefully lift the entire distributor from the engine for inspection and adjustment. This avoids working in cramped quarters and difficulties in trying to crank the engine over to bring the cam peak under the fiber bumper block.

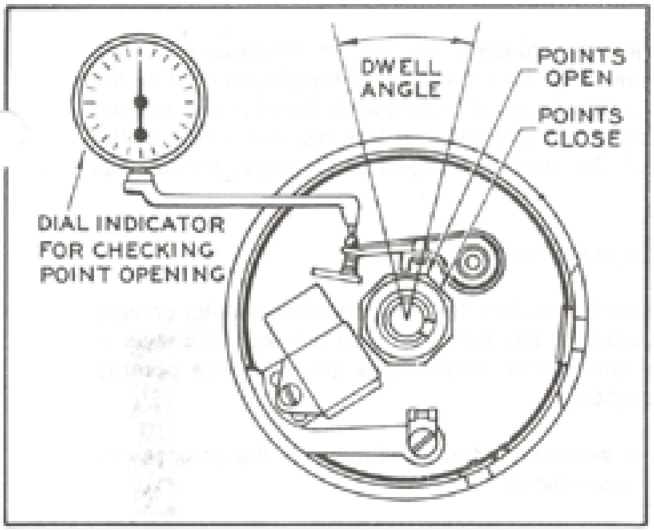
Distributor points do not have to be absolutely free of pits and grey oxide for satisfactory performance. Excessive cratering and build-ups of sharp peaks, however, require new breaker points. Slight point roughness may be cleaned up as much as is practical with a fine hone. Never use abrasive cloth or paper regardless of what the abrasive material is. A file is equally unsatisfactory with regard to continued point life, although improved performance may be obtained for a short while. If points are cleaned up with a fine hone, clean them with chlor-ethylene to remove the oily film which results from honing.

A feeler gauge is not an accurate method of setting points, particularly when there are some inequalities in the contact surfaces. If feeler gauge is used, caution should be taken to make sure gauge is clean and will not contaminate points.

An accurate method of setting points is the use of a dial indicator. Here, the gauge is solidly clamped to the distributor body in whatever manner is convenient. The gauge tip is brought to bear against the movable breaker point just behind the contact surface and the gauge is set to read zero with the fiber bumper on the flat of the cam and the points closed. By rotating the distributor cam with the starter, or with the fingers, if being bench adjusted, the exact point opening in thousandths is read on the dial indicator. This method will reveal worn cams and distributor shafts that are loose in the bushings by erratic opening readings. Clearances are adjusted in the conventional manner by turning the eccentric screw holding the fixed point. Do not forget to retighten the fixed point clamp screw after adjustment. A better method of measuring point opening is by the use of a dwell meter.

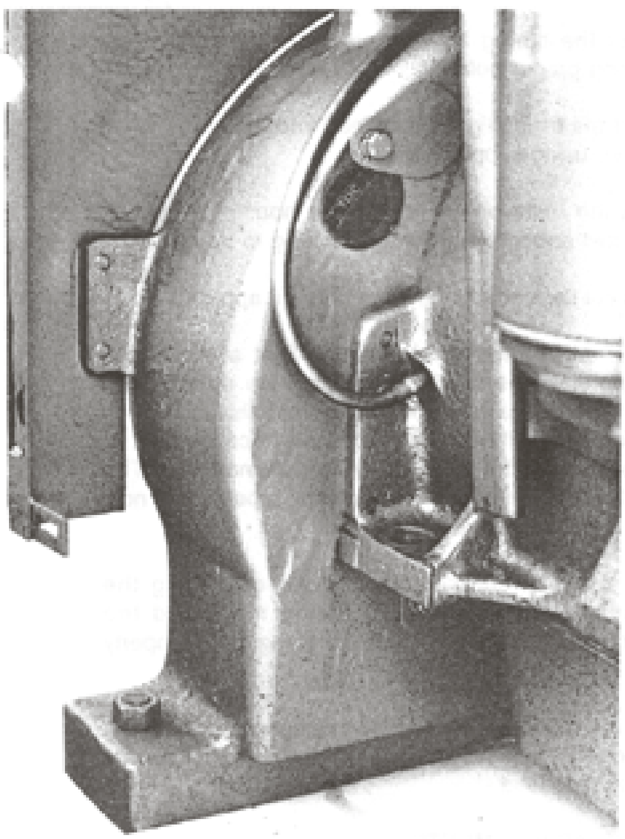


TYPICAL BATTERY IGNITION SYSTEM - SCHEMATIC



SETTING POINTS WITH DIAL INDICATOR

When the breaker point clearance is accurately adjusted, the engine should be turned to firing position on the compression stroke for No. 1 cylinder. This may be determined by aligning the distributor firing degree mark on the flywheel with the timing hole pointer in the flywheel housing. At the same time make sure that both valves on No. 1 cylinder are closed, or remove No. 1 spark plug and feel the compression with thumb.



SETTING ENGINE AT TOP DEAD CENTER

Consult the Basic Engine Data Section of this manual or the timing plate attached to the engine for the correct timing degree.

If the distributor assembly was removed from the engine, turn the rotor to the same position it was in opening with the distributor body held approximately the same as it was when removed.

When the distributor drive strikes its mating member in the crankcase, it may be necessary to rotate the shaft slightly by turning the rotor back and forth until the proper alignment is felt and the distributor drops into position. Tighten the distributor clamp cap screws until they are snug but do not prevent rotating the distributor body.

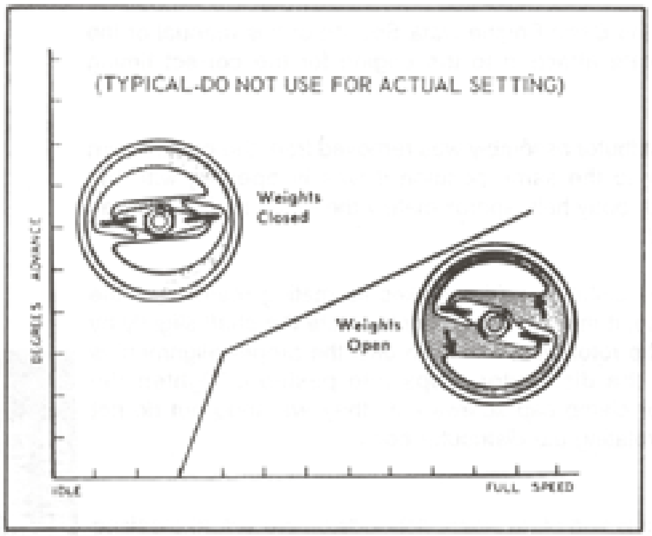
The exact timing of the spark depends on the actual breaking of the electrical circuit by the points. Hence, checking for the apparent mechanical separation with feeler stock, cellophane, etc. is apt to be misleading. To assure accurate timing, make up a simple light circuit consisting of an automotive light bulb with soldered-on leads of a socket with lead wires attached. Clip or wedge one lead to the ungrounded side of the starting battery, and attach the other lead to the primary wire connection at the side of the distributor. Final timing should be done with the engine running, using a powered timing light (see "USING TIMING LIGHT" in this section).

With the above installation, if the bulb is lit the points are closed and the distributor clamps may now be tightened and the flywheel turned backwards about a quarter of a revolution and then brought forward towards the timing mark as before. The light should just go out as the timing mark on the flywheel aligns with the timing hold pointer in the flywheel housing.

Since the engine is set for No. 1 cylinder firing, install the distributor cap and start installing the spark plug wires with No. 1 in the hole to which the rotor points and working clockwise around the cap.

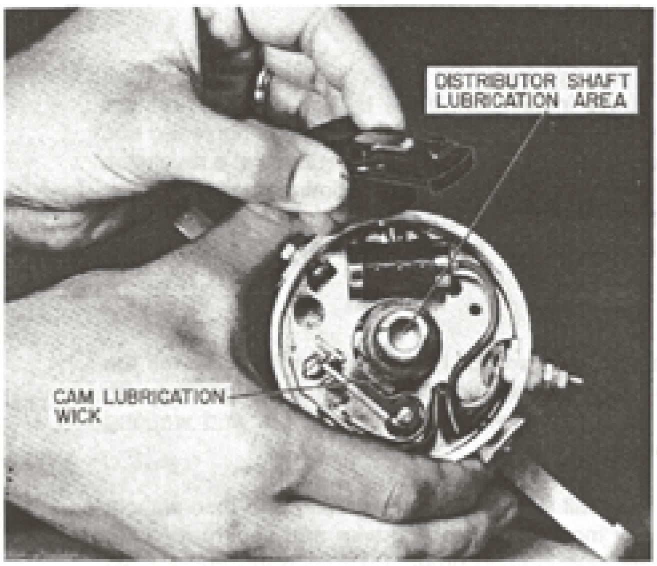
It is best to install a wire at the distributor, and then without installing any more follow up that wire and secure it to the proper spark plug in firing order. Take each in turn to avoid confusion.

Once the timing is properly set for the idle (no-speed) position, the centrifugal weight system of the distributor will automatically advance the spark as required by changes in engine speed. The mechanism involved is matched to each engine application by laboratory tests determining the best spark advance point over the entire speed range. Therefore, substitution of unmatched parts from other equipment will impair timing and engine performance. The advance curve for a distributor similar to that used on the VR Series engines is shown in the accompanying graph. Distributors on some VR Series engines also include a vacuum advance which (along with the centrifugal advance) advances the spark at part load operation to improve fuel economy.



CENTRIFUGAL ADVANCE CURVE

The distributor requires lubrication of the shaft, advance mechanism, breaker cam, and breaker lever pivot. For shaft and advance mechanism lubrication add 20W oil to felt material in center of shaft under rotor (see illustration).



DISTRIBUTOR OIL RESERVOIR LOCATION

Every 500 hours put one drop of light engine oil on the breaker lever pivot, and a few drops on the felt wick under the rotor. Some distributor points come with prelubricated wicks.

The centrifugal advance mechanism can be checked for freeness by turning the breaker cam in the direction of rotation and then releasing it. The advance springs should return the cam to its original position without sticking.

Adjusting Dwell Angle

The dwell angle represents that period of time during which the distributor points are closed as the distributor cam rotates from the peak of one lobe through the peak of the following lobe. As the point gap increases or decreases the dwell angle will change proportionately. The proper distributor point gap will be represented be a specific dwell angle, as read on the dwell meter. This is accomplished while the engine is running at any speed, thereby giving a true representation of the adjustment. To check and adjust dwell angle, proceed as follows:

With the engine stopped:

1. Connect the dwell meter between the distributor primary lead, either at the distributor or at the coil, whichever is more convenient, and engine ground. Note polarity requirement.

2. Set the switches on the dwell meter to the settings per meter instructions.

3. Start the engine and read directly from the meter.

4. If the specified dwell angle is incorrect, stop the engine and adjust the point gap, repeat as required. Increasing the point gap will decrease the dwell angle, decreasing the point gap will increase the dwell angle (see "BASIC ENGINE DATA" in end of REPAIR AND REPLACEMENT for specific dwell angles.

Using Timing Light

With engine stopped:

1. Connect the timing light power leads to the battery (observing proper polarity).

2. Connect the timing light signal lead into the No. 1 spark plug lead, using supplied adaptor.

3. Loosen the bolts on the distributor housing retaining clamps just enough to allow the housing to be rotated.

4. Disconnect the vacuum advance tube (if applicable).

5. Start the engine and aim the timing light at the timing hole pointer in the flywheel housing. Be sure to aim directly towards the center. On some models a button on the timing light will have to be pushed to cause light to flash, on others the light will flash automatically. The correct firing degree mark on the timing tape should now appear under the reference pin.

6. Rotate the distributor housing while observing the relationship of the specified timing mark and the reference pin. When they line up, the engine is properly timed.

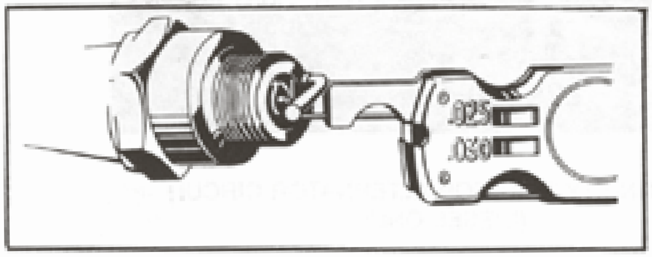
7. Tighten the distributor clamp bolts, reconnect the vacuum advance tube, remove the timing leads and reconnect the spark plug lead.

SPARK PLUG ADJUSTMENTS

Misfiring or ragged operation may be due to faulty spark plugs caused by carbon accumulations and burning of the electrodes. They should be cleaned, inspected, and the gaps checked approximately every 250 hours of operation or oftener if the engine idles for prolonged periods. After 500 hours, it is advisable to replace the entire set when any spark plug is defective.

Deposits on the electrodes and insulator may be removed by commercial abrasive cleaners. Scraping the insulator is not recommended since the resulting scratches increase the tendency of carbon deposits to form.

After the spark plug has been cleaned, adjust the gap with a round wire gauging tool to .025" (gasoline and gaseous fuels) by bending the outer electrode. As the spark plugs will have a tendency to burn the electrodes and widen the gap, it is important that gap be checked whenever the plugs are removed from the engine. Missing at low speeds is very often due to a wide spark plug gap.

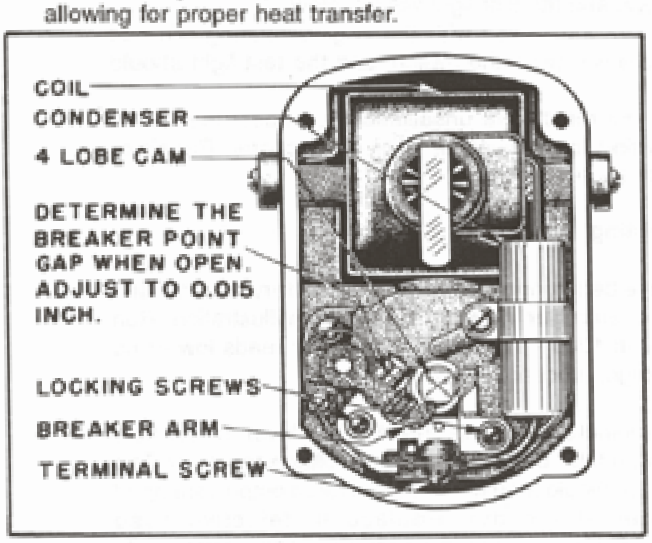


CHECKING SPARK PLUG GAP

Examine for cracked porcelain, leakage, burned electrodes, deposits on center insulator, correct gap, good washers, and clean threads and seating surface. Remember, a plug may bear satisfactory and still miss.

NOTE

When replacing spark plugs, use new gaskets. Proper seating of the gasket is necessary for sealing the combustion chamber and transferring heat from the plug. Use spark plug tap to clean threads, allowing for proper heat transfer.



MAGNETO COVER REMOVED

MAGNETO SERVICING

Minor servicing of the magneto is confined to cleaning, replacement, and adjustment of the breaker points. Magneto point clearance is adjusted in the same manner as distributor point clearance. More extensive repair and over-haul operations require specialized training and equipment and should be made only at authorized service agencies.

TIMING THE MAGNETO

The magneto timing procedure follows very closely the steps given for timing the distributor. The flywheel must be rotated until the proper timing mark aligns with the timing hole pointer in the flywheel housing and number one piston is coming up on compression stroke. This is the point at which firing occurs when the engine is running and the impulse coupling has disengaged.

When the impulse coupling is engaged, as it is when starting to time the magneto, it must be released or "snapped" in order not to incorporate its lag angle in the timing procedure. With the end cap cover removed, turn the magneto impulse coupling backwards as many turns as needed to align the rotor finger with the timing boss marked "6" inside the end cap. Reverse rotation automatically disengages the impulse unit. Connect the magneto to the magneto drive.

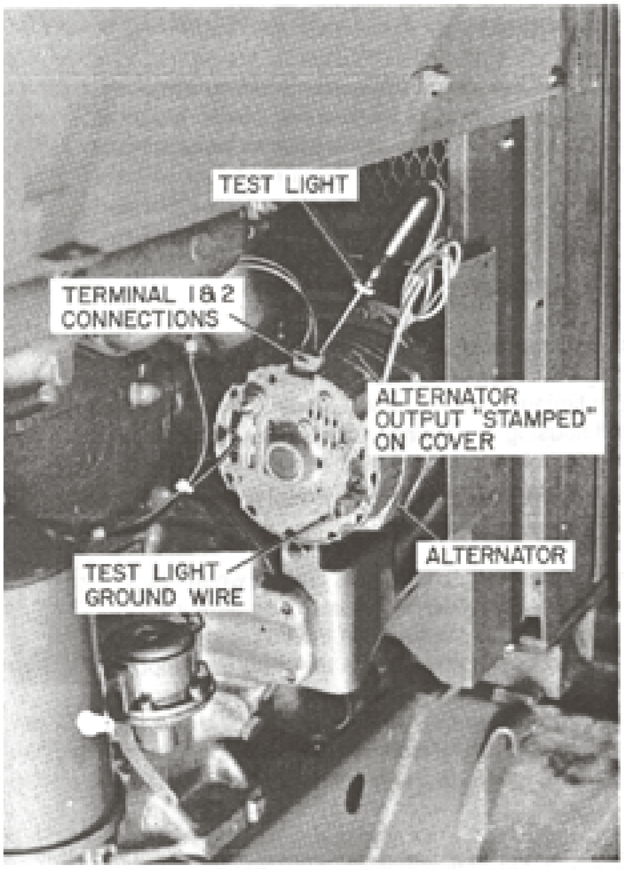
Final timing is done with the flange mounting screws snug. Connect a battery powered timing light to the spark plug lead of number one cylinder and check the timing with the engine running. If timing is not correct, tap the magneto by hand enough to rotate it on the mounting as required, exact timing is readily determined and the flange mounting screws must be tightened.

ALTERNATOR SERVICING

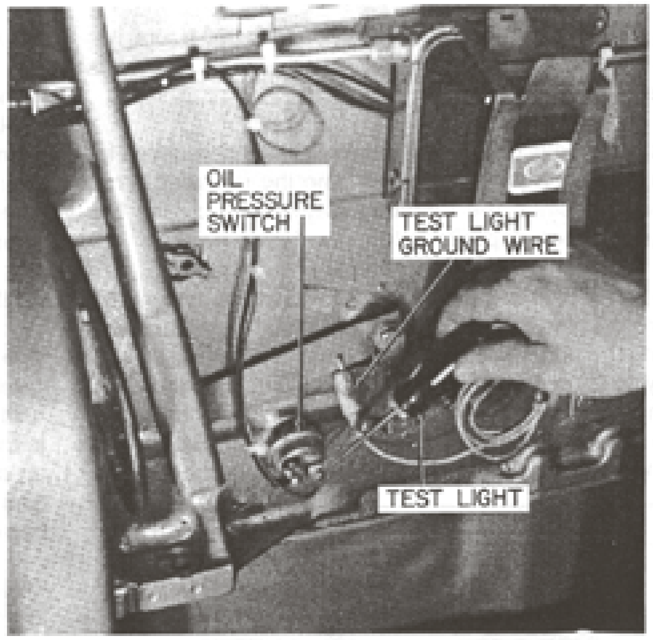
Alternator servicing within this manual is limited to testing the unit on the engine and replacing it if defective. To test the alternator, proceed as follows:

Continuity Testing

1. With engine off, check drive belt for proper tension
2. With ignition switch in the "ON" position (gas and gasoline engines only) and terminal wires connected, check current to each terminal with test light as shown in illustration. For diesel engines a jumper wire is required across terminals on oil pressure switch before making test at alternator terminals. If test light does not light at all terminals, check wires for good connections and frayed or broken wires. Test light will glow on terminal one, but this is normal due to resistance wire.



TESTING ALTERNATOR WIRING



CONTINUITY TEST FOR ALTERNATOR CIRCUIT
(DIESEL ONLY)

NOTE

The wire connected to the terminal one is a "resistance wire" and if replaced it must be matched with a wire of identical resistance.

3. Using a test light, check continuity at the oil pressure switch (diesels only), located on the side of the engine. Mount the test light as shown, with one lead going to ground, and the probe on the switch terminal that leads to the alternator.
   First test the switch with the engine shut down. With the engine off there will be no oil pressure, so the switch will be open and the test light will not glow.
   Then test the switch with the engine running. The oil pressure will close the switch, and the test light should glow.
   If the test results are unsatisfactory, inspect the switch and wiring for damage or poor connections. Repair or replace as necessary.

TESTING ALTERNATOR OUTPUT

Output Testing

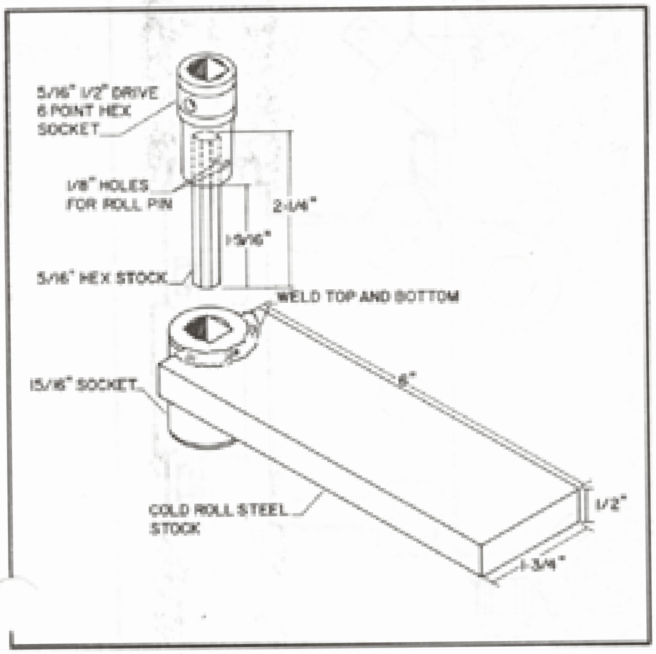
1. Remove battery wire from alternator battery terminal and connect ammeter in series as shown in illustration. Run engine at 1000 - 1200 rpm. If ammeter reads low or no amperage, proceed to next step.

2. With engine still running, insert screwdriver in test hole to ground tab - this by-passes the voltage regulator. The ammeter should read within 10% of rated output (stamped on alternator body). Replace if defective (See "ALTERNATOR PULLEY REMOVAL AND INSTALLATION TOOL" in this section).

NOTE

If alternator charges with tab grounded but does not charge when tab is not grounded, it indicates a defective voltage regulator located inside alternator body. If alternator does not charge its maximum with tab grounded, it indicates a defect in the alternator itself.

ALTERNATOR PULLEY REMOVAL AND INSTALLATION TOOL



ALTERNATOR PULLEY NUT TIGHTENING TOOL

REMOVING ALTERNATOR PULLEY

When replacing the alternator, it is necessary to remove the alternator pulley and retain it for use on the replacement alternator. A special tool has been designed to perform this step, and the materials and dimensions for making this tool included in the illustration.

When installing or removing alternator pulley nut, place pulley nut holder in a vise and position alternator into nut holder as illustrated. Use the allen wrench attachment to loosen or tighten shaft to pulley nut. Pulley nut should be torqued to 60 lbs. ft.

INJECTION PUMP MAINTENANCE

Most pumps have the timing marks located as illustrated. Here, one mark is on the governor weight carrier and on the cam, although not necessarily at the location shown. The mark might be on center, above center as shown, or possibly below center.

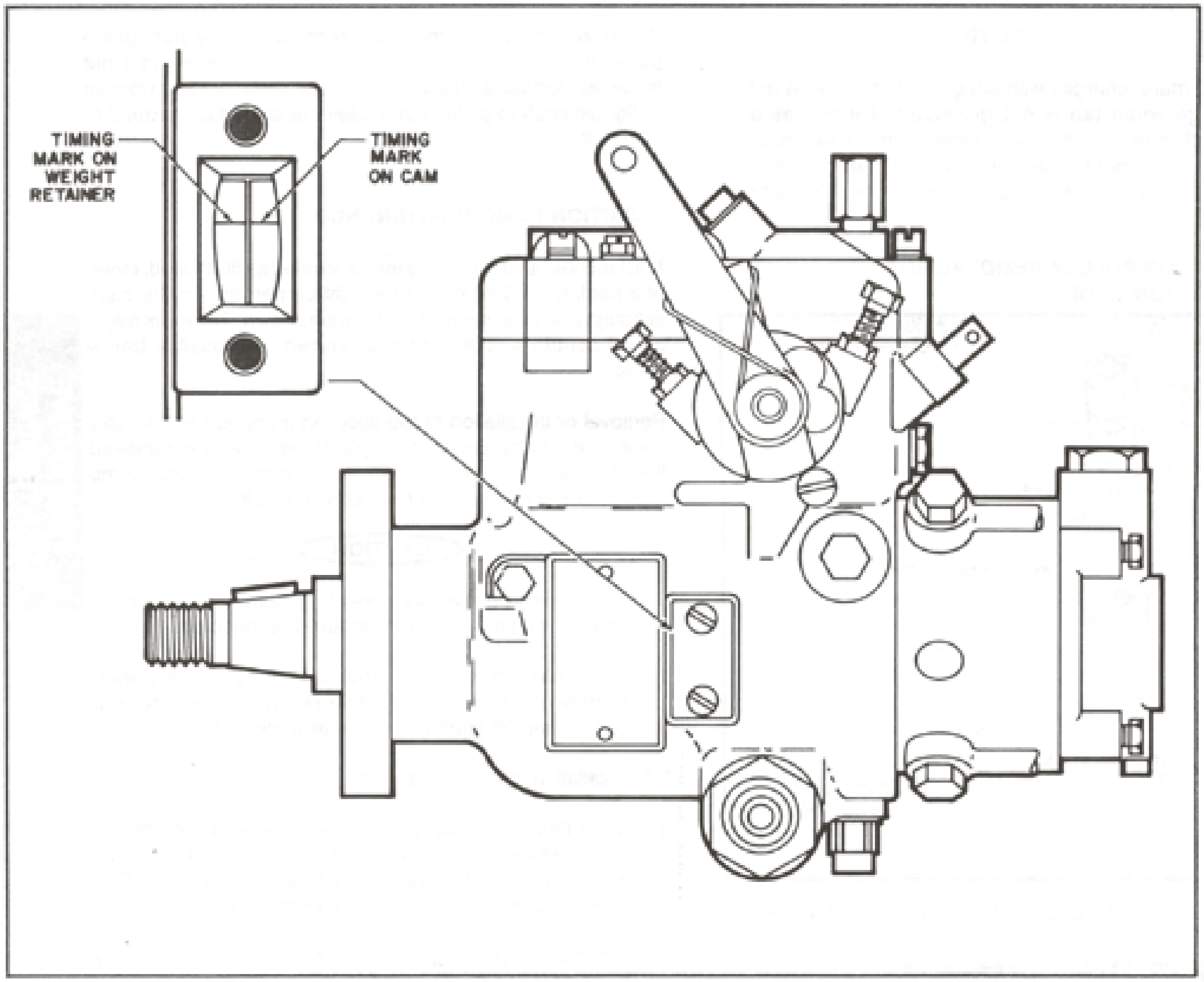
Removal or installation of the injection pump is considerably easier if the complete injection plumbing system is removed first. This is done by removing lines from injectors and pump and removing bracket bolt from engine block.

CAUTION

Clean fittings before disconnecting them and plug or cap all openings after fittings are disconnected.

1. Disconnect throttle and shut-off linkage from pump. Remove nuts holding injection pump to gear housing. Slide pump off shaft towards rear of engine.
2. Installation is in reverse order.
3. When timing injection pump, place the No.1 cylinder on compression stroke, using procedure outlined for valve adjustment, and position flywheel tape to specified degree number under the flywheel reference pin.
4. With the pump timing cover removed, use a clean, long blade screwdriver through the pump opening to turn the pump shaft until the mark on the cam ring and the mark on the weight carrier are aligned (refer to illustration). Slip the pump in place on the shaft and seat the drive. Grease the shaft and the shaft opening in the pump liberally with light grease. Be careful not to damage the lips of the seal when slipping the pump in place. A special tool, Roosa Master tool number 13371, is available to compress the drive shaft seals when installing the pump.
5. Pump should be rotated first in direction of rotation and then in opposite direction, within elongated mounting slots, to perfectly align timing marks, and to remove backlash.
6. Tighten pump retaining bolts.
7. Reconnect throttle and shut-off linkage.
8. Reinstall injection plumbing.

The limits of throttle travel are set by adjusting external screws for proper idling and high speed positions.



INJECTION PUMP TIMING MARKS

NOTE

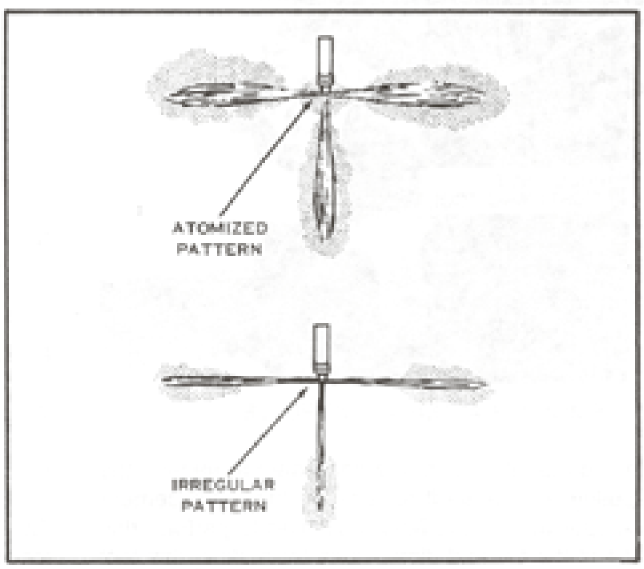
The fuel system must be bled when the injection pump is removed and reinstalled, and also whenever the fuel filter element is changed.

Fuel Injector Test

Unless proper service equipment is available, and the operator is skilled in its use, there is little actual repair work that can be accomplished on injectors.

If a nozzle is suspected of improper operation, it may be given a general test by allowing it to spray into the atmosphere while using a nozzle test stand.

Experience is the best indication of what may be considered a satisfactory spray pattern. Also an apparent chattering of the spray is normal and is easily recognized.



ATOMIZED AND IRREGULAR PENCIL INJECTOR SPRAY PATTERNS

Certain other nozzle conditions, however, are definitely undesirable and will usually reduce engine performance substantially. These conditions are usually the result of valve damage or contamination and are characterized by dribbling, sprays of badly distorted patterns, and other self-evident troubles. The best remedy is replacement with another nozzle.

Sometimes, when the only real difficulty is carbon or gum interfering with the valve action, a thorough cleaning with a solvent such as "GUNK" will improve performance.

If the above operation does not improve the nozzle operation, a new injector is required.

WARNING

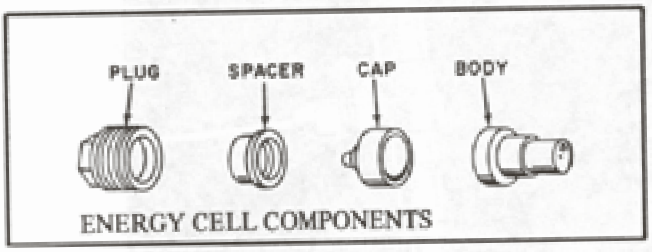
KEEP AWAY FROM INJECTION SPRAY. PENETRATING POWER OF DIESEL FUEL UNDER PRESSURE IS SUFFICIENT TO PUNCTURE SKIN AND CAUSE BLOOD POISONING.

ENERGY CELL SERVICE (VRD 155 AND 232)

Energy cells are made up of the components shown in the accompanying illustration. They are located just below the intake manifold on the right side of cylinder head directly opposite their corresponding injector nozzles.

NOTE

The energy cell must be reassembled as illustrated. If the cap is installed backwards, the cell will rapidly carbon up, leading to reduced engine output.

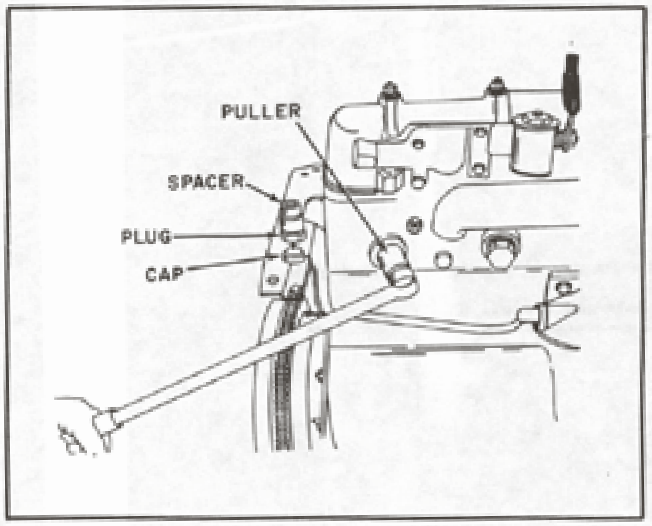


ENERGY CELL COMPONENTS

A stream of fuel injection spray is received by the cells. Channels in cell body and cap turbulate the spray. Since energy cells have no cooling jackets, a high degree of heat is attained and fuel is ignited. Cells are angled slightly so the return flow from the cells enters the combustion chamber at an angle and aids in creating the necessary swirl or turbulence required to thoroughly mix the air and fuel for complete combustion of the main spray in the chamber.

Energy cells should be removed for cleaning or replacement when fuel injectors are found to be faulty or when poor fuel combustion is evident. Excessive exhaust smoke may indicate a carboned up energy cell. Incorrect injection pump timing can carbon up a cell in just a few hours.

It may be necessary to apply a carbon solvent or scrape the outer edge of the cap with a soft metal scraper before removal is possible.



REMOVING ENERGY CELL BODY WITH SPECIAL PULLER (Part Number 494149)

Arrow provides a special puller, part number 494149, for the removal of energy cell bodies.

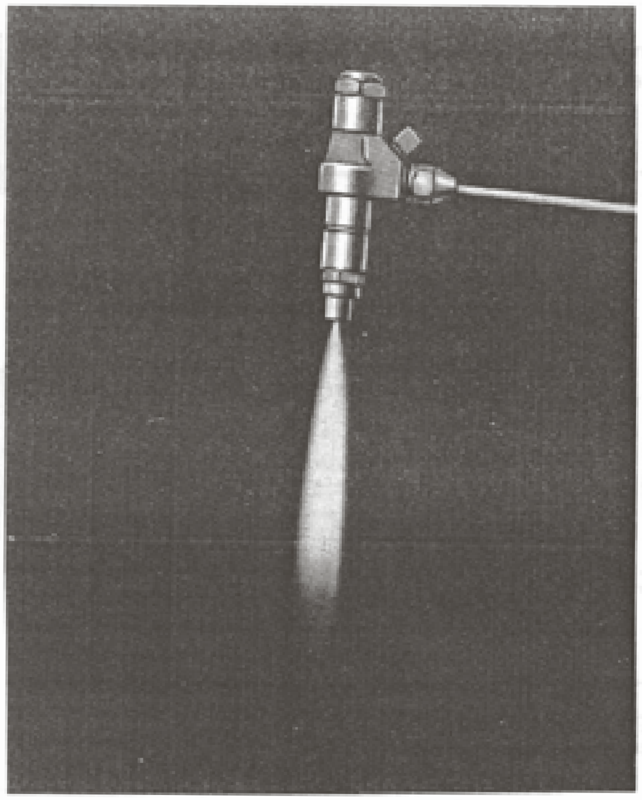
The tool is designed so that it will clean the carbon from the energy cell body internal threads as it is threaded in. Then, the use of the small slide hammer attached to the extractor will allow the energy cell body to be removed quite easily from the cylinder head.

After soaking cell parts in carbon solvent overnight, use brass scrapers and brushes to remove any remaining carbon deposits. Be sure body orifice opening is thoroughly clean. Lap cap and body sealing surfaces if necessary using a lapping compound and plate and a figure eight motion to assure a perfectly flat surface. Be sure body orifice opening is thoroughly clean. Orifice size is No. 32 drill. Check for correct orifice size using No. 33 drill as go, and No. 31 drill as no-go.

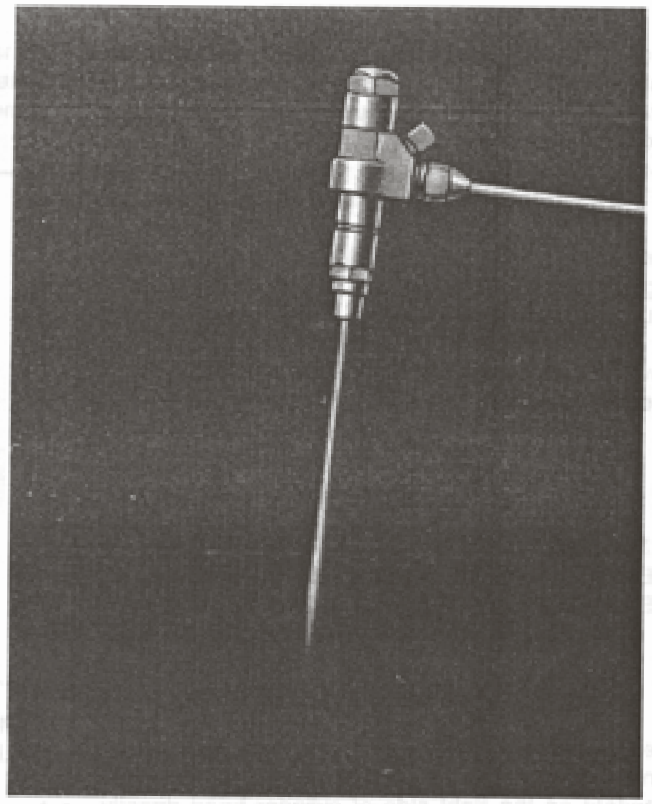
Rinse parts in clean diesel fuel and install energy cell by reversing removal procedure. Always replace energy cell in same cylinder it was removed from. Be sure cap is inserted flat against body surface before installing spacer and plug. Tighten plug to 96-100 ft. lbs. torque setting.

PINTLE NOZZLE SERVICE (VRD155 and 232)

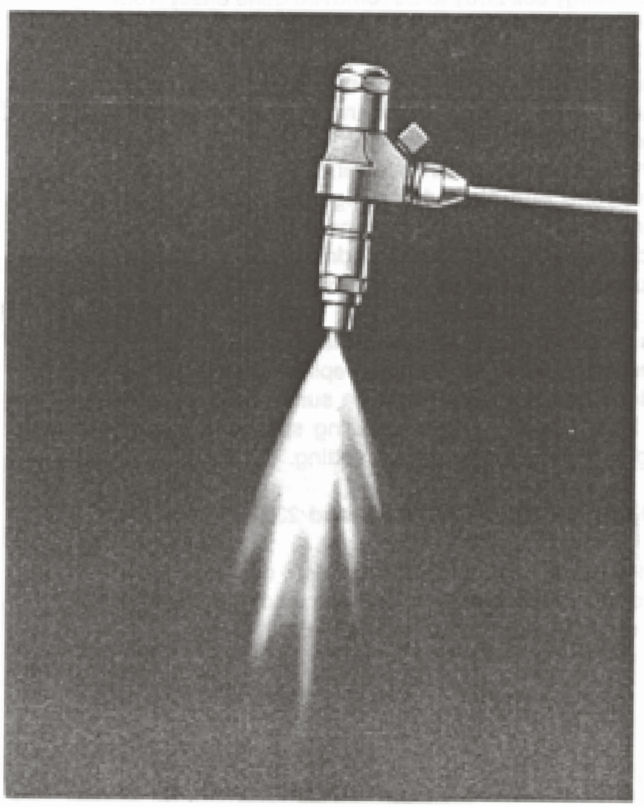
Nozzle service must be performed in a clean, dust free area. Cover injector openings and remove all traces or dirt, paint or carbon with diesel fuel and a brass wire brush.



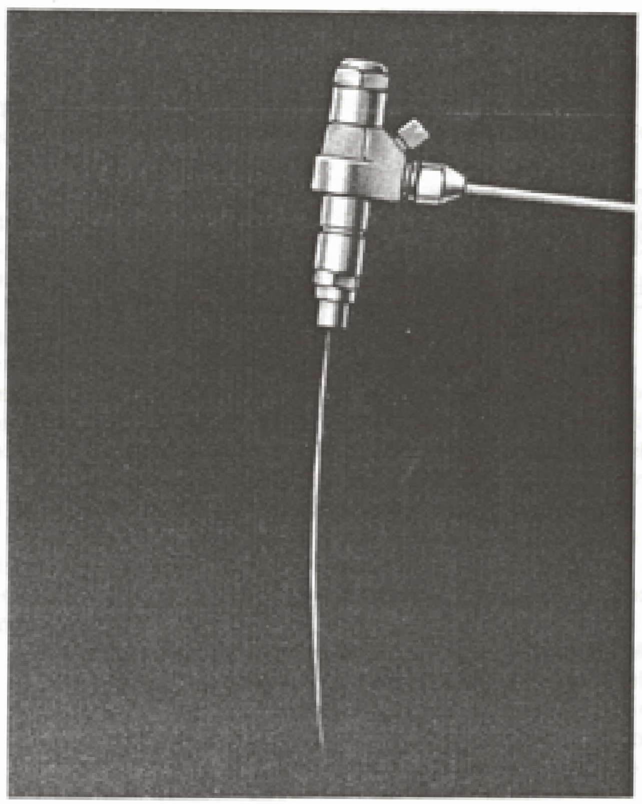
FULL LOAD SPRAY PATTERN
(PINTLE INJECTOR)



IDLE SPRAY PATTERN
(PINTLE INJECTOR)



SPRAY RAGGED - UNSATISFACTORY
(PINTLE INJECTOR)



LEAKING NOZZLE VALVE - UNSATISFACTORY
(PINTLE INJECTOR)

Remove protection cap and gasket. Loosen spring retainer cap nut to release pressure on spring. If spring replacement is required, remove spring retaining cap nut and spring from holder body. Remove nozzle gasket and nozzle cap nut and remove valve body and valve from holder body. Examine valve body for carbon and check if the valve lifts out freely. Soak valve and body in diesel fuel or a carbon solvent for valve removal (if necessary) and prior to inspection for bluing from overheating or other damage.

Pressure surfaces should be lapped only as necessary using a lapping compound and plate. Surfaces should have a fine mirror finish when properly lapped.

Clean small feed channel bores with appropriate size drill or wire. Remove carbon and varnish from valve body seat by rotating and pressing seat scraper on seat. Seat may be polished with tallow and polishing stick.

Insert groove scraper into pressure chamber gallery in valve body, press against side of cavity and rotate to clean away carbon deposit. Use tallow and wooden polishing fixture to clean and polish valve.

Use cleaning stick dipped in tallow to clean valve body pintle orifice. Use diesel fuel or carbon solvent to clean away carbon from surface around orifice; do not scrape surface as serious damage may result.

Use a brass wire brush to clean pintle end of valve. Use a wooden or brass strip to dislodge hard carbon particles. Caution should be exercised to prevent scratching or burring of valve pintle as serious damage may result.

Install valve in valve body while both are immersed in clean diesel fuel.

Make sure pressure surfaces between valve body and holder body are absolutely clean. Center valve body and valve in cap nut using centering sleeve and install valve and body in holder body. Sleeve fits over valve body and its tapered end centers within nozzle cap nut. Sleeve is easily removed after tightening cap nut on holder body.

Install spindle, spring, spring seat and spring retainer cap nut in holder body. Install spring adjusting screw and nut in spring retainer nut.

Install injector on tester, adjust opening pressure and test operation.

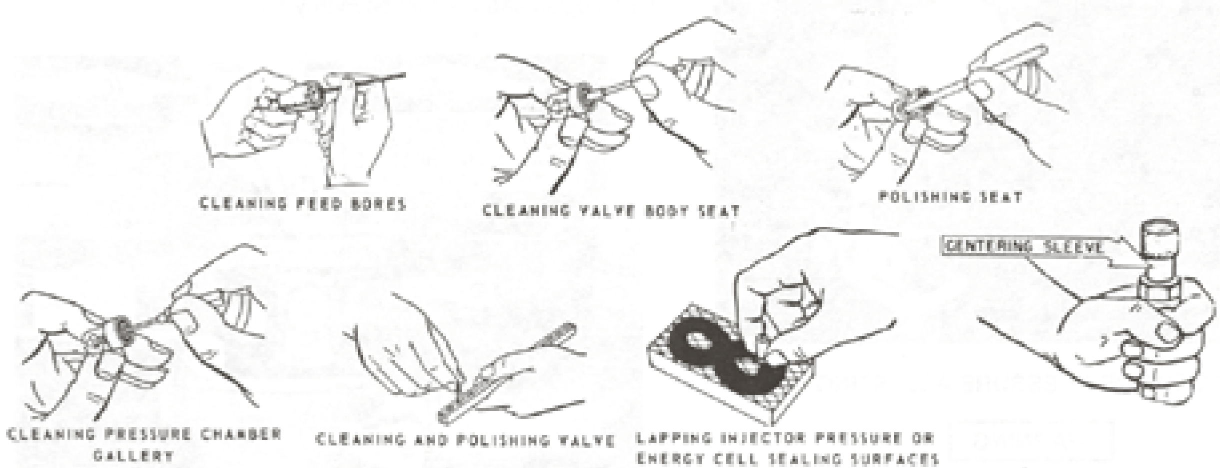
PENCIL INJECTOR ADJUSTMENT

NOTE

A good injector pressure test pump and gauge are needed to make the adjustment. If the proper equipment is not available, the injector should be adjusted by a properly equipped service station.

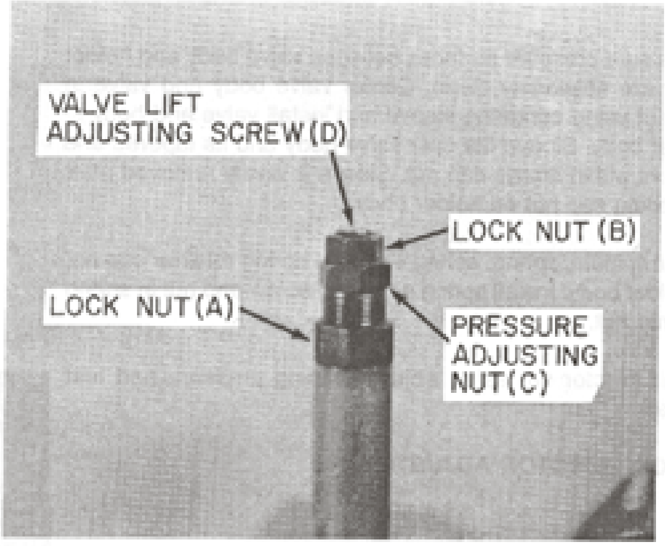
To adjust opening pressure of pencil injectors, proceed as follows:

1. Position injector in a holding device and loosen lock nuts (A) and (B). See Illustration.
2. Turn pressure adjusting nut (C) until injector opening pressure meets specification (see "BASIC ENGINE DATA" in end of REPAIR AND REPLACEMENT for proper pressure settings.)



PINTLE INJECTOR NOZZLE CLEANING OPERATIONS

PREVENTIVE MAINTENANCE

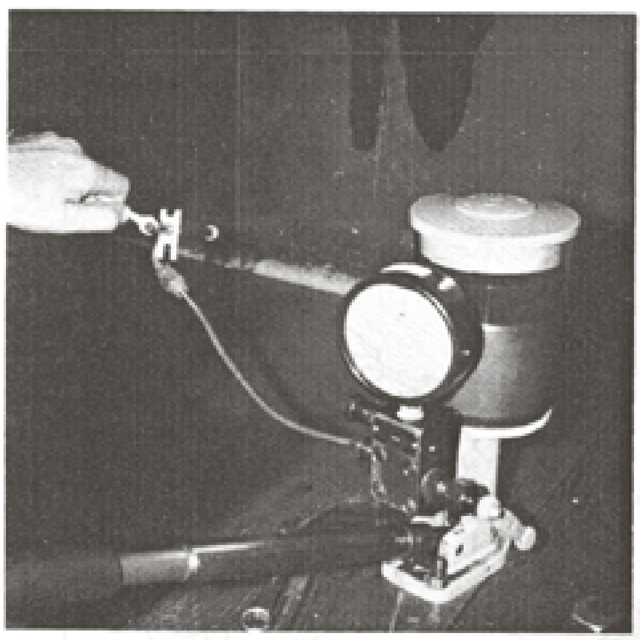


FUEL INJECTOR ADJUSTMENTS

3. Tighten lock nut (A) while holding pressure adjusting nut (C) steady.

4. Carefully turn valve lift adjusting screw (D) clockwise until it bottoms against valve. Then back out screw 1/2 turn ± 1/8 and tighten lock nut (B).

5. Test injector for correct opening pressure and readjust if necessary.



ADJUSTMENT OF PRESSURE ADJUSTING NUT

WARNING

KEEP AWAY FROM INJECTION SPRAY. PENETRATING POWER OF DIESEL FUEL UNDER PRESSURE IS SUFFICIENT TO PUNCTURE SKIN AND CAUSE BLOOD POISONING.

REINSTALLING PENCIL INJECTORS

Replace carbon stop seal before reinstalling injector in engine. Remove old seal by breaking with needle nose pliers. Use Roosa master tool (Part No. 16477) to install new seal. Check upper seal for possible damage, and replace if necessary.

GASOLINE CARBURETOR ADJUSTMENTS

Idle Mixture Adjustments

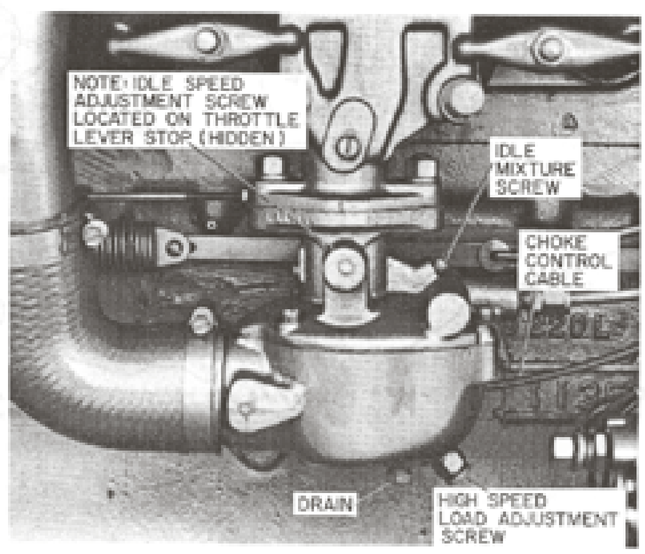
Warm up engine and place the throttle control lever in the idle position. Turn the idle mixture adjusting screw in until the engine begins to lose speed; then turn the valve out until the engine again begins to slow down. Use one-eighth turns and allow sufficient time between each change for the engine to adjust itself to the new setting. Race the engine occasionally to about 1000 rpm to clear the combustion chambers of excess fuel. Continue this adjusting procedure until a maximum idle speed is determined.

Idle Speed Adjustment

Set the idle mixture before making the idle speed adjustment. With the throttle control lever in the idle position, check the tachometer and turn the adjusting screw in or out as required to obtain the desired low idle speed.

High Speed Load Adjustment

Some Models of the VR Series are supplied with a main jet adjustment. Turning the needle clockwise cuts off fuel making the medium and high speed mixtures leaner. The needle should be adjusted to give highest manifold vacuum (or highest R.P.M. on a tachometer) for a set-throttle position. Set the throttle to hold the engine speed just below the governed speed while making the main jet adjustment. If adjustment is set too lean, the engine will lack power and the fuel economy also will be poor. If set too rich, the engine will be sluggish and the fuel economy poor.



TYPICAL GASOLINE CARBURETOR

GAS CARBURETOR ADJUSTMENTS

General

The normal arrangement for natural gas uses a field regulator to reduce pounds pressure to the final value of 5 inches water column (3 oz.) maximum. Excessive pressure will increase gas fuel consumption, and cause hard starting.

For reasons of safety . . . ALL GAS INSTALLATIONS IN CLOSED AREAS OR BUILDINGS SHOULD HAVE A POSITIVE SHUT OFF VALVE TO PREVENT GAS LEAKAGE WHEN THE ENGINE IS AT REST.

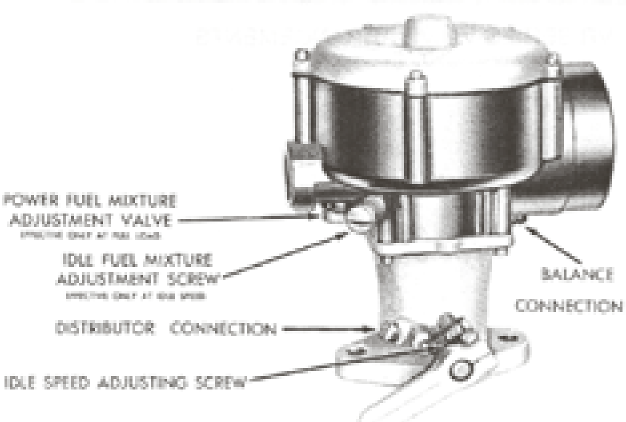
With the Impco carburetor, VR Series engines use a 1" line pressure regulator with a 3/8" orifice. The regulator utilizes spring 1B6538 (red) with 10 to 25 psi inlet line pressure and 5" H_2O column outlet pressure to the carburetor for 1000 BTU LHV gas.

Load Adjustment

1. Set natural gas pressure with engine idling, by adjusting line pressure regulator, to 5" water column plus or minus 1/4 inch, for 1000 BTU LHV gas with idle mixture screw hacked out 3 turns, and power fuel mixture turned to rich (R) position.

2. Full load gas pressure may drop as low as 3" water column at the carburetor gas inlet. Exact pressure at full load is immaterial as long as power mixture adjustment is still effective (carburetor can be set over-rich).

3. With the engine warm and running full load at governed speed, adjust the power fuel mixture from rich (R) towards lean (L) slowly to obtain maximum vacuum. After maximum vacuum is obtained, adjust for slightly leaner mixture to decrease vacuum 1/2" of mercury. This setting will improve fuel economy. If application is such that transient load changes occur, such as a generator set, omit this adjustment to decrease vacuum. The power adjustment is not effective at a fast idle or light load.



NATURAL GAS CARBURETOR

Low Idle Adjustment

1. Reduce throttle speed setting to bring carburetor butterfly lever against low idle stop.

2. Adjust carburetor idle stop screw to obtain desired engine RPM.

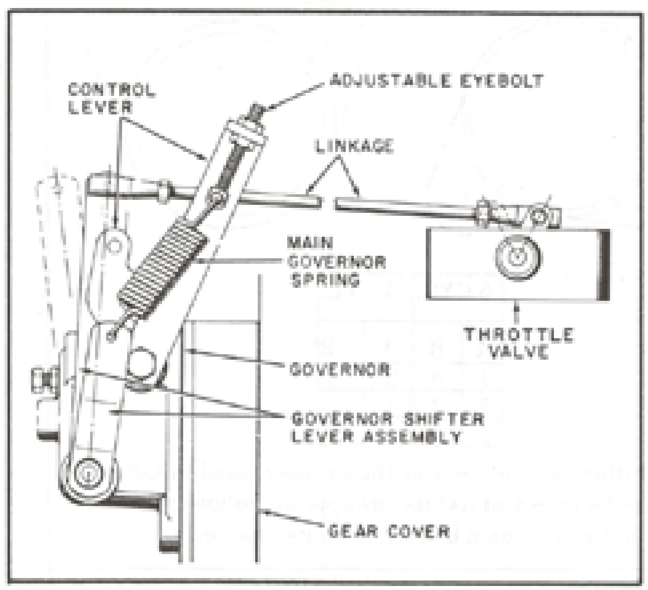
3. Adjust carburetor idle fuel adjustment screw to obtain highest engine RPM.

4. Re-adjust idle stop screw to obtain desired engine RPM.

GOVERNOR ADJUSTMENTS

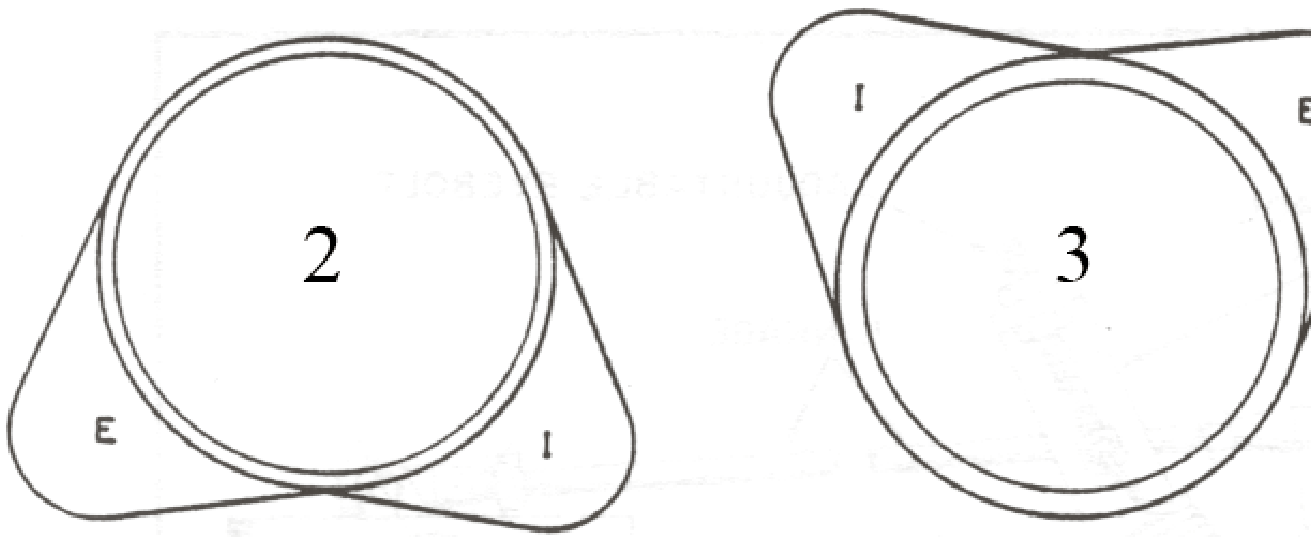
Gasoline Engines

Should the governor and linkage have to be dismantled to permit access to the engine for other service work, there are some basic requirements to be followed. Upon disassembly, the parts of the governor and linkage must be carefully marked so they will be reassembled in exactly the same position. The length of the linkage must be carefully noted so that when the engine is stopped and the throttle lever in full speed position, the throttle valve stands just a trifle toward the closed position. Variation from the proper speed can be corrected by changing the tension of the regulating spring. Increasing the tension increases the maximum speed, and decreasing the tension decreases the maximum speed. To increase and decrease the tension on the VRG155 governor spring, disconnect the governor spring end assembly from the governor lever and turn it to change the number of working coils (see illustration). Fewer working coils increase maximum speed; more working coils decrease maximum speed.



GOVERNOR, THROTTLE VALVE, AND LINKAGE

PREVENTIVE MAINTENANCE



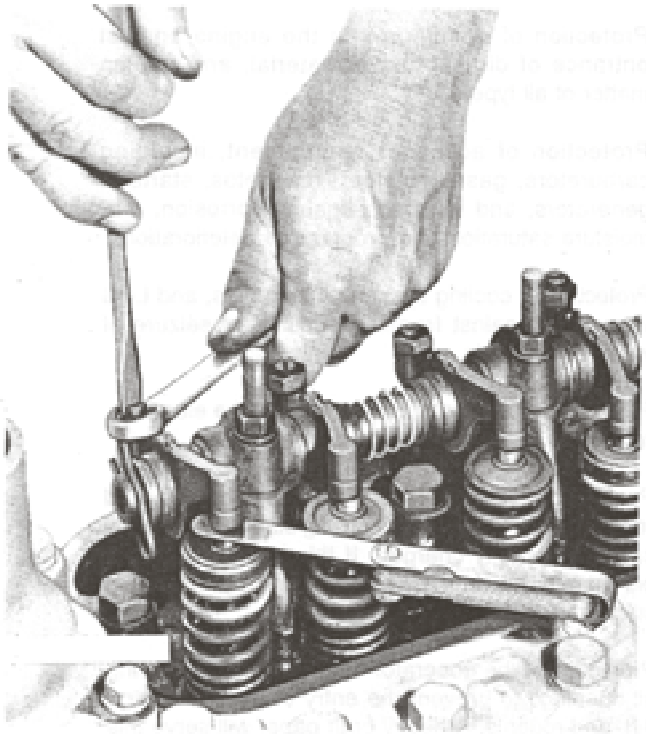
6 CYL.		4 CYL.	
A	B	A	B
1	6	1	4
5	2	2	3
3	4		

I=Intake

E=Exhaust

When either cam follower in the cylinder listed in Col
A is on-the crown of its lobe, its opposite follower liste
the cylinder in Column B is riding on its base circle.

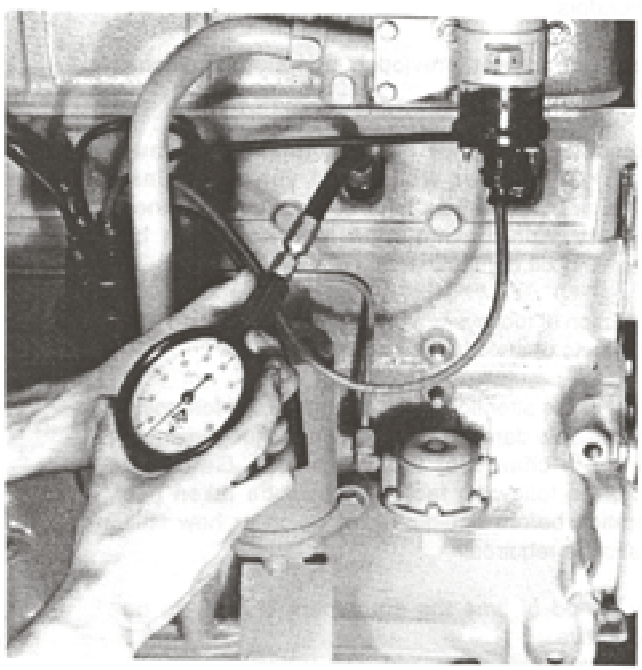
CAMSHAFT RELATIONSHIP



ADJUSTING VALVE CLEARANCE

COMPRESSION TESTING

To check the compression of gas and gasoline engines, a standard automotive type compression tester with threaded adaptor can be used. For diesel engines with pintle injectors, a special adapter (such as the MOTORITE ADAPTER, Part No. 70-0256, made by Bacharach) is required to make a compression test. Diesel engine owners with pencil injectors should contact a Bacharach dealer for correct part number.



COMPRESSION TESTER

Before checking compression, be sure the engine has been warmed up to operating temperature. Gas and gasoline engines must have the throttle held in open position and the ignition switch in off position. Diesel engines must have the fuel shutoff control in off position. Note the number of compression strokes needed to obtain the highest pressure reading. Repeat compression testing for each cylinder using the same number of compression strokes as used for the first cylinder tested.

Normal compression pressures at cranking speed are listed in REPAIR AND REPLACEMENT UNIT under "Basic Engine Data". Uneven compression or pressures lower than normal call for further checking. Valve regrinding, piston ring replacement, or other overhaul procedures may be required to correct the problem.

MANIFOLD VACUUM TEST

Gas and Gasoline Engine

Operate the engine until it is at normal operating temperature.

Connect vacuum gauge to the intake manifold and test with engine operating at idle speed, with no load condition (See tables below).

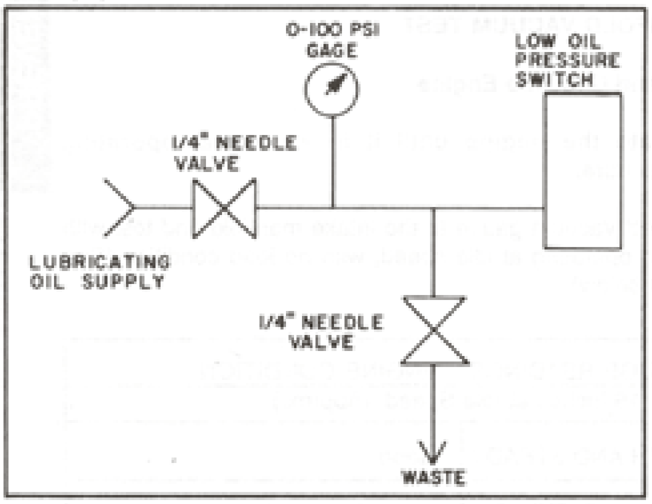
GAUGE READINGS	ENGINE CONDITION
18 - 19 Inches at Idle Speed. (Approx.)	
HIGH AND STEADY	Good
LOW AND STEADY	Loss of power in all cylinders caused possibly by late ignition or valve timing, or loss of compression due to leakage around the rings.
VERY LOW	Manifold, carburetor or cylinder head gasket leak.
NEEDLE FLUCTUATES STEADILY AS SPEED INCREASES	A partial or complete loss of power in one or more cylinders caused by: a leaking valve, cylinder head or intake manifold gasket leak, a defect in the ignition system or a weak valve spring.
GRADUAL DROP IN READING AT ENGINE IDLE	Excessive back pressure in the exhaust system.
INTERMITTENT FLUCTUATION	An occasional loss of power possibly caused by a defect in the ignition system or a sticking valve.
SLOW FLUCTUATION OR DRIFTING OF THE NEEDLE	Improper idle mixture adjustment, or carburetor, spacer or intake manifold gasket leak.

PREVENTIVE MAINTENANCE

TEST PROCEDURES FOR ENGINE PROTECTION DEVICES

Low Oil Pressure (LOP) Test

To test the low oil pressure Swichgage®, install two needle valves, a 0-100psi pressure gauge and piping as shown in the illustration. With the engine in operation, simulate a low oil pressure shutdown by closing the 1/4" needle valve in the oil pressure line to the Swichgage®. This will trap oil pressure in the system. Then slowly open the 1/4" needle valve in the line to waste, observing the oil pressure indicated by the test gauge when the Swichgage® is actuated. If necessary, adjust the Swichgage® as required and repeat the test. After testing, immediately close the needle valve in the line to waste and open the needle valve in the oil pressure line to the Swichgage®.



LOW OIL PRESSURE TEST PIPING ARRANGEMENT

High Water Temperature (HWT) Test

To assure high temperature shutdown, the temperature sensor bulb should be removed from the water manifold and immersed in hot water. Then the water should be heated until it boils. Allow sufficient time for the sensor to actuate the control.

NOTE

The preceding tests apply to the typical safety controls used on Arrow engines. If engines contain special controls, test procedures may be obtained from Arrow Specialty Company Customer Service Department.

ENGINE STORAGE

Preservation of engines and generators in storage involves several basic requirements. For new engines and generators, these are as follows:

1. Protection of machined metal surfaces, cylinders, valves, bearings, and so on, from the effects of both dampness and salt or other corrosive substances in the atmosphere.
2. Protection of openings into the engine against entrance of dirt, abrasive material, and foreign matter of all types.
3. Protection of accessory equipment, including carburetors, gas regulators, magnetos, starters, generators, and fan belts against corrosion, dirt, moisture saturation and progressive deterioration.
4. Protection of cooling system, intercoolers, and LPG vaporizers against freezing, rusting, or seizure of water pump seals.
5. Protection of a general nature against the elements, rain, snow, and extremes of temperature.
6. Protection of batteries by disconnecting and removing them to a slow charging station where they can be kept fully charged. If this is neglected, the plates may be damaged and ruined by becoming sulphated.
7. Protection of the generator or alternator by covering all openings to prevent the entry of dust, moisture, dirt, and rodents. A heavy craft paper will serve this purpose. Where these openings are in the form of screened or louvered guards or covered plates, the protective paper should be placed under these removable parts. If this is not possible a pressure sensitive tape can be used to hold the paper in position. Do not use masking tape -- it is not suitable for this type of service and will be very difficult to remove after extended use. Application of protective paper should be on both inside and outside of large, fixed, louvered surfaces. Large open areas should have a corrugated cardboard backing for the paper.
8. Protect switchboards in the same manner as generators.

In the case of engines previously operated, additional items must be considered.

9. Protection of interior engine parts, particularly bearings, cylinder walls, and valves against corrosion by the products of combustion combined with atmospheric moisture and corrosion by lubricating oil contaminants.
10. Protection of fuel system units against gumming and the effects of stale fuel oil or gas residues.

The extent of the attention given to each of the foregoing points of possible damage depends on the judgement of the person in charge of the equipment. Generally speaking, the following factors should be taken into consideration before deciding how much or how little preservation is required:

1. The period of time the equipment is likely to be inoperative.

2. The severity of the weather and atmospheric conditions at the point of storage. The problems of storing equipment in a tidewater warehouse, for example, differ greatly from storage problems in a location where the air is very dry and dusty.

3. The accessibility of the equipment for periodic inspection and attention. An engine on a showroom floor that may be turned over occasionally and given periodic oiling requires less extensive treatment than engines crated and stocked in a warehouse.

CAUTION

VR Engines received from the factory are internally protected for up to six months. If storage period exceeds six months, the engine should receive additional storage preservatives. Engine stored outdoors or in a humid environment may require more frequent representation.

CONVENTIONAL STORAGE

Storing New Engines

Engines recently received from the factory and not intended to be used for an indefinite period may be stored successfully in the following manner. All VR Engines shipped by Arrow Specialty Company receive storage measures internally which prepare the engine for a storage period of up to 6 months, unless they are test run, operated for any reason, or have the external openings unsealed. Engines stored outdoors or in a humid environment may require more frequent representation. Circumstances may compel omitting some steps and, on the other hand, special conditions may point to greater emphasis on other steps.

1. When engine is installed in an operable unit:

   A. Mix an inhibitive type preservative oil with the engine lubricating oil in the proportions recommended by the manufacturer of the preservative oil, or, no mixing may be necessary. Operate engine until oil is hot. Cooling water used in this run should have inhibitor added in accordance to manufacturer's instructions.

   B. Remove air cleaners of gas engines. With manually operated sprayer, squirt can, or other means, inject preservative oil of a type suited for this purpose into the air intake while the engine is running. Approximately one minute is ordinarily adequate. If possible, stop engine by "slugging" enough oil through intake to stall. Continue injecting oil until engine stops turning.

   CAUTION

   Never inject oil into the air intake of a diesel engine.

   C. Drain oil and water while hot. If extra protection is desired, the rocker arm covers may be removed and a quantity of preservative oil poured over the rocker arm and valve mechanisms.

   D. For diesel engines or for gas engines not stopped by "slugging", remove injectors or spark plugs and squirt or spray several teaspoons of preservative oil into each combustion chamber. Coat injectors or spark plugs and reinstall.

   E. Remove distributor cap or magneto cover and apply small amount of petroleum jelly to polished surface of breaker cam. Where dampness in storage is expected, removal of magneto may be worthwhile.

   F. Refer to "STORAGE OF FUEL INJECTORS" for additional instructions for diesel engines.

   G. Wipe engine clean and dry. Apply wax type masking tape or like material to all openings such as intake openings in air cleaners, exhaust outlets, breathers, magneto vents, and open line fittings.

   H. Relieve tension on belts. This is important because continual tension on belts without the working action that occurs in normal operation causes deterioration of the rubber.

   I. Apply a coating of heavy preservative compound with brush to all exposed machined surfaces such as flywheels.

Engines treated in accordance with these instructions will normally be protected for one year or longer. Continual inspection, however, is the only way to determine if protection is adequate. If possible, crank the engine by hand for one or two turns about once a month. This helps prevent seizure of water pump seals. If this is done, however, it is usually best to add more preservative oil to each cylinder. Some types of preservative oil are not well suited to periodic engine rotation because they are scraped from the cylinder walls which are then unprotected. Other oils are not scraped away, and for this reason the operator should carefully investigate the characteristics of the oil used.

2. When engine is not operable:

   A. Open drains as required to remove oil, water, and fuel.

   B. Remove the injectors or spark plugs and pour or squirt about a teaspoon of preservative oil into each cylinder.

   C. With hand or mechanical operated atomizing spray (do not use ordinary compressed air), inject preservative oil into each cylinder. Crank engine in normal direction about one-quarter turn and spray each cylinder again. Do this about eight times, or until engine has been turned through two complete revolutions. The purpose of this procedure is to bring each valve into an exposed position so the preservative oil will coat it.

D. Depending on the judgement of the operator as to the severity of storage conditions, open oil pan access doors, valve rocker covers, gear cover plates, and as many points as possible where oil may be sprayed, poured, or squirted over the interior parts. Replace all plugs and covers.

E. Remaining steps may be the same as listed in "E" through "I" for an operable engine.

Storing Engines That Have Been In Service

In the course of normal engine operation, residues of various combustion products such as lead and sulphur accumulate in the combustion area and in the lubricating oil. Portions of these residues combine with atmospheric moisture to form corrosive compounds of a destructive nature. The following treatment will help reduce the damage from this source:

1. Engine in operable condition:

   A. Run engine until original oil is hot. Drain.

   B. If practical, run engine with a good flushing oil in crankcase and drain oil and water while still hot.

   C. Refill crankcase with preservative oil, or with the proper grade of lube oil to which an inhibitive type preservative oil has been added in the proportion recommended.

   D. Carry out previous instructions "D" through "I" as the circumstances indicate.

2. When engine is not operable:

   A. Carry out instructions as for an inoperable new engine.

   B. If the judgement of the operator and storage conditions warrant, the engine should be disassembled for treatment as a new engine. Ordinarily, this last procedure is unnecessary except in cases where fuels containing considerable sulphur have been used, or where extremely bad climatic conditions prevail.

PRESERVATION EQUIPMENT AND MATERIALS

Sprays and Atomizers

In the foregoing instructions, it is recognized that many times it is necessary to apply protective compound under difficult field conditions. Several simple tools may be used to atomize preservative oil and force it into the manifolds and combustion chambers. One of these is a manually operated atomizing gun used ordinarily to lubricate inaccessible points on car and truck chassis. Another is a hand operated pump type sprayer with a pointed discharge nozzle commonly used with insecticides. If desired, small oil pumps may be rigged with a motor drive to make a convenient spray unit of the mechanical pressure type. In almost all cases, the air available from shop compressor lines carries too much moisture to be safe for this purpose. Do not use high-pressure air from this source.

Heating of Preservative Compounds

Many preservative compounds are most effective when heated before application. If possible engine should be warmed prior to applying preservatives. Heating reduces their viscosity so as to gain penetration into accessible areas. In addition, the hot compound reduces the moisture film at the metal surface and thus avoids trapping moisture under the preservative layer.

WARNING

Generally speaking, such heating is confined to 200° F.(93°C), or less. These temperatures are easily reached by placing the preservative container in heated water. Direct heating presents a dangerous and unnecessary fire hazard.

PREPARING ENGINE FOR OPERATION AFTER STORAGE

The steps needed to bring an engine into active service after storage in accordance with these instructions are about the same as those normally carried out on any new engine. These are inspection, checking for free rotation, adequate cooling water or antifreeze, ample lubricating oil of the correct type and viscosity, and proper adjustments.

In addition, accumulated dust and dirt should be wiped or washed from the exterior before removing the covers over the engine openings. Removal of installed protection should occur upon normal inspection of the engine, generator, and switchgear interiors prior to start-up. Partial removal may be necessary in the course of installation, but this should be kept at a minimum. Engines that have not been rotated for some time should be oiled through the injector or spark plug openings and cranked by hand or with the starting equipment before actually running. Any resistance to free cranking should be investigated; rust and corrosion can cause severe seizure that cannot be forced clear without engine damage.

CAUTION

All generators and switchgear which have been stored must be checked for installation resistance with a "Megger" prior to being put into service. The megger used should produce 500 V.D.C. Disconnect voltage regulator, rotating diodes, suppressors and any other solid state devices which may be connected to the stator or rotor windings. The megger value should be: operating voltage ÷ 1000 + 1 (i.e., machine voltage of 480 V.A.C. ÷ 1000 = .480 + 1 = 1.480 megohms). If any circuit to ground measures less than calculated value, consult the Arrow Specialty Customer Service Department for any corrective measures as may be necessary.

Never attempt to start an engine that has been stored without first cranking it over with the injectors or spark plugs out. Spurting oil, water or preservative compound from these openings indicates possible hydraulic lock if an attempt had been made to operate. Continue to crank engine with starter until liquid is no longer ejected from openings. Inspect intake passages and manifolds for thickened preservative oil. Oil accumulated in this condition may melt when the engine warms up and cause a runaway.

Specifications for Protective Materials	
Internal Surfaces, Cyls., Etc.	External Surfaces
U.S. Army Spec. 2-126 (Available as SAE 10 or SAE 30)	U.S. Army spec. 2-121 (Waxy Coating) Army Ordinance Spec. AXS 673 (Harder black coating)

STORAGE OF FUEL INJECTORS

Storage

Unless properly protected from corrosion and gumming, injectors, pumps and lines are subject to serious damage while idle for more than a few days' time. To protect against such damage when using conventional storage methods, any of the preservative oils listed at the end of this section are recommended. Carry out the following instructions in the sequence given:

1. Disconnect main fuel supply line wherever convenient, carefully wipe it clean of dirt, and place in container filled with preservative oil.
2. Run engine until all of preservative oil has been taken into fuel system.

When preservative oil has been run through the injectors as in the foregoing instructions, they will ordinarily be protected for short periods of a week up to several months depending on climatic and storage conditions. Whenever dampness or long term storage up to a year seem likely, carry out the following operations after the above steps are completed:

1. Remove the injectors from the engine.
2. Install caps or tape over fuel line outlets and injector connection fittings. Seal injector openings in cylinder heads with plugs. Replace rocker arm covers.
3. Injectors should be serviced by a competent diesel repair station and hot wax sealed for storage.
4. Store injectors in clean, dry location.

Operation After Storage

If injectors were serviced as above, remove sealing wax and reinstall in engine.

If storage has been prolonged over a very long period, the preservative oil should be washed from the filters and lines by thoroughly purging with fuel oil with the fuel control in off position. Purge by operating hand priming pump.

PRESERVATIVE OIL

The following preservative oils are of a type that has been found satisfactory for the protection of fuel injectors. Other equally good oils are probably available and omission of them from this listing does not necessarily mean they are not acceptable. In main, the properties making an oil suitable for preservative requirements are good aging stability; high resistance to gumming, oxidation and polymerization; low pour point and viscosity; freedom from acids, asphalts, resins, tars, and water.

SUPPLIER	PRESERVATIVE OIL
American Oil Company	Amoco Anti-Rust Oil 4-V
Gulf Oil Corporation	No rust Engine Oil Grade 1
Mobil Oil Company	Mobil Arma 522
Shell Oil Company	Donax t-6
Atlantic Richfield Co.	Dexron
Texaco, Inc.	No. 800 Regal Oil A (R O)

NOTE

Dexron automatic transmission fluid may be used if none of the above preservative oils are available.

TURBOCHARGED ENGINES (MODEL VRD310S)

The following information is supplied as a general guide to the better understanding of the operation of turbocharged engines, and is not to be construed as complete engineering or service data.

As shown in the accompanying schematic diagram, the exhaust driven turbine and its impeller are not connected to the working parts of the engine in any physical manner with the exception of the exhaust and the intake air manifolding and the oil lines. Hence, the turbocharger will not be troubled by gear train, belt, or other mechanical drive engine troubles. Moreover, since the supply of hot gases under high velocity supplied to the exhaust turbine is a reflection of the engine speed and load, the turbocharger output is closely matched to the engine air requirements. The schematic diagram illustrates how the high speed impeller driven by the exhaust turbine provides additional air for the combustion process and thus materially boosts the power output of the engine. The exhaust back pressure is actually very slight since it is the velocity of the gas and its unused energy which is put to work. Also, it should be remembered that the temperature of diesel exhaust gas, even with the turbocharger, is considerably lower than is normally encountered at equivalent loads in gasoline engines.

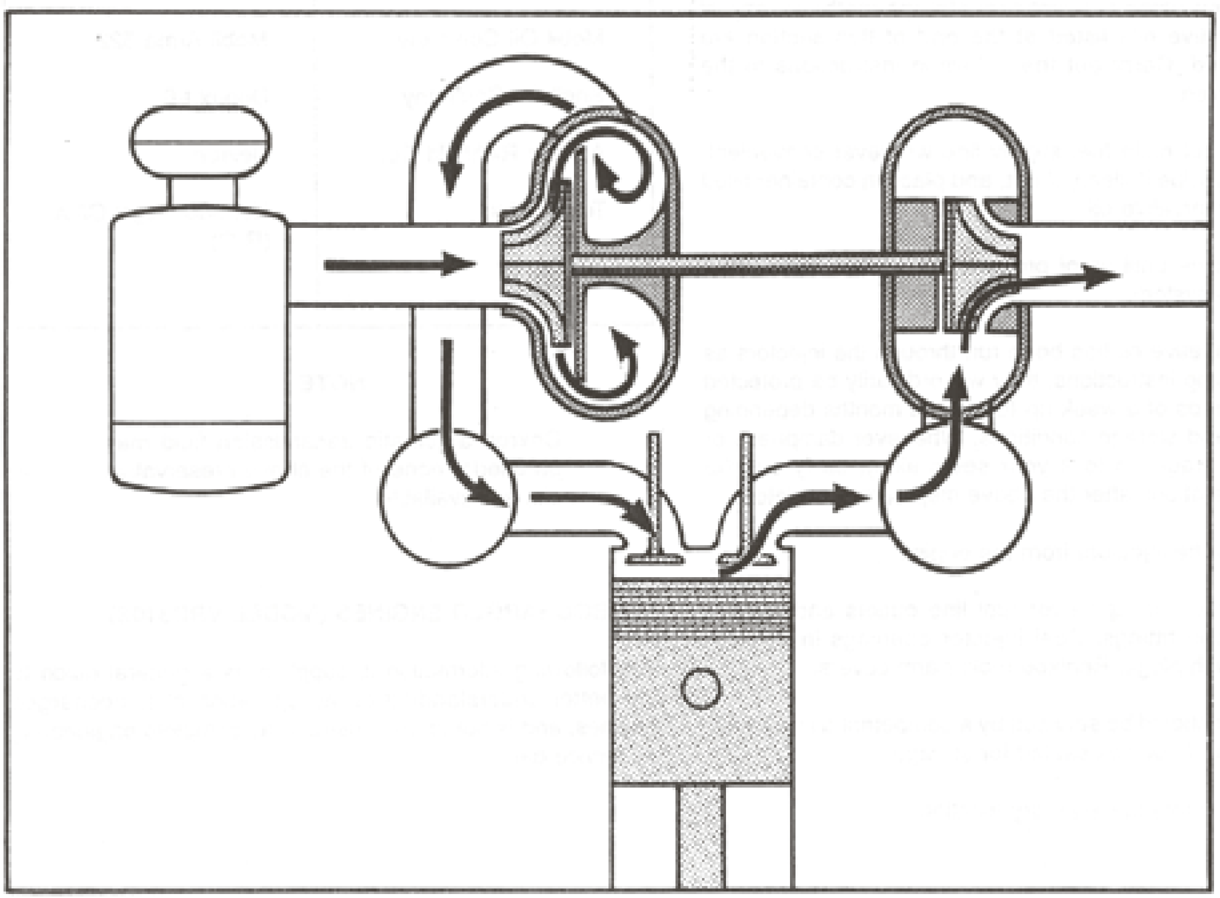
The turbine or driving member of the unit is made of a special heat resisting alloy and is surrounded by a nozzle ring which directs the flow of exhaust gases onto the turbine blades. On the opposite end of the same shaft, which supports the turbine, the precision-made aluminum alloy impeller operates within a surrounding diffuser housing. Both turbine and impeller turn at the same speed. The full load speed of the two units together with their shaft is approximately 90,000 (ninety thousand) RPM. For this reason, these parts must be in as close to perfect balance as possible. Therefore, not even the slightest filing, scraping, sandblasting, drilling, or other cleaning or repair procedure which could conceivably remove or add metal can be permitted in the field. A very small amount of unbalance can cause severe damage at the speeds involved.

The physical construction of the engine proper remains the same for both the turbocharged and the non-turbocharged models and all major components such as the crankshaft, camshaft, and connecting rods are identical.

The possibility of excessive muffling or unusually restrictive exhaust pipe installations should always be considered when checking turbocharger efficiency. In general, the turbocharger is an effective muffling device in itself and mufflers are not ordinarily considered necessary. Where circumstances demand consideration of supplemental muffling, it is suggested that Arrow Specialty Company be consulted. The same factors apply to the use of tail pipes and exhaust pipes other than short direct outlet stacks.

Since the turbocharger is basically a centrifugal air pump driven by a gas turbine, anything which causes leakage or impedes the exhaust gas flow will reduce the efficiency and power output. In all cases where engine turbocharging and power output seem to be less than normal, check first for possible leaks in the connections at the intake manifold and exhaust manifold. Very slight leaks are sometimes serious contributors to low efficiency.

The next point to check under low performance conditions would be the possibility of a partially clogged air cleaner. It is essential that the air cleaners be as efficient and capable as



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possible in order to prevent substantial amounts of dirt from reaching the impeller. Turbocharged engines draw much more air than naturally aspirated engines. Therefore, proper and regular air cleaner maintenance is a must.

Since even the most efficient air cleaner is certain to pass a slight amount of fine dirt, it is possible for some of this material to collect on the impeller if sufficient oil or other binder material is present. This can cause impeller unbalance and will definitely reduce efficiency. Depending on conditions, a periodic program should be established for removal of the air inlet connection at the impeller to inspect for dirt accumulation on the impeller surfaces. When and if dirt is found, caution anyone entrusted with the cleaning against using the common methods of scraping away such material with a screwdriver, dirty rag, sandpaper, or emery or steel wool. Such techniques are certain to damage the impeller. Cleaning may usually be accomplished with a clean, soft brush and solvent such as carbon tetrachloride, tri-chlorethylene, lacquer thinner, or benzol. Carbon tetrachloride has the advantage of being non-flammable so that any residue accumulating in the air inlet will not cause a damaged or runaway engine. Cleaning must be complete and even all the way around.

TURBOCHARGER PREVENTIVE MAINTENANCE - GENERAL

All air duct and gasket connections should be routinely checked for tightness and leaks. Repair any loose or leaking connection immediately. Ingestion of dirt into the compressor can cause severe wear and damage to the turbocharger as well as the engine. Leaking pressure joints cause loss of power and engine overheating. Excessive dirt buildup in the compressor can also cause considerable loss of power and overheating. Accumulations should be removed by use of a non-caustic cleaning solvent.

Observe scheduled oil change periods to ensure normal service life of the turbocharger bearings, using the recommended oil and genuine Arrow replacement filter elements.

Turbocharged engines should be idled for several minutes after starting to prevent "oil lag" failures to turbocharger bearings. This is particularly important during cold weather or when equipment has not been in use for extended periods.

Bearing Clearance Inspection

The purpose of this check is to determine whether it is necessary to replace or repair the thrust bearing, radial bearing, and/or rotating assembly of the center housing rotating assembly. In most cases this bearing check can be made while the turbocharger is still mounted on the engine.

Radial Bearing Check

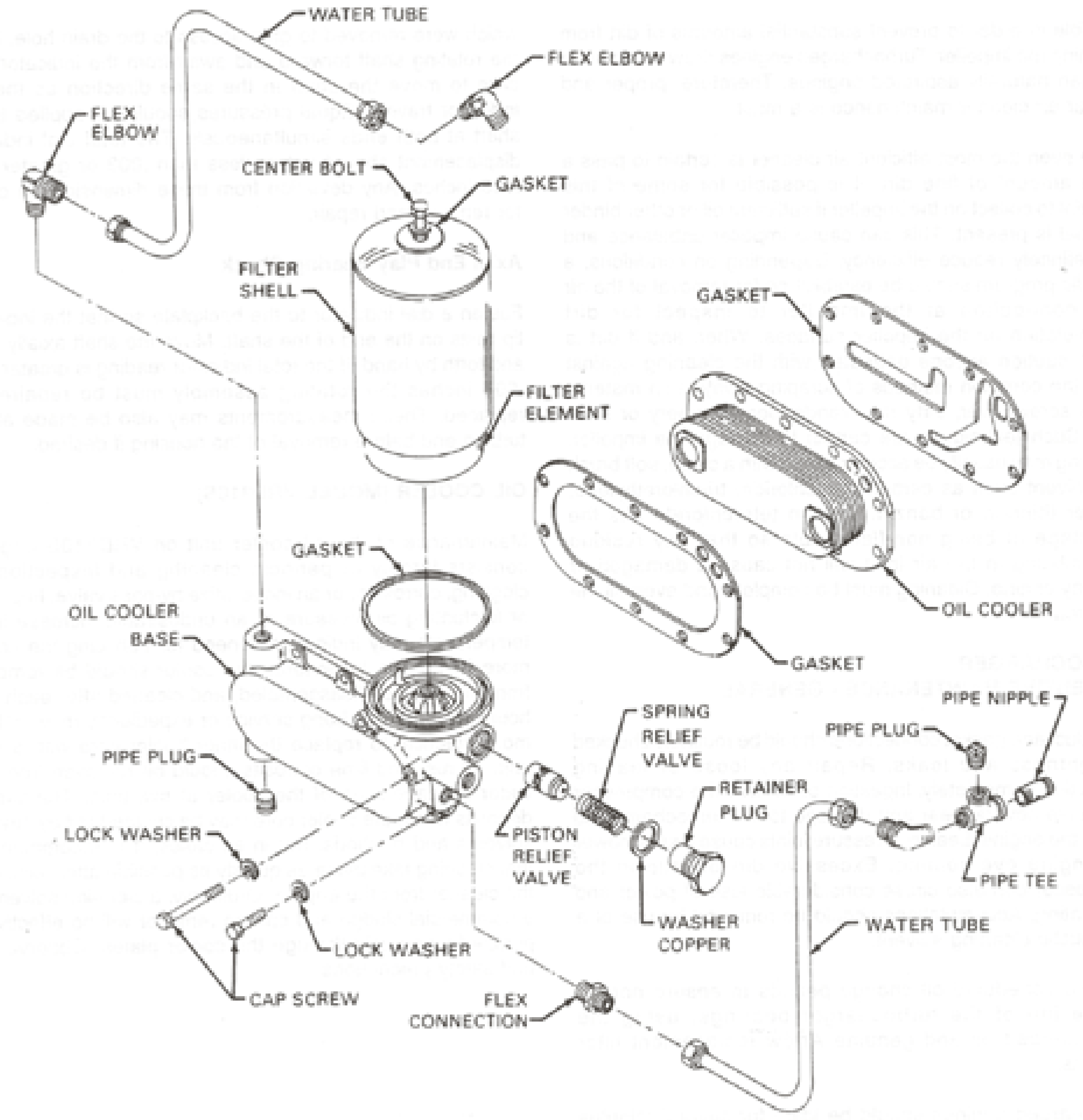
Fasten a dial indicator (plunger type) with one inch travel using a mounting adapter and two inch indicator extension rod to the turbocharger oil drain mounting flange. The mounting plate and indicator can be secured with the blots which were removed to gain access to the drain hole. Move the rotating shaft forward and away from the indicator. Use care to move the shaft in the same direction as the dial indicator travels. Equal pressures should be applied to the shaft at both ends simultaneously. The total dial indicator displacement should not be less than .003 or greater than .006 inches. Any deviation from these dimensions is cause for removal and repair.

Axial End Play Bearing Check

Fasten a dial indicator to the backplate so that the indicator tip rests on the end of the shaft. Move the shaft axially back and forth by hand: If the total indicator reading is greater than .004 inches the rotating assembly must be repaired or replaced. These measurements may also be made at the turbine end before removal of the housing if desired.

OIL COOLER (MODEL VRD310S)

Maintenance of the oil cooler unit on VRD310S engines consists largely of periodic cleaning and inspection for clogging, corrosion, or an inoperative by-pass valve. Improper or fluctuating oil pressure or an undesirable increase in oil temperature may indicate the need for servicing the cooler more frequently. In general, the cooler should be removed from the engine, disassembled, and cleaned after each 500 hours of operation. Long service or expediency may make it more practical to replace the inner cooler core with a new unit. All rust and lime deposits should be removed from the water passage area of the cooler at this time. The sludge deposits within the cooler core may be cleaned out by several solvents and methods, but in all cases, it is recommended that cleaning take place as quickly as possible after removing the cleaner from the engine. Ordinarily, a cleaning solvent or a commercial sludge and carbon remover will be effective if pumped vigorously through the cooler plates. Observe fire and safety precautions.



LUBE OIL COOLER AND FILTER ASSEMBLY

TROUBLE SHOOTING

Good trouble shooting methods determine the cause or causes or unsatisfactory operation and point out the action needed to correct the problem. Knowledge of how engine systems work, together with the trouble shooting chart in this unit and current indications from the engine instrument panel provide the best background information.

OPERATING CONTROLS

Most VR Series engines are equipped with the following operating controls (See illustrations).

a. Ammeter

b. Water temperature gauge

c. Oil pressure gauge

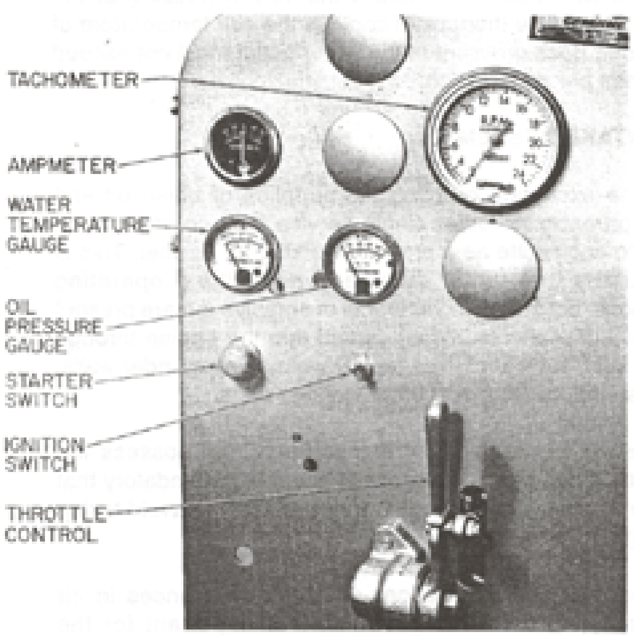
d. Throttle

e. Starter switch

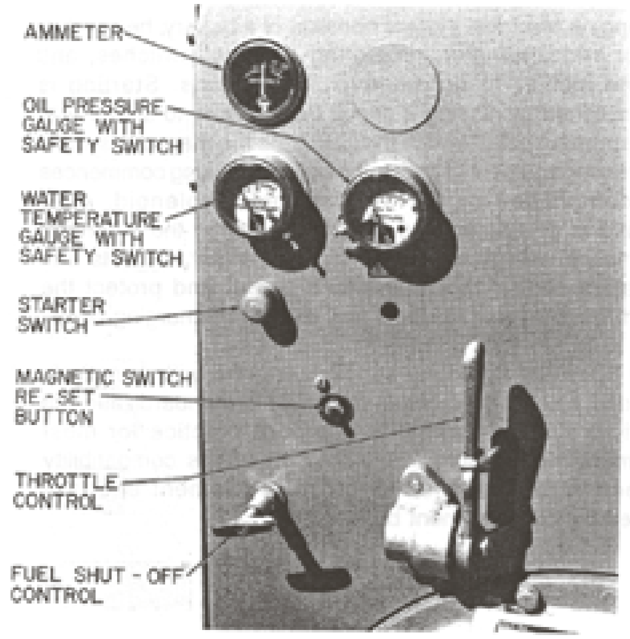
f. Ignition switch (gas and gasoline)

g. Choke control (gasoline only)

h. Fuel shut-off control (diesel)

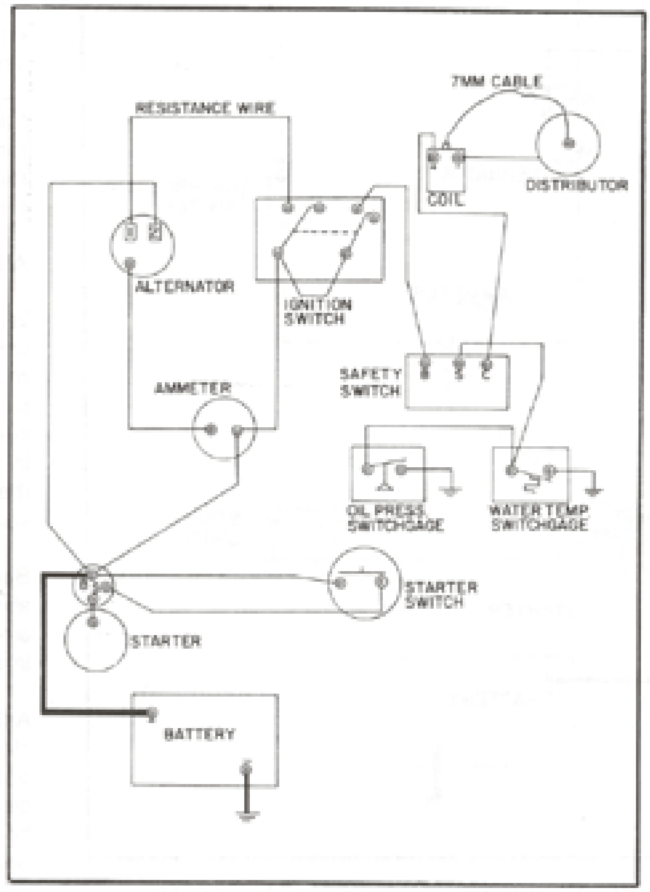


TYPICAL GAS INSTRUMENT PANEL WITHOUT SAFETY SWITCHES



TYPICAL DIESEL INSTRUMENT PANEL WITH SAFETY SWITCHES

ELECTRICAL SYSTEM

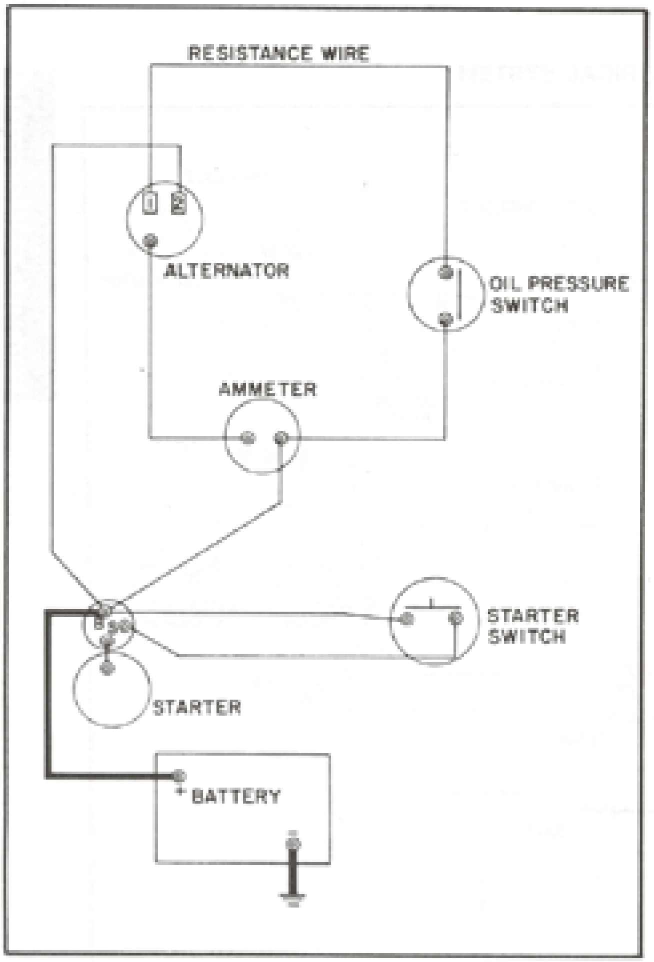


TYPICAL VRG SERIES ELECTRICAL LAYOUT

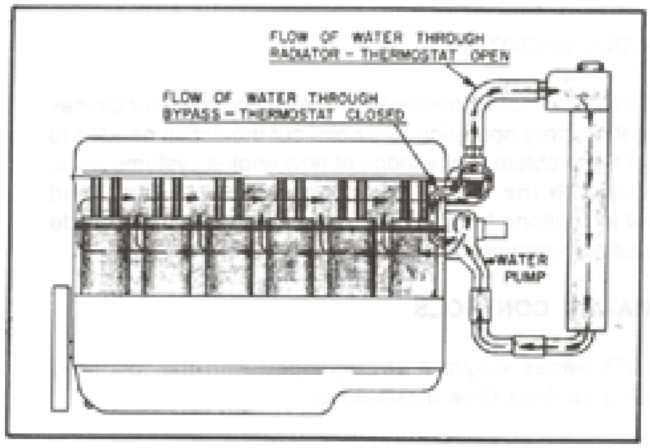
TROUBLESHOOTING

The engine electrical system consists of a battery, heavy-duty starter and alternator, regulating devices, switches, and circuits similar to automotive installations. Starting is accomplished by closing a circuit from battery to starter with the instrument panel switch that actuates the magnetic switch. Positive engagement of the pinion before cranking commences is accomplished by the starting motor solenoid. After cranking is completed and the engine starts, the alternator replenishes energy expended by the battery. Cutouts and regulators control the alternator's output and protect the system from reverse currents and excessive charging rates.

Arrow Specialty Company supplies engines with negatively grounded electrical equipment only. This standardization of electrical system polarity is standard practice for most equipment manufacturers and thus increases compatibility between Arrow supplied electrical equipment and that supplied by the equipment builder.



TYPICAL VRD SERIES ELECTRICAL LAYOUT



TYPICAL COOLING SYSTEM
SCHEMATIC DIAGRAM

Cooling System

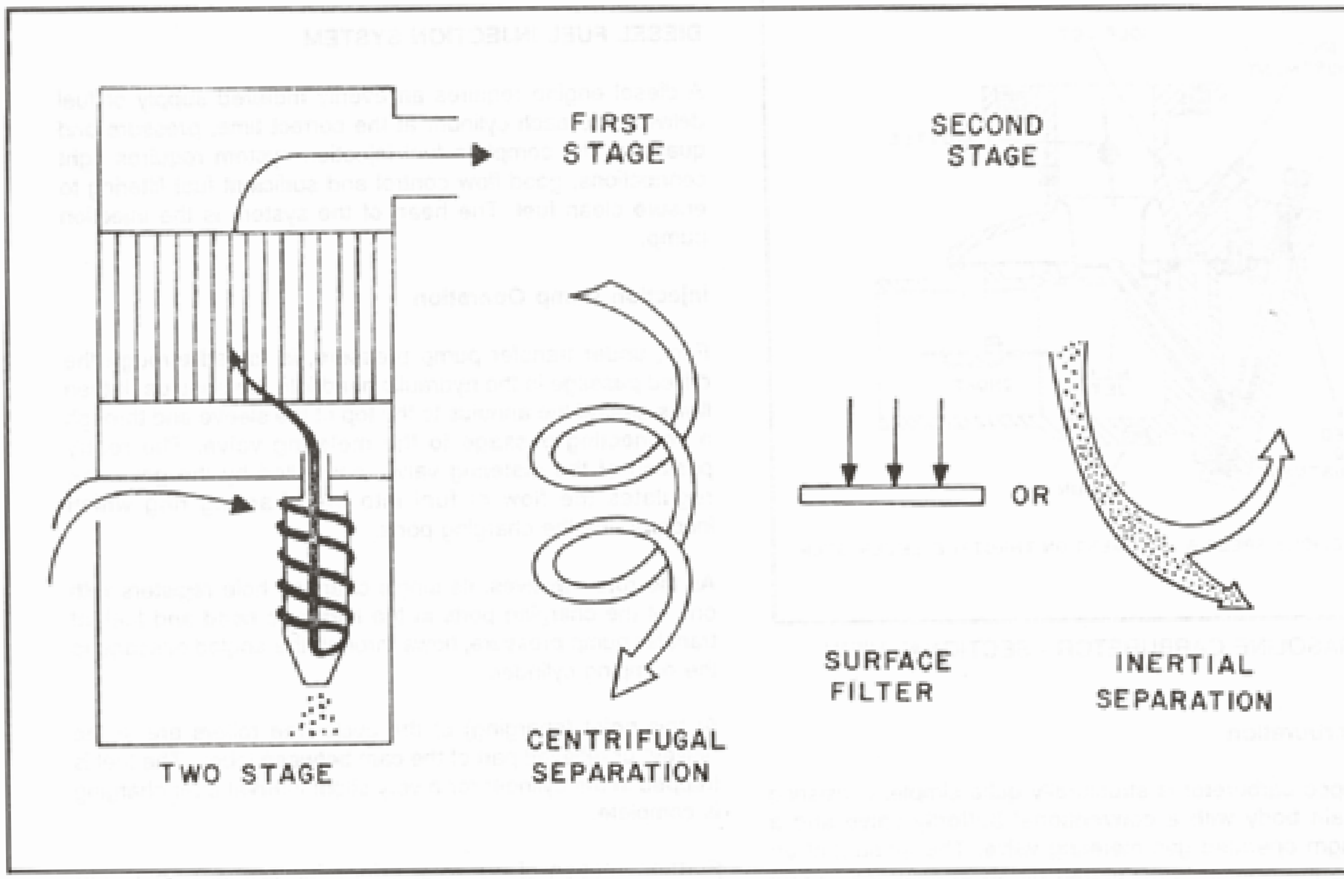
The cooling system used on the VR Series is of the pressure circulating type. The water enters the water pump inlet on the right side of the engine. The centrifugal pump pulls this supply of cool water through the pump body and into a passage leading directly into the engine cylinder jacket. The water enters the engine in the area of the cylinder sleeve lower ends. From here the water flow is directed about the cylinder sleeves in an even manner until it passes upward from the crankcase and into the cored passages in the cylinder heads. These passages are carefully designed to allow cooling water access to all areas around the valves. Water is collected from the cylinder head and enters a thermostat housing at the forward end. The thermostat controls the exit temperature of the water. Back pressure at the water outlet must not exceed 5 pounds per square inch.

AIR INTAKE SYSTEM

With the exception of adequate supplies of clean oil and water probably no other single service item contributes so much to engine life as a properly working air cleaner. This is particularly true under dusty and agricultural operating conditions, but surprising amounts of abrasive dirt are present in most atmospheres. When carried into the engine through the air inlet, such abrasives rapidly wear away cylinder walls, valve stems, bearing and other working parts.

Because the dust particles are so small, yet possess the ability to cause great damage, it is absolutely mandatory that air-inlet connections be kept in tight condition to avoid taking in unfiltered air.

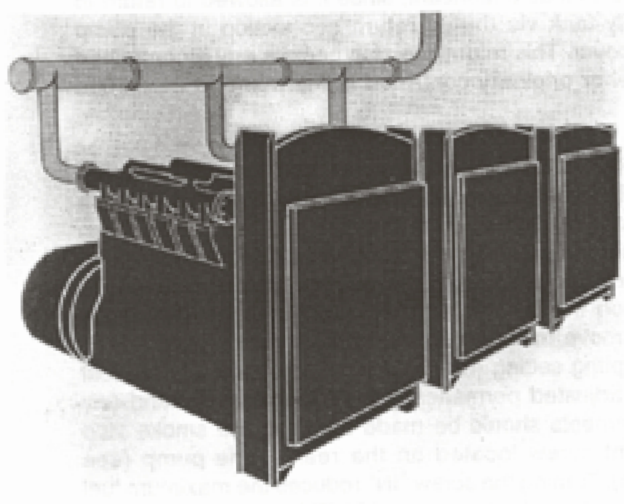
Although various installations will have differences in air cleaner types and arrangements, it is important for the operator to realize that the common purpose of all air cleaners is to collect dirt and grit. Thus the cleaner itself must be cleaned as often as dirt accumulations start to build up. Sometimes this may be several times each day if conditions are especially bad.



TWO STAGE AIR CLEANER

EXHAUST SYSTEM

Proper disposal of the exhaust of an engine is a very critical problem when you visualize its "breathing function". An engine consumes an incredible amount of air, and after combustion takes place, the air and exhaust gases must be pushed out of the cylinders, manifolds and exhaust piping. Every possible provision must be made to minimize the restriction or back pressure on an exhaust system.



NEVER CONNECT THE EXHAUST SYSTEMS OF MORE THAN ONE ENGINE

Some of the adverse effects of excessive back pressure are:

1. Loss of power.
2. Poor fuel economy.
3. Excessive valve temperatures and premature wear.
4. Jacket water overheating.

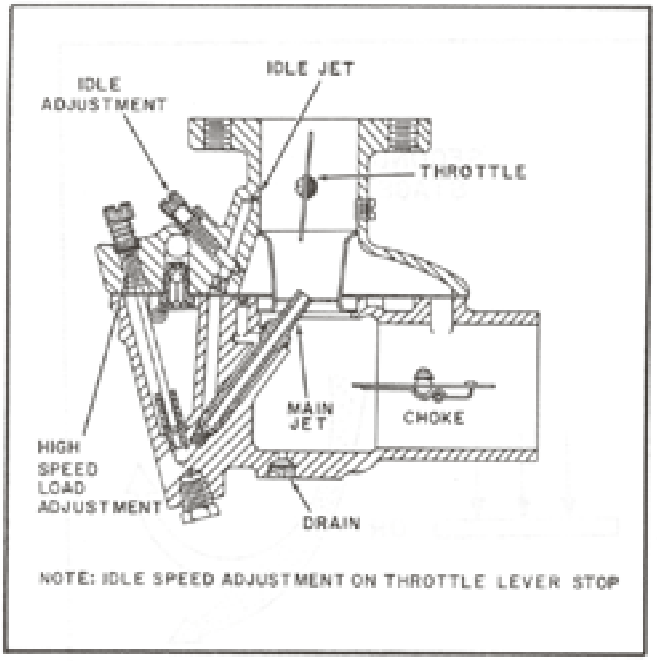
The exhaust system of an engine, particularly long exhaust pipes, can accumulate quite a bit of condensed moisture. If allowed to run back through the piping into the engine after it is shut down, the obvious rusting and sticking of valves, rings, etc. and the possibility of a hydraulic "lock" become serious. Always provide a condensate trap and drain at some low point ahead of the engine manifolds.

FUEL SYSTEMS

Gasoline Carburetion

In the gasoline carburetor the functions of metering and vaporization of fuel are accomplished through a float valve and a series of jets and venturis according to the speed and load of the engine. This process is carried out in three phases; idling, part load, and full load, with each phase involving a particular combination of the carburetor system.

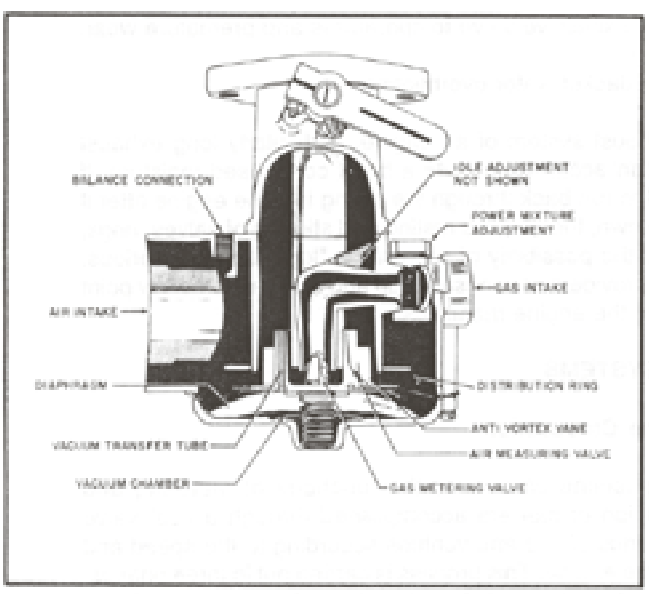
TROUBLESHOOTING



GASOLINE CARBURETOR - SECTIONAL VIEW

Gas Carburetion

The Impco carburetor is structurally quite simple, consisting of a main body with a conventional butterfly valve and a diaphragm operated gas metering valve. The amount of air going to the engine is measured by an air-flow measuring valve which rises in direct proportion to the air volume passing through. The gas metering valve is mechanically fixed to the air measuring valve and rises with it, thus opening the gas passage an amount proportionate to the air entering the engine. This establishes and holds a definite fuel/air ratio throughout the operating range.



GAS CARBURETOR - SECTIONAL VIEW

DIESEL FUEL INJECTION SYSTEM

A diesel engine requires an evenly metered supply of fuel delivered to each cylinder at the correct time, pressure and quantity. The complete fuel injection system requires tight connections, good flow control and sufficient fuel filtering to ensure clean fuel. The heart of the system is the injection pump.

Injection Pump Operation

Fuel, under transfer pump pressure, is forced through the drilled passage in the hydraulic head into the annulus. It then flows around the annulus to the top of the sleeve and through a connecting passage to the metering valve. The rotary position of the metering valve, controlled by the governor, regulates the flow of fuel into the charging ring which incorporates the charging ports.

As the rotor revolves, its single charging hole registers with one of the charging ports in the hydraulic head and fuel, at transfer pump pressure, flows through the angled passage to the pumping cylinder.

At this point (charging) of the cycle, the rollers are in the "valley" or relieved part of the cam between lobes. The fuel is trapped in the cylinder for a very slight interval after charging is complete.

Further rotation of the rotor brings its discharge port into registry with an outlet port of the head at which point the rollers simultaneously contact the opposing cam lobes and the plungers are forced towards each other. The fuel and the plungers are forced towards each other. The fuel trapped between the plungers is forced from the pump through one of the outlet ports to an injection line.

Lubrication of the pump is an inherent characteristic of the Roosa Master design. As fuel, at transfer pump pressure, reaches the charging ring, slots on the rotor shank allow fuel and any entrapped air to bleed to a reduced diameter on the shank. This fuel fills the pump housing cavity and acts as a coolant as well as a lubricant, since it is allowed to return to the supply tank via the oil return connection in the pump housing cover. This return line also permits any air entrained in the fuel or originally contained in the pump to be carried out.

CHARGING CYCLE: As the rotor revolves, the angled passage in the rotor registers with one of the charging ports in the charging ring. Fuel, at transfer pump pressure, then passes into the pumping cylinder, forcing the plungers apart a distance proportionate to the amount of fuel required for injection on the following stroke. Only at full load will the plungers move to the most outward position, controlled by the leaf spring setting (maximum fuel adjustment). This leaf spring is adjusted permanently for maximum fuel and any fuel adjustments should be made by using the smoke stop adjustment screw located on the rear of the pump (see Illustration). Turning the screw "IN" reduces the maximum fuel use. Turning the adjusting screw "OUT" increases fuel use at full load.

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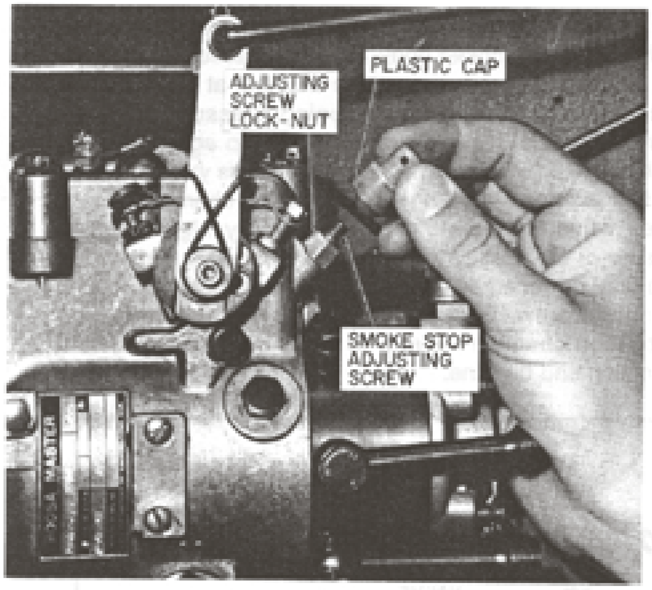
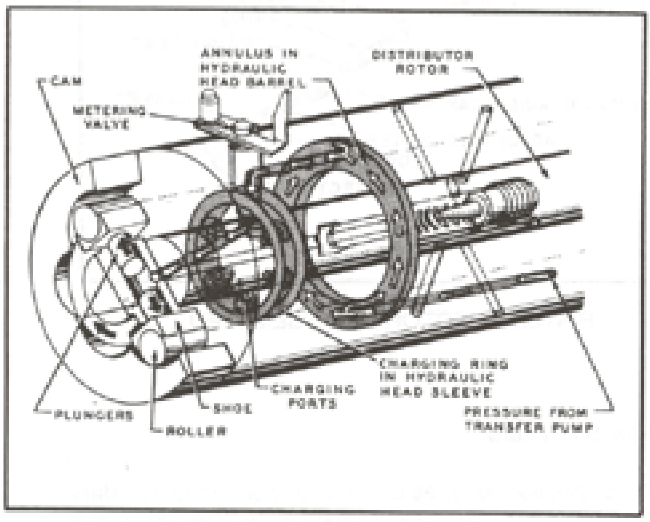
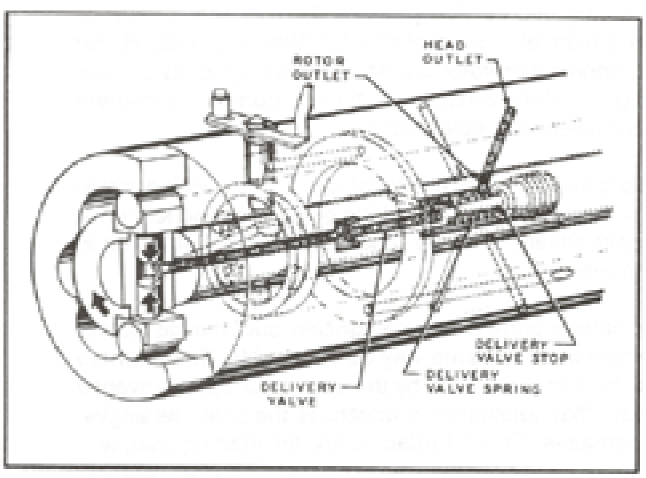


SMOKE STOP ADJUSTING SCREW LOCATION



CHARGE CYCLE SCHEMATIC



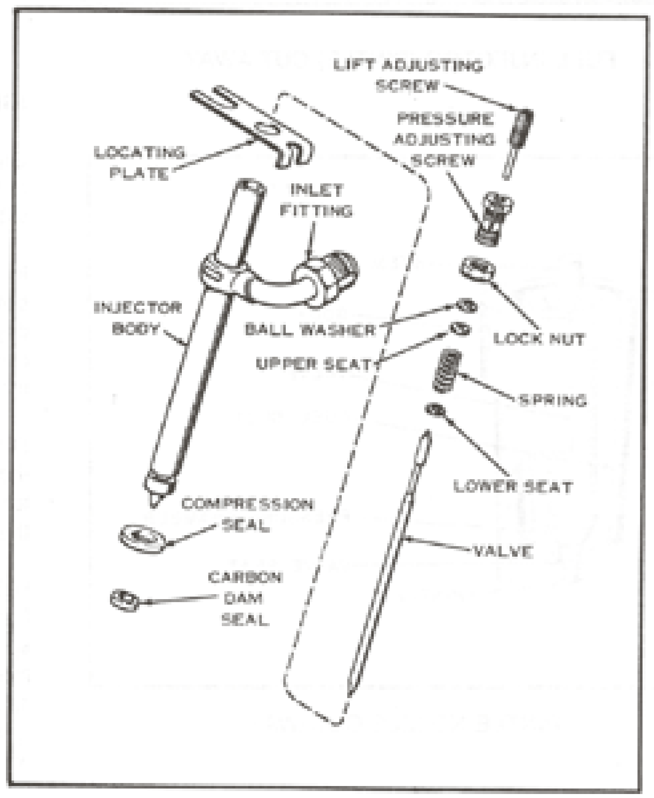
DISCHARGE CYCLE SCHEMATIC

DISCHARGE CYCLE: As the rotor continues to revolve, the angled passage passes out of the registry with the charging port. For a brief interval the fuel is trapped until the rotor outlet registers with one of the head outlets. As this registration takes place both rollers contact the rise of the cam lobes and are forced together. This is the discharge or injection stroke. The fuel trapped between the plungers is forced through the axial passage, through the delivery valve and out the rotor outlet.

Fuel Injector (Pencil)

The operation of the pencil injector used on VRD 283 and 310 engines is simple and positive. A metered quantity of fuel under high pressure from the injection pump flows through the inlet fitting of the injector around the injector valve. At the instant the pressure of the fuel against the valve exceeds the predetermined spring force - the valve is lifted off its seat allowing fuel under high pressure to flow through the four spray orifices to the combustion chamber.

The instant the fuel delivery ceases - the pressure against the valve is reduced and the control spring snaps the injector valve to its seat. This eliminates any possibility of dribbling or dripping after the metered amount of fuel has been delivered. During injection a small amount of fuel leaks through the closely controlled clearance at the guide, lubricating all the moving parts in the injector. This fuel then flows off through a leakoff boot at the top of the injector and returns to the fuel tank.

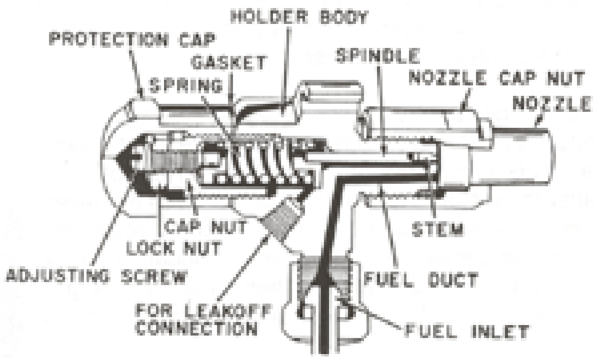


TYPICAL PENCIL INJECTOR COMPONENTS

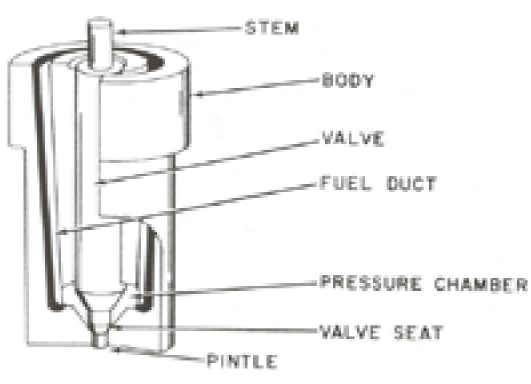
Fuel Injector (Pintle)

Pintle type nozzles are used on VRD 155 and 232 series engines. The nozzles are actually part of an injection system comprised of the injector on one side of the head and the energy cell directly in line with the nozzle on the other.

The injectors are operated hydraulically by the pressure of the fuel delivered from the injection pump. They utilize a spring-loaded valve and a seat located at the spray orifice to close off fuel at the end of injection. The Pintle or pin like protrusion projects into and cleans the spray orifice of carbon accumulation each time injection is ended thereby appreciably increasing nozzle service life.

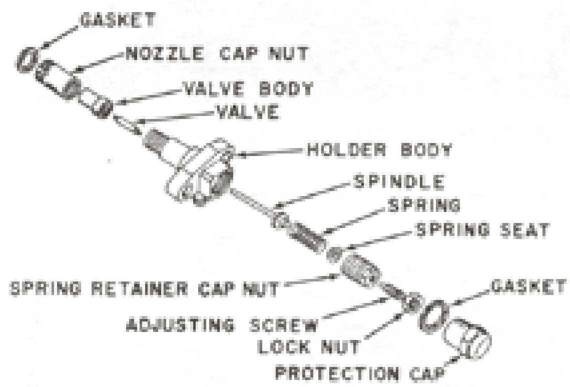


FUEL INJECTOR (PINTLE) CUT AWAY



PINTLE NOZZLE CUTAWAY

Fuel is forced from injection pump through injection tubes to fuel inlet of nozzle holder body. Fuel then passes through fuel duct at high pressure to a pressure chamber at base of valve. When fuel pressure equals opening pressure of spring controlled nozzle, fuel forces valve stem up against spindle which in turn bears against spring. This opens valve in nozzle and fuel is forced into engine combustion chamber. Spring closes valve immediately as momentary high injection pressure of fuel dissipates and ends. Opening pressure of valve may be varied by changing compression of spring with adjusting screw. Excess fuel which is not forced into combustion chamber returns to fuel tank through leakoff connection and drip line.



PINTLE INJECTOR DISASSEMBLED

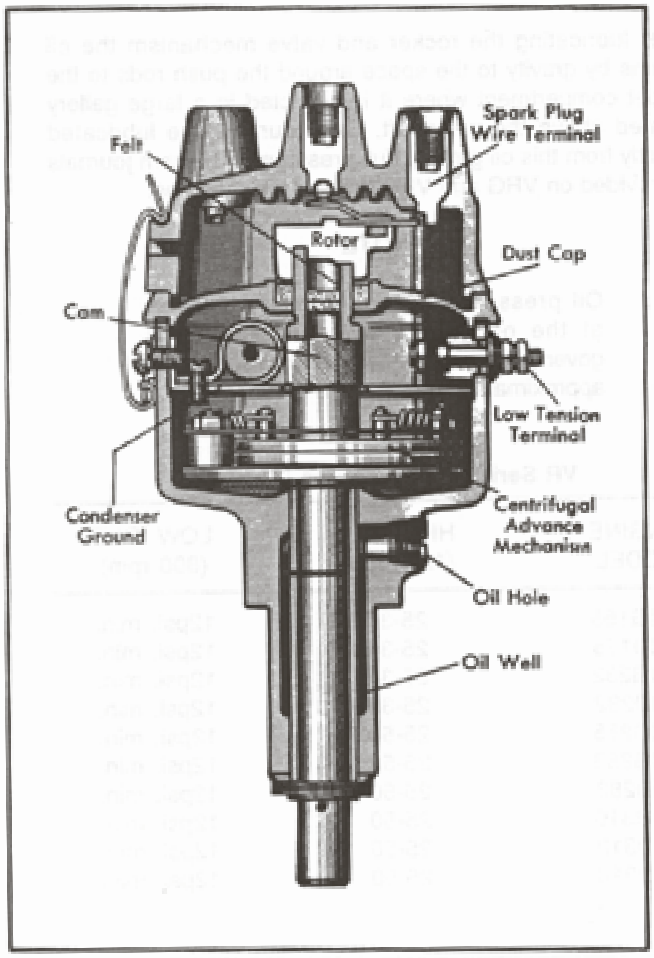
IGNITION SYSTEMS

Smooth combustion requires positive ignition in the cylinders at finely defined intervals. VRG Series engines are equipped with either distributor or magneto ignition.

In both theory and service practice there is little difference between a magneto and a distributor. Whereas a distributor depends upon a generator and storage battery for its primary current generated within itself by rotation of permanent magnets between the pole shoes.

Distributors are driven by a tang which is mated with a slot in the upper face of the oil pump drive gear. The magneto drive for the gear driven, vertically mounted magneto, is driven in the same manner.

Utilizing battery current and an ignition coil, the distributor functions in much the same way as a magneto. The retarded spark for starting is obtained by the centrifugal spark advance mechanism that automatically advances the spark as engine speed increases. The retarded spark for starting magneto ignition engines is obtained by use of an impulse coupling which disengages at operating speeds.



TYPICAL IGNITION DISTRIBUTOR

LUBRICATION SYSTEM

All VR Series engines, except the VR 155 and VR 232 Gas and Diesel engines, have a gear type pump, full flow filter lubrication system. The 155 and 232 engines have a vane type pump and by-pass filtering.

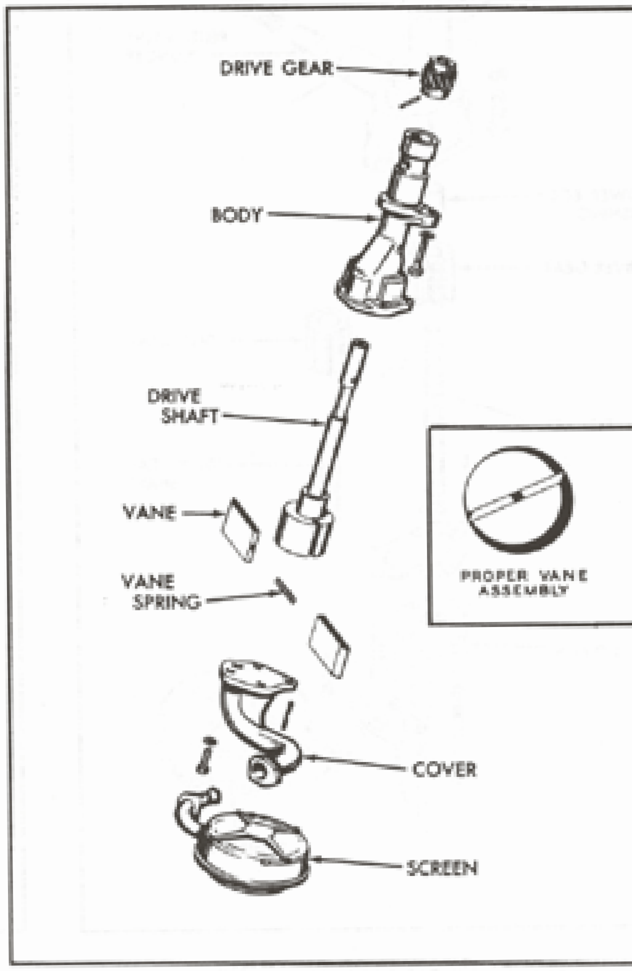
The suction produced on the inlet side of the oil pump draws the oil into the floating inlet screen and conducts it to the oil pressure pump inlet. The oil is discharged under pressure at the top of the pump.

All the oil under pressure enters the full flow (except in the 155 and 232 Gas and Diesel engines), then passes through a passage in the crankcase directly into the main oil header which extends lengthwise along the right side of the engine. In case of excessive pressure build-up due to a clogged full flow oil filter element, a by-pass valve in the oil filter allows the oil to enter directly into the main oil header.

At the front of the gallery (gear-cover end) a pressure relief valve of the non-adjustable type controls the oil gallery pressure. Pressure is increased by adding shims between the spring and screw head of the oil pressure relief valve in the crankcase. Oil gallery pressure of current VRD and VRG 283 and 310 engines is controlled by the pressure relief valve in the oil pump. To adjust pressure, the oil pan must be removed to get at the pump. Turn the relief valve adjusting screw in to increase oil pressure; back it out to decrease pressure. Drilled passages conduct the oil from the gallery to the main bearings and also to the rod bearings of all VR Series engines except the VR 155,232 and 265 Gas engines and the VR155 and 232 Diesel engines.

Oil from the intermediate main bearing metering slots of these engines is conducted to a second gallery extending the length of the engine. This gallery has small jets located directly above the oil holes in the upper flanks of the connecting rod bearings when the connecting rods are in the proper position to receive lubrication. The outlets, or jets, meter the correct amount of oil into each of the rod bearings.

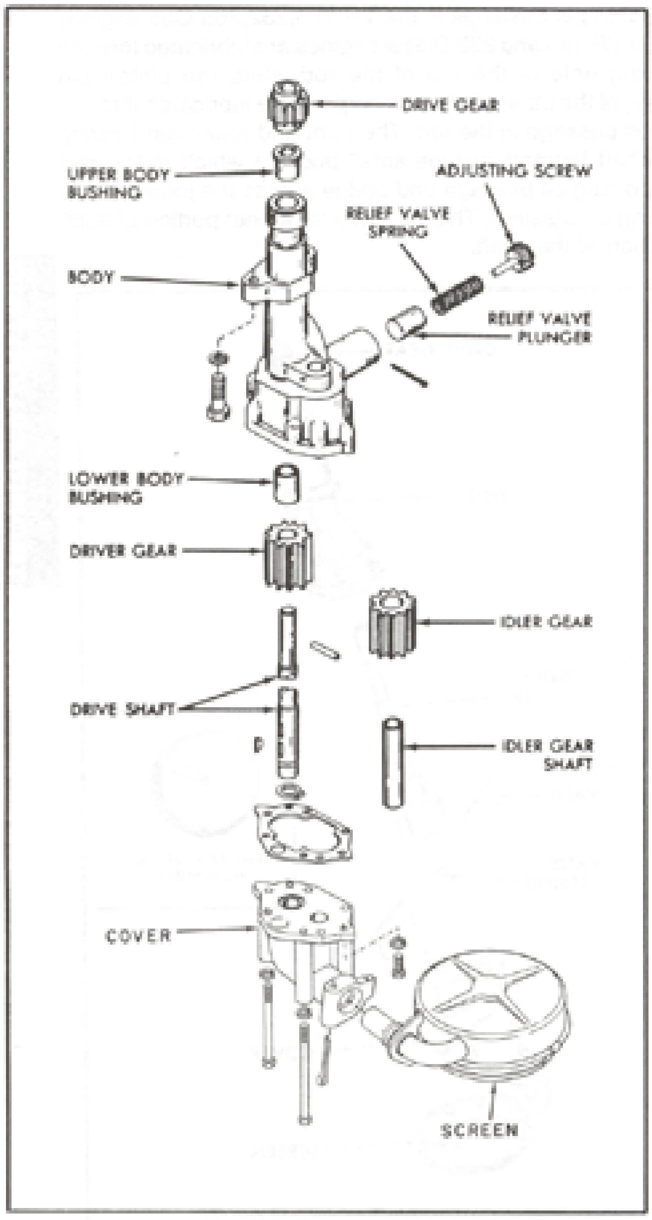
The piston pin bushings in the VR 155,232,265 Gas engines and the VR 155 and 232 Diesel engines are lubricated through an oiling hole in the top of the rod while the piston pin bushing of the other VR Series engines are lubricated through a drilled passage in the rod. The front and rear main bearing crankshaft journals include small pockets which index with the incoming oil passage and bridge across the journal to an outgoing oil passage. This happens for a brief portion of each revolution of the shaft.



TYPICAL VANE TYPE OIL PUMP

Oil leaving the front main bearing through the passage system described above is conducted in part to a small jet just above the camshaft drive gear. This oil floods the meshing surfaces of the timing gears. This passage also connects to the governor gear lubrication passage of VR Series gasoline engines.

Oil leaving the outlet hole of the rear main bearing each time the pockets in the crank journal index passes upward through drilled passages in the crankcase and cylinder head to a tube fitting on the head. From this fitting oil passes to the hollow rocker arm shaft and then to each valve in turn to provide controlled oiling of the valves and guides. Full pressure to the rocker arm shaft and then to each valve in turn to provide controlled oiling of the valves and guides. Full pressure to the rocker arm shaft is provided to the idler gear bushing of VR Series diesel engines.



TYPICAL GEAR TYPE OIL PUMP

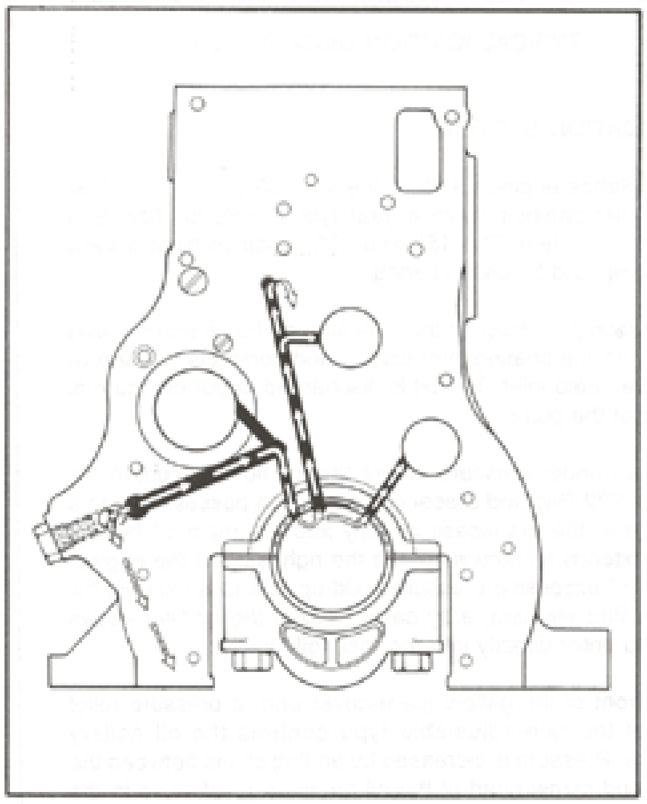
After lubricating the rocker and valve mechanism the oil returns by gravity to the space around the push rods to the tappet compartment where it is collected in a large gallery located above the camshaft. Cam journals are lubricated directly from this oil gallery. Full pressure to the cam journals is provided on VRG and VRD283 and 310 engines.

NOTE

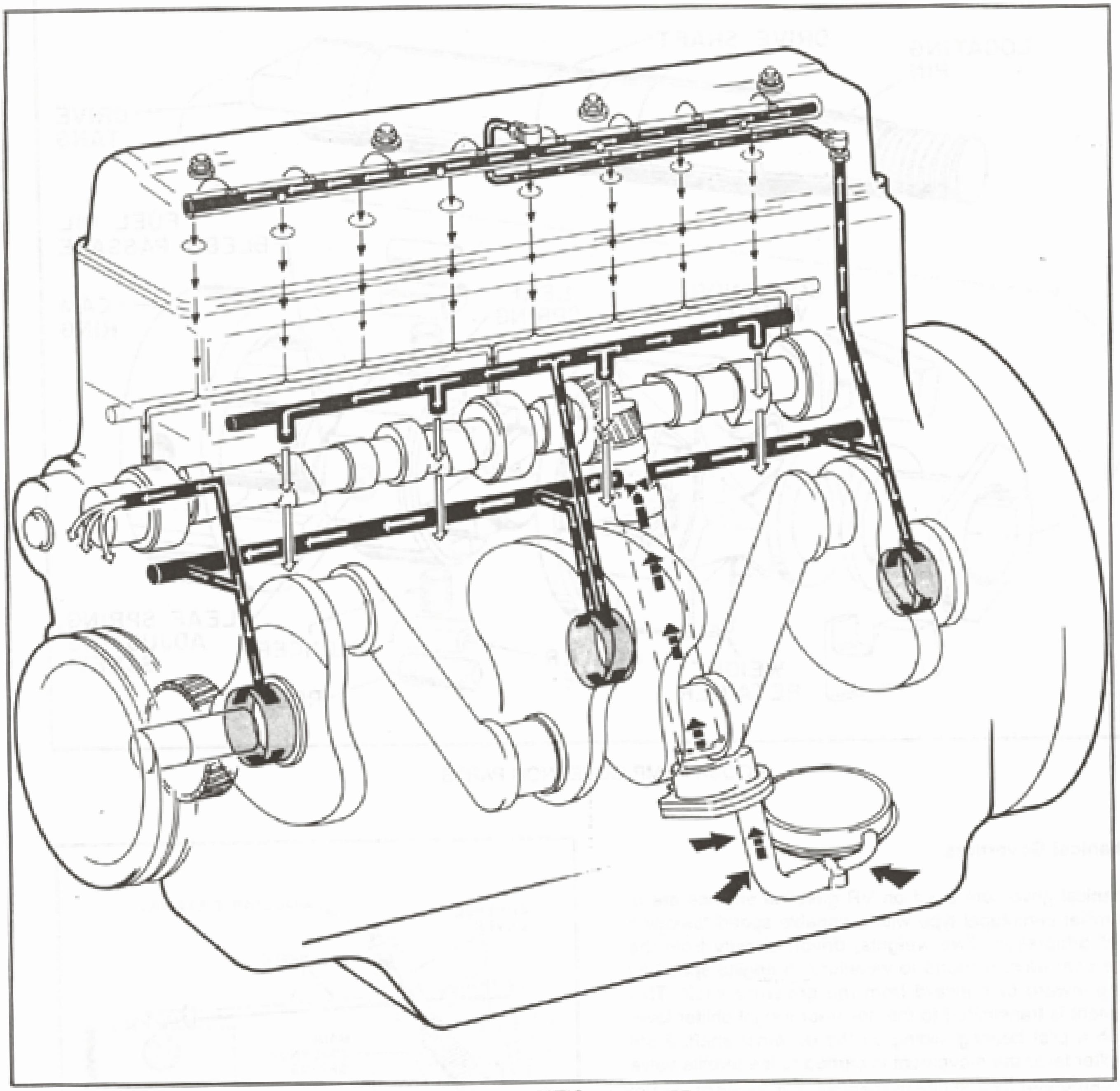
Oil pressure readings should be taken at the oil gallery while engine is at governed speed. Oil temperature should be approximately 200°F.

VR Series Oil Pressures (Average)

ENGINE MODEL	HIGH IDLE (1500 rpm)	LOW IDLE (800 rpm)
VRG155	25-35	12psi. min.
VRD155	25-35	12psi. min.
VRG232	25-35	12psi. min.
VRD232	25-35	12psi. min.
VRG265	25-50	12psi. min.
VRG283	25-50	12psi. min.
VRD283	25-50	12psi. min.
VRG310	25-50	12psi. min.
VRD310	25-50	12psi. min.
VRD310S	25-50	12psi. min.



TYPICAL GEAR OILING - SCHEMATIC



OIL SCHEMATIC - VRG 155

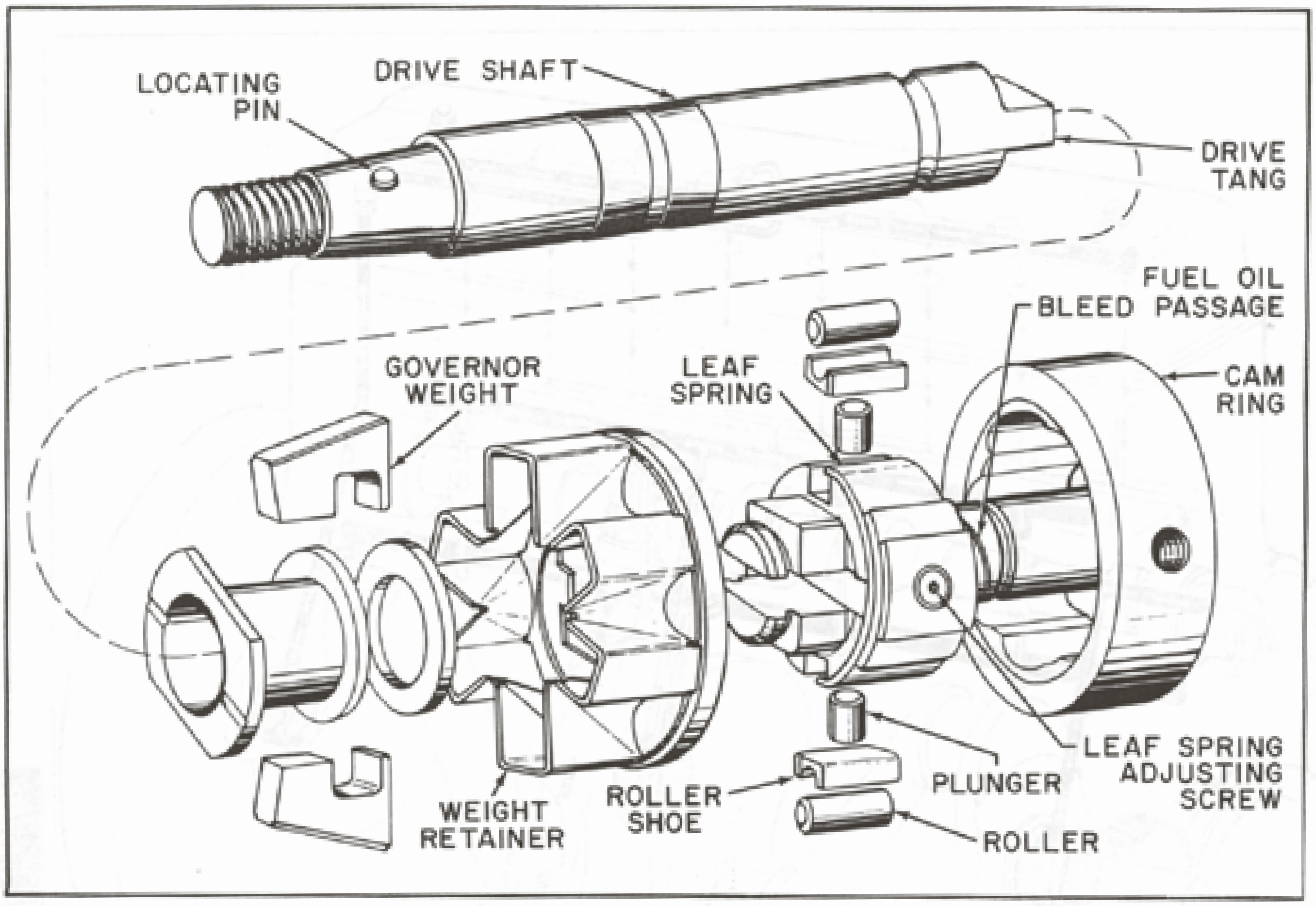
GOVERNING SYSTEMS

Injection pump

In the centrifugal governor the movement of the flyweights against the governor thrust sleeve rotates the metering valve. This rotation varies the registry of the metering valve slot with the passage to the rotor, thus controlling the flow of fuel to the engine.

This type of governor derives its energy from the centrifugal action of the flyweights pivoting on their outer edge of the retainer.

Centrifugal force tips them outward, moving the governor thrust sleeve against the governor arm, which pivots on the knife edge of the pivot shaft, and is connected through a simple positive linkage to the metering valve. The force on the governor arm caused by the centrifugal action of the flyweights is balanced by the compression type governor spring, which is manually controlled by the throttle shaft linkage in regulating engine speed. A light idle spring is provided for more sensitive regulation at the low speed range. The limits of throttle travel are set by adjusting screws for proper idling and high speed positions.

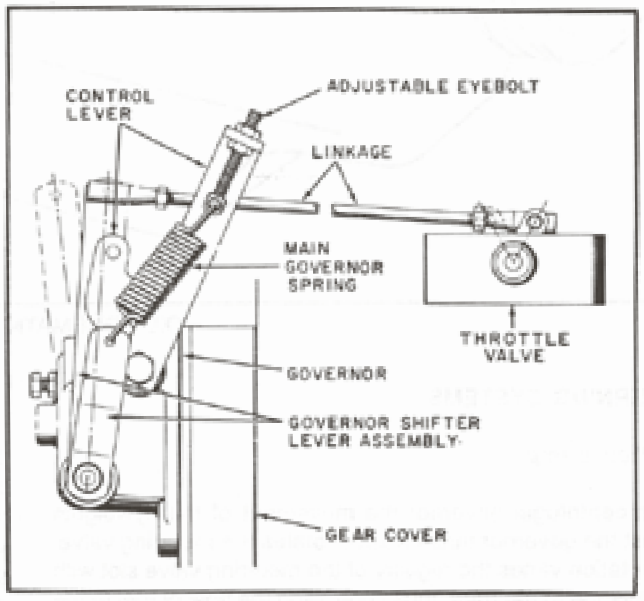


ROOSA PUMP GOVERNOR PARTS

Mechanical Governors

Mechanical governors used on VR gasoline engines are of the familiar centrifugal type with a variable speed "swinging spring" adaptation. Two weights, driven directly from the engine gear train, respond to variations in engine speed by moving inward or outward from the governor shaft. This movement is transmitted to the governor weight shifter lever through a pilot bearing sliding on the governor shaft. From the shifter lever the movement is carried to the throttle valve in the carburetor by a series of linkages. For example, as the engine tends to slow down under an applied load, the weights move inward due to the reduced centrifugal force. Through the linkage system, this weight movement causes the throttle valve to open and admit more fuel and air to the engine, thus restoring normal loaded speed.

The governor also acts as a protective device to prevent engine damage from overspeeding. Here, as the speed increases towards that speed established as the maximum, the weights move outward under the increased centrifugal force. This movement is opposed by the governor spring. When the force acting on the weights is balanced by the spring tension the governor linkage stabilizes. At this point the amounts of fuel and air entering the engine are held to those needed for the selected maximum speed and no more.



MECHANICAL GOVERNOR "SWINGING SPRING" TO BUTTERFLY VALVE AND LINKAGE

An adjustable eyebolt with locking nuts can also be used for closer regulation within the variable range.

TROUBLE SHOOTING CHART

SYMPTOM	PROBABLE CAUSE	REMEDY
Crankshaft cannot be barred over.		CAUTION: DO NOT ATTEMPT TO ROTATE CRANKSHAFT WITH STARTER
	Seized Piston.	Replace piston assembly and possibly sleeve. Determine cause of seizure - insufficient ring gap, insufficient lubrication, inadequate cooling, overload.
	Coolant or obstruction in cylinder:	NOTE: REMOVE SPARK PLUGS OR INJECTORS AND CRANK ENGINE TO VENT CYLINDERS OF ACCUMULATED COOLANT.
	a. Cracked head.	a. Replace head.
	b. Cracked sleeve	b. Replace sleeve.
	c. Blown head gasket.	c. Replace head gasket.
	Bearings too tight:	
	a. High spots on bearings.	a. Replace bearings.
	b. Improper torque.	b. Loosen bearing caps and re-torque.
	c. Main bearing caps installed out of location.	c. Check each bearing cap, place in proper location.
	Fuel in cylinder (diesels) from leaking injector	NOTE: REMOVE INJECTORS AND CRANK ENGINE TO VENT CYLINDERS OF ACCUMULATED FUEL. Replace or overhaul injector.
	Load not disengaged from engine.	Disengage load.

TROUBLESHOOTING

TROUBLE SHOOTING CHART (cont.)

SYMPTOM	PROBABLE CAUSE	REMEDY
Engine will crank but will not start.	Ignition switch in OFF position or defective (gasoline engines).	Place switch in ON position - replace defective switch.
	Insufficient cranking speed:	
	a. Run down battery or electric starter system malfunction.	a. Charge or replace battery; check starter system.
	b. Lube oil viscosity too high.	b. Change to lower viscosity as recommended in PREVENTIVE MAINTENANCE.
	Mistimed or faulty ignition system (gasoline engines).	Re-time, repair or replace components as required.
	Poor compression:	
	a. Worn rings.	a. Renew rings.
	b. Leaking valves.	b. Recondition head and valves.
	c. Leaking head gasket.	c. Replace head gasket.
	Fuel shut-off control in off position (diesels).	Place fuel shut-off control in on position.
	Fuel system inoperative:	
	a. Air bound (diesels)	a. Operate hand primer until air is expelled. Repair source of air entering into system.
	b. Water in fuel.	b. Drain water at strainers, filters, and fuel tank. Replace filter elements.
	c. Insufficient fuel supply.	c. Fill fuel tank (diesels and gasoline engines) - check gas pressure and carburetor adjustments (gas engines).
	d. Clogged fuel filters and strainers.	d. Clean strainers and replace fuel filter elements.
	e. Inoperative fuel supply pump.	e. Rebuild or replace pump.
	f. Improper timing of injection pump (diesels).	f. Re-time injection pump.
	g. Malfunctioning injectors.	g. Repair or replace injectors.
	h. Ruptured line pressure regulator diaphragm (gas engines).	h. Replace diaphragm.
	i. Stiff carburetor diaphragm or worn air-gas valve assembly (gas engines).	i. Replace air-gas valve assembly.

SYMPTOM	PROBABLE CAUSE	REMEDY
Engine will crank but will not start (continued).	j. Bent line pressure regulator control rod (gas engines).	j. Replace control rod.
	Governor inoperative or binding control linkage:	
	a. Linkage dirty.	a. Clean.
	b. Linkage broken.	b. Repair linkage.
	c. Linkage pivot points.	c. Re-adjust or replace pivot point bearing surfaces.
	Poor compression:	
	a. Worn rings.	a. Renew rings.
	b. Leaking valves.	b. Recondition heads and valves.
	c. Leaking head gaskets.	c. Replace head gaskets.
	Clogged intake air filter.	Remove and clean.
	Safety shut-down control not re-set.	Re-set safety shut-down control.
Engine stops suddenly.	Fuel:	
	a. Water in fuel.	a. Drain water at strainers, filters and fuel tank. Replace filter elements.
	b. Air in fuel (diesels).	b. Operate hand primer until air is expelled. Repair source of air entering into system.
	c. Insufficient fuel supply.	c. Fill tank (diesels and gasoline engines) - Check gas pressure (gas engines).
	d. Clogged fuel strainers and filters.	d. Clean strainers and replace fuel filter elements.
	e. Loose fuel control linkage.	e. Readjust and tighten.
	f. Clogged fuel supply line.	f. Replace line.
	g. Fuel supply pump failure.	g. Repair or replace pump.
	Obstructed exhaust manifold.	Determine obstruction and remedy cause.
	Faulty ignition system (gasoline engines).	Repair or replace components as required.
	Clogged intake air filter.	Remove and clean.
	Engine overspeed causes safety control to shut down engine.	Determine and correct cause of overspeed.
	Excessive oil causes engine to stall.	Determine and correct cause of overload.

TROUBLE SHOOTING CHART (cont.)

SYMPTOM	PROBABLE CAUSE	REMEDY
Engine stops suddenly (continued).	Piston seizure:	
	a. Insufficient ring gap (applicable only immediately after overhaul).	a. Replace scored piston, sleeve and rings. Adjust ring gap.
	b. Insufficient lubrication	b. Replace scored piston, sleeve and rings. Clean oil passages and/or determine cause of lack of lubrication.
	c. Insufficient cooling.	c. Replace scored piston, sleeve and rings. Clean and/or fill cooling system.
	Seizure of bearing - main connecting rod, piston pin or camshaft.	Replace bearings - clean up or replace crankshaft, camshaft, or piston pins as required.
	a. Lack of lubrication.	a. Check lube oil system - correct cause.
	b. Dirt in lube oil.	b. Check lube oil filter.
	Obstruction in cylinder.	Replace all parts that failed.
	Low oil pressure causes safety control to shut down engine.	Inspect lubricating oil system and components - correct cause.
	High coolant temperature causes safety control to shut down engine.	Inspect cooling system and components - correct cause.
Engine Power Loss.	Low compression pressure:	
	a. Leaking head gasket.	a. Replace head gasket - inspect for warped cylinder head and/or crankcase - replace if necessary.
	b. Leaking exhaust; intake valves.	b. Recondition head and valves.
	c. Worn rings (excessive blow-by).	c. Replace rings.
	d. Worn pistons/liner.	d. Replace as necessary.
	e. Cracked piston.	e. Replace.
	f. Cracked cylinder head.	f. Replace.
	g. Misadjusted intake and exhaust valves (if recently overhauled).	g. Adjust valves.
	h. Dirty air cleaner element.	h. Replace.
	i. Restriction in intake and/or exhaust system.	i. Check for obstruction.
	j. Turbocharger malfunction (VRD 310S only).	j. Repair or replace.
	k. Insufficient warm up period.	k. Follow recommended procedures.

TROUBLE SHOOTING CHART (cont.)

SYMPTOM	PROBABLE CAUSE	REMEDY
Engine power loss (continued).	Insufficient fuel:	
	a. Dirty fuel filters or strainers.	a. Clean strainer and replace fuel filter elements.
	b. Cracked fuel lines/filters.	b. Replace cracked line/filter.
	c. Worn or improperly calibrated fuel injection pump (diesels).	c. Overhaul, replace, or recalibrate.
	d. Worn fuel supply pump.	d. Overhaul or replace.
	e. Low gas pressure (gas engines).	e. Check gas fuel system.
	f. Clogged or improperly adjusted main carburetor jet (gasoline engines).	f. Clean or adjust.
	Injectors malfunction (diesels):	
	a. Clogged spray tip.	a. Overhaul injector, clean tip or replace.
	b. Dirty.	b. Overhaul and clean.
	Excessive exhaust system back pressure.	Correct as required.
	Dirty intake air filter.	Remove and clean or replace.
	Ignition or injection system out-of-time.	Re-time.
	Air in fuel (diesels).	Operate hand primer until air is expelled. Repair source of air entering system.
	Engine misfiring (gasoline engines):	
	a. Incorrect carburetor or regulator adjustment.	a. Readjust.
	b. Faulty ignition system.	b. Repair or replace components as required.

TROUBLESHOOTING

TROUBLE SHOOTING CHART (cont.)

SYMPTOM	PROBABLE CAUSE	REMEDY
Engine will not reach rated speed.	Injection or ignition not properly timed.	Re-time.
	Injection pump or carburetor improperly adjusted.	Re-adjust.
	Engine overload.	Determine and correct cause of overload.
	One or more defective injectors (diesels).	Replace or overhaul injectors.
	Tachometer inaccurate.	Calibrate or replace tachometer.
	Insufficient fuel supply.	Check fuel supply system.
	Governor misadjusted or faulty.	Readjust or repair.
	Restricted air intake.	Correct cause.
	Turbocharger malfunction (VRD310S only).	Repair or replace.
Engine hunts or surges	Misadjusted governor surge screw (gasoline only).	Adjust.
	Governor linkage sticky or sloppy.	Remove all dirt and burrs from linkage. Realign and re-set.
	Turbocharger malfunction (VRD310s only).	Repair or replace.
Low or fluctuating lubricating oil pressure.		CAUTION: SHUT DOWN ENGINE IMMEDIATELY.
	Insufficient oil.	Add oil as required.
	Gauge inaccurate.	Compare to master gauge - replace gauge.
	Oil gauge line plugged.	Renew gauge line.
	Engine operated at angles in excess of maximum safe tilt angles.	Operate within maximum safe tilt angles.
	oil pump pressure regulating valve set too low (VRD and VRG283, 310 and 310S).	Turn valve adjusting screw in to increase pressure to 25-50 psi at 1500 rpm
	Crankcase oil pressure relief valve relieves at low pressure.	Replace relief valve spring and/or shim it to increase pressure to 25-30 psi for VRD and VRG 155 and 232 and 25-50 psi for VRG265 at 1500 rpm.

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TROUBLE SHOOTING CHART (cont.)

SYMPTOM	PROBABLE CAUSE	REMEDY
Low or fluctuating lubricating oil pressure (continued).	Lubricating oil pressure regulating valve stuck in open position.	Free valve.
	Lube oil filter plugged (full flow only).	Change element. Clean filter.
	Worn lubricating oil pump.	Repair or replace pump.
	Worn bearing (connecting rod, main, and camshaft).	Replace worn bearings.
	Lubricating oil dilution	Change oil and filter element. Determine and correct source. of dilution.
	Cracked or leaking lubricating oil piping.	Repair or replace piping.
	Lubricating oil of low viscosity.	Change to higher viscosity oil, as recommended in PREVENTIVE MAINTENANCE.
	Lubricating oil foaming.	Use oil grade recommended in PREVENTIVE MAINTENANCE. Check for water leaks into oil.
	Clogged oil inlet screen.	Remove and clean screen.
High lubricating oil pressure	Gauge inaccurate.	Compare to master gauge - replace gauge.
	Lubricating oil temperature too low.	Raise temperature.
	Oil pressure regulating valve stuck in closed position.	Free valve.
	Oil pump pressure regulating valve set too high. (VRD and VRG283, 310, 310S)	Back valve adjusting screw out to lower pressure to 25-50 psi at 1500 rpm.
	Lubricating oil of high viscosity.	Change to lower viscosity oil as recommended in PREVENTIVE MAINTENANCE.
High fuel oil pressure	Gauge inaccurate.	Compare to master gauge - replace gauge.
	Transfer pump regulating valve faulty.	Repair or replace.

TROUBLE SHOOTING CHART (cont.)

SYMPTOM	PROBABLE CAUSE	REMEDY
Low fuel oil pressure (diesels).	Gauge inaccurate.	compare to master gauge - replace gauge.
	Transfer pump regulating valve faulty.	Repair or replace.
	Fuel filters and strainers clogged.	Clean strainers and replace filter elements.
	Clogged or collapsed fuel supply line.	Replace line.
	Air leak on suction side of pump.	Locate and repair leak.
	Defective fuel supply pump.	Repair or replace pump.
Low cooling water temperature.	Gauge inaccurate.	Compare to master gauge - replace gauge.
	Inoperative thermostat.	Replace thermostat.
High cooling water temperature.		NOTE: COOL ENGINE SLOWLY.
	Gauge inaccurate.	Compare to master gauge - replace gauge.
	Cooling system is air bound.	Purge air from cooling system.
	Low coolant level.	Fill cooling system.
	Worn water pump.	Replace or overhaul pump.
	Frozen coolant.	Completely thaw cooling system before re-starting engine.
	Poor coolant circulation.	Check entire cooling system.
	Blown head gasket.	Replace head gasket.
	Insufficient circulation of air (radiator cooling).	Correct as required.
	Cracked head.	Replace head.

SYMPTOM	PROBABLE CAUSE	REMEDY
High cooling water temperature (continued).	Cracked sleeve.	Replace sleeve.
	Inoperative thermostat.	Replace thermostat.
	Late ignition or injection timing.	Re-time.
High lubricating oil consumption.	Oil leaks in lubricating oil system.	Find and repair leaks.
	Improper viscosity.	Change to recommended viscosity for operating temperatures in PREVENTIVE MAINTENANCE.
	Leaking oil seal(s) - rear and/or front.	Change seal(s).
	Worn intake valve guides.	Change head/renew guides, or valve stem seals.
	Turbocharger seal damaged. (VRD310S only).	Repair or replace.
	Stuck/worn piston rings.	Renew rings.
	Turbocharger drain restricted. (VRD310S only).	Repair or replace.
	One or more pistons with rings upside down (if recently over-hauled).	Remove piston - correct position of rings.
	Excessive connecting rod bearing running clearance.	Replace bearings.
	Crankcase breather plugged.	Clean.
Lubricating oil contaminated.		NOTE: CHANGE OIL.
	Lubricating oil diluted with diesel fuel:	
	a. Injector(s) leaking.	a. Replace or overhaul injector(s).
	b. Injection pump shaft seals worn.	b. Replace seals; check pilot tube for grooves in seal area.
	Lubricating oil contaminated with water.	
	a. Sleeve seals leaking or sleeve cracked.	a. Replace sleeve and/or o-rings.
	b. Cracked crankcase.	b. Replace crankcase.

TROUBLE SHOOTING CHART (cont.)

SYMPTOM	PROBABLE CAUSE	REMEDY
Lubricating oil contaminated (continued).	Lubricating oil contaminated with dirt.	
	a. Lube oil filter by-pass valve opening because element is plugged.	a. Replace element.
	b. Lube oil filter element punctured.	b. Replace element.
	c. Air intake filter punctured.	c. Replace air intake filter.
Excessive vibration.		NOTE: STOP ENGINE AT ONCE. INVESTIGATE CAUSE.
	Foundation bolts:	
	a. Loose. b. Cracked.	a. Torque. b. Replace bolts - torque all bolts.
	Vibration dampener loose or failed (VRD310 and VRD310S only).	Retorque bolts/ replace dampener.
	Unbalanced cylinders:	
	a. One or more injectors inoperative (diesels). b. Misfiring ignition system (gasoline engines).	a. Replace all defective injectors. b. Repair or replace components as required.
	Crankshaft:	
	a. Cracked.	a. Conduct a complete investigation of entire engine for damage.
	b. Main bearing bolts loose.	b. Determine reason for loosening, investigate the entire lower crankcase before torquing and subjecting engine to use. Replace main bearing bolts.
	Loose flywheel.	Replace and/or torque as required.
Blue-White exhaust (diesels).	Worn or stuck piston rings.	Replace rings.
	Worn sleeves.	Replace sleeves.
	Worn valve guides.	Replace guides.
	Cracked piston.	Replace piston.
	Turbo seal leakage. (VRD310S only).	Repair or replace.
	Dirt buildup in turbo compressor housing. (VRD310S only).	Repair or replace.
	Carbon buildup behind turbine. wheel. (VRD310S only.)	Repair or replace.

TROUBLE SHOOTING CHART (Cont.)

SYMPTOM	PROBABLE CAUSE	REMEDY
Black Exhaust.	Insufficient intake air due to:	
	Intake air filter clogged.	Clean or replace.
	Engine overloaded.	Determine and correct cause of overload.
	Late injection or ignition timing.	Re-time.
	Inoperative injector (diesels).	Replace or repair defective injector.
	Carboned energy cell. (VRD155 and VRD232 only.)	Clean.
	Low compression:	
	a. Insufficient valve clearance.	a. Reset valves.
	b. Burned valves.	b. Replace or overhaul head.
	c. Worn/ stuck rings and sleeves.	c. Overhaul.
	Over-rich fuel/air mixture (gasoline engines).	Readjust.
	Turbo seal leakage. (VRD310S only).	Repair or replace.
	Dirt buildup in turbo compressor housing. (VRD310S only.)	Repair or replace.
	Carbon buildup behind turbine wheel. (VRD310S only.)	Repair or replace.
High lubricating oil temperature.	Gauge inaccurate.	Compare to master gauge - replace gauge.
	Engine overloaded.	Determine and correct cause of overload.
	High cooling water temperature.	See High Cooling Water Temperature causes.
	Low lubricating oil pressure.	See Low Lubricating Oil Pressure causes.
Knocking or unusual noises.	Low octane fuel (gasoline engines)	Change to higher octane fuel.
	Engine overload.	Determine and correct cause of overload.
	Turbo seal leakage (VRD310S only.)	Repair or replace.
	Dirt buildup behind turbine wheel. (VRD310S only.)	Repair or replace.
	Turbo malfunction. (VRD310S only.)	Repair or replace.

TROUBLE SHOOTING CHART (cont.)

SYMPTOM	PROBABLE CAUSE	REMEDY
Knocking or unusual noises (continued).	Overly advanced ignition or injection timing.	Re-time.
	Loose bearings (failed).	Replace bearings.
	Loose piston pins (failed).	Replace piston pins and/or pin bushings as required.
	Damaged or excessively worn accessory drives.	Repair or replace components as required.
	Excessive crankshaft end play.	Replace main thrust bearing.
	Excessive valve clearance.	Readjust valve clearance.
	Sticking valves or rocker arms.	Free up or replace.
	Misfitted or excessively worn timing gears.	Replace.
Excessive fuel consumption.	Carburetors adjusted over-rich (gasoline engines).	Readjust.
	Excessively worn fuel injectors (diesels).	Repair or replace.
	Leaks in fuel system.	Repair as required.
	Faulty ignition system (gasoline engines).	Repair or replace components as required.
	Late ignition or injection timing.	Re-time.
	Engine overload.	Determine and correct cause of overload.
	Poor compression.	Determine cause(s) and effect. Repair
	Improper matching of torque convertor to engine and load.	Replace torque convertor.

TROUBLE SHOOTING CHART

SYMPTOM	PROBABLE CAUSE	REMEDY
Excessive fuel consumption (continued).	Injection pump shaft seals worn and leak fuel oil into crankcase (diesels).	Replace seals; check pilot tube for grooves in seal area.
	Injection pump improperly calibrated (diesels).	Recalibrate pump.
Low gas pressure (gas engines).	Incorrectly adjusted gas regulator.	Readjust.
	Insufficient line pressure.	Increase line pressure.
	Incorrect orifice and/or spring in gas regulator.	Replace orifice and/or spring.
	Undersize gas regulator.	Replace with gas regulator of adequate size.
	Undersize piping.	Replace with piping of adequate size.
	Gas regulator mounted too far from engine.	Remount gas regulator as close to carburetor as possible.
High gas pressure (gas engines).	Incorrectly adjusted gas regulator.	Readjust.
	Incorrect spring or orifice in gas regulator.	Replace spring or orifice.
	Excessive line pressure.	Reduce line pressure.

CRANKCASE

The crankcase of the VR Series engines is a single piece iron casting incorporating three, four, or seven main bearing supports and locations for four or six wet-type cylinder sleeves. The cooling water passages are formed between the side-wall structure of the crankcase casting and the cylinder sleeves. Thus, the sleeves are always in direct contact with the coolant. Since the cylinder sleeves are of the removable type, it is necessary to maintain a seal at the upper and lower sleeve-to-crankcase contact surfaces. This is done by the head gasket which seals the mating surfaces at the joint between the sleeve flange and the crankcase deck at the upper end, and by two rubber seal rings at the lower end of the sleeve.

The crankcase has three or four support locations for the camshaft journals. These support the camshaft at the front and rear and at one or two intermediate points. The front camshaft support of the VRD and VRG 155 and 232 and the VRG 265 engines has a pressed-in bushing. All four camshaft supports of the other VR Series engines have pressed-in bushings. Immediately above the camshaft lobes are locations for the mushroom type valve lifters.

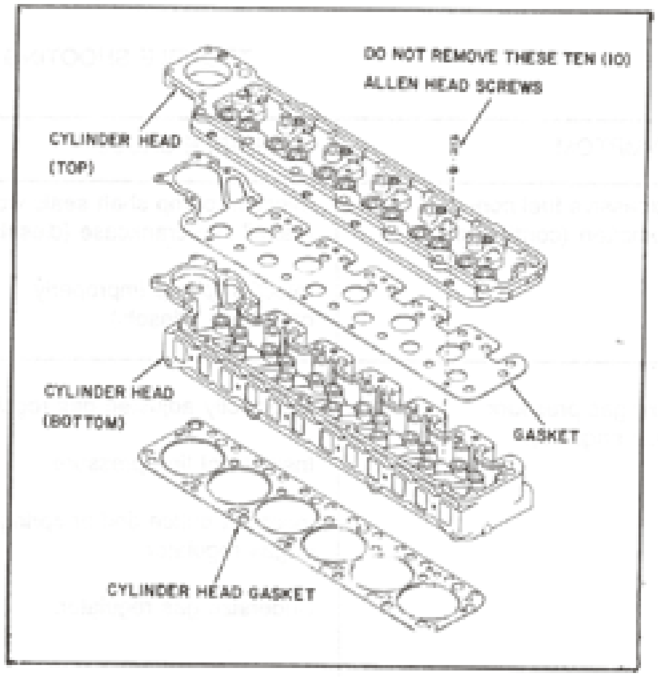
At the rear end of the crankcase is a mounting surface for a flywheel housing and a lip type crankshaft oil seal cover. To ensure accurate mounting of the clutch or other drive unit in the flywheel housing, the rear surface of the engine is held to very close tolerances and the housing itself is machined true after the engine has been assembled. Whenever the power take-off, flywheel, or flywheel housing are removed, the run-out and eccentricity of the related parts should be checked and adjusted as required (see Installation section).

Faced mounting bosses and connections are provided at various points on the crankcase exterior for mounting accessories, lines, and other equipment selected by the engine operator. Crankcase ventilation is accomplished by a breather tube located in the valve cover.

CYLINDER HEADS AND VALVES

The cast-iron cylinder head is designed and fabricated especially for the temperatures and pressures of industrial use. The cylinder head of VRG 283 and VRG 310 engines is of two piece construction. It is emphasized that this two piece head is factory assembled and is difficult to reassemble (see illustration). If it is necessary to disassemble this head, refer to service bulletin 7 - 1841B for detailed instructions.

Intake and exhaust valves are both of the poppet type with hardened tips and recesses for split-taper locks. Positive type valve rotators are used on the exhaust valves of all VRG Series engines and on the intake valves of VRD 155 and 232 engines to prevent prolonged exposure of any given area of the face to any hot spot that may have developed on the seat. All VR Series engines use intake valve stem seals, and VRD 283 and 310 engines also use exhaust valve stem seals. Diesel engine valve stem seals consist of a small rubber o-ring and are easily installed.



CYLINDER HEAD CONSTRUCTION
(VRG 283 AND 310 MODELS ONLY)

Gasoline engines use a more complex seal consisting of a teflon insert embedded in a rubber jacket.

To install these seals, proceed as follows:

1. Make sure valve and guide assemblies are clean.
2. Insert valve through guide. Cover keeper grooves with plastic cap to protect the sealing surface of the teflon insert.
3. Gently slide seal over plastic cap, and down until it comes into contact with valve guide. The end of the seal with the retaining ring must be closest to guide (see illustration).
4. Clamp seal installation tool firmly around seal just behind the metal retaining ring. (Under field conditions, if the special installation tool is not available, valve seals can be installed with the use of 2 screwdrivers, positioned on opposite sides of the seal, and 90° from the ring. Please note that this procedure is to be used only when the valve seal installation tool is not available, as improper seal installation is more likely to occur with this technique.)
5. Press seal into place. In order to keep teflon insert in place, all downward pressure should be exerted on the metal ring, not on the rubber part of the seal.

If the head has not been removed and the valve seals are to be replaced, care must be taken so the valves do not fall into the cylinder when the valve tapers are removed. For diesel engines, this can be accomplished by moving the piston of the cylinder you are working on to TDC. The valve will drop only thousandths of an inch, and come to rest on the piston surface.

To secure the valves in gasoline engines, remove spark plug. Fit an air hose adaptor to the spark plug hole, and fill cylinder with compressed air. The cylinder must be kept pressurized at all times. The air pressure will be enough to keep the valves in closed position.

The exhaust valves of all VRG Series engines and the intake valves of VRD 155 and 232 engines seat on hardened seat inserts in the cylinder heads. These inserts are shrunk and pressed into place. Intake and exhaust guides are pressed into place in the cylinder heads and may be pulled to replace.

Valves and springs are retained by hardened washers stepped to center the springs and seating on split-taper locks.

Valve actuation is obtained through chilled and polished mushroom type valve lifters, riding directly on the camshaft. This motion is transmitted to rocker arms through tubular steel push rods equipped with hardened sockets at each end.

The formed steel rocker arms pivot on a hardened hollow steel shaft. Rocker arm bushings are not replaceable. The rocker arms are curved to align with their respective intake or exhaust valve tips. To ensure long wear and accurate adjustment they are hardened in the valve-tip contact area. Drilled openings along the shaft mate with passages in the rocker arms to permit lubrication of the entire overhead mechanism.

CYLINDER SLEEVES

The wet-type cylinder sleeves are cast from iron and hardened for long wearing qualities and resistance to distortion. Each sleeve has a shoulder and flange at the upper end to locate it in the crankcase upper deck and prevent shifting and leakage when the cylinder head and gasket are secured above it. This flange, and the crankcase deck recess into which it fits, both have precision-finished mating surfaces to form a water seal in this area. The cylinder sleeve projects above the deck to insure a tight crush gasket joint. Whenever sleeves are installed, this should be checked. The lower end of the sleeves is tapered, and immediately above the taper are two grooves for the rubber seal rings. The top groove contains a black seal ring and the bottom groove a red seal ring.

The following procedure should be used to measure cylinder sleeve projection:

1. After removal of head, clean carbon and other deposits from face of block and sleeve projections.
2. Place metal bar across center of sleeve and bolt both ends into place using 150 ft. lbs. torque. This step will force the sleeve into the position it normally occupies when head is in place.
3. Use dial indicator to measure height of sleeve projection above face of block.

PISTONS

The aluminum alloy pistons are heavy-duty castings. The piston pins are of the full floating type and are retained in the piston by spring type clips. Two compression and one oil control ring are utilized on all pistons except VRG and VRD 155 and 232 pistons which use three compression and one oil control ring. Pistons for all VR Series engines, except VRG and VRD 155 and 232 engines, are marked with the word FRONT and an arrow, and must be installed with the arrow pointing towards the gear cover end of the engine.

CONNECTING RODS

I-section connecting rods of the split big end type are used in the VR Series. The rods and caps are forged, heat-treated, and machined in one piece, then separated at the crank pin end to accommodate steel backed, precision-type bearings. Hard bronze bushings are a press fit in the piston-pin end and are burnished in place, then diamond bored for precise alignment. Connecting rods for all VR Series engines, except VRG and VRD 155 and 232 engines, are marked FRONT and should always be assembled with this mark towards the gear cover end of the engine. Model VRG and VRD 155 and 232 connecting rods are offset and must be replaced exactly as removed, with the pin ends farther apart than the journal ends for each pair of cylinders. Connecting rods are never bent for alignment purposes, neither at the factory nor in the field. Two heat-treated bolts with self-locking nuts or place type bolts retain the bearing caps in place. The upper and lower halves of connecting rod bearings are interchangeable. The orientation of the split line on the piston pin bushing should be within 45° on either side of the top center of the rod.

CRANKSHAFT

The crankshaft is precision ground from a heat-treated steel forging. The crankshaft has flame-hardened main-bearing journals which run in steel backed, alloy hearing shells. The upper and lower halves of the main bearings are interchangeable except for those in VRG and VRD 283 and 310 engines. These are stamped "upper" and "lower". Connecting rod bearings are of similar construction for maximum serviceability.

The rear extremity of the shaft has an integral mounting flange for the flywheel. This flange is drilled and tapped for six flywheel mounting bolts. One bolt hole is offset 1/16 inch in order to ensure the installation of the flywheel in the proper relationship to the crankshaft. The front extension of the crankshaft provides a keyed mounting surface to support the crankshaft drive gear and fan pulley, which are press fitted and retained by a crank bolt.

NOTE

The following information relates only to special application engines designed and approved by the Arrow engineering department.

Special application crankshafts for models VRD and VRG 283 and VRD 310 and 310S are different from the standard crankshaft. Standard shafts use a woodruff key to retain the crankshaft gear. The special application shafts use a chrome alloy steel ball. This ball protrudes from a hole drilled into the nose of the crankshaft. During servicing, take care not to lose the ball if removing the crankgear. The gear can be reinstalled by resting the ball in the drilled hole, and pressing the heated gear into place.

CAMSHAFT

The camshaft is a single casting, with ground cams and journals. Individual hardened cams actuate each of the valve lifters. An integral worm gear drive drives the internal oil pump. The forward end of the camshaft is drilled and reamed and keyed for the retention of the cam-drive gear. Thrust and end play are absorbed by a spring loaded thrust button which rides against a thrust pad on the gear cover. Lubricating oil is supplied to each of the four journal areas. A steel backed babbitt bushing, pressed in the main crankcase, supports the camshaft at the front journal of VRG and VRD 155, 232, and the VRG265 engines, and at all four journals of all other VR Series engines.

PROTECTION OF ENGINE AND PARTS

During all repair and replacement procedures, care should be exercised to prevent damage to parts in handling. All machined surfaces should be protected and kept separate from other parts. Parts that are easily damaged require particular care to prevent bending, denting, or breakage. All parts should be covered to protect them from dirt. This will also speed reassembly by reducing clean-up time at assembly.

When parts are removed, openings into the engine or liquid or air systems should be covered to prevent dirt or other foreign matter from entering the engine or the system involved.

CLEANING AND INSPECTION OF ENGINE PARTS

Inspection of parts and assemblies can frequently be performed without removal or complete disassembly. Judgement should be exercised to avoid disassembly beyond that necessary to correct the fault and put the part or assembly in serviceable condition.

The following paragraphs describe cleaning procedures and, where applicable, name cleaning materials to be used if available. The different metals used in the engine and components require different techniques and materials, so a generalization of cleaning methods cannot readily be supplied.

Carbon Removal

Carbon must be removed during maintenance operations from valves, pistons, and cylinder head.

Carbon can be removed from the hardened surfaces by softening the carbon with a suitable carbon remover. Never scrape parts with a metallic scraper.

Soften the carbon by soaking the parts in a carbon removing compound. Rinse in kerosene or hot water and remove softened carbon with a rag or soft brush.

Castings

Clean inner and outer surfaces of castings and all areas subject to oil and grease with cleaning solvent.

Remove sludge and gum deposits with a stiff brush.

Blow out all tapped holes with compressed air and dry castings thoroughly, after cleaning, with compressed air.

Oil passages

Clean passages with wire brushes or probes to break up any sludge or gum deposits.

Wash passages by flushing with cleaning solvent and dry thoroughly with compressed air.

CAUTION

Do not use any material that will leave lint or other foreign particles when cleaning lube oil passages. Clogging or interference in passages may be caused by any foreign material. Such material would be worked into the bearings upon operating the engine.

Oil Seals and Hoses

Clean seals and hoses with soap and water. Do not allow cleaning solvent to contact seals and hoses.

Ball and Roller Bearings

CAUTION

Do not spin bearings with air.

Anti-friction bearings should receive special handling. As soon as a bearing is removed, cover it to keep out dirt and abrasives. Wash bearings in kerosene and inspect races and balls or rollers. Discard bearings if they are pitted, scored, or burned. If bearing is serviceable, coat it with light oil and wrap it in clean paper. Do not unwrap bearings until ready for installing.

Always use proper tool or fixture for pulling or pressing out bearings. Normally, it is unnecessary to remove bearings unless replacement is required.

When installing bearing against shoulder on shaft, be sure chamfered side is toward shoulder. When bearing is to be pressed in, lubricate mating surfaces prior to assembly.

Oil Seals

Oil seals should not be removed unless they are to be replaced due to damage or wear. If it becomes necessary to cut through seal to remove it, care must be taken not to damage seating area around it.

Evidence of lubricant leakage around shaft or bearing is usually a sign of oil seal failure.

Oil seals that leak or are worn to a point where they may begin to leak must be replaced. An oil leak corrected in time will prevent overheated bearings resulting from loss of lubricant. Never use oil seals a second time; once removed, they must be discarded.

When possible, soak new rawhide seals in oil (120° - 125° F.) for one-half hour before installing. Install seal with wiping edge turned in direction recommended (towards area to be sealed). Be careful not to cut leather seal as it is installed or when installing a shaft through the seal. Use shim stock if necessary to protect seal from shoulders or sharp edges during installation. Packing-type seals should always be renewed if contacting part is removed. Lubricant must be applied to lip of all shaft-type rubber seals before installation. This will prevent damage to seal during initial running until oil being sealed has contacted sealing face.

Attaching Parts

Use screws of correct length. A screw which is too long may "bottom" before head is tight against part it is to hold. In addition, threads may be damaged when screw is removed. If a screw is too short. There will not be enough threads to hold parts securely.

In addition to size variations, attaching parts may vary in material and heat treatment. Do not mix attaching parts.

Lock washers, cotter pins, or other locks should be used to lock each nut and cap screw when specified.

Gears

Always use tools recommended (or equivalent) for removal and installation. Gears must be carefully inspected for damaged or worn teeth. Always align keyway to gear with keyway in shaft before installing. Lubricate mating surfaces of gear and shaft when pressing gear on shaft.

If crankshaft gear removal is necessary, use an appropriate heavy duty puller to remove it. Never apply heat to remove gear as this may damage crankshaft. Before installing new crankshaft gear, heat it in an oven or other even source of heat to maximum of 400° F. to facilitate installation. Do not use torch to heat gear.

WARNING

Use asbestos gloves when handling a hot gear.

Quickly place heated gear on crankshaft and hold it securely in place until gear cools and contracts on crankshaft. Gear may be carefully tapped into place with soft face hammer or driving tool if slight cocking or binding causes it to stick.

Shims

Be sure to remove all shims where used. Keep shims together and identify them as to location. Keep shims clean and flat until they are reinstalled.

Gaskets

Install gaskets where required and use new one whenever possible. Never use cork or felt gaskets a second time. Be sure holes in gaskets correspond with lubricant passages in mating parts. It is necessary to fabricate gaskets, select stock of proper type and thickness and be sure to cut sufficient holes in the right places. Blank or incorrectly installed gaskets can cause serious damage.

Bushings

Do not remove bushings unless inspection reveals damage or wear that exceeds specified clearance or if bushing is loose in its mating bore. Bushings should be pressed out whenever possible. When pressing or driving (in or out) apply pressure directly in line with bore. If bushing must be driven, use driver of largest possible diameter of bar with a smooth, flat end. Never drive bushings with a hammer. If bushing has an oil hole, be sure to line up hole in bushing with oil hole in part in which it is assembled.

NOTE

Service cam bushings should be installed when cam bushings need replacing. Service cam bushings are manufactured with dimensions to allow for proper bearing clearance and alignment without line reaming.

Shafts

If a shaft offers unexpected resistance to removal, check carefully to see that all nuts, keys and cap screws have been removed before using force. Also check to see if another part is interfering which must be removed first. Clean rust preventive compound from all machined surfaces of new parts before installing. Shafts fitted to other parts with tapers should fit very tight. If they are not tight when disassembled, inspect tapers and discard part if worn. Before assembling shafts with tapers be sure tapers are clean, dry and free from burrs. Press mating parts together tightly.

Flexible Hose Lines

Fittings should be installed by threading the swivel nuts on by hand until they are finger tight. Hold the socket, on the hose behind the nut, with one wrench and tighten the swivel nut securely with another wrench. This method prevents twisting the hose and does not exert any strain on the hose. Correct installation prevents breaking of the hose plies or damaging the hose so that it may become separated or broken and leak under pressure.

REPAIRING DAMAGED THREADS

Damaged threads should be repaired by use of thread restorer or by chasing in lathe. Internal threads should be repaired using a tap of correct size. If threads cannot be satisfactorily repaired, install Heli-Coil or other standard insert or replace part.

REPAIR OF DAMAGED MACHINED AND POLISHED SURFACES

Smooth rough spots, scores, burrs, galling, and gouges from damaged machined and polished surfaces so that part will efficiently perform its normal function. Finish of repaired part is to approximate that of original finish. In performing any of these operations, critical dimensions must not be altered.

REMOVAL OF RUST OR CORROSION

Remove corrosion from all parts of material. To remove rust or corrosion, use brass wire brush, abrasive cloth, sand blast, vapor blast equipment, or rust remover except on highly polished surfaces. On these surfaces, buffing or use of crocus cloth is recommended.

INSTALLATION OF PISTONS AND RINGS

The type of oil ring used in VR Series diesel engines (except VRD 155 and 232 models) must be installed with the spring towards the top of the piston as illustrated.

On gas engines, two oil ring rails are separated by an oil ring rail spacer. The ends of the spacer are butted against each other with the upper and lower rail gaps staggered 120° and 140° respectively from the spacer gap.

CAUTION

Do not expand rings more than is necessary to slip over the piston. Over-expansion of rings causes stress and may lead to early failure. Ring gaps should be staggered 180° to prevent blowby during initial starting. Rings must be thoroughly lubricated with engine oil before being installed in cylinder sleeve.

Compression rings of VR Series engines which are notched on the inner edge must be installed with the notch towards the top of the piston. Compression rings of VR Series engines which are notched on the outer edge must be installed with the notch towards the bottom of the piston.

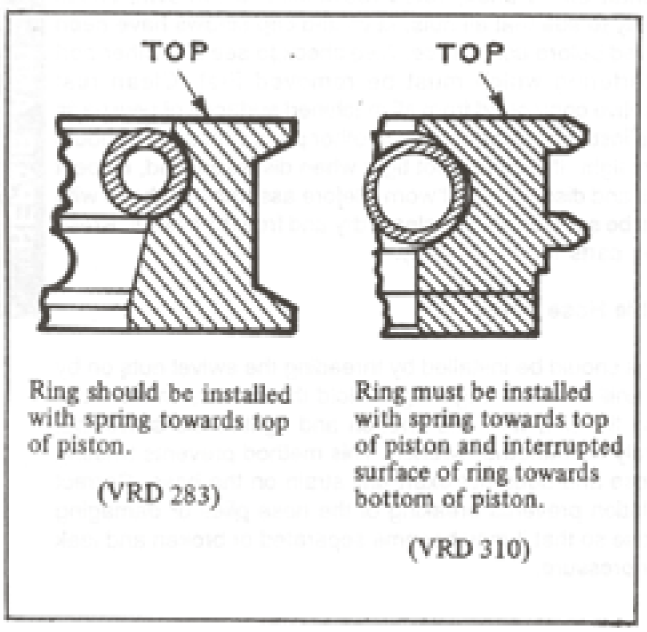
All VR Series engine pistons (except VRG and VRD 155 and 232) are marked with an arrow and the word FRONT, and the pistons must be installed with the arrow pointing towards the front of the engine.

OIL PUMP INSTALLATION (GASOLINE ENGINES)

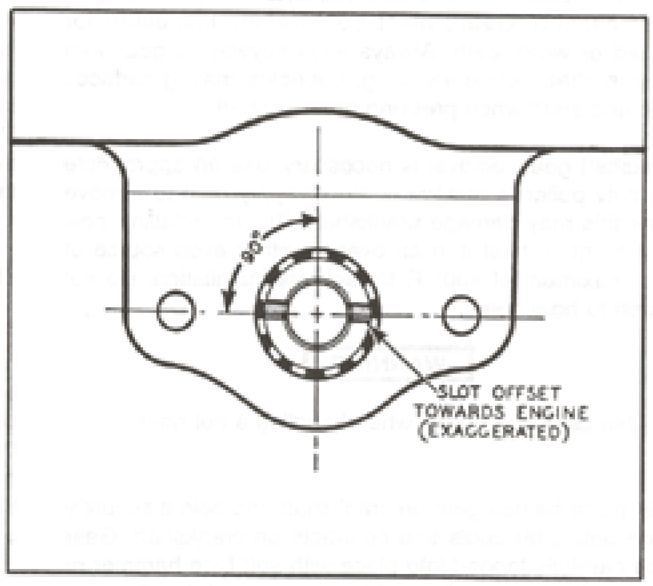
When the oil pump of VR Series gasoline engines is removed, it must be re-installed so the ignition drive keyway is positioned as illustrated, with the number one piston on compression stroke and the timing mark aligned.

WATER PUMP SEAL INSTALLATION

When installing a new water pump seal, carefully wipe the carbon sealing surface and the mating ceramic surface with a soft cloth of absorbent paper to remove all traces of wax, grease, or oil. Use a small amount of solvent if necessary. To provide for initial lubrication of the seal, apply either a 1% soluble oil and water solution or ethylene glycol type antifreeze to both sealing faces.



PROPER INSTALLATION OF OFFSET SPRING OIL RING



DISTRIBUTOR AND MAGNETO DRIVE KEYWAY IN OIL PUMP GEAR

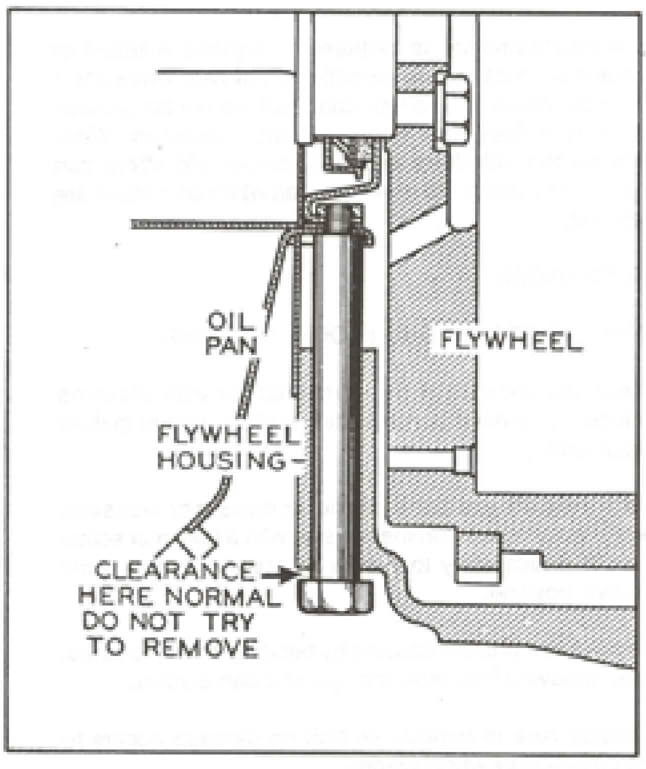
WATER PUMP PULLEY INSTALLATION

Before replacing the water pump pulley, carefully check all joining surfaces. The pulley is held on by an interference fit. If the joining surfaces are marred, scored or tapered, the pulley will not seat tightly. If the surfaces are in questionable condition, or if there is any doubt the pulley will seat tightly, Loctite bearing mount should be used to secure the pulley.

OIL PAN REMOVAL AND REPLACEMENT

The oil pans used on VR Series engines are held at the rear flange by two long, special bolts extending downward through the flywheel housing. This is necessary in order to provide adequate gasket pressure in this area and at the same time avoid placing the oil pan bolts in an inaccessible position. These long cap screws must be removed before removing the oil pan.

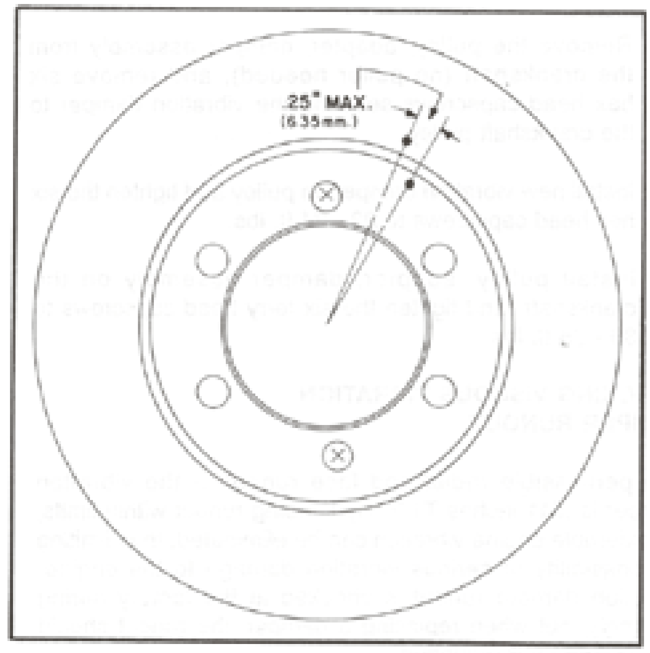
On reinstalling these cap screws it will be found that the heads do not seat on the flywheel housing. This is done to insure full pressure at the pan gasket. Attempting to seat the heads against the flywheel housing will strip the threads at the oil pan to rear oil seal joint.



OIL PAN BOLT INSTALLATION

RUBBER VIBRATION DAMPER REPLACEMENT

The rubber vibration dampers used on standard VRD310 and 310S engines have radially aligned center punches on the inner and outer members. When the angular displacement between these marks equals or exceeds 1/4 inch, the damper has exceeded its useful life and should be replaced.



DETERMINING RUBBER VIBRATION DAMPER REPLACEMENT

To replace the rubber vibration damper, use the following procedure:

1. Remove cap screw securing crankshaft pulley to the crankshaft.
2. Using a pulling device remove crankshaft pulley from the crankshaft.
3. Remove four screws securing vibration damper to the crankshaft pulley. The two (2) dowels should remain in the crankshaft pulley.
4. Install new vibration damper on pulley and tighten bolts to 27 - 29 foot pounds (3.7 - 4.0 kgm).
5. Install pulley-damper assembly on the crankshaft and tighten crank bolt to 229 - 238 foot pounds (31.7 - 32.9 kgm).

VISCOUS VIBRATION DAMPER

Viscous vibration dampers are used on model VRD and VRG 283 and VRD 310 and 310S Special Application Engines. The basic construction consists of a flywheel member floating in a silicone fluid and surrounded by a lighter outer shield. The clearance between the inner member and the shield is very small and any dent deeper than 1/32" will destroy the damper for further use.

To replace the viscous vibration damper, use the following procedure:

1. Remove six ferry head capscrews securing adapter to the crankshaft.

2. Remove the pulley, adapter, damper assembly from the crankshaft (no puller needed), and remove six hex head capscrews securing the vibration damper to the crankshaft pulley.

3. Install new vibration damper on pulley and tighten the six hex head capscrews to 22 - 24 ft. lbs.

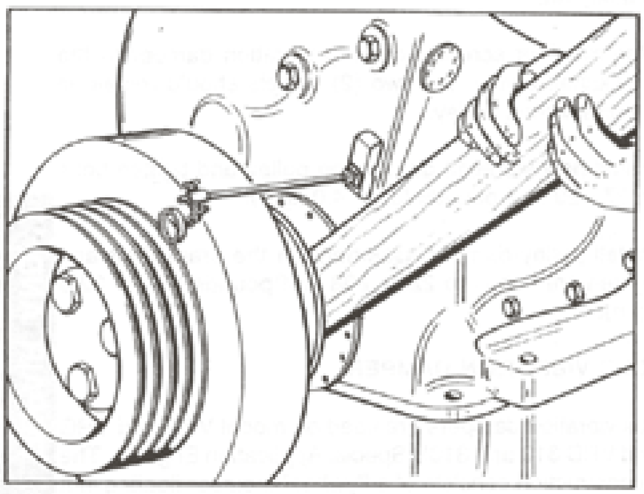
4. Install pulley, adapter, damper assembly on the crankshaft and tighten the six ferry head capscrews to 36 - 38 ft. lbs.

CHECKING VISCOUS VIBRATION DAMPER RUNOUT

The permissible radial and face runout of the vibration damper is .011 inches T.I.R. By keeping runout within limits, considerable engine vibration can be eliminated, thus limiting the possibility of serious vibration damage to the engine. Vibration damper runout is checked at the factory during assembly, but when replacing a damper, the runout should be checked after mounting.

Position the damper with the mounting bolts and tighten bolts evenly to the specified torque. Now check the face runout of the replacement damper.

Mount the base of a dial indicator on the front of the crankcase and place the indicator button on the face of the damper at the outside edge. Then, by barring the engine over, it is possible to observe the indicator reading. NOTE that the permissible runout is the TOTAL indicator reading.



To avoid introducing crankshaft end play into this reading, the crankshaft must be forced either rearward or forward (but always in the same direction) against the thrust bearing at each point of reading.

Should the damper face runout be excessive, shift the damper 90 degrees on the crankshaft and try again. If this does not reduce the runout sufficiently, remove the damper and check the crankshaft and pulley mounting surfaces. It may be necessary to mount the damper in a lather and check the damper itself.

CAUTION

A true running damper does not indicate the quality of the damper. The quality can only be determined by test. The viscous damper, manufactured by Idex Corp. (formerly Houdaille Industries, Inc. can be returned to their factory for testing. However, they can only determine that the damper is good at the time of test and cannot assure possible service life. There is a service charge for the test. Arrow Specialty Company recommends that a viscous damper be replaced at major overhaul periods.

REPLACING COOLING FAN

The VR Series engines are available with either a "pusher" or "suction" cooling fan. Special attention must be given to the fan blade spacer. Refer to your VR parts book for correct parts numbers.

INSTALLATION OF NEW VALVE LIFTERS ALONG WITH NEW CAMSHAFT

When a new camshaft is installed to replace a failed or excessively worn camshaft, an entire set of new valve lifters must also be installed. The new camshaft will not be covered by warranty unless new lifters are also installed. Wear patterns on the old lifters and/or damaged old lifters can result in early failure of the new camshaft when new lifters are not installed.

TURBOCHARGER

OVERHAUL INSTRUCTIONS (MODEL VRD310S)

1. Clean the exterior of the turbocharger with cleaning solvent to remove accumulated surface matter before disassembly.

2. Mark related positions of the compressor housing, center housing and turbine housing with a punch or scribe prior to disassembly to assure reassembly in the same relative position.

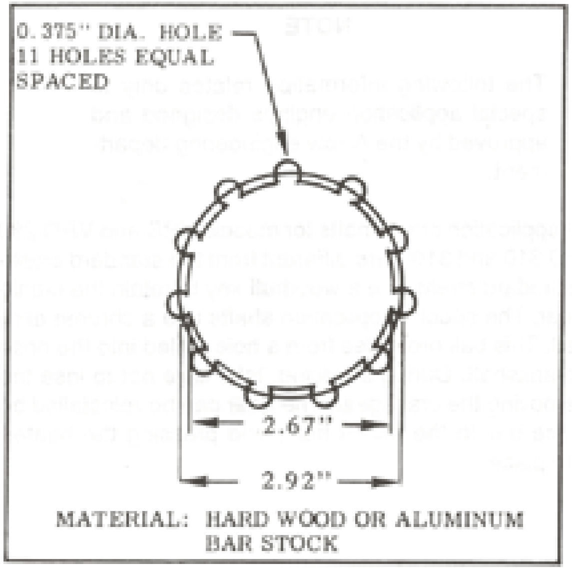
3. Remove compressor housing by bending down lock tabs, then removing lock tabs, clamps and cap screws.

   Exercise care in removal so that no damage occurs to the compressor wheel blades.

4. Bend down ends of turbine bolt lockplates and remove lockplates, clamps and cap screws. Tap housing with lead or brass hammer if force is needed for removal.

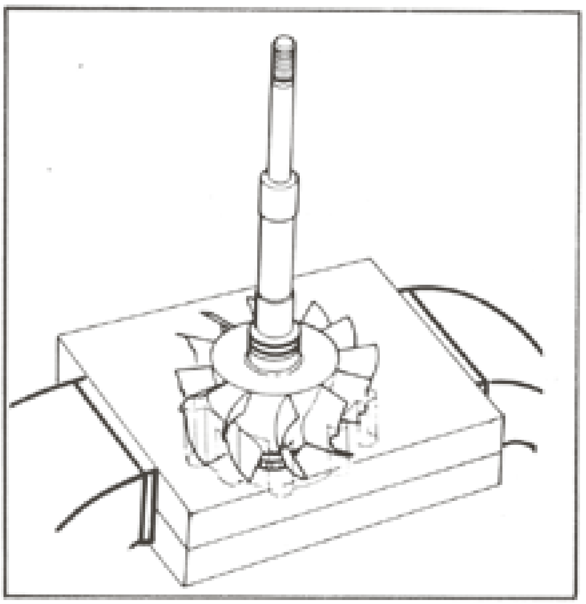
5. Clamp a suitable socket or box end wrench in a vise and place extended hub on shaft in the socket or wrench. Hold the center housing upright and remove the shaft locknut with a double universal socket wrench.

   If desired the holding fixture as depicted may be used.



1" DEEP
1/2" THICK - BASE CAN BE BOLTED OR ATTACHED WITH SCREWS

SHAFT WHEEL HOLDING FIXTURE



SHAFT WHEEL ASSY IN FIXTURE

6. Lift the compressor wheel off the shaft and remove the shaft wheel assembly from the center housing. The wheel shroud which is not retained will fall free when the shaft wheel is removed.

7. Remove and discard the turbine seal piston ring.

8. Bend down ends of lock tabs and remove backplate retaining bolts.

9. Tap backplate lightly for removal from center housing recess.

10. Remove and discard the square seal ring.

11. Lift the thrust collar and thrust washer off the center housing retaining pins. Discard the thrust washer.

12. Remove and discard thrust collar piston ring.

13. Remove bearing retainers and bearings from center housing and discard.

Cleaning

Before cleaning, inspect all parts for signs of burning and rubbing or other damage which may not be evident after cleaning.

Clean all parts in a non-caustic cleaning solution. Use a bristle brush, a plastic blade scraper and dry compressed air to remove surface accumulation. Completely remove all surface matter. Do not use abrasive cleaning method which might destroy or damage machined surfaces. Especially check center housing cavity and remove all carbonized oil.

Reassembly

1. Install inboard bearing retainers in center housing with rounded shoulder facing the bearing.

2. Insert bearings and secure outboard bearing retainers also with rounded shoulders facing bearings.

3. Install piston ring in groove on turbine shaft wheel.

4. Place shroud over the shaft and guide the shaft through the bearings. A gentle rocking action will allow the piston ring to seat and the shaft to bottom. Do not force the piston ring since it is easily broken.

5. Install piston ring in groove on thrust collar.

6. Place thrust washer on thrust collar and engage over pins on center housing. Channeled face of thrust washer faces against the center housing.

7. Install seal ring in groove in center housing.

8. Ensure that thrust spring is installed in backplate. Align mounting holes of center housing and backplate and install over shaft and thrust collar. Use care not to break the piston ring when engaging into seal bore. Backplate is easily installed if open end position of piston ring is engaged in bore first.

9. Install cap screws and lockplates. Torque to 90 - 75 in. lbs. and secure lockplates.

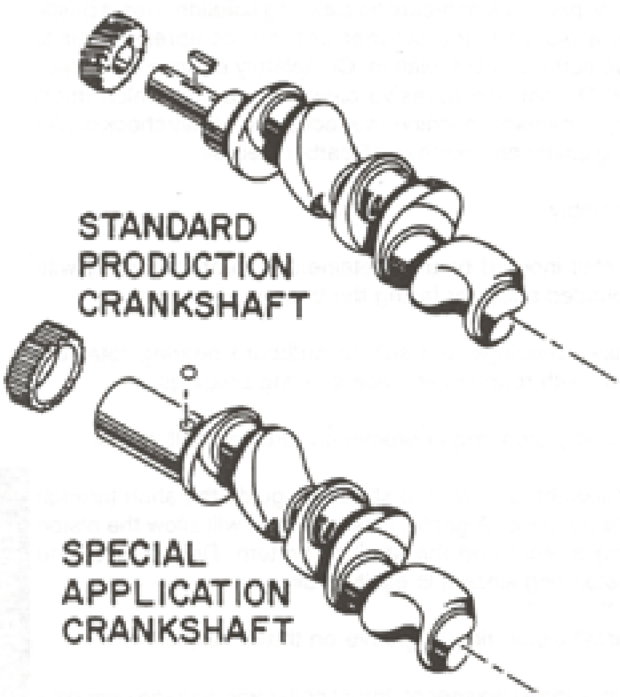
10. Place turbine wheel upright in fixture, socket or box end wrench and install compressor over shaft. Tighten locknut with double universal socket wrench to 18 - 20 in. lbs. Continue to tighten through an angle of 90°. This is sufficient to stretch shaft the required .0065 to .0055 inches for proper nut attachment.

11. Orient turbine housing to center housing and install bolts, clamps and lockplates. Torque to 130 - 110 in. lbs. Secure lockplates. It is advisable to coat bolt threads with FEL-PRO or similar high temperature compound before installing. Torque stainless steel bolts to 140 - 170 in. lbs.

12. Install compressor housing, bolts, clamps and lockplates; torque bolts to 130 - 110 in. lbs. and secure lockplates.

13. After reassembly check unit for binding. If unit is to be stored lubricate internally and install protective coverings on openings.

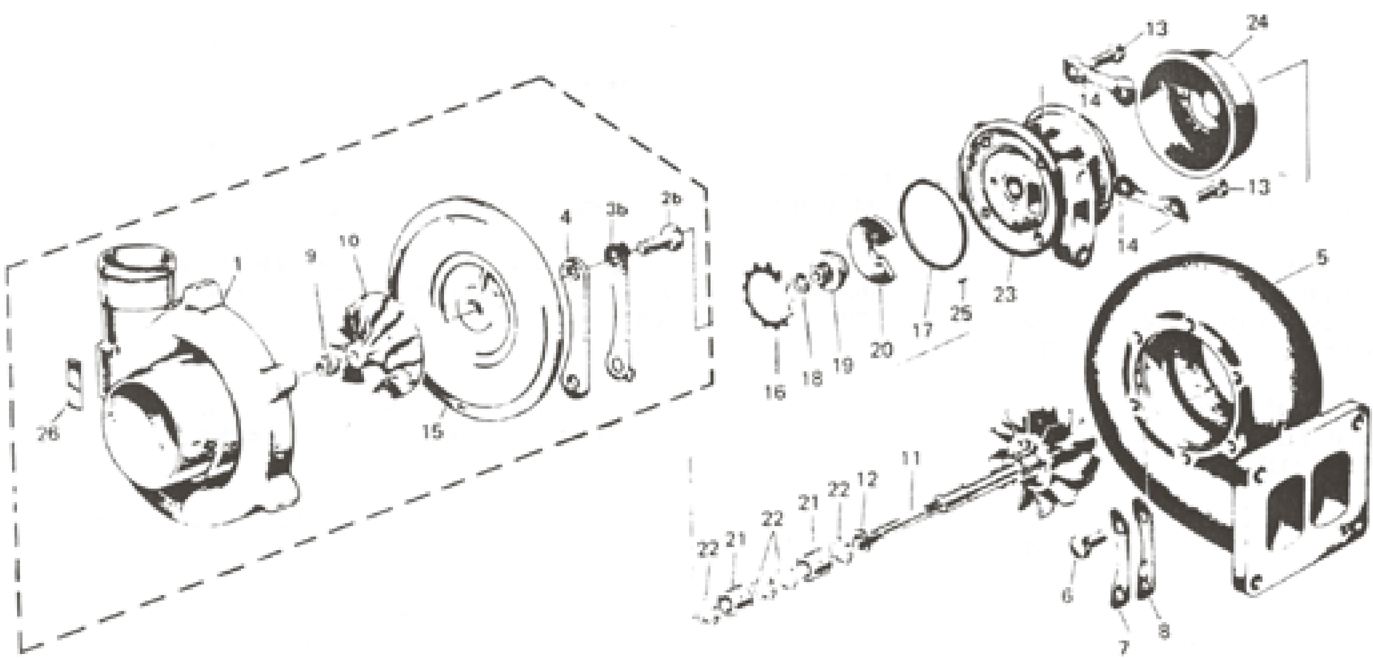
SPECIAL APPLICATION CRANKSHAFTS



NOTE

The following information relates only to special application engines designed and approved by the Arrow engineering department.

Special application crankshafts for models VRD and VRG 283 and VRD 310 and 310S are different from the standard crankshaft. Standard shafts use a woodruff key to retain the crankshaft gear. The special application shafts use a chrome alloy steel ball. This ball protrudes from a hole drilled into the nose of the crankshaft. During servicing, take care not to lose the ball if removing the crankgear. The gear can be reinstalled be resting the ball in the drilled hole, and pressing the heated gear into place.



INDEX NO.	DESCRIPTION	QTY.
1	COMPRESSOR HOUSING	1
2b	BOLT, 5/16 - 18	6
3b	LOCKPLATE	3
4	CLAMP	3
5	TURBINE HOUSING	1
6	BOLT, 5/16 - 18	6
7	LOCKPLATE	3
8	CLAMP	3
9	LOCKNUT	1
10	COMPRESSOR WHEEL	1
11	TURBINE WHEEL ASSEMBLY	1
12	PISTON RING	1
13	BOLT, 1/4 - 20	4
14	LOCKPLATE	2
15	BACKPLATE	1
16	THRUST SPRING	1
17	SEAL RING	1
18	PISTON RING	1
19	THRUST COLLAR	1
20	BEARING, THRUST	1
21	BEARING, JOURNAL	2
22	RETAINING RING	4
23	CENTER HOUSING	1
24	WHEEL SHROUD	1
25	PIN, SPRING	2
26	NAMEPLATE	1

REPAIR & REPLACEMENT

INSPECTION

Observe the following table of limits to determine parts replacement.

TABLE OF SERVICE LIMITS

Nomenclature	Manufacturing Minimum	Manufacturing Maximum	Service Maximum	Notes
Center Housing				Bore surfaces msut be free of scores. Scrape carbonized oil from internal surfaces if present.
Bearing Bore I.D.	.6220	.6223	.6228	
Seal Bore I.D. (Standard)	.699	.701	.703	
Seal Bore I.D. (Stepped)	.709	.711	.713	
Turbine Shaft Wheel				Journal surfaces must not be scored. Polish surfaces with crocus cloth.
Journal O.D.	.3997	.4000	.3994	
Seal Hub O.D.	.682	.683	.681	
Back Plate				Thrust surface must be clean and smooth.
Seal Bore I.D.	.4995	.5005	.5010	
Thrust Collar				Ring groove shoulders must be free of step wear. Thrust faces must be smooth.
Washer Groove Width	.1740	.1748	.1752	
Ring Groove Width	.064	.065	.066	
Thrust Washer				Recommended 100% replacement at overhaul.
Thickness	.1716	.1720	-	
aring				Recommended 100% replacement anytime unit is disassembled.
.D.	.6182	.6187	-	
).	.4010	.4014	-	
sor Wheel				Replace if any evidence of rubbing, erosion or nicks noted.
	.2498	.2501	.2504	
aft Wheel				Ring groove shoulders must be free of step wear.
ve Width	.0645	.0685	.0735	
or Housing				Replace if heavily damaged by wheel rub. Clean up of light rub is permissible.
ousing				Replace if discharge opening warped out of round, shows erosion, cracks, or heavy wheel.
heel Blades				Slight erosion permissible. Blade tips must not be feather edged or torn. Minimum tip thickness 0.025 in.
Turbine Wheel Shroud				Replace if warped, eroded, or heavily rubbed.

* Because of the high speeds and internal stresses to which the compressor wheel is subject, the presence of nicks, gouges or other surface imperfection is cause for rejection of this part. Zyglo inspection is recommended.

METRIC CONVERSION FORMULAS

In order to convert the data in this manual into metric values, use the following conversion formulas. Examples of applying each conversion formula are included.

Less Than One (1) Inch to Millimeters
25.4 x Fraction in Decimal
Example: 15/16" = .9375 x 25.4 = 23,8125 mm

More Than One (1) Inch to Millimeters
25.4 x Inches and Decimal Fraction
Example: 2-5/8" = 2.625 x 25.4 = 66,675

Cubic Inches to Liters
.01639 x Cubic Inches
Example: 9388 Cubic Inches = 9388 x .01639 = 153,8 Liters

Ounces to Grams
28.35 x Ounces
Example: 21 Ounces = 21 x 28.35 = 595,35 grams

Pounds to Kilograms
.4536 x Lbs.
Example: 22,550 x .4536 = 10,228Kg

Inch Pounds to Newton-meters
Inch Lb. x .11298
Example: 360 In. Lb. = 360 x .11298 = 40,67 N-m

Foot Pounds to Newton-meters
Foot Lb. x 1.3558
Example: 145 Ft. Lb. = 145 x 1.3558 = 196,6 N-m

PSI to KG per Sq. Centimeter
PSI x .0703
Example: 45 PSI = 45 x .0703 = 3,16 KG per Sq. Centimeter

Ounces (fluid) to Cubic Centimeters
29.57 x Ounces
Example: 8 Ounces = 8 x 29.57 = 236,56 cc

Gallons to Liters
Gallons x 3.7853
Example: 148 Gal. = 148 x 3.7853 = 560 Liters

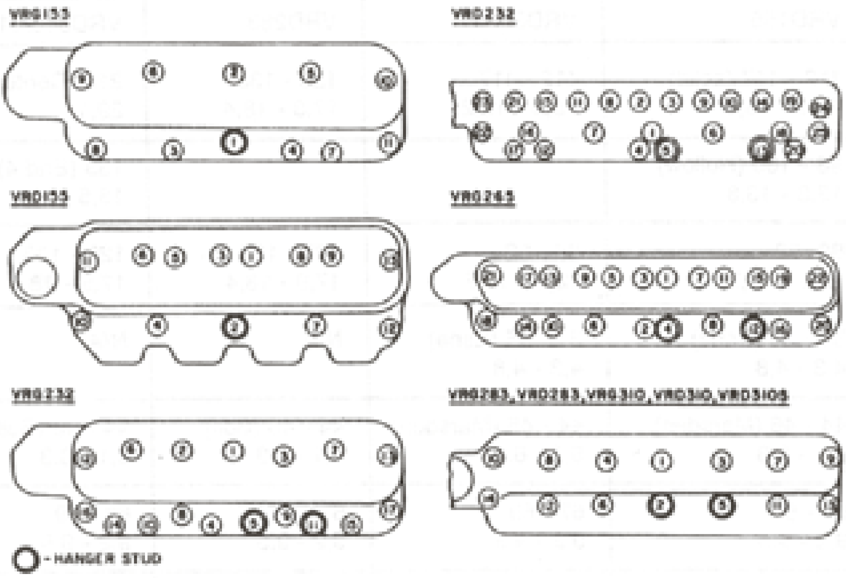
Degree Fahrenheit to Degrees Centigrade
Degrees Fahrenheit -32 x 5/9
Example: 212°F. = 212 -32 x 5/9 = 180 x 5/9 = 100°C.

GENERAL TORQUE RECOMMENDATIONS

The values specified below are to be used only in the absence of specified torquing instructions and are not to be construed as authority to change existing torque values. A tolerance of ± 3% is permissible on these values, which are for oiled threads.

HEAT TREATED MATERIAL SAE GRADE 5 & GRADE 8				
	NOTE: INCREASE VALUES 1/3 FOR DRY THREADS			
	GRADE 5 (3 radial dashes on bolt or cap screw head)		GRADE 8 (6 radial dashes on bolt or cap screw head)	
THREAD SIZE	U.S. Pounds - Feet	Metric Kgm	U.S. Pounds - Feet	Metric Kgm
1/4-20	6	0,8	9	1,2
1/4-28	7	0,9	11	1,5
5/16-18	13	1,8	18	2,5
5/16-24	15	2,1	21	2,9
3/8-16	24	3,3	34	4,7
3/8-24	27	3,7	38	5,3
7/16-14	38	5,3	54	7,5
7/16-20	42	5,8	60	8,7
1/2-13	58	7,9	82	11,3
1/2-20	65	8,9	90	12,4
9/16-12	84	11,7	120	16,6
9/16-18	93	12,9	132	18,3
5/8-11	115	15,7	165	22,8
5/8-18	130	17,9	185	25,6
3/4-10	205	28,4	290	40,1
3/4-16	230	31,8	320	44,3
7/8-9	305	42,2	455	62,9
7/8-14	335	46,3	515	71,2
1-8	455	62,9	695	96,1
1-14	510	70,5	785	108,6
1-1/8-7	610	84,4	990	136,9
1-1/8-12	685	94,7	1110	153,5
1-1/4-7	860	118,9	1400	193,6
1-1/4-12	955	132,1	1550	214,4
1-3/8-6	1130	156,3	1830	253,1
1-3/8-12	1290	178,4	2085	288,4
1-1/2-6	1500	207,5	2430	336,1
1-1/2-12	1690	233,7	2730	277,5
1-3/4-5	2370	327,8	3810	526,9
2-4-1/2	3550	490,9	5760	796,6

TORQUE RECOMMENDATIONS



Cylinder heads should always be torqued in the proper sequence as illustrated. The first time through the torque sequence use 25 percent of the total torque value; each succeeding time through the torque sequence increase the torque setting by 25 percent of total torque value until final torque is reached. In order to be sure of proper torque, the torque sequence should again be repeated with the torque wrench set to the total torque value. Remember to retorque all replaced cylinder heads after first start and after approximately 50 hours of operation with engine warm.

VR GAS AND GASOLINE TORQUE VALUES - FOOT POUNDS (Kgm)

	VRG 155	VRG232	VRG265	VRG283 and 310
Cylinder Head Cap Screw (Solid)	112 - 117 15,5 - 16,2	112 - 117 15,5 - 16,2	112 - 117 15,5 - 16,2	129 - 133 17,9 - 18,5
Cylinder Head Cap Screw (Drilled)	96 - 100 13,3 - 13,8	92 - 100 12,7 - 13,8	96 - 100 13,3 - 13,8	129 - 133 17,9 - 18,5
Main Bearings	88 - 92 12,1 - 12,7	88 - 92 12,1 - 12,7	108 - 112 15,0 - 15,6	129 - 133 17,9 - 18,5
Connecting Rods	31 - 35 (Esna) 4,3 - 4,8	31 - 35 (Esna) 4,3 - 4,8	31 - 35 (Esna) 4,3 - 4,8	N/A
	44 - 46 (Marsden) 6,1 - 6,3	44 - 46 (Marsden) 6,1 - 6,3	44 - 46 (Marsden) 6,1 - 6,3	44 - 46 (Bolt) 6,1 - 6,3
Flywheel	67 - 69 9,2 - 9,5	67 - 69 9,2 - 9,5	67 - 69 9,2 - 9,5	67 - 69 9,2 - 9,5
Crank Bolt	75 - 85 10,4 - 11,8	75 - 85 10,4 - 11,8	75 - 85 10,4 - 11,8	75 - 85* 10,4 - 11,8
Spark Plug	32 - 38 (Dry) 4,4 - 5,3	32 - 38 (Dry) 4,4 - 5,3	26 - 30 (Dry) 3,6 - 4,2	26 - 30 (Dry) 3,6 - 4,2
	24 - 28 (Oil) 3,3 - 3,9	24 - 28 (Oil) 3,3 - 3,9	20 - 23 (Oil) 2,7 - 3,2	20 - 23 (Oil) 2,7 - 3,2

VR DIESEL TORQUE VALUES - FOOT POUNDS (Kgm)

	VRD155	VRD232	VRD283	VRD310/310S
Cylinder Head	112 - 117 (solid) 15,5 - 16,2	112 - 117 15,5 - 16,2	125 - 133 17,3 - 18,4	210 (Center 10) 29,1
	96 - 100 (Hollow) 13,3 - 13,8			133 (End 4) 18,5
Main Bearings	88 -92 12,1 - 12,7	88 - 92 12,1 - 12,7	129 - 133 17,9 - 18,4	129 - 133 17,9 - 18,4
Connecting Rods	31 - 35 (Esna) 4,3 - 4,8	31 - 35 (Esna) 4,3 - 4,8	N/A	N/A
	44 - 46 (Marsden) 6,1 - 6,3	44 - 46 (Marsden) 6,1 - 6,3	44 - 46 (Bolt) 6,1 - 6,3	44 - 46 (Bolt) 6,1 - 6,3
Flywheel	67 - 69 9,2 - 9,5	67 - 69 9,2 - 9,5	67 - 69 9,2 - 9,5	67 - 69 9,2 - 9,5
Crank Bolt	75 - 85 10,4 - 11,8	75 - 85 10,4 - 11,8	75 - 85* 10,4 - 11,8	229 - 238* 31,7 - 32,9
Fuel Injector	12 - 17 1,7 - 2,4	12 - 17 1,7 - 2,4	10 - 11 1,4 - 1,5	10 - 11 1,4 - 1,5
Energy Cell	96 - 100 13,6 - 13,8	96 - 100 13,3 - 13,8	N/A	N/A
Injection Pump Lock Nut	35 - 40 4,8 - 5,5	35 - 40 4,8 - 5,5	35 - 40 4,8 - 5,5	35 - 40 4,8 - 5,5
Vibration Damper	N/A	N/A	N/A*	27 - 29* 3,7 - 4,0

NOTE: ALL TORQUE VALUES ARE BASED ON OILED THREADS UNLESS SPECIFIED AS DRY.

* Special Application Engines (Models VRG and VRD 283 and VRD310S) use a viscous vibration damper with torque of 22-24 foot-pounds (3,0-3,3 kgm) and crank pulley screws torque of 36-38 foot-pounds (5,0-5,2 kgm).

BASIC ENGINE DATA

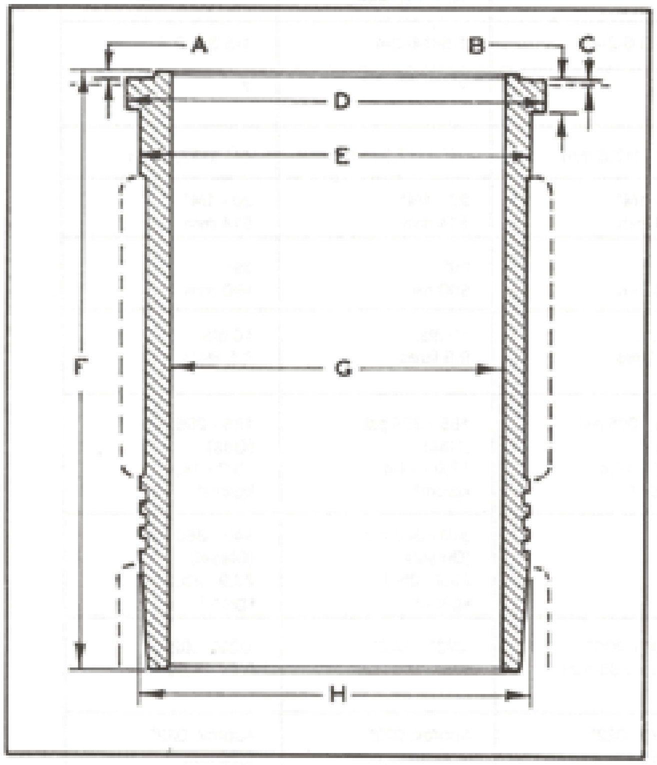
	VRG 155 VRD 155	VRG 232 VRD232	VRG 265	VRG 283 VRD 283	VRG310 VRD 310/310S
Number of Cylinders	4	6	6	6	4
Compression Ratio	8.01:1 (Gas) 16.5:1 (Diesel)	8.01:1 (Gas) 16.5:1 (Diesel)	8.5:1 (Gas)	8.5:1 (Gas) 16.7;1 (Diesel)	8.5:1 (Gas) 16.7:1 (Diesel)
Firing Order	1-2-4-3	1-5-3-6-2-4	1-5-3-6-2-4	1-5-3-6-2-4	1-5-3-6-2-4
Number of Main Bearings	3	4	4	7	7
Engine Length	31 1/2" 800,1 mm	42 1/4" 1073,2 mm	44" 1117,6 mm	44" 1117,6 mm	44" 1117,6 mm
Engine Width	17 - 1/2" 444,5 mm	20 - 1/4" 514 mm	20 - 1/4" 514 mm	20 - 1/4" 514 mm	20 - 1/4" 514 mm
Engine Height	21 - 1/2" 546,1 mm	37 - 1/2" 952 mm	39" 990 mm	39" 990 mm	39" 990 mm
Crankcase Capacity (Including Filter)	6 qts. 5,7 litres	7 qts. 6,6 litres	10 qts. 9,5 litres	10 qts. 9,5 litres	10 qts. 9,5 litres
Cylinder Compression at Cranking Speed	170 - 195 psi (Gas) 11,95 - 13,7 kg/cm²	170 - 195 psi (Gas) 11,95 - 13,7 kg/cm²	185 - 205 psi (Gas) 13,0 - 14,4 kg/cm²	185 - 205 psi (Gas) 13,0 - 14,4 kg/cm²	185 - 205 psi (Gas) 13,0 - 14,4 kg/cm²
	200 - 240 psi (Diesel) 14,1 - 16,9 kg/cm²	200 - 240 psi (Diesel) 14,1 - 16,9 kg/cm²	N/A	340 - 360 psi (Diesel) 23,9 - 25,3 kg/cm²	340 - 360 psi (Diesel) 23,9 - 25,3 kg/cm²
Distributor Point Gap (Holly-except VRG 155)	.021" - .023" 0,53 - 0,58 mm (Delco-Remy)	.023" - .026" 0,58 - 0,66 mm	.023" - .026" 0,58 - 0,66 mm	.023" - .026" 0,58 - 0,66 mm	.023" - .026" 0,58 - 0,66 mm
(Mallory)	N/A	Approx..022" 0,56 mm	Appox..022" 0,56 mm	Approx..022" 0,56 mm	Approx..022" 0,56 mm
Distributor Dwell Angle (Holly-except VRG 155)	31° - 34° (Delco-Remy)	33° - 38°	33° - 38°	33° - 38°	33° - 38°
(Mallory)	N/A	32° - 36°	32° - 36°	32° - 36°	32° - 36°
Magneto Point Gap	N/A	.014" - .016" 0,36 - 0,40 mm	.014" - .016" 0,36 - 0,40 mm	.014" - .016" 0,36 - 0,40 mm	.014" - .016" 0,36 - 0,40 mm
Injection Pump Timing	2° BTDC	2° ATDC	4° BTDC	4° BTDC	4° BTDC (VRD 310) 1° ATDC (VRD 310S)
Valve Clearance Cold (Intake)	.011" - .013" 0,28 - 0,33 mm	.011" - .013" 0,28 - 0,33 mm	.019" - .021" 0,48 - 0,53 mm	.019" - .021" (Gas) 0,48 - 0,53 .029" - .031" (Diesel) 0,74 - 0,79	.019" - .21" (Gas) 0,48 - 0,53 .029" - .031" (Diesel) 0,74 - 0,79
Valve Clearance Cold (Exhaust)	.019" - .021" 0,48 - 0,53 mm	.019" - .021" 0,48 - 0,53 mm	.029" - .031" 0,74 - 0,79 mm	.029" - .031" (Gas) 0,74 - 0,79 .029" - .031" (Diesel) 0,74 - 0,79	.029" - .031" (Gas) 0,74 - 0,79 .029" - .031" (Diesel) 0,74 - 0,79
Injector Nozzles Release Pressure	1975 psi (New) 138.8 kg per sq. centimeter	1975 psi (New) 138.8 kg per sq. centimeter	N/A	2800 psi (New) 224.9 kg per sq. centimeter	3200 psi (New) 224.9 kg per sq. centimeter
	1800 psi (Service) 126.5 kg per sq. centimeter	1800 psi (Service) 126.5 kg per sq. centimeter	N/A	2600 psi (Service) 210.9 kg per sq. centimeter	3000 psi (Service) 210.9 kg per sq. centimeter

NOTE: Additional Basic Engine Data is located in front of manual.

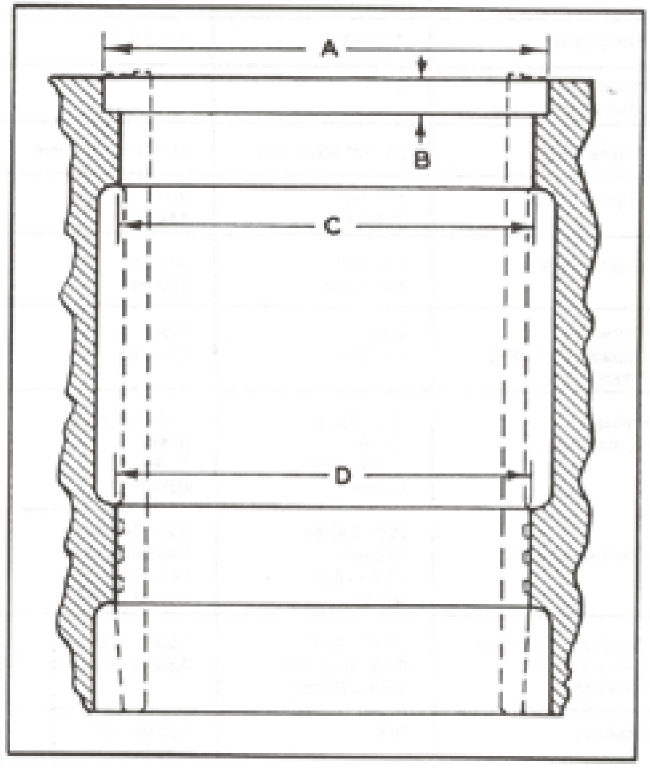
REPAIR & REPLACEMENT

FITS AND CLEARANCES

ILLUSTRATIONS FOUND IN THIS SECTION ARE FOR THE LOCATION OF MEASUREMENTS ONLY. THEY ARE NOT INTENDED TO BE ACCURATE REPRESENTATIONS OF THE PARTS INVOLVED.



TYPICAL CYLINDER SLEEVE



TYPICAL SECTION THROUGH CRANKCASE

VRG FITS AND CLEARANCES

	VRG 155	VRG 232	VRG 265	VRG 283/310
CYLINDER SLEEVES				
(A) Heat Dam Projection	-------	-------	------	.030 - .034 0,762 - 0,863
(B) Flange Height	.251 - .252 6,375 - 6,400	.251 - .252 6,375 - 6,400	.251 - .252 6,375 - 6,400	.251 - .252 6,375 - 6,400
(C) Sleeve Projection Above Crankcase	.001 - .004 0,025 - 0,101	.001 - .004 0,025 - 0,101	.001 - .004 0,025 - 0,101	.001 - .004 0,025 - 0,101
(D) Flange Diameter	4.3100 - 4.3085 109,474 - 109,423	4.3100 - 4.3085 109,474 - 109,423	4.5600 - 4.5585 115,824 - 115,773	4.5600 - 4.5585 115,824 - 115,773
(E) Sleeve Diameter Below Flange	4-3/32" 104 mm	4-3/32" 104 mm	4-11/32" 110 mm	4-11/32" 110 mm
(F) Sleeve Length Less Heat Dam	7-1/16" 179 mm	7-1/16" 179 mm	7-5/16" 186 mm	7-7/16" 189 mm
(G) Sleeve Bore Diameter ("B" size only)	3.6253 - 3.6257 92,082 - 92,092	3.6253 - 3.6257 92,082 - 92,092	3.7503 - 3.7507 95,257 - 95,267	3.8753 - 3.8757 98,432 - 98,442
(H) Sleeve Diameter Lower Seal Area	4.0290 - 4.0275 102,336 - 102,298	4.0290 - 4.0275 102,336 - 102,298	4.2790 - 4.2775 108,686 - 108,648	4.2800 - 4.2785 108,712 - 108,673
Sleeve Bore Maximum Out-of-Round	.002" 0,050 mm	.002" 0,050 mm	.002" 0,050 mm	.002" 0,050 mm
Sleeve Bore Maximum Taper	.002" 0,050 mm	.002" 0,050 mm	.002" 0,050 mm	.002" 0,050 mm
Sleeve Seal Area to Crankcase Clearance	.0045 - .002" 0,114 - 0,050 mm	.0045 - .002" 0,114 - 0,050 mm	.0045 - .002" 0,114 - 0,050 mm	.0035 - .001" 0,088 - 0,025 mm

VRD FITS AND CLEARANCES

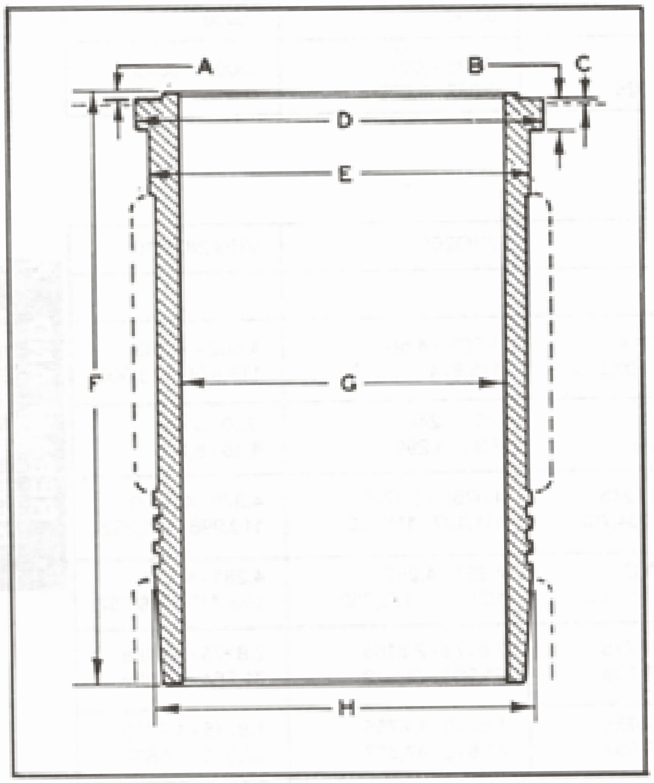
	VRD 155/232	VRD 283	VRD310	VRD310S
CYLINDER SLEEVE				
(A) Heat Dam Projection		.030 - .034 0,762 - 0,863	.030 - .034 0,762 - 0,863	.030 - .034 0,762 - 0,863
(B) Flange Height	.251 - .252 6,375 - 6,400	.251 - .252 6,375 - 6,400	.251 - .252 6,375 - 6,400	.251 - .252 6,375 - 6,400
(C) Sleeve Projection Above Crankcase	.001 - .004 0,025 - 0,101	.001 - .004 0,025 - 0,101	.001 - .004 0,025 - 0,101	.001 - .004 0,025 - 0,101
(D) Flange Diameter	4.3100 - 4.3085 109,474 - 109,423	4.5600 - 4.5585 115,824 - 115,773	4.5600 - 4.5585 115,824 - 115,773	4.5600 - 4.5585 115,824 - 115,773
(E) Sleeve Diameter Below Flange	4 - 3/32 104	4 - 11/32 110	4 - 11/32 110	4 - 11/32 110
(F) Sleeve Length Less Heat Dam	7 - 1/16 179	7 - 7/16 189	7 - 7/16 189	7 - 7/16 189
(G) Sleeve Bore Diameter ("B" size only)	3.6253 - 3.6257 92,082 - 92,092	3.8753 - 3.8757 98,432 - 98,442	3.8753 - 3.8757 98,432 - 98,442	3.876 - 3.875 98,450 - 98,425
(H) Sleeve Diameter Lower Seal Area	4.0290 - 4.0275 102,336 - 102,298	4.2800 - 4.2785 108,712 - 108,673	4.2800 - 4.2785 108,712 - 108,673	4.2805 - 4.2785 108,725 - 108,673
Sleeve Bore Maximum Out-of-Round	.002 0,050	.002 0,050	.002 0,050	.0015 0,038
Sleeve bore Maximum Taper	.002 0,050	.002 0,050	.002 0,050	.002 0,050
Sleeve Seal Area to Crankcase Clearance	.0045 - .002 0,114 - 0,050	.0035 - .001 0,088 - 0,025	.0035 - .001 0,088 - 0,025	.0005 - .0045 0,013 - 0,114

VRG FITS AND CLEARANCES

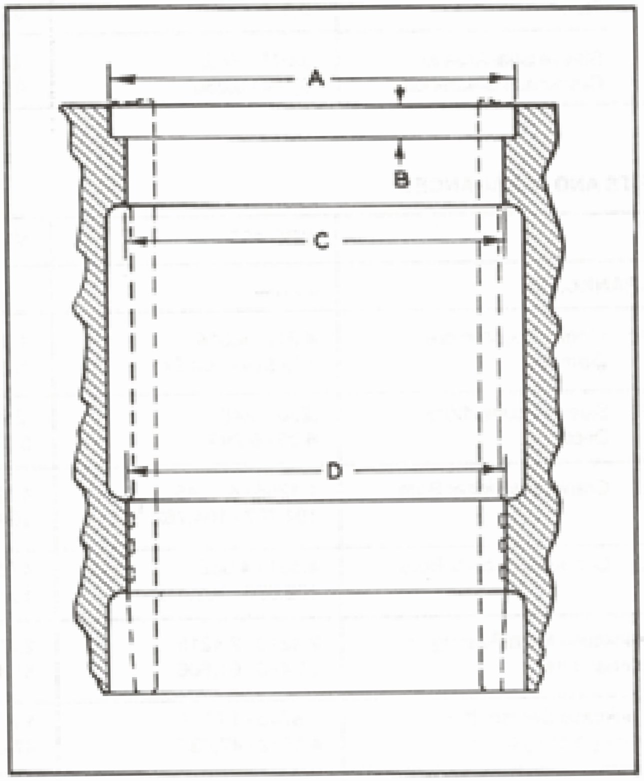
	VRG 155	VRG 232	VRG265	VRG 283/310
CRANKCASE				
(A) Sleeve Counterbore Diameter	4.312 - 4.314 109,524 - 109,575	4.312 - 4.314 109,524 - 109,575	4.562 - 4.563 115,874 - 115,900	4.562 - 4.563 115,874 - 115,900
(B) Sleeve Counterbore Depth	.250 - .248 6,35 - 6,299	.250 - .248 6,35 - 6,299	.250 - .248 6,35 - 6,299	.250 - .248 6,35 - 6,299
(C) Crankcase Upper Bore	4.1255 - 4.1245 104,787 - 104,762	4.1255 - 4.1245 104,787 - 104,762	4.3755 - 4.3745 111,137 - 111,112	4.370 - 4.3800 110,998 - 111,252
(D) Crankcase Lower Bore	4.031 - 4.032 102,387 - 102,412	4.031 - 4.032 102,387 - 102,412	4.281 - 4.282 108,737 - 108,762	4.281 - 4.282 108,737 - 108,762
Crankcase Main Bearing Journal Bore	2.4210 - 2.4215 61,493 - 61,506	2.4210 - 2.4215 61,493 - 61,506	2.8175 - 2.8165 71,564 - 71,539	2.8175 - 2.8165 71,564 - 71,539
Crankcase Camshaft Bearing Bore (No. 1)	1.8745 - 1.8755 47,612 - 47,637	1.8745 - 1.8755 47,612 - 47,637	1.8745 - 1.8755 47,612 - 47,637	1.8745 - 1.8755 47,612 - 47,637
Crankcase Camshaft Bearing Bore (Nos. 2,3, & 4)	1.7515 - 1.7520 44,488 - 44,500	1.7515 - 1.7520 44,488 - 44,500	1.7515 - 1.7520 44,488 - 44,500	1.8745 - 1.8755 47,612 - 47,637

VRD FITS AND CLEARANCES

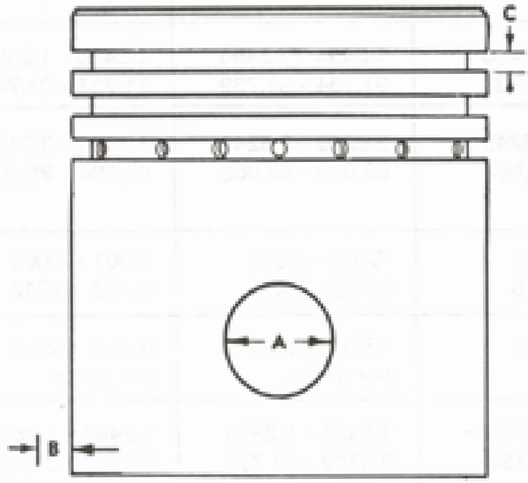
	VRD155/232	VRD 283	VRD310	VRD310S
CRANKCASE				
(A) Sleeve Counterbore Diameter	4.312 - 4.314 109,524 - 109,575	4.562 - 4.563 115,874 - 115,900	4.562 - 4.563 115,874 - 115,900	4.562 - 4.563 115,874 - 115,900
(B) Sleeve Counterbore Depth	.250 - .248 6,350 - 6,299	.250 - .248 6,350 - 6,299	.250 - .248 6,350 - 6,299	.250 - .248 6,350 - 6,299
(C) Crankcase Upper Bore	4.1255 - 4.1245 104,787 - 104,762	4.370 - 4.3800 110,998 - 111,252	4.370 - 4.3800 110,998 - 111,252	4.380 - 4.3800 110,998 - 111,252
(D) Crankcase Lower Bore	4.031 - 4.032 102,387 - 102,412	4.281 - 4.282 108,737 - 108,762	4.281 - 4.282 108,737 - 108,762	4.281 - 4.283 108,737 - 108,788
Crankcase Main Bearing Journal Bore	2.4210 - 2.4215 61,493 - 61,506	2.8175 - 2.8165 71,564 - 71,539	2.8175 - 2.8165 71,564 - 71,539	2.8175 - 2.8165 71,564 - 71,539
Crankcase Camshaft Bearing Bore (No. 1)	1.8745 - 1.8755 47,612 - 47,637	1.8745 - 1.8755 47,612 - 47,637	1.8745 - 1.8755 47,612 - 47,637	1.8745 - 1.8755 47,612 - 47,637
Crankcase Camshaft Bearing Bore (Nos. 2,3, & 4)	1.7515 - 1.7520 44,488 - 44,500	1.8745 - 1.8755 47,612 - 47,637	1.8745 - 1.8755 47,612 - 47,637	1.8745 - 1.8755 47,612 - 47,637



TYPICAL CYLINDER SLEEVE



TYPICAL SECTION THROUGH CRANKCASE



TYPICAL PISTON

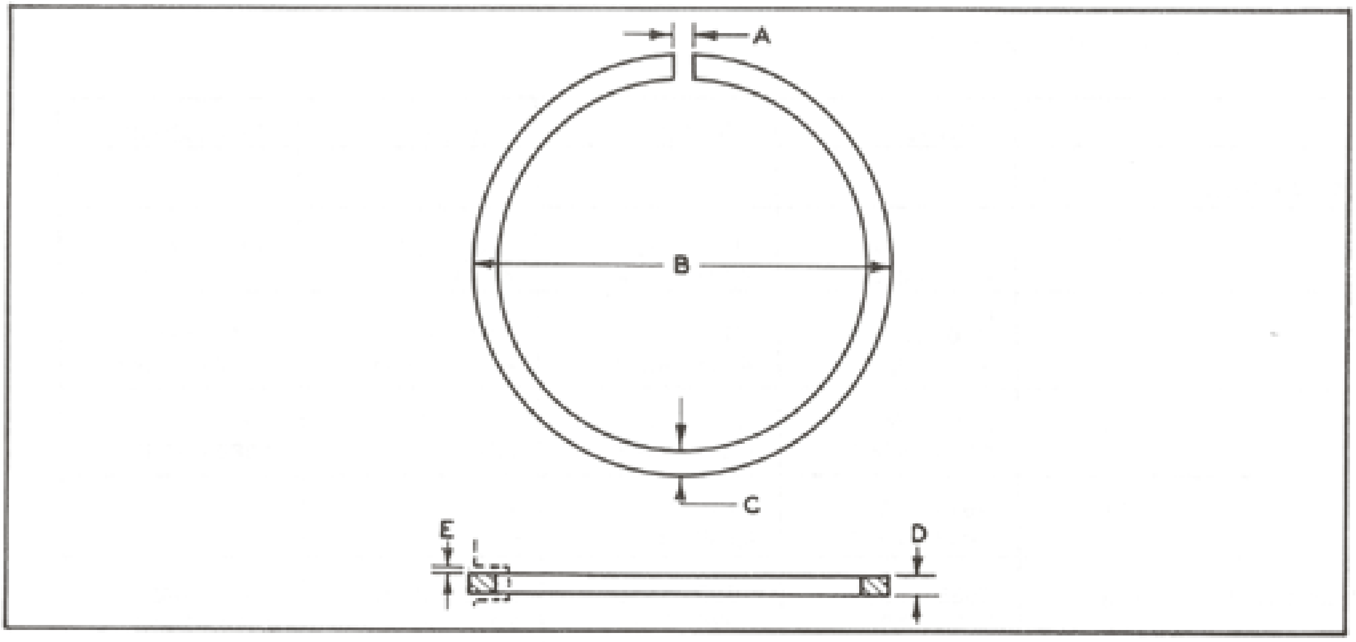
VRD FITS AND CLEARANCES

	VRD155/VRD232	VRD283	VRD310	VRD310S
PISTON AND PIN				
Piston Pin Diameter	1.2494 - 1.2496 31,734 - 31,739	1.2495 - 1.2497 31,737 - 31,742	1.2495 - 1.2497 31,737 - 31,742	1.2495 - 1.2497 31,737 - 31,742
Piston Skirt Diameter ("B" size only)	3.6229 - 3.6245 92,022 - 92,062	3.8713 - 3.8727 98,331 - 98,366	3.8703 - 3.8717 98,306 - 98,341	3.8699 - 3.8709 98,295 - 98,321
Piston Pin Fit (Room Temp.)	.0001 - .0006 0,002 - 0,015	.0002 - .0007 0,005 - 0,017	.0002 - .0007 0,005 - 0,017	.0002 - .0007 0,005 - 0,017
Weight Variation	737±3 grams per piston	1185±5 grams per piston	1073±5 grams per piston	1130±4 grams per piston
(A) Piston Pin Hole Bore	1.2497 - 1.2500 31,742 - 31,750	1.2499 - 1.2502 31,747 - 31,755	1.2499 - 1.2502 31,747 - 31,755	1.2499 - 1.2505 31,747 - 31,755
(B) Piston Skirt To Sleeve Clearance	.0008 - .0028 0,020 - 0,071	.0026 - .0044 0,066 - 0,111	.0036 - .0054 0,091 - 0,137	.0041 - .0061 0,104 - 0,155
(C) Groove -Top Width	.096 - .097 2,438 - 2,463	.096 - .097 2,438 - 2,463	.096 - .097 2,438 - 2,463	Keystone Type
-2nd	.096 - .095 2,438 - 2,413	.0955 - .0965 2,425 - 2,451	.0955 - .0965 2,425 - 2,451	.0955 - .0965 2,425 - 2,451
-3rd	.096 - .095 2,438 - 2,413	.188 - .189 4,775 - 4,800	.188 - .189 4,775 - 4,800	.188 - .189 4,775 - 4,800
-4th	.188 - .189 4,775 - 4,800	---	---	---

REPAIR & REPLACEMENT

VRG FITS AND CLEARANCES

	VRG 155	VRG 232	VRG 265	VRG 283/310
PISTON AND PIN				
Piston Pin Diameter	1.2494 - 1.2496 31,734 - 31,739	1.2494 - 1.2496 31,734 - 31,739	1.2495 - 1.2497 31,737 - 31,742	1.2495 - 1.2497 31,737 - 31,742
Piston Skirt Diameter ("B" size only)	3.6229 - 3.6245 92,022 - 92,062	3.6229 - 3.6245 92,022 - 92,062	3.7478 - 3.7482 95,194 - 95,204	3.8728 - 3.8732" (283) 3.8718 - 3.8732" (310) 98,344 - 98,379 mm
Piston Pin Fit (Room Temp.)	.0001 - .0006 0,002 - 0,015	.0001 - .0006 0,002 - 0,015	.0001 - .0005 0,002 - 0,012	.0002 - .0007 0,005 - 0,017
Weight Variation	737±3 grams per piston	737±3 grams per piston	828±4 grams per piston	1113±4 grams per piston
(A) Piston Pin Hole Bore	1.2497 - 1.2500 31,742 - 31,750	1.2497 - 1.2500 31,742 - 31,750	1.2497 - 1.2500 31,742 - 31,750	1.2499 - 1.2502 31,747 - 31,755
(B) Piston Skirt to Sleeve Clearance	.0008 - .0028 0,020 - 0,071	.0008 - .0028 0,020 - 0,071	.0021 - .0029 0,053 - 0,073	.0021 - .0029 (283) .0021 - .0039 (310) 0,053 - 0,099 mm
(C) Groove Width -Top	.096 - .097 2,438 - 2,463	.096 - .097 2,438 - 2,463	.096 - .097 2,438 - 2,463	.096 - .097 2,438 - 2,463
-2nd	.096 - .095 2,438 - 2,413	.096 - .095 2,438 - 2,413	.0965 - .0955 2,451 - 2,425	.0965 - .0955 2,451 - 2,425
-3rd	.096 - .095 2,438 - 2,413	.096 - .095 2,438 - 2,413	.188 - .189 4,775 - 4,800	.188 - .189 4,775 - 4,800
-4th	.188 - .189 4,775 - 4,800	.188 - .189 4,775 - 4,800	---	---



TYPICAL PISTON RING

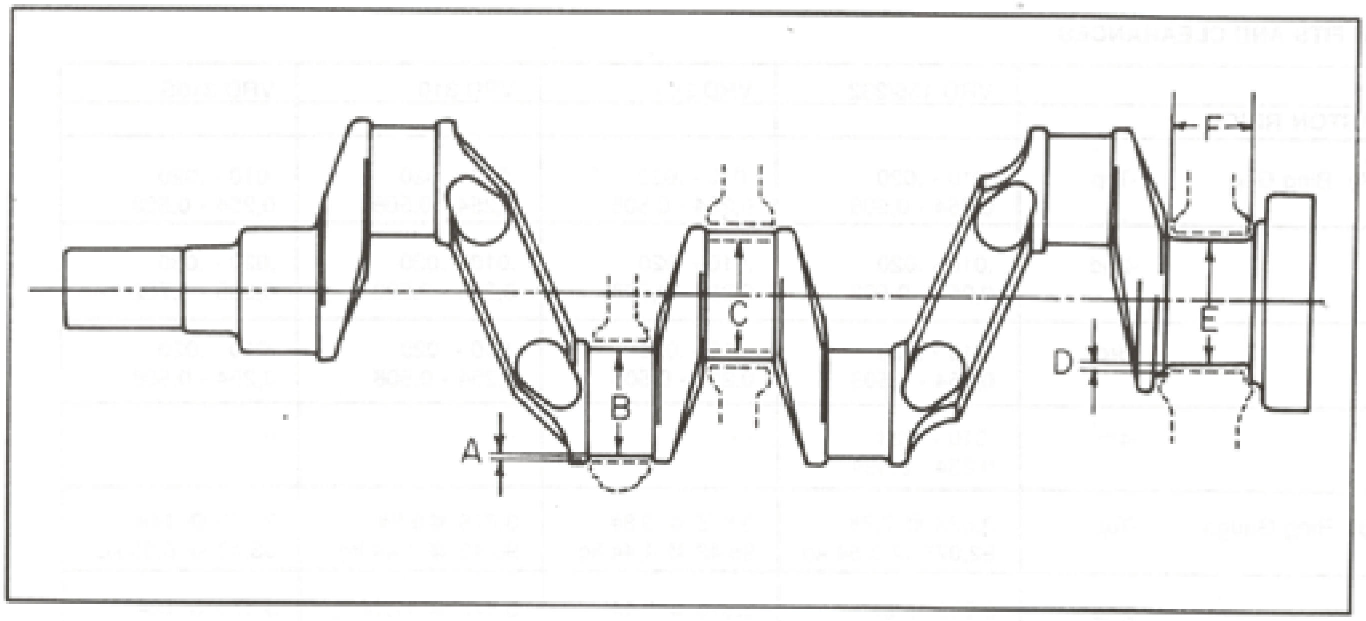
VRG FITS AND CLEARANCES

		VRG 155	VRG 232	VRG 265	VRG 283/310
PISTON RINGS					
(A) Ring Gap	-Top	.010 - .020 0,254 - 0,508	.010 - .020 0,254 - 0,508	.010 - .020 0,254 - 0,508	.010 - .020 0,254 - 0,508
	-2nd	.010 - .020 0,254 - 0,508	.010 - .020 0,254 - 0,508	.010 - .020 0,254 - 0,508	.010 - .020 0,254 - 0,508
	-3rd	.010 - .020 0,254 - 0,508	.010 - .020 0,254 - 0,508	.015 - .055 0,381 - 1,397	.015 - .055 0,381 - 1,397
	-4th	.015 - .055 0,381 - 1,397	.015 - .055 0,381 - 1,397	---	---
(B) Ring Gauge	-Top	3.625 @ 7.8# 92,075 @ 3,54 kg	3.625 @ 7.8# 92,075 @ 3,54 kg	3.750 @9.0# 95,25 @ 4,08 kg	3.875 @9.8# 98,42 @ 4,44 kg
	-2nd	3.625 @ 8# 92,075 @ 3,63 kg	3.625 @ 8# 92,075 @ 3,63 kg	3.750 @ 9.6# 92,25 @ 4,35 kg	3.875 @ 10.4# 98,42 @ 4,72 kg
	-3rd	3.625 @ 8# 92,075 @ 3,63 kg	3.625 @ 8# 92,075 @ 3,63 kg	3.750 @ 20# 95,25 @ 9,07 kg	3.875 @ 29.0# 98,42 @ 13,15 kg
	-4th	3.625 @ 16# 92,075 @ 7,26 kg	3.625 @16# 92,075 @ 7,26 kg	---	---

		VRG 155	VRG 232	VRG 265	VRG 283/310
PISTON RINGS					
(C) Ring Wall	-Top	.170 - .160 4,318 - 4,064	.170 - .160 4,318 - 4,064	.187 - .177 4,749 - 4,495	.194 - .184 4,927 - 4,673
	-2nd	.170 - .160 4,318 - 4,064	.170 - .160 4,318 - 4,064	.187 - .177 4,749 - 4,495	.171 - .181 4,597 - 4,343
	-3rd	.170 - .160 4,318 - 4,064	.170 - .160 4,318 - 4,064	.156 - .150 3,963 - 3,81	.161 - .155 4,089 - 3,937
	-4th	.161 - .155 4,089 - 3,937	.161 - .155 4,089 - 3,937	---	---
(D) Ring Width	-Top	.0935 - .0930 2,374 - 2,362	.0935 - .0930 2,374 - 2,362	.0935 - .0930 2,374 - 2,362	.0935 - .0930 2,374 - 2,362
	-2nd	.0935 - .0925 2,374 - 2,349	.0935 - .0925 2,374 - 2,349	.0935 - .0925 2,374 - 2,362	.0935 - .0925 2,374 - 2,349
	-3rd	.0935 - .0925 2,374 - 2,349	.0935 - 0.925 2,374 - 2,349	.1825 - .1885 4,635 - 4,788	.1825 - .1885 4,635 - 4,788
	-4th	.1825 - .1885 4,635 - 4,788	.1825 - .1885 4,635 - 4,788	---	---
(E) Side Clear-ance	-Top	.0025 - .0040 0,063 - 0,101	.0025 - .0040 0,063 - 0,101	.0025 - .0040 0,063 - 0,101	.0025 - .0040 0,063 - 0,101
	-2nd	.0015 - .0035 0,038 - 0,089	.0015 - .0035 0,038 - 0,088	.0020 - .0035 0,050 - 0,088	.002 - .004 0,050 - 0,101
	-3rd	.0015 - .0035 0,038 - 0,088	.0015 - .0035 0,038 - 0,088	.0065 Max. 0,165	.0065 Max. 0,165
	-4th	.0065 Max. 0,165	.0065 Max. 0,165		

VRD FITS AND CLEARANCES

PISTON RINGS		VRD 155/232	VRD 283	VRD 310	VRD 310S
(A) Ring Gap	-Top	.010 - .020 0,254 - 0,508	.010 - .020 0,254 - 0,508	.010 - .020 0,254 - 0,508	.010 - .020 0,254 - 0,508
	-2nd	.010 - .020 0,254 - 0,508	.010 - .020 0,254 - 0,508	.010 - .020 0,254 - 0,508	.020 - .030 0,508 - 0,762
	-3rd	.010 - .020 0,254 - 0,508	.010 - .020 0,254 - 0,508	.010 - .020 0,254 - 0,508	.010 - .020 0,254 - 0,508
	-4th	.010 - .023 0,254 - 0,584	---	---	---
(B) Ring Gauge	-Top	3.625 @ 7.8# 92,075 @ 3,54 kg	3.875 @ 9.8# 98,42 @ 4,44 kg	3.875 @9.8# 98,42 @ 4,44 kg	3.875 @ 14# 98,42 @ 6,35 kg
	-2nd	3.625 @ 8# 92,075 @ 3,63 kg	3.875 @ 9.4# 98,42 @ 4,26 kg	3.875 @ 11.1# 98,42 @ 5,03 kg	3.875 @ 12# 98,42 @ 5,44 kg
	-3rd	3.625 @ 8# 92,075 @ 3,63 kg	3.875 @ 14.1# 98,42 @ 6,39 kg	3.875 @ 19# 98,42 @ 8,62 kg	3.875 @ 12.6# 98,42 @ 5,71 kg
	-4th	3.625 92,075	---	---	---
(C) Ring Wall	-Top	.170 - .160 4,318 - 4,064	.194 - .184 4,927 - 4,673	.194 - .184 4,927 - 4,673	.158 - .168 4,013 - 4,267
	-2nd	.170 - .160 4,318 - 4,064	.194 - .184 4,927 - 4,673	.171 - .181 4,343 - 4,597	.158 - .168 4,013 - 4,267
	-3rd	.170 - .160 4,318 - 4,064	.135 - .145 3,429 - 3,683	.135 - .145 3,429 - 3,683	.130 - .140 3,302 - 3,556
	-4th	.144 - .134 3,658 - 3,404	---	---	---
(D) Ring Width	-Top	.0935 - .0930 2,374 - 2,362	.0935 - .0930 2,374 - 2,362	.0935 - .0930 2,374 - 2,362	Keystone Type
	-2nd	.0935 - .0925 2,374 - 2,349	.0935 - .0930 2,374 - 2,362	.0935 - .0925 2,374 - 2,349	.0935 - .0925 2,374 - 2,349
	-3rd	.0935 - .0925 2,374 - 2,349	.1865 - .1860 4,737 - 4,724	.1870 - .1860 4,750 - 4,724	.1865 - .1855 4,737 - 4,711
	-4th	.1865 - .1860 4,737 - 4,724	---	---	---
(E) Side Clear- ance	-Top	.0025 - .0040 0,063 - 0,101	.0025 - .0040 0,063 - 0,101	.0025 - .0040 0,063 - 0,101	Keystone Type
	-2nd	.0015 - .0035 0,038 - 0,088	.0020 - .0035 0,050 - 0,088	.002 - .004 0,050 - 0,101	.002 - .004 0,050 - 0,101
	-3rd	0015 - .0035 0,038 - 0,088	.0015 - .0030 0,038 - 0,076	.001 - .003 0,025 - 0,076	.0015 - .0035 0,038 - 0,088
	-4th	.0015 - .003 0,038 - 0,076	---	---	---



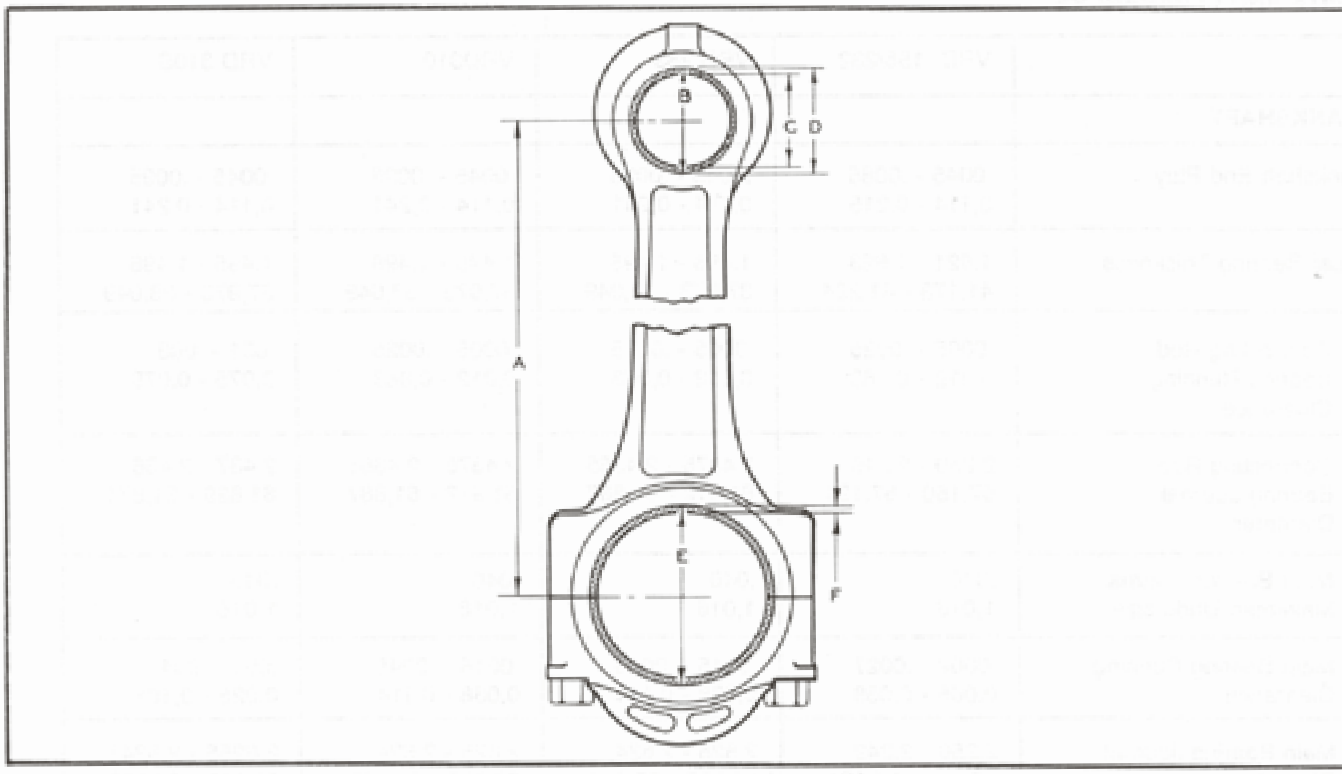
TYPICAL CRANKSHAFT

VRG FITS AND CLEARANCES

CRANKSHAFT	VRG 155	VRG 232	VRG 265	VRG 283/310
Crankshaft End Play	.0045 - .0085 0,114 - 0,215	.0045 - .0085 0,114 - 0,215	.0045 - .0085 0,114 - 0,215	.0045 - .0095 0,114 - 0,241
Thrust Bearing Thickness	1.621- 1.623 41,173 - 41,224	1.621 - 1.623 41,173 - 41,224	1.746 - 1.748 44,348 - 44,399	1.495 - 1.498 37,973 - 38,049
(A) Connecting Rod Bearing Running Clearance	.0005 - .0025 0,012 - 0,063	.0005 - .0025 0,012 - 0,063	.0005 - .0025 0,012 - 0,063	.0005 - .0025 0,012 - 0,063
(B) Connecting Rod Bearing Journal Diameter	2.250 - 2.249 57,150 - 57,124	2.250 - 2.249 57,15 - 57,124	2.250 - 2.249 57,15 - 57,124	2.4375 - 2.4365 61,912 - 61,887
(C) Main Bearing Journal Maximum Undersize	.040 1,016	.040 1,016	.040 1,016	.040 1,016
(D) Main Bearing Running Clearance	.0002 - .0027 0,005 - 0,068	.0002 - .0027 0,005 - 0,068	.0005 - .0035 0,012 - 0,088	.0015 - .0045 0,038 - 0,114
(E) Main Bearing Journal Diameter	2.250 - 2.249 57,150 - 57,124	2.250 - 2.249 57,150 - 57,124	2.625 - 2.624 66,675 - 66,649	2.625 - 2.624 66,675 - 66,649
(F) Crankshaft Thrust Length (face to face)	1.6275 - 1.6295 41,338 - 41,389	1.6275 - 1.6295 41,338 - 41,389	1.7525 - 1.7545 44,513 - 44,564	1.5025 - 1.5045 38,163 - 38,214
Main and Rod Journal Maximum Out-of Round	.001 0,025	.001 0,025	.001 0,025	.001 0,025
Main and Rod Journal Maximum Taper	.001 0,025	.001 0,025	.006 0,015	.006 0,015
Main Bearing Shell Thickness	.0854 - .0849 2,169 - 2,156	.0854 - .0849 2,169 - 2,156	.0955 - .0950 2,425 - 2,413	.0945 - .0950 2,400 - 2,413

VRD FITS AND CLEARANCES

	VRD 155/232	VRD 283	VRD310	VRD 310S
CRANKSHAFT				
Crankshaft End Play	.0045 - .0085 0,114 - 0,215	.0045 - .0095 0,114 - 0,241	.0045 - .0095 0,114 - 0,241	.0045 - .0095 0,114 - 0,241
Thrust Bearing Thickness	1.621 - 1.623 41,173 - 41,224	1.495 - 1.498 37,973 - 38,049	1.495 - 1.498 37,973 - 38,049	1.495 - 1.498 37,973 - 38,049
(A) Connecting Rod Bearing Running Clearance	.0005 - .0025 0,012 - 0,063	.0005 - .0025 0,012 - 0,063	.0005 - .0025 0,012 - 0,063	.001 - .003 0,075 - 0,076
(B) Connecting Rod Bearing Journal Diameter	2.250 - 2.249 57,150 - 57,124	2.4375 - 2.4365 61,912 - 61,887	2.4375 - 2.4365 61,912 - 61,887	2.437 - 2.436 61,899 - 61,874
(C) Main Bearing Journal Maximum Undersize	.040 1,016	.040 1,016	.040 1,016	.040 1,016
(D) Main Bearing Running Clearance	.0002 - .0027 0,005 - 0,068	.0015 - .0045 0,038 - 0,114	.0015 - .0045 0,038 - 0,114	.001 - .004 0,025 - 0,101
(E) Main Bearing Journal Diameter	2.250 - 2.249 57,150 - 57,124	2.625 - 2.624 66,675 - 66,649	2.625 - 2.624 66,675 - 66,649	2.6255 - 2.6245 66,687 - 66,662
(F) Crankshaft Thrust Length (face to face)	1.6275 - 1.6295 41,338 - 41,389	1.5025 - 1.5045 38,163 - 38,214	1.5025 - 1.5045 38,163 - 38,214	1.5025 - 1.5045 38,163 - 38,214
Main and Rod Journal Maximum Out-of-Round	.001 0,025	.001 0,025	.001 0,025	.001 0,025
Main and Rod Journal Maximum Taper	.001 0,025	.006 0,015	.006 0,015	.006 0,015
Main Bearing Shell Thickness	.0854 - .0849 2,169 - 2,156	.09465 - .0950 2,400 - 2,413	.0945 - .0950 2,400 - 2,413	.0945 - .0950 2,400 - 2,413



TYPICAL CONNECTING ROD, BUSHING, AND BEARING

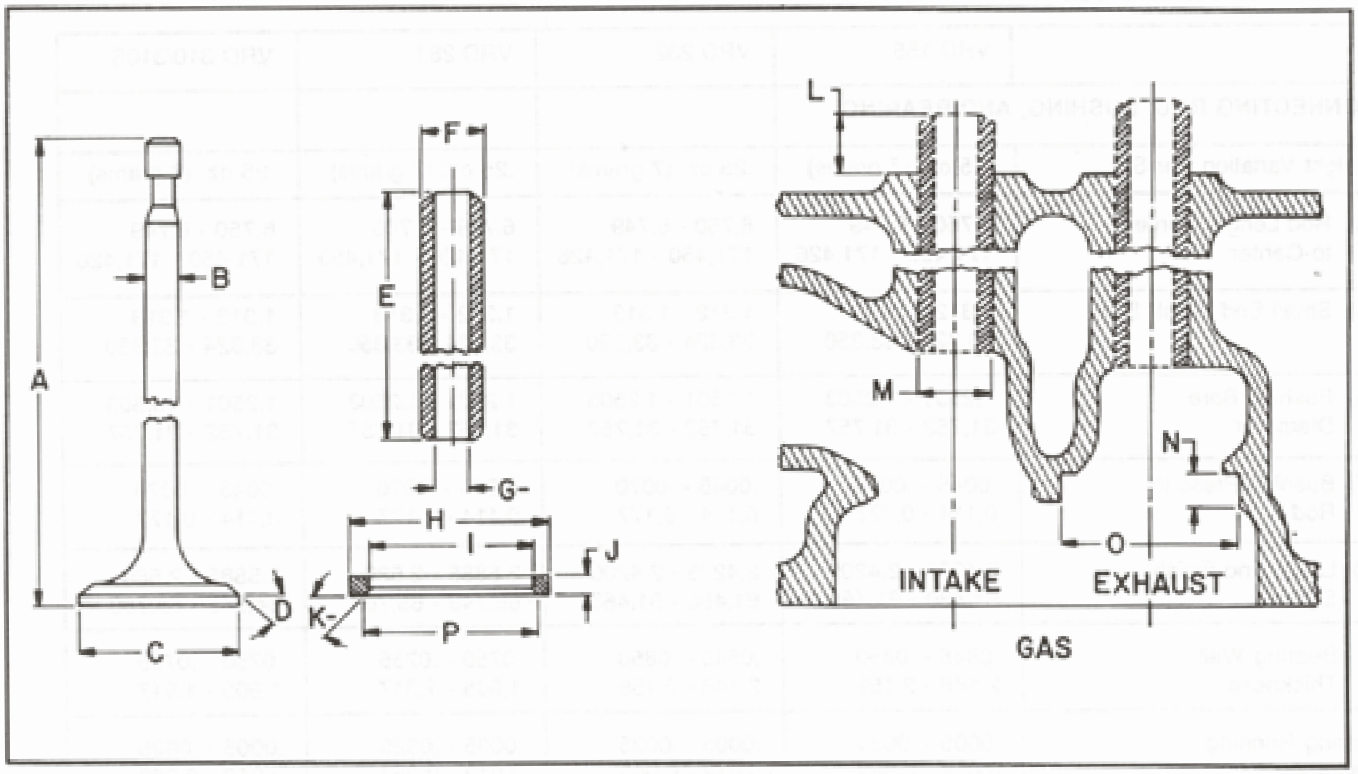
VRG FITS AND CLEARANCES

	VRG 155	VRG 232	VRG 265	VRG 283/310
CONNECTING ROD, BUSHING, AND BEARING				
Weight Variation Per Set	.25 oz. (7 grams)	.25 oz. (7 grams)	.25 oz. (7 grams)	.25 oz. (7 grams)
(A) Rod Length Center-to-Center	6.750 - 6.749 171,450 - 171,426	6.750 - 6.749 171,450 - 171,426	6.747 - 6.750 171,373 - 171,450	6.750 - 6.749 171,450 - 171,426
(B) Small End Finish Size	1.312 - 1.313 33,324 - 33,350	1.312 - 1.313 33,324 - 33,350	1.312 - 1.313 33,324 - 33,350	1.312 - 1.313 33,324 - 33,350
(C) Bushing Bore Diameter	1.2501 - 1.2503 31,752 - 31,757	1.2501 - 1.2503 31,752 - 31,757	1.2501 - 1.2503 31,752 - 31,757	1.2501 - 1.2503 31,752 - 31,757
(D) Bushing Press In Rod	.0045 - .0070 0,114 - 0,177	.0045 - .0070 0,114 - 0,177	.0045 - .0070 0,114 - 0,177	.0045 - .0070 0,114 - 0,177
(E) Large End Finish Size	2.4205 - 2.4200 61,480 - 61,468	2.4205 - 2.4200 61,480 - 61,468	2.4205 - 2.4200 61,480 - 61,468	2.5885 - 2.589 65,748 - 65,760
(F) Bearing Wall Thickness	.0845 - .0850 2,146 - 2,159	.0845 - .0850 2,146 - 2,159	.0845 - .0850 2,146 - 2,159	.0750 - .0755 1,905 - 1,917
Bearing Running Clearance	.0005 - .0025 0,012 - 0,063	.0005 - .0025 0,012 - 0,063	.0005 - .0025 0,012 - 0,063	.0005 - .0025 0,012 - 0,063
Rod Side Clearance	.0075 - .0135 0,190 - 0,342	.0075 - .0135 0,190 - 0,342	.0075 - .0135 0,190 - 0,342	.0075 - .0135 0,190 - 0,342
Rod Large End Width	1.3655 - 1.3675 34,684 - 34,734	1.3655 - 1.3675 34,684 - 34,734	1.3655 - 1.3675 34,684 - 34,734	1.3655 - 1.3675 34,684 - 34,734

VRD FITS AND CLEARANCES

	VRD 155	VRD 232	VRD 283	VRD 310/310S
CONNECTING ROD, BUSHING, AND BEARING				
Weight Variation Per Set	.25 oz. (7 grams)	.25 oz. (7 grams)	.25 oz. (7 grams)	.25 oz. (7 grams)
(A) Rod Length Center-to-Center	6.750 - 6.749 171,450 - 171,426	6.750 - 6.749 171,450 - 171,426	6.749 - 6.750 171,426 - 171,450	6.750 - 6.749 171,450 - 171,426
(B) Small End Finish Size	1.312 - 1.313 33,324 - 33,350	1.312 - 1.313 33,324 - 33,350	1.312 - 1.313 33,324 - 33,350	1.312 - 1.313 33,324 - 33,350
(C) Bushing Bore Diameter	1.2501 - 1.2503 31,752 - 31,757	1.2501 - 1.2503 31,752 - 31,757	1.2501 - 1.2503 31,752 - 31,757	1.2501 - 1.2503 31,752 - 31,757
(D) Bushing Press In Rod	.0045 - .0070 0,114 - 0,177	.0045 - .0070 0,114 - 0,177	.0045 - .0070 0,114 - 0,177	.0045 - .0070 0,114 - 0,177
(E) Large End Finish Size	2.4205 - 2.4200 61,480 - 61,468	2.4205 - 2.4200 61,480 - 61,468	2.5885 - 2.589 65,748 - 65,760	2.5885 - 2.589 64,748 - 65,760
(F) Bearing Wall Thickness	.0845 - .0850 2,146 - 2,159	.0845 - .0850 2,146 - 2,159	.0750 - .0755 1,905 - 1,917	.0750 - .0755 1,905 - 1,917
Bearing Running Clearance	.0005 - .0025 0,012 - 0,063	.0005 - .0025 0,012 - 0,063	.0005 - .0025 0,012 - 0,063	.0005 - .0025 0,012 - 0,063
Rod Side Clearance	.0075 - .0135 0,190 - 0,342	.0075 - .0135 0,190 - 0,342	.0075 - .0135 0,190 - 0,342	.0075 - .0135 0,190 - 0,342
Rod Large End Width	1.3655 - 1.3675 34,684 - 34,734	1.3655 - 1.3675 34,684 - 34,734	1.3655 - 1.3675 34,684 - 34,734	1.3655 - 1.3675 34,684 - 34,734

REPAIR & REPLACEMENT

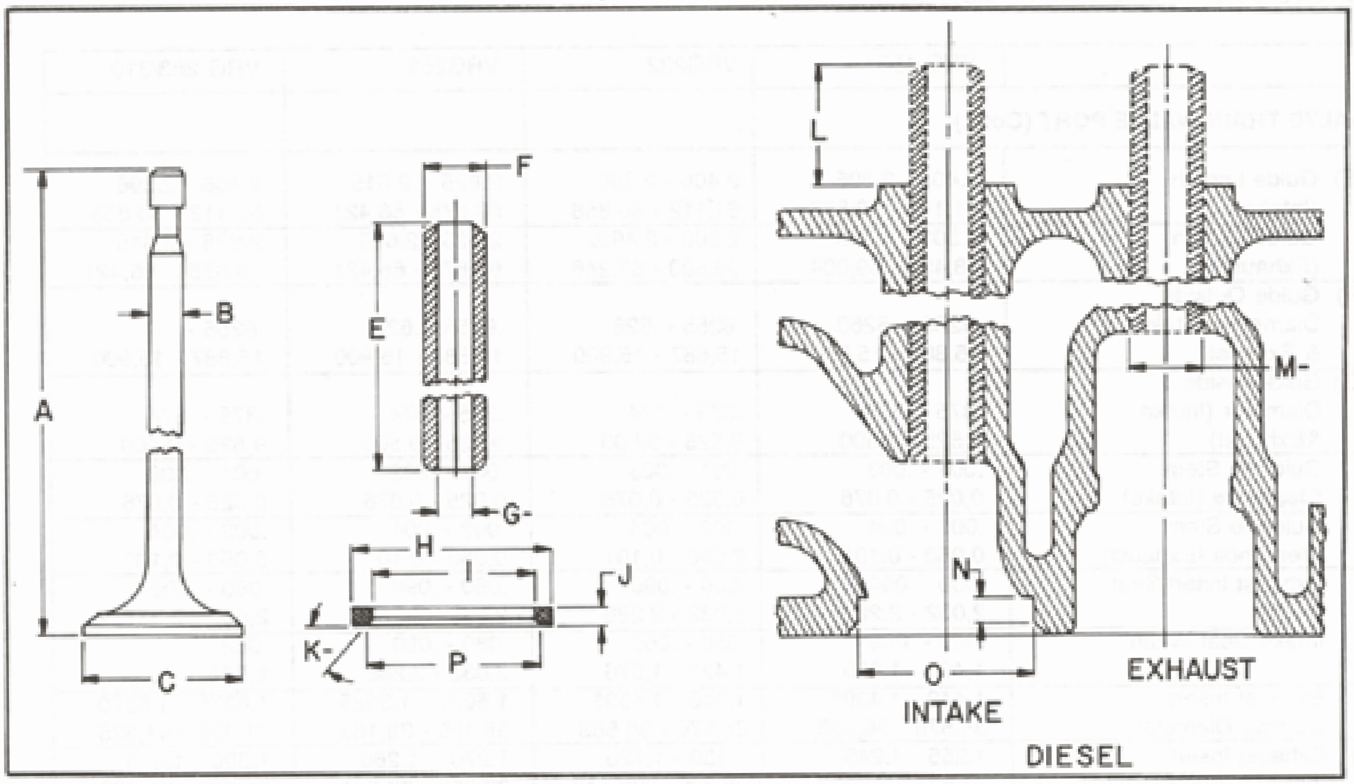


TYPICAL VALVE TRAIN, VALVE PORT CLEARANCES
GAS/GASOLINE ENGINES

VRG FITS AND CLEARANCES

	VRG 155	VRG 232	VRG 265	VRG 283/310
VALVE TRAIN, VALVE PORT				
(A) Valve Length (Intake)	4.984 126,594	5.047 128,193	5.406 - 5.396 137,312 - 137,058	5.418 - 5.408 137,617 - 137,363
Valve Length (Exhaust)	4.984 126,594	5.078 - 5.068 128,981 - 128,727	5.469 138,912	5.418 - 5.408 137,617 - 137,363
(B) Valve Stem Diameter (Intake)	.3730 - .3720 9,474 - 9,448	.3730 - .3720 9,474 - 9,448	.373 - .372 9,474 - 9,448	.373 - .372 9,474 - 9,448
Valve Stem Diameter (Exhaust)	.372 - .371 9,448 - 9,423	.372 - .371 9,448 - 9,423	.372 - .371 9,448 - 94,23	.372 - .371 9,448 - 9,423
Valve Lip Thickness (Intake)	.063 1,600	.063 1,600	.063 1,600	.063 1,600
Valve Lip Thickness (Exhaust)	.063 1,600	.063 1,600	.063 1,600	.063 1,600
Valve Face & Seat Run-out (Maximum)	.002 0,050	.002 0,050	.002 0,050	.002 0,050
(C) Valve Head Diameter (Intake)	1.449 - 1.459" 36,805 - 37,059 mm	1.339 - 1.389 35,535 - 35,281	1.514 - 1.504 38,455 - 38,201	1.625 41,275
Valve Head Diameter (Exhaust)	1.389 - 1.399" 35,281 - 35,535 mm	1.258 - 1.251 31,953 - 31,775	1.400 - 1.390 35,56 - 35,306	1.518 - 1.508 38,557 - 38,303
(D) Valve Face Angle (Intake)	44° 30' ± 15'	44° 30' ± 15'	44° 30' ± 15'	44° 30' ± 15'
Valve Face Angle (Exhaust)	44° 30' ± 15'	44° 30' ± 15'	44° 30' ± 15'	44° 30' ± 15'

	VRG 155	VRG232	VRG265	VRG 283/310
VALVE TRAIN, VALVE PORT (Cont.)				
(E) Guide Length (Intake)	2.406 - 2.396 61,112 - 60,858	2.406 - 2.396 61,112 - 60,858	2.625 - 2.615 66,675 - 66,421	2.406 - 2.396 61,112 - 60,858
Guide Length (Exhaust)	2.303 - 2.323 58,496 - 59,004	2.500 - 2.490 63,500 - 63,246	2.625 - 2.615 66,675 - 66,421	2.625 - 2.615 66,675 - 66,421
(F) Guide Outside Diameter (Intake & Exhaust)	.6255 - .6260 15,887 - 15,900	.6255 - .626 15,887 - 15,900	.6255 - .626 15,887 - 15,900	.6255 - 15,887 - 15,900
(G) Guide Inside Diameter (Intake &Exhaust)	.375 - .374 9,525 - 9,500	.375 - .374 9,525 - 9,500	.375 - .374 9,525 - 9,500	.375 - .374 9,525 - 9,500
Guide to Stem Clearance (Intake)	.001 - .003 0,025 - 0,076	.001 - .003 0,025 - 0,076	.001 - .003 0,025 - 0,076	.001 - .003 0,025 - 0,076
Guide to Stem Clearance (Exhaust)	.002 - .004 0,050 - 0,101	.002 - .004 0,050 - 0,101	.002 - .004 0,050 - 0,101	.002 - .004 0,050 - 0,101
Exhaust Insert Seat Width	.080 - .090 2,032 - 2,286	.080 - .090 2,032 - 2,286	.080 - .090 2,032 - 2,286	.080 - .090 2,032 - 2,286
Intake Seat Width	.056 - .066 1,422 - 1,676	.056 - .066 1,422 - 1,676	.080 - .090 2,032 - 2,286	.062 1,574
(H) Exhaust Insert Outside Diameter	1.440 - 1.4395 36,576 - 36,563	1.440 - 1.4395 36,576 - 36,563	1.5020 - 1.5025 38,150 - 38,163	1.6275 - 1.6270 41,338 - 41,325
(I) Exhaust Insert Inside Diameter	1.255 - 1.245 31,877 - 31,623	1.130 - 1.120 28,702 - 28,448	1.270 - 1.260 32,258 - 32,004	1.390 - 1.385 35,306 - 35,179
(J) Exhaust Insert Depth	.250 - .248 6,350 - 6,299	.250 - .248 6,350 - 6,299	.2105 - .2055 5,346 - 5,219	.209 - .207 5,308 - 5,257
(K) Insert Seat Angle (Exhaust)	45°	45°	45°	45°
Seat Angle (Intake)	45°	45°	45°	45°
(L) Guide Extends Above Head (Intake)	.843 - .833 21.412 - 21.158	.843 - .833 21.412 - 21.158	.781 - .771 19.837 - 19.583	.843 - .833 21.412 - 21.158
Guide Extends Above Head (Exhaust)	.937 - .927 23,799 - 23,545	.937 - .927 23,799 - 23,545	.937 - .927 23,799 - 23,545	.937 - .927 23,799 - 23,545
(M) Guide Bore in Head	.624 - .625 15,849 - 15,875	.624 - .625 15,849 - 15,875	.624 - .625 15,849 - 15,875	.624 - .625 15,849 - 15,875
(N) Exhaust Insert Counterbore Depth	.260 - .263 6,604 - 6,680	.260 - .263 6,604 - 6,680	.217 - .219 5,512 - 5,563	.217 - .220 5,512 - 5,588
(O) Exhaust Insert Counterbore Diameter	1.500 - 1.499 38,100 - 38,075	1.4375 - 1.4365 36,512 - 36,487	1.500 - 1.499 38,100 - 38,075	1.624 - 1.625 41,250 - 41,275
(P) Exhaust Insert Seat O.D.	1.250 31,750	1.250 31,750	1.375 34,925	1.500 38,100
Intake Seat O.D.	1.315 33,401	1.343 34,112	1.500 38,100	1.593 40,462
Valve Spring Free Length (Intake)	2-25/32 in. ± .010 in. 70.64 mm ± .25 mm	2.562 ± .062" 65,074 ± 1,574 mm	2.562 ± .062" 65,074 ± 1,574 mm	2.562 ± .062" 65,074 ± 1,574 mm
Valve Spring Free Length (Exhaust)	2-5/16 ± .010 in. 58.78 mm ± .25 mm	2.440 ± .062" 61,976 ± 1,574 mm	2.440 ± .062" 61,976 ± 1,574 mm	2.440 ± .062" 61,976 ± 1,574 mm
Valve Closed Spring Length (Intake)	1-5/16 @ 48# ± 4# 49.21 @21.77 Kg ± 1.81 Kg	1.906 @ 59# 48,412 @ 26.7kg	1.906 @ 59# 48,412 @ 26.7kg	1.906 @ 59# 48,412 @ 26.7kg
Valve Closed Spring Length (Exhaust)	1-47/64 @ 45# ± 2# 43.97 @ 20.41 Kg ± 90 Kg	1.750 @ 57# 44,450 @ 25.8kg	1.750 @ 57# 44,450 @ 25.8kg	1.750 @ 57# 44,450 @ 25.8kg
Valve Open Spring Length (Intake)	1-19/32 @ 71# ± 6# 40.48 @ 32.21 Kg ± 2.72 Kg	1.506 @ 95# 38,252 @ 43.1kg	1.506 @ 95# 38,252 @ 43.1kg	1.506 @ 95# 38,252 @ 43.1kg
Valve Open Spring Length (Exhaust)	1-25/64 @ 82# ± 4# 35.32 @ 37.20 Kg ± 1.81 Kg	1.350 @ 90# 34,290 @ 40.8 kg	1.350 @ 90# 34,290 @ 40.8 kg	1.350 @ 90# 34,290 @ 40.8 kg



TYPICAL VALVE TRAIN, VALVE PORT CLEARANCES
DIESEL ENGINES

VRD FITS AND CLEARANCES

	VRD 155	VRD 232	VRD283	VRD310/310S
VALVE TRAIN, VALVE PORT				
(A) Valve Length (Intake)	5.953 - 5.943 151,206 - 150,952	5.953 - 5.943 151,206 - 150,952	6.812 - 6.802 173,024 - 172,770	6.812 - 6.802 173,024 - 172,770
Valve Length (Exhaust)	5.000 - 4.990 127,000 - 126,746	5.000 - 4.990 127,000 - 126,746	6.824 - 6.814 173,330 - 173,076	6.824 - 6.814 173,330 - 173,076
(B) Valve Stem Diameter (Intake)	.373 - .372 9,474 - 9,448	.373 - .372 9,474 - 9,448	.3725 - .3720 9,461 - 9,448	.3725 - .3720 9,461 - 9,448
Valve Stem Diameter (Exhaust)	.372 - .371 9,448 - 9,423	.372 - .371 9,448 - 9,423	.372 - .3715 9,448 - 9,436	.372 - .3715 9,448 - 9,436
Valve Lip Thickness (Intake)	.052 - .062 1,321 - 1,574	.052 - .062 1,321 - 1,574	.055 1,397	.055 1,397
Valve Lip Thickness (Exhaust)	.052 - .062 1,321 - 1,574	.052 - .062 1,321 - 1,574	.067 1,702	.067 1,702
Valve Face & Seat Run-out (Maximum)	.002 0,050	.002 0,050	.002 0,050	.002 0,050
(C) Valve Head Diameter (Intake)	1.447 - 1.437 36,753 - 36,499	1.447 - 1.437 36,753 - 36,499	1.640 - 1.630 41,656 - 41,402	1.718 - 1.708 43,637 - 43,383
Valve Head Diameter (Exhaust)	1.255 - 1.245 31,877 - 31,623	1.120 - 1.110 28,448 - 28,194	1.505 - 1.495 38,227 - 37,973	1.505 - 1.495 38,227 - 37,973
(D) Valve Face Angle (Intake)	44° 30' ± 15'	44° 30' ± 15'	29° 30' ± 15'	29° 30' ± 15'
Valve Face Angle (Exhaust)	44° 30' ± 15'	44° 30' ± 15'	44° 30' ± 15'	44° 30' ± 15'
(E) Guide Length (Intake)	3.187 - 3.177 80,949 - 80,695	3.187 - 3.177 80,949 - 80,695	3.500 - 3.490 88,900 - 88,646	3.500 - 3.490 88,900 - 88,646
Guide Length (Exhaust)	2.312 - 2.302 58,724 - 58,470	2.312 - 2.302 58,724 - 58,470	3.500 - 3.490 88,900 - 88,646	3.500 - 3.490 88,900 - 88,646

VRD FITS AND CLEARANCES (Continued)

	VRD 155	VRD232	VRD265	VRD 310/310S
VALVE TRAIN, VALVE PORT (Cont.)				
(F) Guide Outside Diameter (Intake & Exhaust)	.6255 - .6260 15,887 - 15,900	.6255 - .626 15,887 - 15,900	.6255 - .626 15,887 - 15,900	.6255 - .626 15,887 - 15,900
(G) Guide Inside Diameter (Intake & Exhaust)	.375 - .374 9,525 - 9,500	.375 - .374 9,525 - 9,500	.374 - .373 9,500 - 9,474	.374 - .373 9,500 - 9,474
Guide to Stem Clearance (Intake)	.001 - .003 0,025 - 0,076	.001 - .003 0,025 - 0,076	.0005 - .002 0,012 - 0,050	.0005 - .002 0,012 - 0,050
Guide to Stem Clearance (Exhaust)	.002 - .004 0,050 - 0,101	.002 - .004 0,050 - 0,101	.001 - .0025 0,025 - 0,063	.001 - .0025 0,025 - 0,063
Intake Insert Seat Width	.062 1,574	.062 1,574	.091 2,311	.091 2,311
Exhaust Seat Width	.070 1,778	.070 1,778	.062 - .072 1,574 - 1,829	.062 - .072 1,574 - 1,829
(H) Intake Insert Outside Diameter	1.5650 - 1.5645 39,751 - 39,738	1.5650 - 1.5645 39,751 - 39,738	---	---
(I) Intake Insert Inside Diameter	1.315 - 1.309 33,401 - 33,248	1.315 - 1.309 33,401 - 33,248	---	---
(J) Intake Insert Depth	.2055 - .2105 5,219 - 5,346	.2055 - .2105 5,219 - 5,346	---	---
(K) Insert Seat Angle (Intake)	45°	45°	30°	30°
Seat Angle (Exhaust)	45°	45°	45°	45°
(L) Guide Extends Above Head (Intake)	.937 - .927 23,799 - 23,545	.937 - .927 23,799 - 23,545	.875 - .865 22,225 - 21,971	.875 - .865 22,225 - 21,971
Guide Extends Above Head (Exhaust)	1.137 - 1.177 28,879 - 29,896	.937 - .927 23,799 - 23,545	.875 - .865 22,225 - 21,971	.875 - .865 22,225 - 21,971
(M) Guide Bore in Head	.624 - .625 15,849 - 15,875	..624 - .625 15,849 - 15,875	.6245 - .625 15,862 - 15,875	.6245 - .625 15,862 - 15,875
(N) Intake Insert Counterbore Depth	.314 - .318 7,976 - 8,077	.314 - .318 7,976 - 8,077	---	---
(O) Exhaust Insert Counterbore Diameter	1.5615 - 1.5625 39,662 - 39,687	1.5615 - 1.5625 39,662 - 39,687	---	---
(P) Intake Insert Seat1.406 O.D.	1.406 35,712	1.546 35,712	1.609 39,268	40,869
Exhaust Seat O.D.	1.228 31,191	1.109 28,169	1.437 36,500	1.437 36,500
Valve Spring Free Length (Intake)	2.440 ± .062 61,976 mm ± 1,574 mm	2.440 ± .062 61,976 ± 1,574 mm	2.562 ± .062 65,074 ± 1,574 mm	2.562 ± .062 65,074 ± 1,574 mm
Valve Spring Free Length (Exhaust)	2.562 ± .062 65,074 ± 1,574 mm	2.562 ± .062 65,074 ± 1,574 mm	2.562 ± .062 65,074 ± 1,574 mm	2.562 ± .062 65,074 ± 1,574 mm
Valve Closed Spring Length (Intake)	1-3/4 @ 57# ± 4# 44.45 @ 25.8 Kg ± 1.8 Kg	1-3/4 @ 57# ± 4# 44.45 @ 25.8 Kg ± 1.8 Kg	1.906 @ 59# 48,412 @ 26.7 kg	1.906 @ 59# 48,412 @ 26.7 kg
Valve Closed Spring Length (Exhaust)	1-29/32 @ 59# ± 4# 48.41 @ 26.7 Kg ± 1.8 Kg	1-29/32 @ 59# ± 4# 48.41 @ 26.7 Kg ± 1.8 Kg	1.906 @ 59# 48,412 @ 26.7 kg	1.906 @ 59# 48,412 @ 26.7 kg
Valve Open Spring Length (Intake)	1-11/32 @ 90# ± 4# 34.29 @ 40.8 Kg ± 1.8 Kg	1-11/32 @ 90# ± 4# 34.29 @ 40.48 Kg ± 1.8 Kg	1.506 @ 95# 38,252 @ 43.1 kg	1.506 @ 95# 38,252 @ 43.1 kg
Valve Open Spring Length (Exhaust)	1-1/2 @ 95# ± 4# 38.25 @ 43.1 Kg ± 1.8 Kg	1-1/2 @ 95# ± 4# 38.25 @ 43.1 Kg ± 1.8 Kg	1.506 @ 95# 38,252 @ 43.1 kg	1.506 @ 95# 38,252 @ 43.1 kg
*Valve Extension Above Head -Intake	---	---	.029 .736	.029 .736
-Exhaust	---	---	.041 1.04	.041 1.04

* This dimension must be checked after installing valve seat inserts.

REPAIR & REPLACEMENT

ARROW ENGINE COMPANY

VRG FITS AND CLEARANCES

CAMSHAFT	VRG 155	VRG 232	VRG 265	VRG 283/310
Camshaft Journal Diameter (No. 1)	1.749 - 1.750 44,425 - 44,450	1.749 - 1.750 44,425 - 44,450	1.749 - 1.750 44,425 - 44,450	1.749 - 1.750 44,425 - 44,450
Camshaft Journal Running Clearance	.0015 - .0035 0,038 - 0,088	.0015 - .0035 0,038 - 0,088	.0015 - .0035 0,038 - 0,088	.0015 - .0035 0,038 - 0,088
Camshaft Journal Diameter (Nos.2,3, & 4)	1.7495 - 1.7485 44,437 - 44,411	1.7495 - 1.7485 44,437 - 44,411	1.7495 - 1.7485 44,437 - 44,411	1.7495 - 1.7485 44,437 - 44,411
Camshaft End Play	SPRING AND BUTTON CONTROLLED			
Camshaft Bushing I.D. (Pre-reamed to Size)	1.7515 - 1.752 44,488 - 44,500	1.7515 - 1.752 44,488 - 44,500	1.7515 - 1.752 44,488 - 44,500	1.7515 - 1.752 44,488 - 44,500
Cam Lift Intake	.226 - .214 5,740 - 5,435	.226 - .214 5,740 - 5,435	.300 - .294 7,62 - 7,467	.300 - .294 7,62 - 7,467
Cam Lift Exhaust	.206 - .194 5,232 - 4,927	.206 - .194 5,232 - 4,927	.305 - .299 7,747 - 7,594	.305 - .299 7,747 - 7,594

OIL PUMP	VRG 155	VRG 232	VRG 265	VRG283/310
Backlash Oil Pump --- Pressure Gears	---	.010 - .016	.010 - .016 0,254 - 0,406	0,254 - 0,406
Drive Shaft Bushing I.D. (Top)	.4955 - .4970 12,585 - 12,624	.4955 - .4970 12,585 - 12,624	.4965 - .4955 12,611 - 12,585	.4965 - .4955 12,611 - 12,585
Drive Shaft Bushing I.D. (Bottom)	1.0005 - 1.0015 25,413 - 25,438	1.0005 - 1.0015 25,413 - 25,438	.6265 - .6270 15,913 - 15,926	.6265 - .6270 15,913 - 15,926
Drive Shaft Running Surface O.D. (Top)	.495 - .4945 12,573 - 12,560	.495 - .4945 12,573 - 12,560	.4945 - .494 12,560 - 12,547	.4945 - .494 12,560 - 12,547
Drive Shaft Running Surface O.D. (Bottom)	1.000 - .9995 25,400 - 25,387	1.000 - .9995 25,400 - 25,387	.6245 - .6240 15,862 - 45,850	.6245 - .6240 15,862 - 15,850
Idler Shaft O.D.	---	---	.622 - .6225 15,799 - 15,811	.622 - .6225 15,799 - 15,811
Idler Gear I.D.	---	---	.626 - .6265 15,900 - 15,913	.626 - .6265 15,900 - 15,913

ROCKER ARMS	VRG 155	VRG 232	VRG 265	VRG 283/310
Rocker Arm I.D.	.7445 - .7455 18,910 - 18,936	.7445 - .7455 18,910 - 18,936	.7445 - .7455 18,910 - 18,936	.7445 - .7455 18,910 - 18,936
Rocker Arm Shaft O.D.	.742 - .743 18,847 - 18,872	.742 - .743 18,847 - 18,872	.742 - .743 18,847 - 18,872	.742 - .743 18,847 - 18,872
Rocker Arm Running Clearance	.0015 - .0035 0,038 - 0,088	.0015 - .0035 0,038 - 0,088	.0015 - .0035 0,038 - 0,088	.0015 - .0035 0,038 - 0,088

FLYWHEEL HOUSING	VRG 155	VRG 232	VRG 265	VRG 283/310
Pilot Bearing Runout	.005" 0,127 mm	.005" 0,127 mm	.005" 0,127 mm	.005" 0,127 mm
Flywheel Face Runout	.008" 0,203 mm	.008" 0,203 mm	.008" 0,203 mm	.008" 0,203 mm
Flywheel Housing Bore Runout	.006" 0,152 mm	.008" 0,203 mm	.008" 0,203 mm	.008" 0,203 mm
Flywheel Housing Face Runout	.006" 0,152 mm	.008" 0,203 mm	.008" 0,203 mm	.008" 0,203 mm

VRD FITS AND CLEARANCES

CAMSHAFT	VRD 155	VRD 232	VRD 283	VRD 310/310S
Camshaft Journal Diameter (No. 1)	1.749 - 1.750 44,425 - 44,450	1.749 - 1.750 44,425 - 44,450	1.7495 - 1.7485 44,437 - 44,411	1.7495 - 1.7485 44,437 - 44,411
Camshaft Journal Running Clearance	.0015 - .0035 0,038 - 0,088	.0015 - .0035 0,038 - 0,088	.002 - .0035 0,050 - 0,088	.002 - .0035 0,050 - 0,088
Camshaft Journal Diameter (Nos.2,3, & 4)	1.7495 - 1.7485 44,437 - 44,411	1.7495 - 1.7485 44,437 - 44,411	1.7495 - 1.7485 44,437 - 44,411	1.7495 - 1.7485 44,437 - 44,411
Camshaft End Play	SPRING AND BUTTON CONTROLLED			
Camshaft Bushing I.D. (Pre-reamed to Size)	1.7515 - 1.752 44,488 - 44,500	1.7515 - 1.752 44,488 - 44,500	1.7515 - 1.752 44,488 - 44,500	1.7515 - 1.752 44,488 - 44,500
Cam Lift Intake	.226 - .214 5,740 - 5,435	.226 - .214 5,740 - 5,435	.302 7,670	.302 7,670
Cam Lift Exhaust	.206 - .194 5,232 - 4,927	.206 - .194 5,232 - 4,927	.302 7,670	.302 7,670

OIL PUMP	VRD 155	VRD 232	VRD 283	VRD310/310S
Backlash Oil Pump Pressure Gears	---	---	.010 - .016 0,254 - 0,406	.010 - .016 0,254 - 0,406
Drive Shaft Bushing I.D. (Top)	.4955 - .497 12,585 - 12,624	.4955 - .497 12,585 - 12,624	.4965 - .4955 12,611 - 12,585	.4965 - .4955 12,611 - 12,585
Drive Shaft Bushing I.D. (Bottom)	1.0005 - 1.0015 25,413 - 25,438	1.0005 - 1.0015 25,413 - 25,438	.6265 - .6270 15,913 - 15,926	.6265 - .6270 15,913 - 15,926
Drive Shaft Running Surface O.D. (Top)	.495 - .4945 12,573 - 12,560	.495 - .4945 12,573 - 12,560	.4945 - .494 12,560 - 12,547	.4945 - .494 12,560 - 12,547
Drive Shaft Running Surface O.D. (Bottom)	1.000 - .9995 25,400 - 25,387	1.000 - .9995 25,400 - 25,387	.6245 - .6240 15,862 - 15,850	.6245 - .6240 15,862 - 15,850
Idler Shaft O.D.	---	---	.622 - .6225 15,799 - 15,811	.622 - .6225 15,799 - 15,811
Idler Gear I.D.	---	---	.626 - .6265 15,900 - 15,913	.626 - .6265 15,900 - 15,913

ROCKER ARMS	VRD 155	VRD 232	VRD 283	VRD 310/310S
Rocker Arm I.D.	.7445 - .7455 18,910 - 18,936	.7445 - .7455 18,910 - 18,936	.7445 - .7455 18,910 - 18,936	.7445 - .7455 18,910 - 18,936
Rocker Arm Shaft O.D.	.742 - .743 18,847 - 18,872	.742 - .743 18,847 - 18,872	.7425 - .7435 18,859 - 18,885	.7425 - .7435 18,859 - 18,885
Rocker Arm Running Clearance	.0015 - .0035 0,038 - 0,088	.0015 - .0035 0,038 - 0,088	.001 - .003 0,025 - 0,076	.001 - .003 0,025 - 0,076

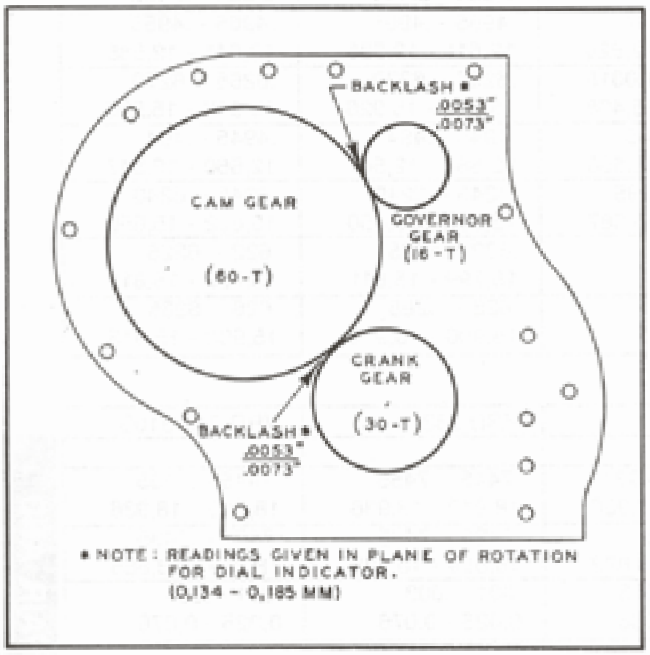
FLYWHEEL HOUSING	VRD 155	VRD 232	VRD 283	VRD 310/310S
Pilot Bearing Runout	.005" 0,127 mm	.005" 0,127 mm	.005" 0,127 mm	.005" 0,127 mm
Flywheel Face Runout	.008" 0,203 mm	.008" 0,203 mm	.008" 0,203 mm	.008" 0,203 mm
Flywheel Housing Bore Runout	.006" 0,152 mm	.008" 0,203 mm	.008" 0,203 mm	.008" 0,203 mm
Flywheel Housing Face Runout	.006" 0,152 mm	.008" 0,203 mm	.008" 0,203 mm	.008" 0,203 mm

ENGINE TIMING DATA

VR Natural Gas and Gasoline Ignition Timing

	VRG 155	VRG 232	VRG 265/283	VRG 310
Distributor Timing (Gasoline)	TDC @ 450 RPM	TDC @ 450 RPM	TDC @ 450 RPM	TDC @ 450 RPM
Distributor Timing (Natural Gas)	TDC @ 450 RPM	TDC @ 450 RPM	TDC @ 450 RPM	TDC @ 450 RPM
Magneto Timing (Gasoline)	20° BTDC @ 12 - 1500 RPM 24° BTDC @ 16 - 1800 RPM 26° BTDC @ 19 - 2200 RPM	20° BTDC @ 12 - 1500 RPM 24° BTDC @ 16 - 1800 RPM 26° BTDC @ 19 - 2200 RPM	20° BTDC @ 12 - 1500 RPM 24° BTDC @ 16 - 1800 RPM 26° BTDC @ 19 - 2200 RPM	20° BTDC @ 12 - 1500 RPM 24° BTDC @ 16 - 2200 RPM 26° BTDC @ 19 - 2400 RPM
Magneto Timing (Natural Gas)	20° BTDC @ 12 - 1500 RPM 24° BTDC @ 16 - 1800 RPM 26° BTDC @ 19 - 2200 RPM	20° BTDC @ 12 - 1500 RPM 24° BTDC @ 16 - 1800 RPM 26° BTDC @ 19 - 2200 RPM	30° BTDC @ 12 - 1500 RPM 34° BTDC @ 16 - 1800 RPM 36° BTDC @ 19 - 2200 RPM	30° BTDC @ 12 - 1500 RPM 36° BTDC @ 16 - 2200 RPM 38° BTDC @ 22 - 2400 RPM

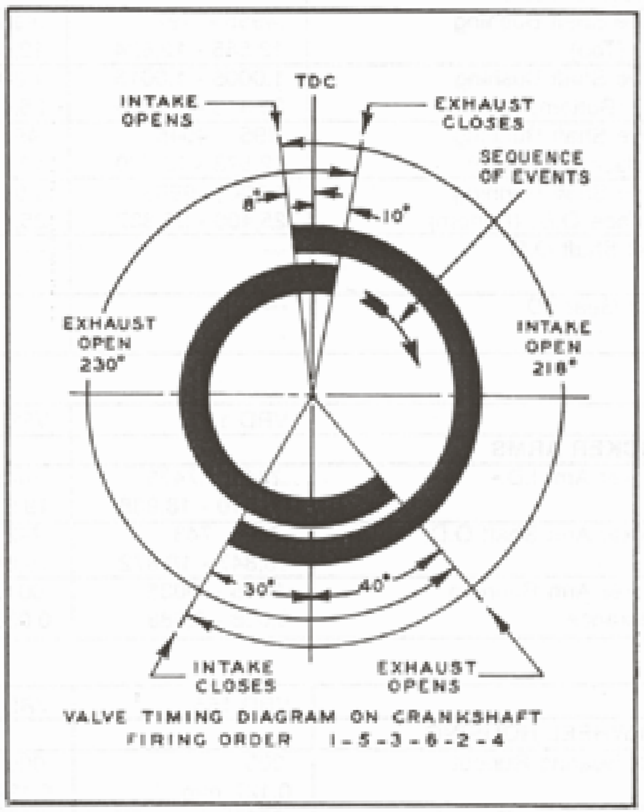
Timing Gear Backlash



TIMING GEAR BACKLASH DIAGRAM

Note: Backlash stated for reading with a dial indicator. If feeler gauge is to be used, backlash will be .004 - .006" (0,101 - 0,152 mm).

Valve Timing



TYPICAL VALVE TIMING DIAGRAM

Timing Gear Bushings

	VRG Series		VRD Series
Governor Gear Bushing I.D.	1.0022 - 1.0033 25,456 -25,476	Idler Spindle Bushing I.D.	1.0015 - 1.002 25,438 - 25,451
Governor Gear Hub O.D.	.999 - .9995 25,375 - 25,387	Idler Spindle O.D.	1.000 - .999 25,400 - 25,375

SCOPE

These are general installation requirements. For more specific and detailed installation requirements, refer to the Arrow Specialty Company Installation Manual.

AUTOMATIC STARTING

We recommend the inclusion of lube oil heaters and automatic prelube systems for installations of Arrow engines which are subjected to unscheduled automatic starts and instantaneous loading.

SPACE REQUIREMENTS

In order to ensure adequate access for engine installation, ventilation and in-service maintenance, engine location must be carefully considered.

The engines described in this manual require a minimum of 24 inches between engines or between engine and wall. End clearance required to remove camshaft is 36 inches. Sufficient overhead clearance is required to permit the use of a chain hoist for removal of heavy engine parts. The heaviest part of these engines is the crankcase which weighs approximately 270 lbs.

To prevent foreign objects from entering the engine, leave covers on all engine openings until ready to connect the openings during installation.

STATIONARY INSTALLATIONS

Engine Foundations

Nearly all stationary engine applications require a foundation or mounting base. This base serves to isolate the engines from the surrounding structure and absorb or inhibit vibration. A base provides a permanently accurate surface upon which the engine (and usually the driven equipment) may be mounted and aligned. To serve these purposes, the foundation must have a suitable size and mass, rest on an adequate soil or bearing surface, be provided with an accurately finished mounting surface for the engine, and be equipped with properly sized retaining bolts in the correct locations to secure the engine firmly in position.

Mounting

No engine will perform properly if incorrectly installed and aligned. Any misalignment of mountings imposes stresses on engine structure with possible damage to flywheel housing, flywheels, crankshafts and thrust bearings. When making a new installation, a well-planned arrangement of the fuel, water, and exhaust systems is important. Because of the variety of power application, the VR Series engines will be found mounted in mobile and stationary applications. In all cases it is most important that proper mountings be selected for the specific application. If the engine and driven equipment have separate foundations, alignment is critical. To insure proper alignment inspect foundations for weld spatter, burrs, foreign matter or uneven surfaces. It is plainly a waste of time to attempt alignment if the foundation is not level and clean.

Alignment

It is always desirable to have some shims under both engine and driven equipment so future alignment problems at time of rebuilding or replacement will not present a problem.

The nature of any shimming procedure is essentially "cut and try". Use easily cut steel or brass shim stock to make up trial shim pads. Remember the area of the shim pad must be large enough to support the weight of the engine when the bolts are tightened.

After the engine has been leveled and tightened down, the driven equipment can be aligned. In the case where the driven equipment is mounted permanently, the engine will have to be aligned relative to the driven equipment.

When engine and driven equipment are mounted on a common skid base, shims should be used under both units which will compensate for roughness and unevenness of the rolled or fabricated skid rails. This will also provide shims under drive and driven units for final alignment. Usually the heaviest machine is permanently mounted and the lightest aligned to the heaviest.

The correct aligning procedure may vary slightly with different types of drive equipment. Many manufacturers of driven equipment will specify the method used to align their equipment. In general, the object is the same; to make the driven shaft concentric with the driver shaft and to make the centerline of the driven shaft parallel with the centerline of the driver shaft.

If at all possible, final shims should be steel plates of such thickness that only the last few odd thousandths need be filled out with thinner shim stock. Always use shims of adequate width to permit the full base mounting area to bear on them. Do not shim just the outer edge of the engine base.

PREPARING UNIT FOR SERVICE

Inspect all identification and data plates and comply with all servicing instructions. Compare data plates with information contained in invoices or packing slips to insure receipt of equipment as ordered.

Inspect entire engine for damage, loose connections, broken or sharply bent lines, and loose nuts or bolts. If tape or temporary coverings are torn or missing from engine openings, such as intake, exhaust, water or fuel, a thorough inspection is required to determine the possible presence of foreign objects in these openings.

The steps needed to bring an engine into active service are basically the same for a new engine or one that has been in storage. In addition to a very detailed visual inspection, check for free rotation. Any accumulated dust and dirt should be wiped or washed from the exterior before removing engine opening covers. Engines that have not been rotated for some time should be oiled through the spark plug or injector openings and cranked by hand before actual running. Any resistance to free cranking should be investigated; rust and corrosion can cause severe seizure that cannot be cleared without engine disassembly.

Never attempt to start a diesel engine that has been stored without first inspecting intake passages and manifolds for thickened preservative oil. Then crank it over with the injectors out. Spurting oil, water or preservative compound from these openings indicates the possibility of a hydraulic lock. Continue to crank engine with starter until liquid is no longer ejected from openings.

Fill the crankcase with proper grade and viscosity oil to the full mark on the oil depth gauge. Fill oil bath air cleaners with engine oil to proper level as required.

If conditions permit, the cooling system should be filled with soft water. After the cooling system has been checked and any leaks have been repaired, drain a portion of the water and add an inhibitor or antifreeze as required. Soluble oil may be used as an inhibitor, one ounce oil per gallon of coolant.

Fill the fuel tank with appropriate fuel. The fuel supply should be checked for adequate flow as well as leads. Diesel engine supply is considered adequate when there is a solid stream of fuel at the inlet to the injection pump. All air should be purged from the diesel fuel supply system. The diesel fuel system should be hand primed until the operator determines that fuel is delivered to the injection transfer pump. Ordinarily it is not necessary to purge the fuel lines between the injection pump and the injectors. If necessary, this can be done by loosening the injector lines at the injectors and cranking the engine until solid fuel is ejected during cranking.

Check connections for proper battery polarity. Pour the acid into the dry batteries and see that the battery plates are covered with solution. Connect the batteries and control wires. When a dry charge battery is used, the battery should be charged prior to use.

COOLING SYSTEM

Cooling System Design

Premature engine component failures and abnormal operating and maintenance conditions can often be traced to improper design or sizing of radiators or other coolers.

Arrow Specialty Company will not be responsible for engine or component failure when the following cooling system design and application recommendations are not followed.

Recommendation for Specifying a Radiator or Other Cooler Design for Continuous Duty Operation.

1. Use 180°F. (195°F. for VR155) engine water outlet temperature. On compressor applications, use 180°F. engine water outlet temperature to agree with A.P.I. Standard 11K.
2. Base water flow and temperature rise across radiator core or cooler on jacket water pump curve.
3. Pressure drop through radiator core or cooler with full water flow at rated speed must not exceed 3 to 5 psi.
4. Allow 15% reserve for variations in application and environmental conditions, i.e., wind direction, dirt and debris. This is in addition to normal design fouling factors.
5. When possibility of using 50-50 solution of ethylene glycol exists, radiator core or cooler area should be sized 15% larger since there is a 15% reduction in heat transfer coefficient for ethylene glycol when compared with water.
6. Select radiator or cooler for highest ambient or sea water temperature that will be experienced in operation. For radiators, allowance must be made for air temperature rise across engine with blower fan, or in engine room if suction fan is used.
7. Radiators and surge tanks must have 7 psi pressure caps.
8. Provision must be made for de-aeration of coolant, such as divided top tank or separate surge tank.
9. Provision must be made for balance line connection to engine pump suction to prevent pump cavitation.
10. Adequate expansion volume for complete cooling system must be provided in radiator or separate surge tank.
11. Maximum back pressure, feeding into radiator or cooler, should not exceed 5 psi at 2000 RPM.
12. Maximum inlet head to jacket water pump is 20 feet of water.

Recommendation for Specifying a Radiator or Other Cooler Design for Intermittent or Standby Operation:

Same as for Continuous Duty Operation, except:

1. Use 200°F. (instead of 185°F.) engine outlet temperature.
2. Allow 5% (instead of 15%) reserve for variations in application and environmental conditions.

Recommendation for Specifying a Radiator or Other Cooler Design for Torque Converter Application.

When the engine cooler is used for cooling a torque converter in addition to the engine, the core or cooler surface should be at least 30% larger than the core required for the engine alone.

COOLING SYSTEM INHIBITOR

To prevent rust when using water alone, either use a recommended corrosion preventive or inhibitor, or add one ounce of soluble oil for every gallon of coolant in the cooling system.

Ethylene Glycol	Radiator Glycerine (G.P.A.)	Freezing Points °F.	°C.
16%	37%	20	-7
25%	55%	10	-12
33%	70%	0	-18
39%	81%	-10	-23
44%	92%	-20	-29
48%	100%	-30	-35

Cooling System
Installation Recommendations

After the cooler installation is completed and prior to filling the cooling system, clean all dirt and welding spatter from low points in the system. Flush accessible sections of the piping and cooler to eliminate as much dirt as possible prior to operation of the engine.

After filling the system, check closely for leaks. Tighten all clamps and fittings prior to engine start-up to avoid loss of time at start-up.

The following installation suggestions are offered to improve cooling system performance and make future maintenance easier and less time consuming:

1. Mount all cooling system components such as water inlet connections, control valves, and raw water pumps with at least enough clearance to permit normal maintenance and removal and replacement of accessories at the front of the engine without major disruption of the cooling system.

2. Use suitable couplings so large portions of the piping and valves and raw water pump complex may be disconnected and moved aside as a unit for engine repair and maintenance. This avoids removal of individual pieces of pipe and "working backwards" to reach a given threaded connection.

3. Provide convenient drainage points to remove water from both fresh water and raw water systems.

4. Provide easily opened air vents to remove air blocks from cooling system piping and allow immediate priming of system.

5. Mount all belt driven water pumps so belts may be tightened easily while operating. Locate pump couplings and drive pulleys so packing can be removed and replaced without major disassembly or pump removal.

6. Keep the system clean!

7. Avoid electrolysis; use zinc anodes or other cathodes protection.

AIR INTAKE SYSTEM

Huge quantities of combustion air are required for all internal combustion engines. Combustion air requirements for VR Series engines may be obtained from your Arrow sales engineer.

Certain factors must be considered to ensure an adequate clean supply of combustion air for internal combustion engines. These are as follows:

1. Combustion air required for engines installed in heated, air conditioned buildings may upset heating and ventil ating calculations unless it is supplied via an external air intake.

2. If an external air intake is required, it must be suitably designed to supply intake air of the proper temperature range (high intake air temperature results in power loss while extremely cold intake air may hinder starting of automatic standby units), to prevent pick up of exhaust gas materials or exhaust from other industrial operations (such as foundry dust or paint spray), to prevent pick up of flammable vapors, and to prevent entry of rain and water.

3. All ducting, as well as air cleaner to manifold connections, must be airtight to avoid the intake of unfiltered air.

4. The restriction through the air intake system must be kept to a minimum. Restricted inlets, sharp or numerous bends and undersized ducting will all increase restriction unnecessarily.

5. Engine heat radiation will affect ambient air temperatures in building installations. Properly located intake and exhaust fans will be required when necessary to ventilate engine rooms.

EXHAUST SYSTEM

The huge quantities of combustion air consumed by internal combustion engines must be properly exhausted after combustion occurs. Therefore, every possible provision must be made to minimize restriction with resultant back pressure of an exhaust system.

Some of the adverse effects of excessive back pressure are loss of power, poor fuel economy, excessive valve temperatures and engine coolant overheating.

If exhaust back pressure is found to be excessive, check for undersized piping, undersized or inefficient silencer or muffler, or excessive bends or restrictions in the exhaust line. Correct any deficiencies.

Exhaust pipes must be adequately sized and supported. A condensate trap and drain must be provided at some low point ahead of the engine exhaust manifold. The back pressures caused by elbows and other pipe bends prohibit their use in a well designed exhaust system. Always use welded tube turns with radius of four or five diameters. Multiple exhaust connections to a common header are not recommended, as this can result in erratic operation and damage.

Sometimes, pulsing effects can set up interferences in a single straight pipe, thus making it advantageous in every installation to locate the silencer as close to the engine as possible.

Attention must be given to adequate silencing of the engine, as unnecessary noise is objectionable and a public nuisance. Objectionable noise is unnecessary today with the available mufflers which can be used for silencing.

Before using any vent passage or chimney in an existing structure not specifically designed for service as an engine exhaust passage, it should be carefully checked for compliance with all fire and venting codes. It is extremely poor practice to discharge engine exhaust into a brick, tile, cement block, or structure of like material. The characteristics of the exhaust pulsations are very capable of causing severe structural damage.

Exhaust flow requirements for VR Series engines may be obtained from your Arrow sales engineer.

CAUTION

Maximum distortion of flexible exhaust connector, due to connected exhaust piping is ± 1/4 inch offset and ± 1/4 inch axial deflection.

LUBRICATING OIL SYSTEM

Lubricating oil specification recommendations are contained in the Preventive Maintenance Unit. The installation should include adequate provisions for draining lube oil.

Angular Operating Limits

The angular operating limits are important to successful operation in many engine applications. Engine users should be cautioned when job requirements put the engine at extreme angles. This sometimes occurs when machines have been modified for jobs different from their original purpose without proper consideration to the type of oil pan or oil pump used. In other cases the ramps or stockpiles on which the machine is working are too steep and the engine loses oil pickup each time the engine is tilted. Obviously, loss of oil pressure, even for brief periods, can have destructive results.

Maximum engine tilt angles outlined below are for intermittent periods only; a one minute duration in 5 minutes.

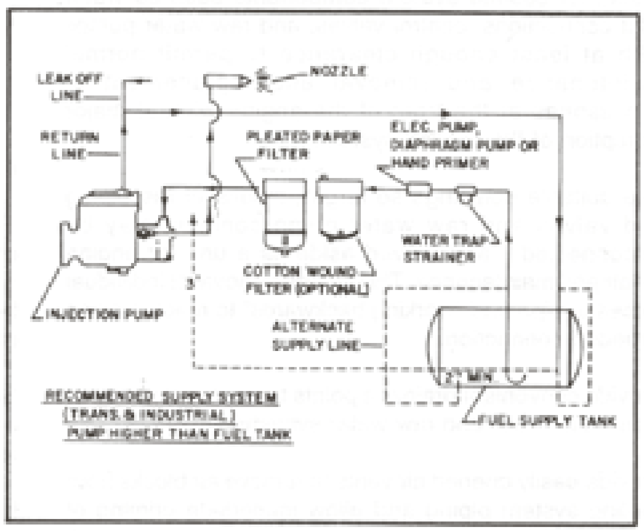
Model	Oil pan & Pump	Front & Rear Down Angle	Right & Left Side Down Angle
VR155	Standard	15°	15°
VR232	Standard	15°	25°
VR265	Standard	15°	30°
VR283	Standard	15°	30°
VR310	Standard	15°	30°
VR310S	Standard	15°	30°

Continuous duty operation at any angle is not permitted unless approved by Arrow Engineering Department.

FUEL SYSTEM

The fuel piping, if a remote fuel tank is used, must be adequately supported to prevent breakage from weight or vibration. A flexible section should be installed in the line, or lines, as close to the engine as possible. Back flush all fuel lines into an open container prior to final connection. This simple procedure will further eliminate the possibility of fuel contamination. Connections and couplings must be tight to eliminate leaks and air leakage into the fuel system.

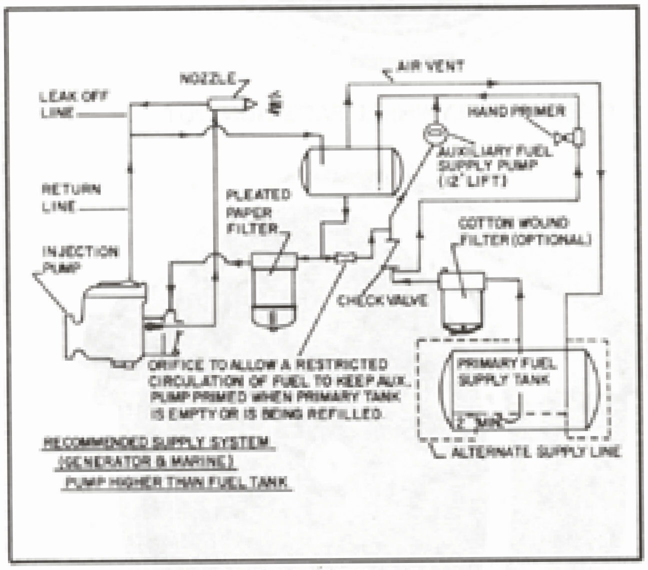
Industrial engines may require a different piping arrangement to suit application peculiarities and performance demands. Generator sets, for example, are particularly sensitive to air and usually require a separate electrically or mechanically driven auxiliary supply pump to deliver fuel, at low pressure, to the unit day tank. This places a positive head of fuel at the transfer pump and virtually eliminates entrance of air to the system. (See accompanying illustrations.)



(FUEL SUPPLY PIPING DIAGRAM)

Proper selection of piping sizes, filter capacities and layout of the system must be made to prevent undue restriction which would affect pump and engine performance. Of equal importance is the necessity for utmost cleanliness of fuel before and during handling. Admission of minute foreign particles, even in small quantities, will seriously wear the close clearances necessary to seal the engine against internal hydraulic leakage.

Outside storage, as well as vehicle and unit tanks, should be guarded against entrance of dirt. They should have drains to remove water and settlings periodically, be adequately vented and kept as full as possible to prevent condensation. Attendant piping should not be galvanized. Rigid observance of fuel cleanliness standards from time of purchase to ultimate use will do much to assure trouble-free operation.



(FUEL SUPPLY PIPING DIAGRAM)

CAUTION

Never use galvanized or zinc alloy piping in the fuel system. The sulphur in the fuel will corrode these metals, gumming up the injectors and the injection pump.

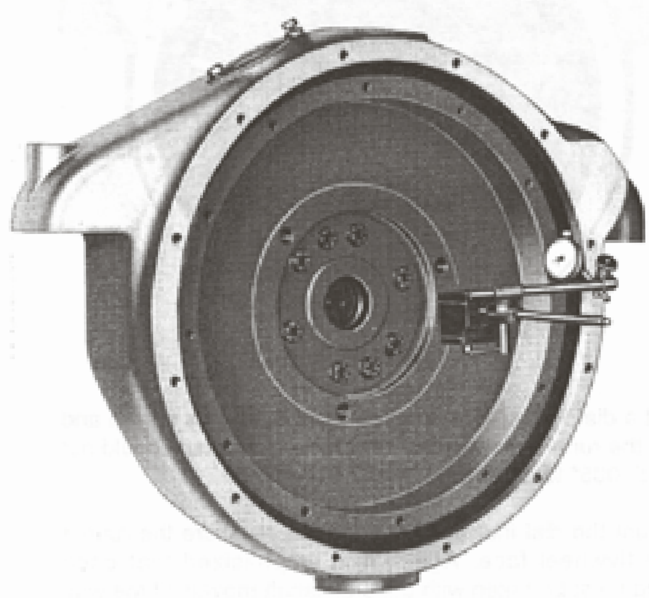
CHECKING FLYWHEEL AND HOUSING RUN-OUT AND CRANKSHAFT ENDPLAY

Even with the best maintenance, an engine can encounter trouble if such things as proper mounting, alignment with other equipment, flywheel and housing runout and sufficient crankshaft endplay are disregarded in the initial installation or in subsequent relocations of the engine. Although flywheel and housing runout and crankshaft endplay are firmly established within limits at the factory, such things as rough handling or improper installation of power takeoffs or clutches may adversely affect these clearances and lead to serious engine damage. These items should be checked prior to operation.

A major factor in obtaining long service life from any engine and clutch or power takeoff assembly is the proper alignment of the flywheel housing, flywheel and pilot bearing bore. Distortion or lack of a common center on either of these parts will set up forces sure to be destructive to bearings, crankshaft, clutch, and the driven equipment. In addition, because of normal manufacturing tolerances, when an engine is installed in a mounting formerly occupied by another engine, it is not safe to assume that the drive shaft of the power takeoff will automatically line up with a coupling located for the previous engine. In such circumstances, either the engine mounts must be shimmed or adjusted, or the driven mechanism must be relocated and adjusted a few thousandths to bring the engine drive line from crankshaft bearing to driven shaft coupling into good alignment.

Make the following check for flywheel housing bore concentricity:

1. Support a dial indicator in the same general manner as shown and check the runout of the housing bore all the way around.



CHECKING HOUSING BORE RUNOUT

2. If the flywheel housing is out of alignment, loosen all of the flywheel housing bolts and proceed as follows.

3. Use a small bar inserted in a bolt hole to correct misalignment until the runout does not exceed .008" (.006" for VRD and VRG 155) total indicator reading.

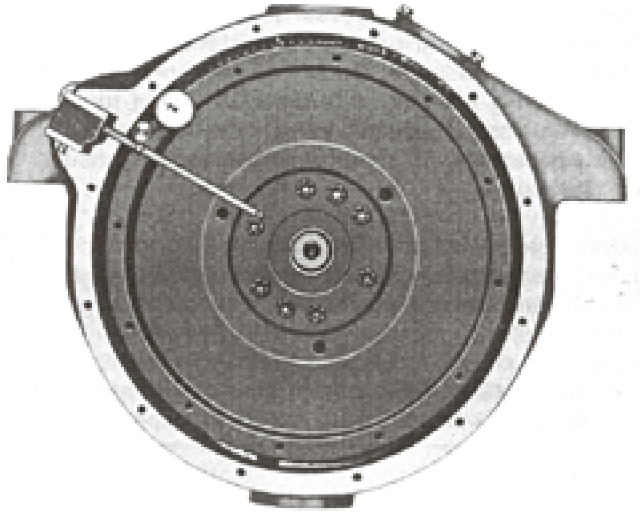
4. Tighten bolts partially, working back and forth across the housing. Recheck bore concentricity with dial indicator.

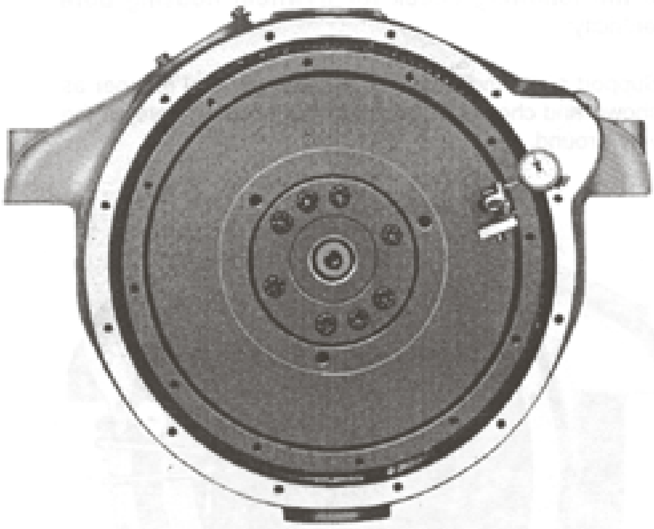
Relocate the dial indicator as shown to indicate the flywheel housing face.

1. Housing face runout should not exceed .008" (.006" for VRD and VRG 155) total indicator reading. If correction is required, it should be done with a cutting tool mounted on a radius arm and firmly attached to the flywheel. Thus, by rotating the crankshaft by means of a suitable drive, the cutting tool will dress the housing face into a plane in alignment with the carnkshaft flange.

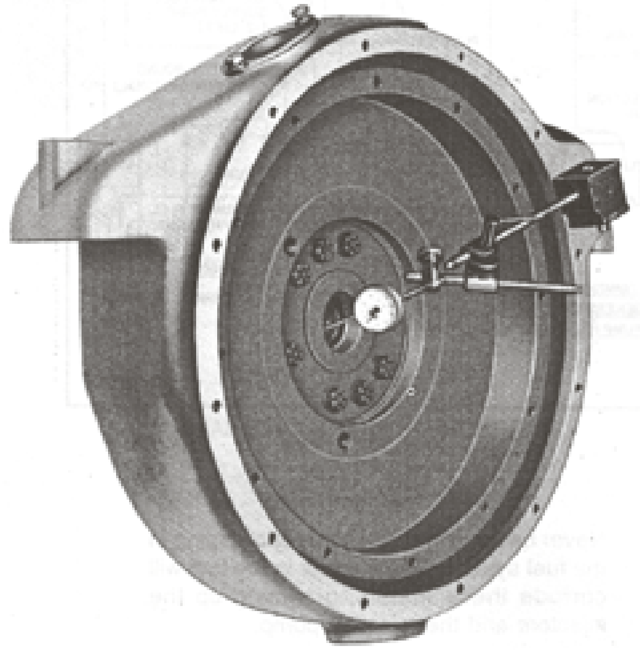
2. When making the above inspection, it is very important not to be misled by end movement of the crankshaft. To prevent this, use a pry bar to bring the shaft into full forward position at each point where the indicator reading is taken.

CHECKING HOUSING FACE RUN-OUT





CHECKING FLYWHEEL FACE RUN-OUT



CHECKING PILOT BEARING BORE RUN-OUT

Mount a dial indicator on the flywheel housing as shown and check the runout of the pilot bearing bore. Runout should not exceed .005" total indicator reading.

Remount the dial indicator as shown to measure the runout of the flywheel face. Again, it is emphasized that each reading must be taken with the crankshaft moved all the way forward to contact the thrust bearing. Unless tough handling has somehow distorted the wheel or crankshaft flange, maximum runout should not exceed .008" total indicator reading.

Measure crankshaft endplay with a dial indicator mounted on the crankcase. Use a small pinch bar to move the crankshaft fully forward. Set the indicator at zero and use the bar to thrust the shaft to fully rearward. Check endplay reading on dial indicator with the tolerance given in the Fits and Clearances section.

CAUTION

The importance of correct crankshaft endplay cannot be overstressed. Operation of an engine having insufficient or excessive crankshaft endplay can result in serious damage. Insufficient clearance will prevent proper lubrication of the thrust surfaces, causing main bearings to overheat and lock on the shaft.

Express Limited Warranty for
VR Products Used in Continuous Duty Applications

CONTINUOUS DUTY DEFINITION: The highest load and speed which can be applied, subject to Arrow Specialty Company's ratings in effect at time of sale.

I. TERMS OF EXPRESS LIMITED WARRANTY

Arrow Specialty Company warrants that it will repair or replace, at its election and expense, any part of an engine, or product (hereinafter referred to as "Products") manufactured by Arrow Specialty Company, which proves to have had a defect in material or workmanship.

II. TERM LIMITATIONS OF EXPRESS LIMITED WARRANTY

A. This coverage shall commence upon initial new Products start-up date and shall expire upon the earlier of the following:
   1. 1 year after the initial new Products start-up date; or
   2. 18 months after the original shipment date of the covered Products by Arrow Specialty Company.

III. ARROW SPECIALTY COMPANY'S RESPONSIBILITIES UNDER THE EXPRESS LIMITED WARRANTY

Arrow Specialty Company shall be responsible for:

A. The repair or replacement, at Arrow Specialty Company's election of covered defective parts and all reasonable labor required regarding a warranted failure during the express limited warranty and term. All such labor shall be provided by Arrow Specialty Company's authorized contractor or distributor.
B. Reasonable and necessary travel and expenses incurred by Arrow Specialty Company's authorized contractor or distributor.
C. Replacement of lubricating oil, coolant, filter elements, or other normal maintenance items that are contaminated and/or damaged as a direct result of a warranted failure.

NOTWITHSTANDING THE FOREGOING, ARROW SPECIALTY COMPANY SHALL NOT BE RESPONSIBLE FOR LABOR COSTS ASSOCIATED WITH WARRANTY CLAIMS.

IV. OWNER'S RESPONSIBILITIES UNDER THE EXPRESS LIMITED WARRANTY

Owner shall be responsible for:

A. The operation and maintenance of the Products within the guidelines established by Arrow Specialty Company.
B. Making the Products available to Arrow Specialty Company or Arrow Specialty Company's authorized contractors or distributors for any warranty repair, during normal business hours.
C. All additional costs incurred for premium or overtime labor, should owner request that repairs be made on a premium overtime schedule.
D. All costs incurred as the result of removal or reinstallation of the Products as may be required to effect any warranted repair.
E. All administrative costs and expenses resulting from a warranted failure.
F. Any costs of transportation, towing, repair facilities, or associated costs.
G. Loss of revenue and loss of/or damage to real and/or personal property.

V. LIMITATION OF ARROW SPECIALTY COMPANY'S OBLIGATIONS

The obligations of Arrow Specialty Company under this express limited warranty shall be waived and voided, and Arrow Specialty Company shall not, thereafter, be responsible for:

A. Any failure resulting from owner or operator abuse or neglect, including but not by way of limitation, any operation, installation, application, or maintenance practice not in accordance with guidelines or specifications established by Arrow Specialty Company; or
B. Any failure resulting from unauthorized modifications or repairs of the Products or;
C. Any failure resulting from overload, overspeed, overheat, accident, improper storage; or
D. Failure of owner to promptly provide notice of a claimed defect; or
E. Failure of Products for which Arrow Specialty Company did not receive properly completed start-up reports; or
F. Repairs of a covered failure performed with non-genuine Arrow Specialty Company parts; or
G. Repairs of a covered failure performed by non-authorized contractors or distributors; or
H. Failure to make Products available to Arrow Specialty Company or its authorized representatives, or
I. Failure to supply documents such as drawings and specifications relating to the specific application of the Products.

VI. APPLICABILITY AND EXPIRATION

The warranties set out above are extended to all owners in the original chain of distribution. The warranties and obligations of Arrow Specialty Company shall expire and be of no further effect upon the dates of expiration of the applicable warranty periods.

The foregoing sets forth Arrow Specialty Company's only obligations and owners' exclusive remedy for breach of warranty, whether such claims are based on breach of contract, tort (including negligence and strict liability), or other theories, and the foregoing is expressly in lieu of other warranties whatsoever expressed, implied, and statutory, including without limitation, the IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS.

Notwithstanding the preceding, in no event shall Arrow Specialty Company be liable for any direct, special, incidental or consequential damages (whether denominated in contract, tort, strict liability, negligence or other theories) arising out of this Agreement or the use of any Products provided under this Agreement.

Any action arising hereunder or relating hereto, whether based on breach of contract, tort (including negligence and strict liability), or other theories must be commenced within one (1) year after the cause of action accrues or it shall be barred.

Express Limited Warranty for
VR Products Used in Stand-By Applications

STAND-BY DEFINITION: A product used as backup or secondary source of electrical power, which operates at Arrow Specialty Company's stand-by rating, for the duration of a prime power source outage.

I. **TERMS OF EXPRESS LIMITED WARRANTY**
Arrow Specialty Company warrants that it will repair or replace, at its election and expense, any part of an engine, or product (hereinafter referred to as "Products") manufactured by Arrow Specialty Company, which proves to have had a defect in material or workmanship.

II. **TERM LIMITATIONS OF EXPRESS LIMITED WARRANTY**

A. This coverage shall commence upon initial new Products start-up date and shall expire upon the earlier of the following:
   1. 36 months after the initial new Products start-up date; or
   2. 48 months after the original shipment date of the covered Products by Arrow Specialty Company.
   3. 2,100 hours of operation of the covered Products.

III. **ARROW SPECIALTY COMPANY'S RESPONSIBILITIES UNDER THE EXPRESS LIMITED WARRANTY**
Arrow Specialty Company shall be responsible for:

A. The repair or replacement, at Arrow Specialty Company's election of covered defective parts and all reasonable labor required regarding a warranted failure during the express limited warranty and term. All such labor shall be provided by Arrow Specialty Company's authorized contractor or distributor.
B. Reasonable and necessary travel and expenses incurred by Arrow Specialty Company's authorized contractor or distributor.
C. Replacement of lubricating oil, coolant, filter elements, or other normal maintenance items that are contaminated and/or damaged as a direct result of a warranted failure.

NOTWITHSTANDING THE FOREGOING, ARROW SPECIALTY COMPANY SHALL NOT BE RESPONSIBLE FOR LABOR COSTS ASSOCIATED WITH WARRANTY CLAIMS.

IV. **OWNER'S RESPONSIBILITIES UNDER THE EXPRESS LIMITED WARRANTY**
Owner shall be responsible for:

A. The operation and maintenance of the Products within the guidelines established by Arrow Specialty Company.
B. Making the Products available to Arrow Specialty Company or Arrow Specialty Company's authorized contractors or distributors for any warranty repair, during normal business hours.
C. All additional costs incurred for premium or overtime labor, should owner request that repairs be made on a premium overtime schedule.
D. All costs incurred as the result of removal or reinstallation of the Products as may be required to effect any warranted repair.
E. All administrative costs and expenses resulting from a warranted failure.
F. Any costs of transportation, towing, repair facilities, or associated costs.
G. Loss of revenue and loss of/or damage to real and/or personal property.

V. **LIMITATION OF ARROW SPECIALTY COMPANY'S OBLIGATIONS**
The obligations of Arrow Specialty Company under this express limited warranty shall be waived and voided, and Arrow Specialty Company shall not, thereafter, be responsible for:

A. Any failure resulting from owner or operator abuse or neglect, including but not by way of limitation, any operation, installation, application, or maintenance practice not in accordance with guidelines or specifications established by Arrow Specialty Company; or
B. Any failure resulting from unauthorized modifications or repairs of the Products or;
C. Any failure resulting from overload, overspeed, overheat, accident, improper storage; or
D. Failure of owner to promptly provide notice of a claimed defect; or
E. Failure of Products for which Arrow Specialty Company did not receive properly completed start-up reports; or
F. Repairs of a covered failure performed with non-genuine Arrow Specialty Company parts; or
G. Repairs of a covered failure performed by non-authorized contractors or distributors; or
H. Failure to make Products available to Arrow Specialty Company or its authorized representatives, or
I. Failure to supply documents such as drawings and specifications relating to the specific application of the Products.

VI. **APPLICABILITY AND EXPIRATION**
The warranties set out above are extended to all owners in the original chain of distribution. The warranties and obligations of Arrow Specialty Company shall expire and be of no further effect upon the dates of expiration of the applicable warranty periods.

The foregoing sets forth Arrow Specialty Company's only obligations and owners' exclusive remedy for breach of warranty, whether such claims are based on breach of contract, tort (including negligence and strict liability), or other theories, and the foregoing is expressly in lieu of other warranties whatsoever expressed, implied, and statutory, including without limitation, the IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS.

Notwithstanding the preceding, in no event shall Arrow Specialty Company be liable for any direct, special, incidental or consequential damages (whether denominated in contract, tort, strict liability, negligence or other theories) arising out of this Agreement or the use of any Products provided under this Agreement.

Any action arising hereunder or relating hereto, whether based on breach of contract, tort (including negligence and strict liability), or other theories must be commenced within one (1) year after the cause of action accrues or it shall be barred.

NOTES

ARROW MANUFACTURED
REPLACEMENT PARTS

Caterpillar® Engines
G379 G3304
G398 G3306
G399

Ford® Engines
300 Industrial Engine
Governor

Waukesha® Engines
F2895 P9390
F3521 145G/F817
F5108 140G/F554
L5790 WAK/1197
L7042

Gemini® Engines
G26 G40
Compressor Parts

Fairbanks® Engines
ZC-118 ZC-503
ZC-208 ZC-739
ZC-346

Ajax® Engines
5 x 6½
EA-22, 6½ x 8 CMA
EA-30, 7¼ x 8 CMA
E-30, 7½ x 10 CMA
E-42, 8½ x 10 CMA
DP-60, 9½ x 10 CMA
DP-70/80/160, 11 x 14 CMA
DP-115/230, 13¼ x 16

Piston & Rod Assemblies
180
360
600
800

Arrow Engine Company is in no way associated with Caterpillar®, Ford®, Fairbanks®, Ajax®, Gemini® or Waukesha®. All manufacturers' names and descriptions are for reference only.

OEM

C-Series
*C-46 *C-96
*C-66 *C-106
*C-255

VR-Series
VR-155 VR-310
VR-220 *VR-330
VR-232 *VR-330CF
*VR-260 VR-265
VR-283 *VR-380

A-Series
*A42 *A54 *A62

*K6 Slow Speed Engine

Lufkin Engines
L-333 L-1770
*L-795 L-2165

Witte Engines
98 E15 F32
B12 E20 F42

Arrow Chemical Pumps
*10 Series (beam operated)
*12 & 13 Series (pneumatic)
*430 Series (electric)
*500 & 510 Series (pneumatic)
*Solar Chempump

*VRC-2 Gas Compressor

Gas Products
*Volume Tanks
*Vertical & Horizontal Separators
*Suction Scrubbers
*Meter Runs
*Coalscers
*Skids

* Products currently manufactured by Arrow Engine Company & owned as OEM

ARROW ENGINE COMPANY™
a TRIMAS company

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local 918 583-5711
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