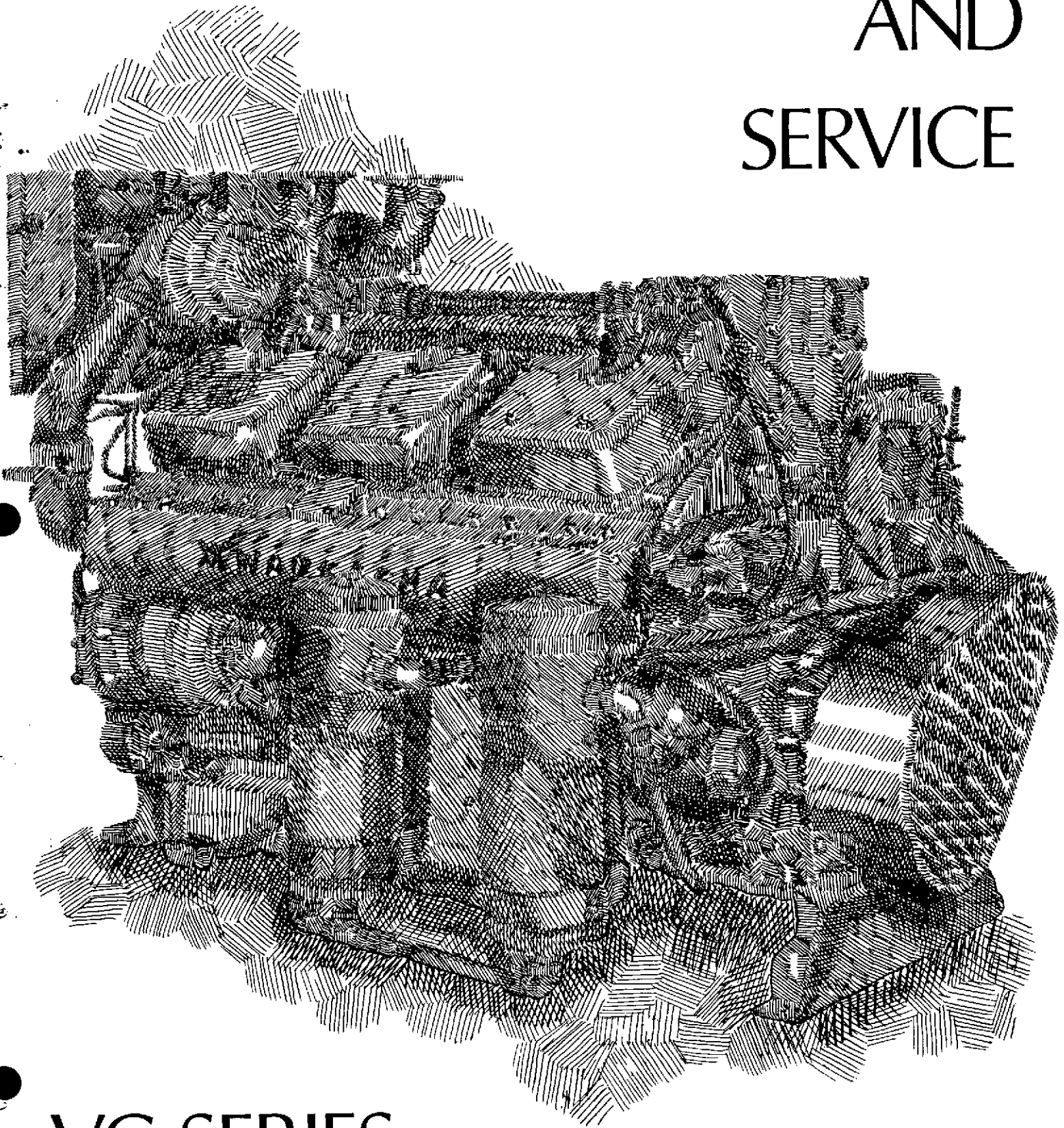


# OPERATION AND SERVICE



VC SERIES

**OPERATION  
AND  
SERVICE  
MANUAL**

**WAUKESHA VC SERIES  
GAS AND DIESEL ENGINES**

**H1077G**

**H1077D**

**L1616G**

**L1616D**

**P2154G**

**P2154D**

**Waukesha**

**DRESSER**

## SAFETY PRECAUTIONS

### EXHAUST GASES

The exhaust products of an internal combustion engine are toxic and may cause injury or death if inhaled. All engine installations, especially those within a closed shelter or building, should be equipped and maintained with an exhaust discharge pipe so that exhaust gases are delivered into the outside air. A closed building or shelter must be adequately vented. A means of providing fresh air into a closed building or shelter is necessary.

### ENGINE FUELS

All internal combustion 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.

### POSITIVE FUEL SHUT-OFF

All engine installations should be equipped with a means of positive fuel shut-off for emergency use when fuel is conducted to the engine from a remote source. Fuels under pressure such as natural gas or liquified petroleum gas, should be controlled by a positive shut-off valve, preferably automatic, other than those integral with the carburetor or gas pressure regulation equipment. It shall be 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 potentially explosive ambient atmospheres should be specially equipped to eliminate spark hazard and it is the responsibility of the engine owner to specify or provide such connections and equipment.

### SAFETY GUARDS

Internal combustion engines must be properly provided with guards against hazards to persons or structures in close proximity to rotating or heated parts and 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 when regulations require their installation on engine crankcases.

### IGNITION SYSTEMS

Breakerless, magneto and battery ignition systems can cause electrical shocks. Avoid contacting these units or their wiring. The reaction from the shock could cause persons to fall or jerk their hands, thus striking other objects and injuries could occur.

### ENGINE SURGE TANK AND RADIATOR 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 cap is removed. Wait until engine and coolant have cooled down before removing 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 to personnel coming in contact with any part of the electrical system during operation. Severe, possibly fatal, shock may result. 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. Before restarting, make sure that all tools and other material are removed from the engine and equipment.

Proper service and repair is important to the safe reliable operation of engines and related equipment. The procedures recommended by Waukesha 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 Waukesha 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 conducive to better work performance and morale, and is a major factor in accident prevention. Accidents resulting from poor housekeeping include tripping over loose objects on the floor, stairs, or platforms, slipping on greasy, oily, wet, or dirty floors, falling of poorly piled material, and cuts from sharp edges.

## ENGINE FAN BLADES

If a fan blade or fan drive shaft is bent or damaged in any way, it should be replaced. No attempt should be made to repair the damaged parts. Fan assemblies must remain in proper balance. When damaged, an unbalanced fan can fly apart during use and create an extremely dangerous condition.

## TURBOCHARGERS

Turbochargers are specifically designed for applicable engine horsepower and altitude ratings. 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.

## ENGINE STORAGE CHEMICALS

Nucle-Oil contains Petroleum Distillate. Harmful or fatal if swallowed. Avoid contact with skin. Vapor is harmful. Causes irritation of eyes, nose, throat and skin. Use only with adequate ventilation. Avoid prolonged or repeated breathing of vapor. Avoid contact with skin, 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 speaking, 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 for the engine installation. Select alternate routes of escape from any engine installation and post such routes in accordance with local and government requirements.

### CLEANING SOLVENTS

Use approved cleaning solvents in a well ventilated area. Avoid breathing fumes. Keep away from open flames or sparks. Do not use gasoline or paint thinners or other highly volatile fluids for cleaning. Breathing carbon tetrachloride or carbon disulfide fumes can be fatal. 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

If a welding gas cylinder is damaged by falling or being struck, it could burst with destructive force. Cylinders must be stored in accordance with manufacturer's specifications and applicable safety requirements.

When welding, brazing or cutting with acetylene, check valves should be installed between the regulators and hoses to prevent flashback into the regulators and supply tanks. Without these check valves, the 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 an 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.

### 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 outlet; instead grasp the plug to remove it from 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 accidentally shorting an electrical connection.

Never expose batteries to open flame or electric spark. Battery action generates hydrogen gas which is flammable and explosive. Don't 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 because the battery may rupture or explode. If a frozen battery is suspected, 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.

Both charged and discharged 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.

## WAUKESHA VC SERIES

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

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

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 body of foreign materials. A highly compressed stream of air flowing through a very small opening 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 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 as the sodium or sodium residue can cause severe burns. Sodium burns on the skin are of the same nature as caustic burns. They must be washed with large volumes of cold water before being neutralized with vinegar. The affected parts should then be treated as a burn and medical attention sought.

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

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.

### SAFE DRESS

When around machinery, loose clothing, neckties, rings, wrist watches, bracelets, etc., should not be worn. Severe injuries have resulted from this all too common practice.

### HAIR LENGTH

Long hair worn around rotating equipment is dangerous. Hair is charged with static electricity and can be drawn to a piece of rotating machinery like a magnet. Persons with long hair must wear complete head covering when around rotating machinery.

NOISE PROTECTION

Wear O.S.H.A. approved hearing protection devices when around excessive noise.

FOOT PROTECTION

Wear O.S.H.A. approved steel tip safety shoes.

HEAD PROTECTION

Wear O.S.H.A. approved safety helmets.

EYE PROTECTION

Wear O.S.H.A. approved eye shields, safety glasses, and sweat bands.

RESPIRATORY SYSTEM PROTECTION

Wear O.S.H.A. approved equipment when near dust and toxic fumes to protect the eyes and respiratory system. This type of equipment must be checked and maintained on a regular basis.

REFERENCES

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

The publication of these safety precautions is done for your information. The Waukesha Engine Division, Dresser Industries, Inc. does not, by the publication of these precautions, imply or in anyway 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 insure 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 Waukesha 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.

# INTRODUCTION

The Waukesha Engine Division, Dresser Industries, Inc., supplies this manual as a guide for operating and servicing Waukesha engines. For the convenience of the user certain conventional and well-established maintenance practices have been omitted or included by brief mention only. In such instances, good judgment and common sense should be used as a basis for whatever mechanical operation is involved.

Occasionally, unusual or extreme circumstances may appear to justify some degree of variation from the recommended procedures. When this happens, it is strongly suggested that the problem be submitted to the Service Department of your local Authorized Waukesha Distributor. When requesting information or ordering parts always be sure to include the engine model and serial number from the engine nameplate. In addition, any special features of the installation, or conversions made by the owner, should be mentioned.

Where tabulated data is provided, the user should realize the clearances, part numbers, and so on, are subject to change. Consult your local Authorized Waukesha Distributor if any doubt arises as to the suitability of a given part or clearance.

Throughout this manual we have used symbols to stress important information. These symbols and their meanings are as follows:



. . . . . This symbol precedes information which, if disregarded, may result in injury or death of the user of the engine or to others.



. . . . . This symbol precedes information which, if disregarded, may result in damage to the engine.

Note . . . . .

This symbol precedes information which is vital to the operation or maintenance of the engine.

1	DESCRIPTION
2	INSTALLATION
3	OPERATION
4	SERVICE
5	TROUBLE SHOOTING
6	STORAGE
7	REPAIR AND REPLACEMENT
8	FITS AND CLEARANCES

## DISTRIBUTORS AND SERVICE

The Waukesha Engine Division, Dresser Industries, Inc., has established a system of reputable distributors with trained mechanics and full facilities for maintenance and rebuilding, and to carry an adequate parts stock in all areas of major engine population all over the world. Their sales engineers are available for installation consultation. If you cannot locate a Waukesha distributor in your area, contact the Waukesha Service Department, 1000 West St. Paul Avenue, Waukesha, Wisconsin 53186, or call (414) 547-3311.

Authorized distributors can respond to your service needs more quickly if the following procedures are observed:

1. Give engine model, serial number and specification number which are stamped on the nameplate attached to the crankcase. The serial number is also stamped on the crankcase at either the gear cover or flywheel housing end.
  2. When ordering parts, always furnish the complete description and part number, where known, of the parts wanted. Do not use the words "complete" or "sets" - state the quantity of each item required.
  3. Tell the distributor how and where to ship parts--state whether to ship by freight, express or parcel post--furnish shipping point and post office address. Without specific shipping instructions the distributor will use his own discretion and will not be responsible for any charges by doing so. Be sure to mark your name, address, and where you can be reached on any order for parts as well as on any correspondence.
  4. *Terms on repair--to avoid delay, all repairs will be C.O.D. unless prior arrangements are made with the distributor.*
- In situations which may fall within the parameter of the Waukesha standard warranty obligations, proceed as follows:
1. When placing a request for service, specifically state that the repair is believed to be within the terms of warranty (this may be indicated on the purchase order if desired). Produce documentation showing the date of start up or installation of the engine and the engine model, serial number and specification number.
  2. Once the service or repair is completed, pay for the service and/or parts in accordance with whatever terms were previously arranged, but indicate with the payment that a claim is pending under the provisions of warranty.
  3. Confirmation of the submission of a warranty claim can be requested from the Waukesha distributor handling the repair. This is usually done by a notation on the distributor's invoice to the end user.
  4. The Waukesha Distributor will notify you via letter or credit on an invoice of the decision of Waukesha as to the request for warranty on a particular repair.
  5. Any parts replaced in the repair which may be subject to warranty should be left with the distributor for proper handling.
  6. Any part replaced under warranty assumes the identity of the part which it replaces in regard to warranty. That is to say, if the engine is six months old the new part placed in that engine for a failed part is six months old in regard to any future warranty determination.

Remember - you own the best. If repairs are needed use only Genuine Waukesha Parts purchased from Authorized Waukesha Distributors.



## Waukesha Engine Division Dresser Industries, Inc.

### WARRANTY AND LIMITATION OF REMEDY AND LIABILITY

Effective September 1, 1976

A. Seller warrants only that its products and parts, when shipped, and its work (including start-up), when performed, will meet all applicable specifications and other specific product and work requirements, including those of performance, if any, of this agreement, and will be free from defects in material and workmanship. With respect to products, parts and work not manufactured or performed by Seller, Seller's only obligation shall be to assign to Buyer, to the extent possible, whatever warranty Seller receives from the Manufacturer. All claims for defective products or parts under this warranty must be made in writing immediately upon discovery and, in any event, within eighteen (18) months after shipment, but not to exceed twelve (12) months of service or 4000 operating hours after initial startup, whichever occurs first, and all claims for defective work must be made in writing immediately upon discovery and in any event within one (1) year of completion thereof by Seller. Defective items must be held for Seller's inspection and if requested by Seller returned to the original f.o.b. point, transportation prepaid. THE FOREGOING IS EXPRESSLY IN LIEU OF ALL OTHER WARRANTIES WHATSOEVER, EXPRESS, IMPLIED AND STATUTORY INCLUDING WITHOUT LIMITATION THE IMPLIED WARRANTIES TO MERCHANTABILITY AND FITNESS. It is understood that Seller's warranty shall not apply to products or parts, which in Seller's opinion, have been damaged as a result of overloading, overspeeding, overheating, inadequate maintenance, accident or improper installation or storage.

B. Upon Buyer's submission of a claim as provided above and its substantiation Seller shall at its option either (i) repair or replace its product, part or work at the business establishment of a Waukesha Distributor or other location authorized by Waukesha, during said Distributor normal business hours. This Warranty does not include reimbursement of any costs for transporting the product or part to such establishment, or for removal or reinstallation of a product when necessary in connection with a Warranty repair, or (ii) refund an equitable portion of the purchase price. In no event shall Seller be liable for the cost of labor in connection with replacement or repair of defective parts when the engine or power unit has been in the possession of the using owner or rental operator for a period of six (6) months or longer.

C. THE FOREGOING IS SELLER'S ONLY OBLIGATION AND BUYER'S EXCLUSIVE REMEDY FOR BREACH OF WARRANTY AND, EXCEPT FOR GROSS NEGLIGENCE WILLFUL MISCONDUCT AND REMEDIES PERMITTED UNDER THE PERFORMANCE, INSPECTION AND ACCEPTANCE AND THE PATENTS CLAUSES HEREOF, THE FOREGOING IS BUYER'S EXCLUSIVE REMEDY AGAINST SELLER FOR ALL CLAIMS ARISING HEREUNDER OR RELATING HERETO WHETHER SUCH CLAIMS ARE BASED ON BREACH OF CONTRACT, TORT (INCLUDING NEGLIGENCE AND STRICT LIABILITY) OR OTHER THEORIES; BUYER'S FAILURE TO SUBMIT A CLAIM AS PROVIDED ABOVE SHALL SPECIFICALLY WAIVE ALL CLAIMS FOR DAMAGES OR OTHER RELIEF, INCLUDING BUT NOT LIMITED TO CLAIMS BASED ON LATENT DEFECTS. IN NO EVENT SHALL BUYER BE ENTITLED TO INCIDENTAL OR CONSEQUENTIAL DAMAGES. ANY ACTION ARISING HEREUNDER OR RELATING HERETO WHETHER BASED ON BREACH OF CONTRACT, TORT (INCLUDING NEGLIGENCE AND STRICT LIABILITY) OF OTHER THEORIES, MUST BE COMMENCED WITHIN ONE (1) YEAR AFTER THE CAUSE OF ACTION ACCRUES OR IT SHALL BE BARRED.

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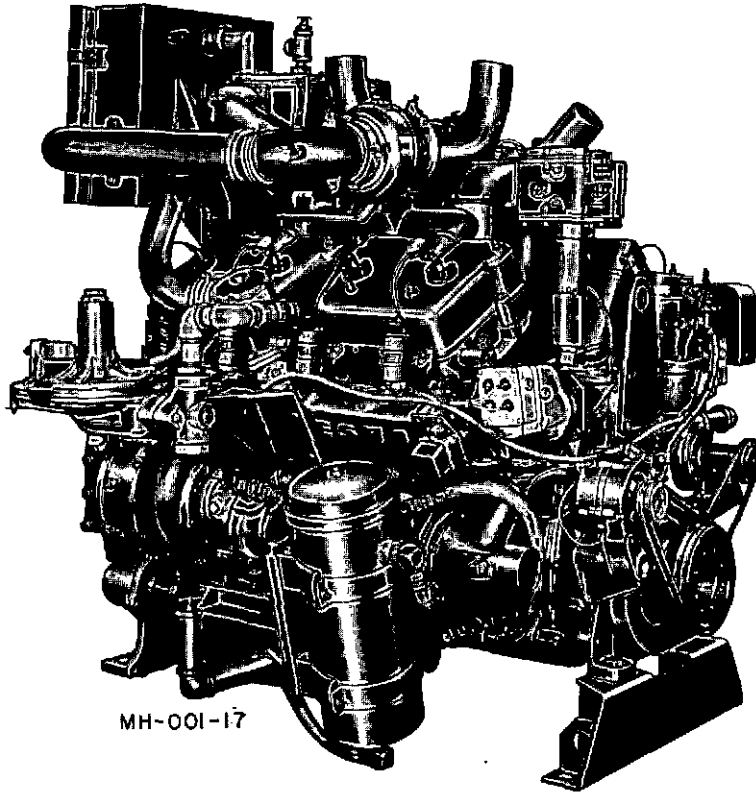
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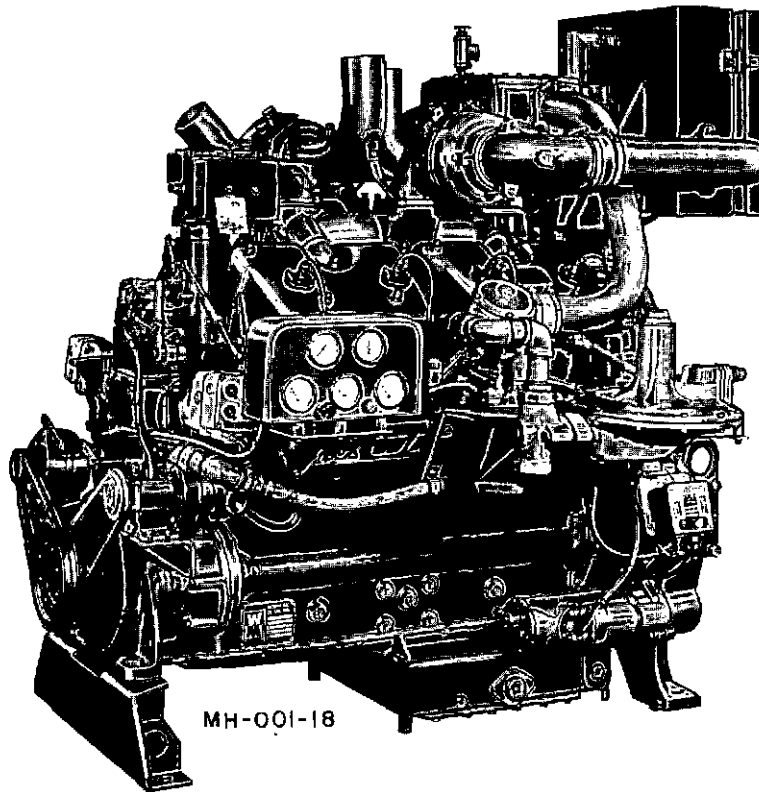
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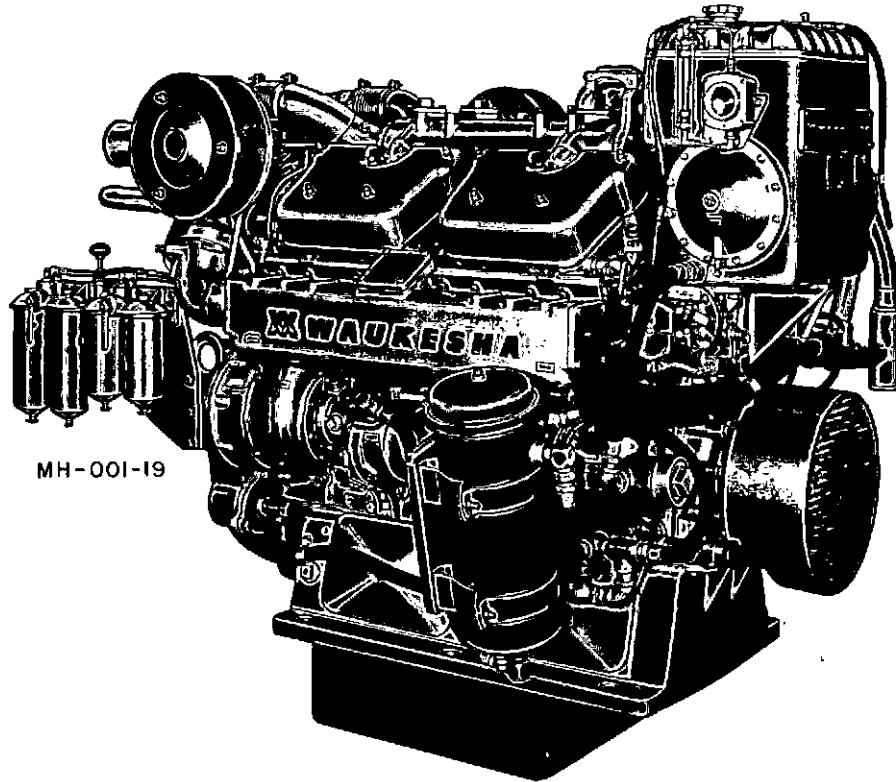
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RIGHT SIDE OF MODEL H1077GSI ENGINE



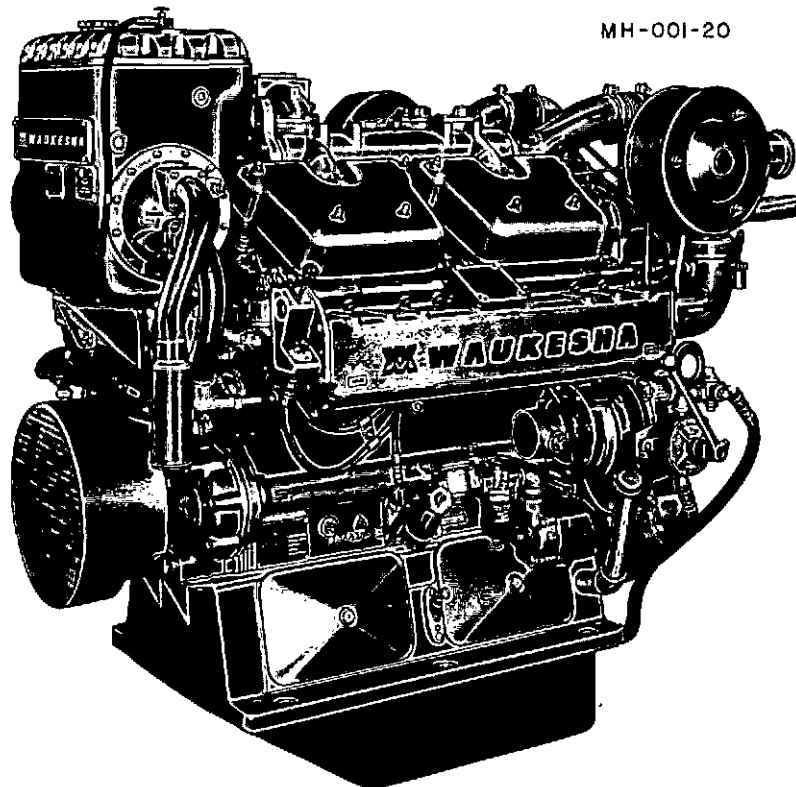
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LEFT SIDE OF MODEL H1077GSI ENGINE



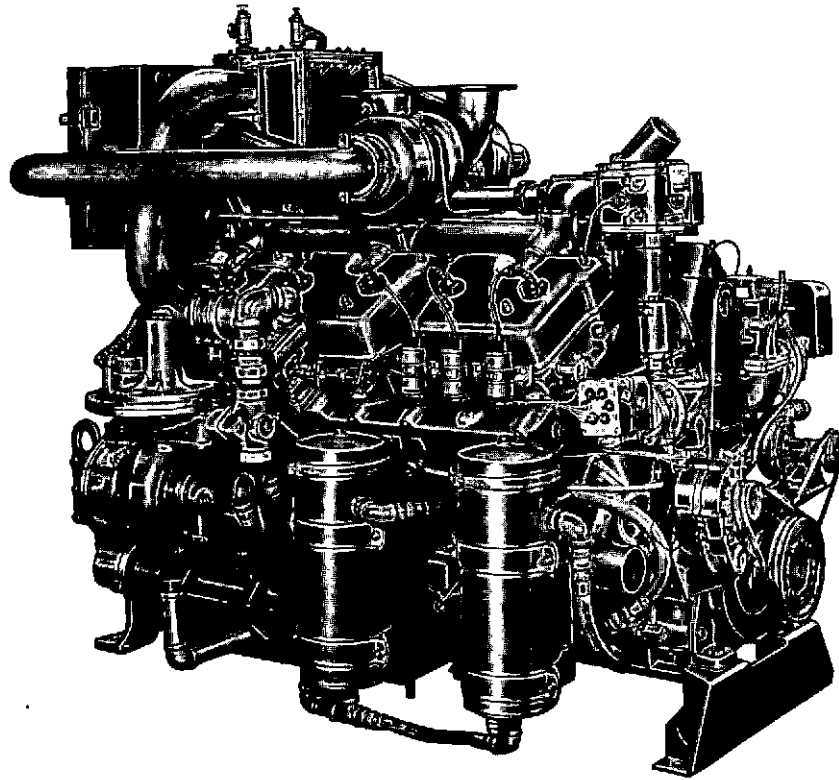
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RIGHT SIDE OF MODEL H1077DSIM ENGINE



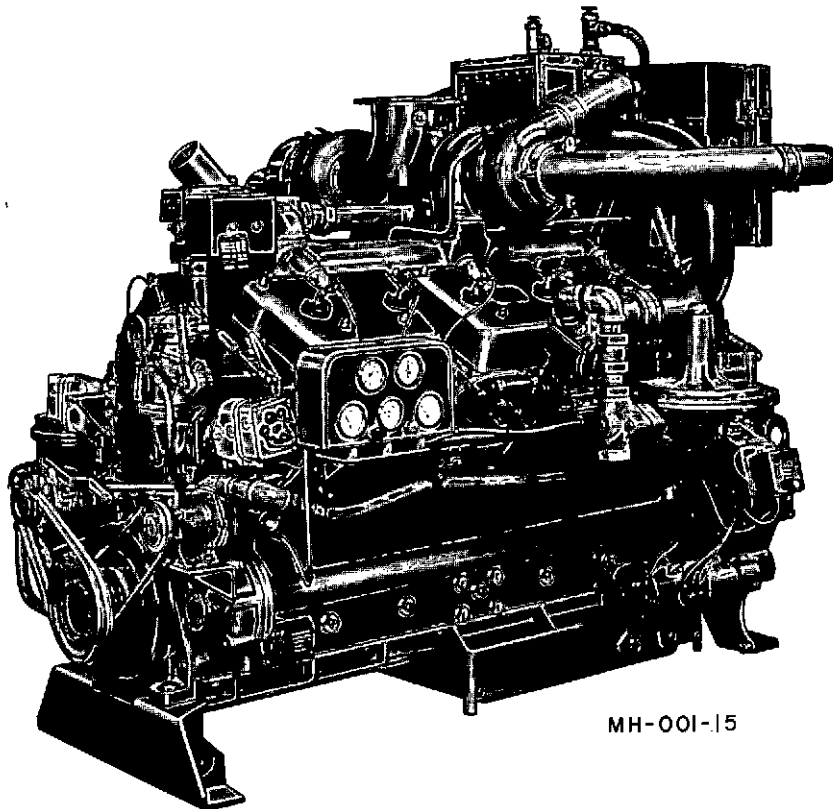
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LEFT SIDE OF MODEL H1077DSIM ENGINE



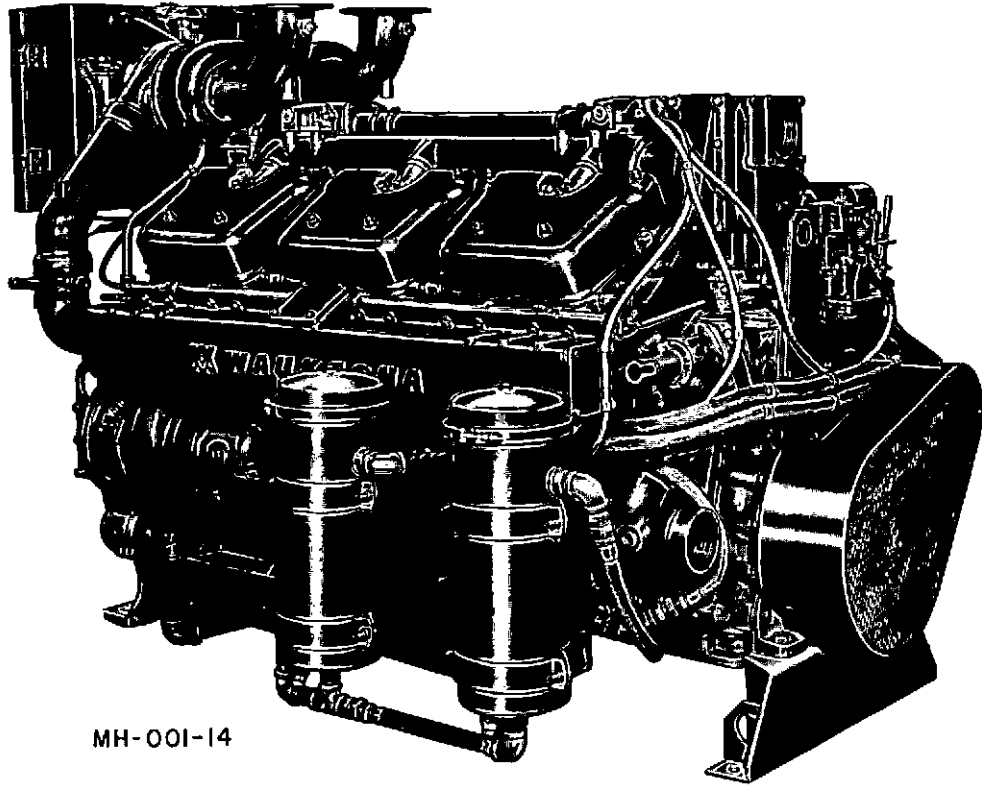
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RIGHT SIDE OF MODEL L1616GSI ENGINE



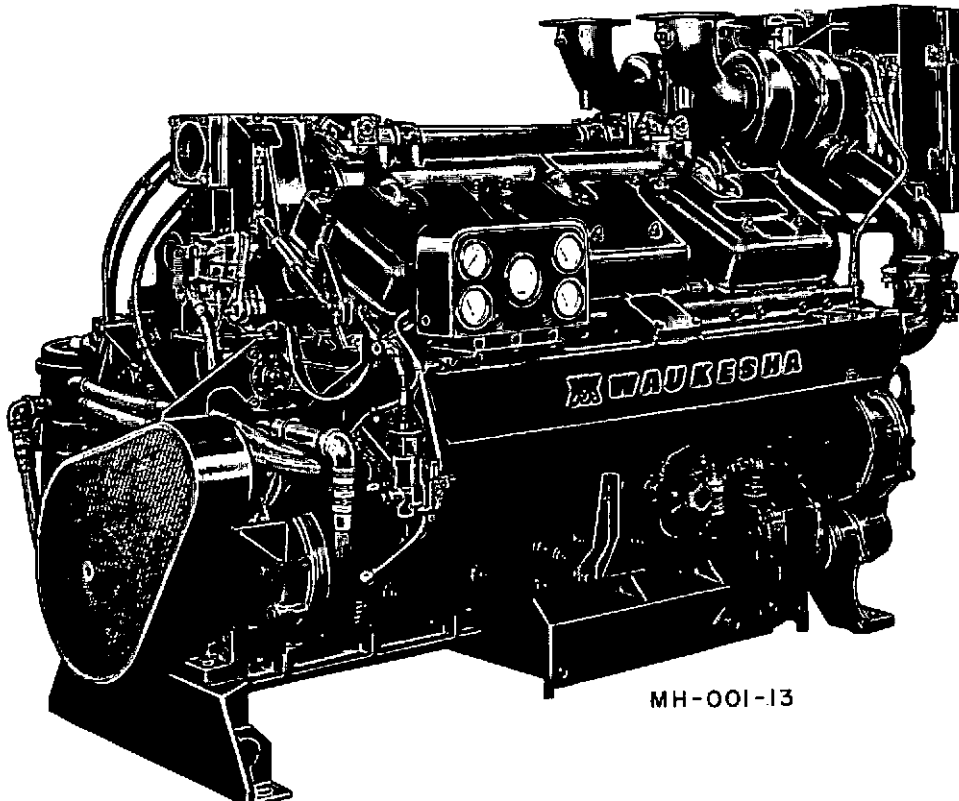
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LEFT SIDE OF MODEL L1616GSI ENGINE



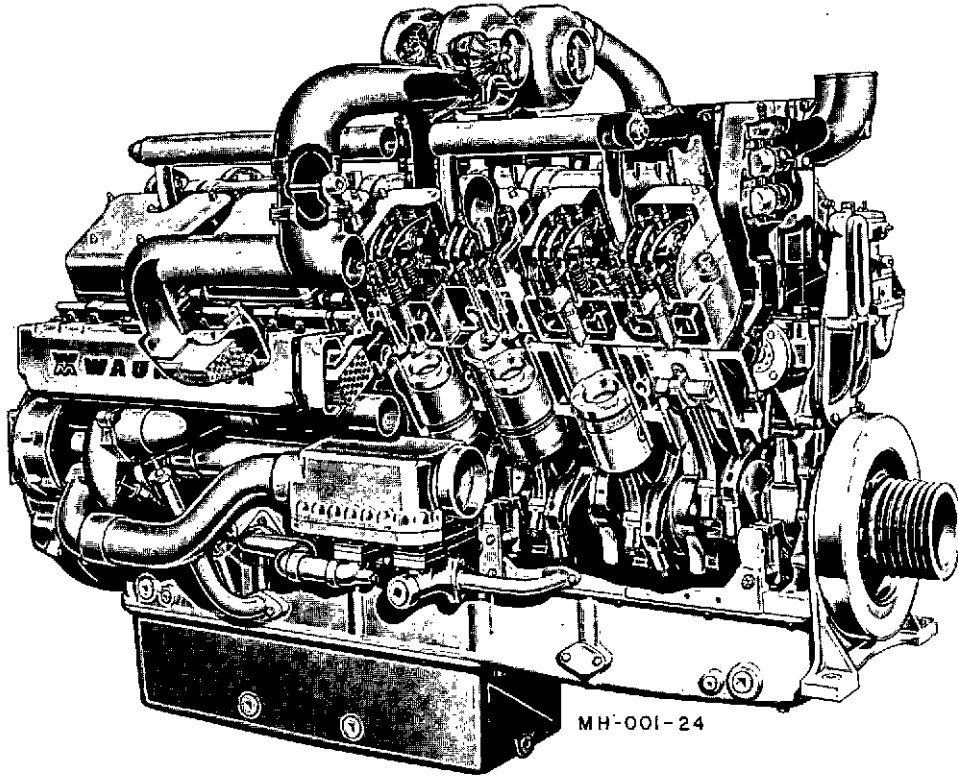
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RIGHT SIDE OF MODEL L1616DSI ENGINE



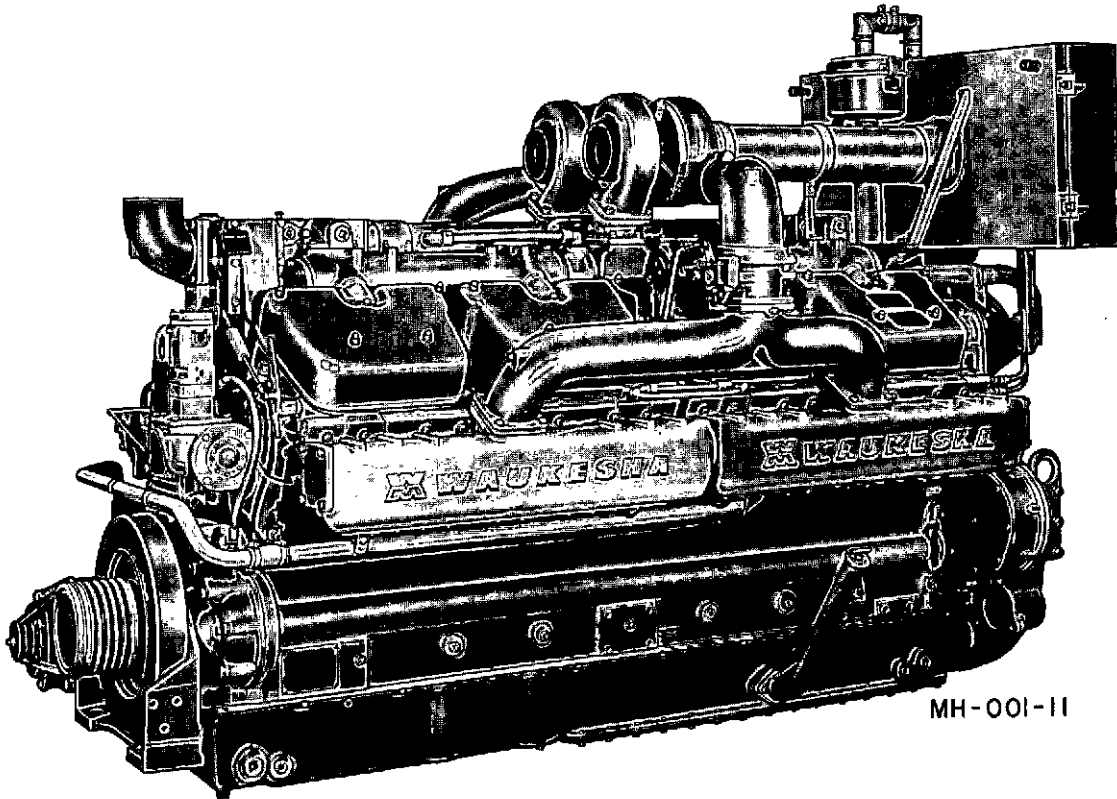
MH-001-13

LEFT SIDE OF MODEL L1616DSI ENGINE



MH-001-24

RIGHT SIDE OF MODEL P2154DSI ENGINE - SECTIONAL VIEW



MH-001-11

LEFT SIDE OF MODEL P2154DSI ENGINE

# CHAPTER 1

## GENERAL INFORMATION & DESCRIPTION

### SECTION I - GENERAL INFORMATION

#### MODEL DESIGNATIONS

The Waukesha Model VC Series gas and diesel engines are "V" type, four-stroke cycle, overhead valve engines, of 5-3/4" bore and 5-3/16" stroke.

The information in this operation and service manual applies to the eight, twelve and sixteen cylinder versions of the VC series gas and diesel engines. Model designations may be interpreted as follows. The prefix letters "H", "L" and "P", as the 8th, 12th and 16th letters of the alphabet, indicate the number of cylinders, that is, 8 cylinders, 12 cylinders and 16 cylinders. The numbers 1077, 1616 and 2154 indicate the nominal displacement in cubic inches. The suffix letters indicate the type of fuel ("G" for gaseous or "D" for diesel) and if the engine is turbo supercharged ("S") and intercooled ("I"). Marine diesels include an ("M"), complete power units include a ("U") and off-highway automotive diesels include an ("A") in the suffix letters. Thus, a Model L1616GSI is a 12 cylinder, 1616 cubic inch displacement engine, operates on gaseous fuel and is turbo supercharged and intercooled.

#### APPLICABILITY OF INFORMATION

Since all of the VC series gas and diesel engines are basically similar, that is, all are the same bore and stroke, utilize rear gear trains, one cylinder head for each two cylinders, (the same head for all gas engines or the same head for all diesel engines), and similar standard accessories, references throughout this manual do not refer to any of the three basic models (H1077, L1616 or P2154) unless certain information is peculiar only to one or two of the three basic models. For example, since the balancing system is peculiar only to the H1077 series, this is pointed out. Conversely, since most of the variations between gas and diesel versions are obvious, this is not pointed out unless necessary for clarification. For example, discussions of gas and diesel fuel systems obviously apply respec-

tively to gas and diesel versions of the VC series; however, diesel engine intercoolers are incorporated in the intake manifolds, while gas engine intercoolers are of a different construction and are mounted on top of the engine and this variation is pointed out.

#### EXTENT AND TYPE OF COVERAGE

Since VC series engines are used in various applications, with corresponding engine component and accessory variations, manual coverage will be limited to the standard design engines and the most commonly used optional equipment and accessories.

This manual is intended to be used for operation and service and does not include overhaul instructions; however, the fits and clearances data will enable a competent mechanic to determine excessively worn parts and to check vital running clearances when replacing precision components. Also, certain important parts relationships and special disassembly and reassembly instructions are included as part of the REPAIR AND REPLACEMENT PROCEDURES Chapter. The exploded and sectional views should prove useful for disassembly and reassembly.

All tabular data and recommendations contained in this manual represent the latest information available at the time of printing, and are of course subject to change.

The operation and service data has been prepared from a practical viewpoint. Consistently careful maintenance of the engine and its fuel, oil and coolant will more than pay for itself in prolonged good performance and reliability. Never overlook the important contribution that properly serviced air cleaners make to extended engine life. In addition, reasonable storage care, especially of the precision parts of the engine, is extremely important.

## WAUKESHA VC SERIES

### ENGINE REFERENCE POINTS

For location and discussion purposes, the following reference points have been established:

**CYLINDER NUMBERING**—Cylinders are numbered consecutively from one to four, or six, or eight, starting from the front of the engine for each bank, i.e. 1R, 1L, 2R, 2L, etc.

**FRONT AND REAR**—The crankshaft pulley end of the engine is designated as the front end

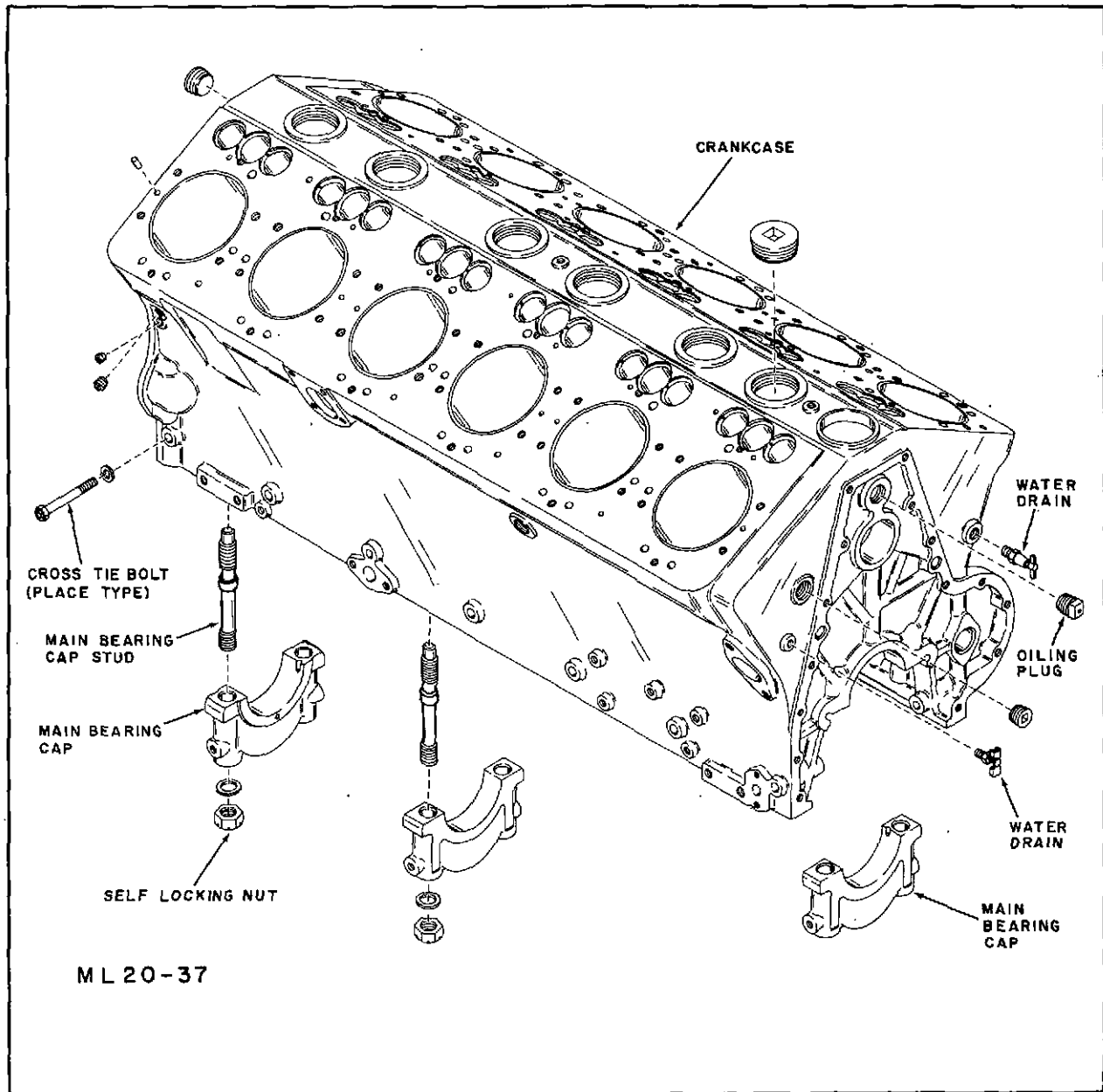
and the flywheel end of the engine is designated as the rear end.

**RIGHT AND LEFT**—This means the right and left as viewed standing at and facing the flywheel end (rear) of the engine.

### ENGINE ROTATION

**STANDARD ROTATION**—Counterclockwise rotation as viewed from the flywheel end.

**OPPOSITE ROTATION**—Clockwise rotation as viewed from the flywheel end.



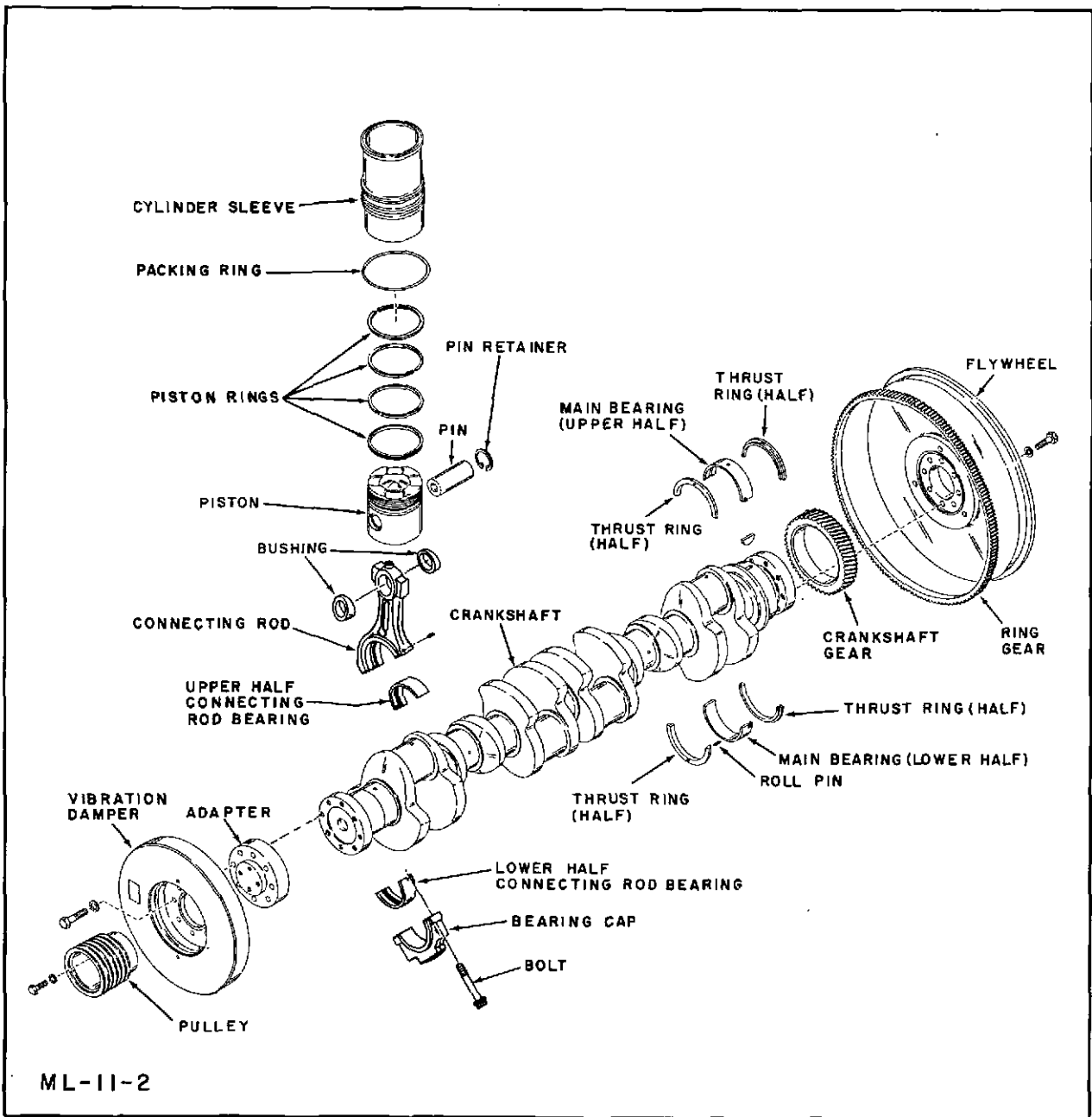
L1616D CRANKCASE - EXPLODED VIEW

SECTION II - GENERAL DESCRIPTION

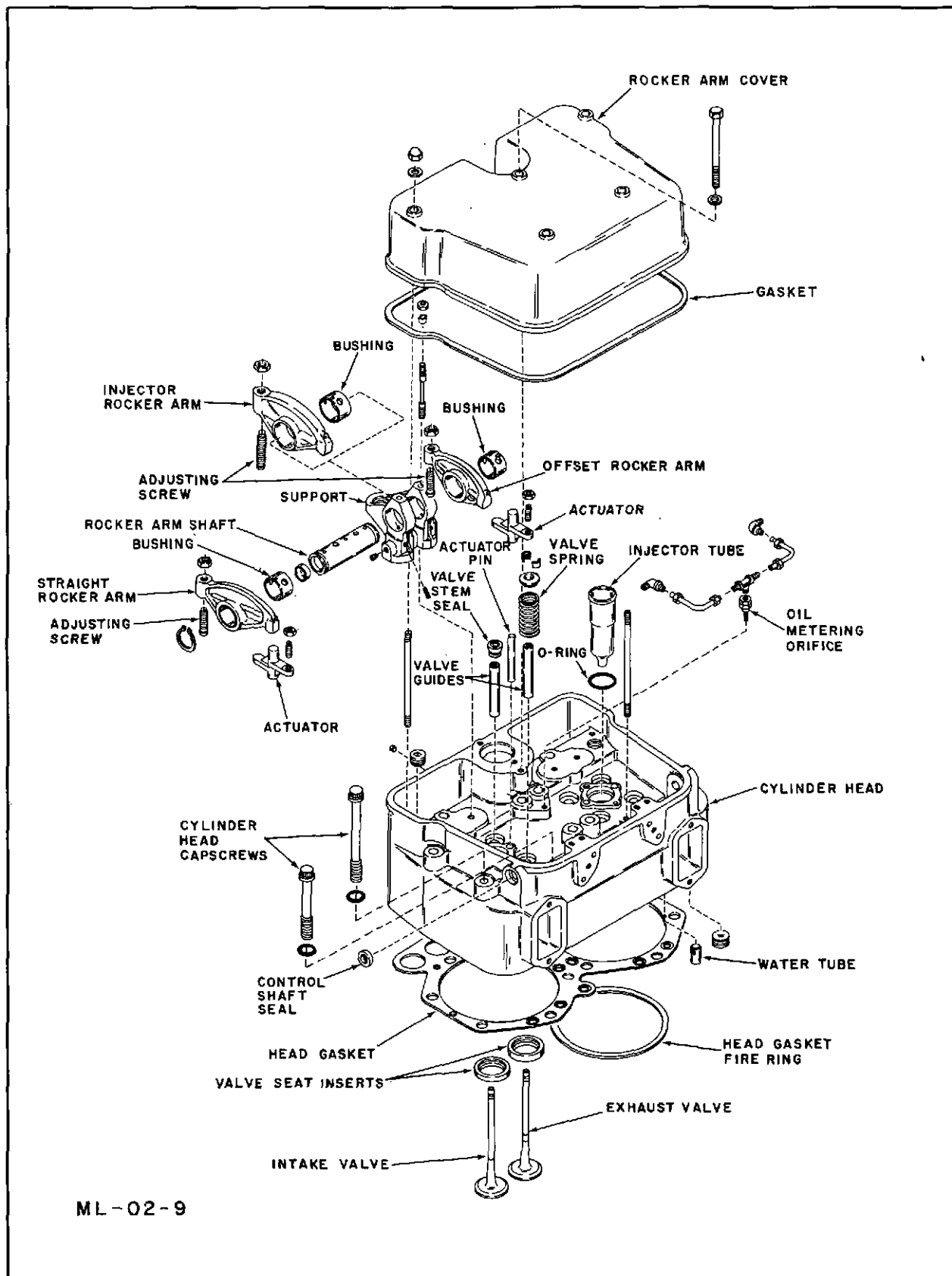
ENGINE CONSTRUCTION

VC series engines are ruggedly built for industrial service, including off-highway automotive and marine applications. Cylinder sleeves are wet-type and are easily replaceable. Main bearing rigidity is assured by side

bolts as well as studs and self-locking nuts. Current main bearing caps are securely positioned by being press fitted in the case instead of by the previously used body-bound studs or dowel pins. Connecting rod caps are securely positioned by a serrated joint as well as by horizontal roll pins through the serrations.



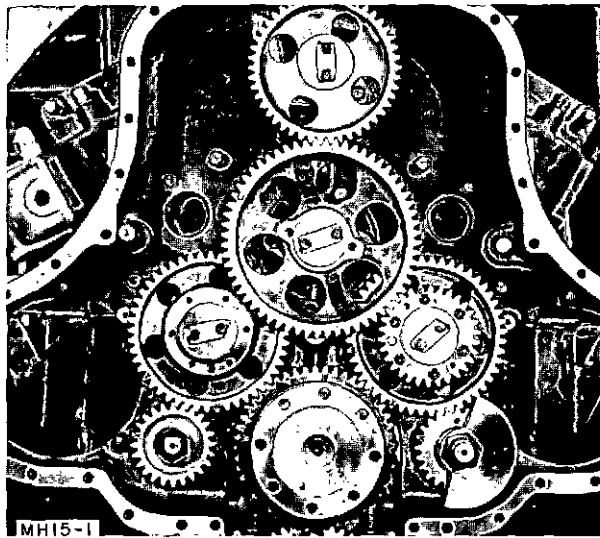
L1616D CRANKSHAFT - PISTON - CONNECTING ROD - BEARINGS



ML-02-9

DIESEL CYLINDER HEAD - EXPLODED VIEW





"X" Balance Shaft Timing Marks  
 "B" or "W" Idler to Crank Timing Marks  
 "C" Camshaft Timing Marks

**H1077G REAR GEAR DRIVES**

Either electric or air starting is used, depending upon the engine application.

**LUBRICATION SYSTEM**

An internally mounted, gear driven, gear type oil pump supplies more than adequate pressure and flow to the engine lubrication system. The oil pump is equipped with a non-adjustable safety relief valve, with an externally mounted, adjustable oil pressure regulating valve (set to 40-50 psi for all applications). The self-priming oil pick-up is protected by a screen and is located at the rear of the oil pan. A combination scavenger and pressure oil pump, which includes a set of scavenging gears in addition to the set of pressure gears, as well as scavenging pick-up and discharge, is utilized when required by the engine application.

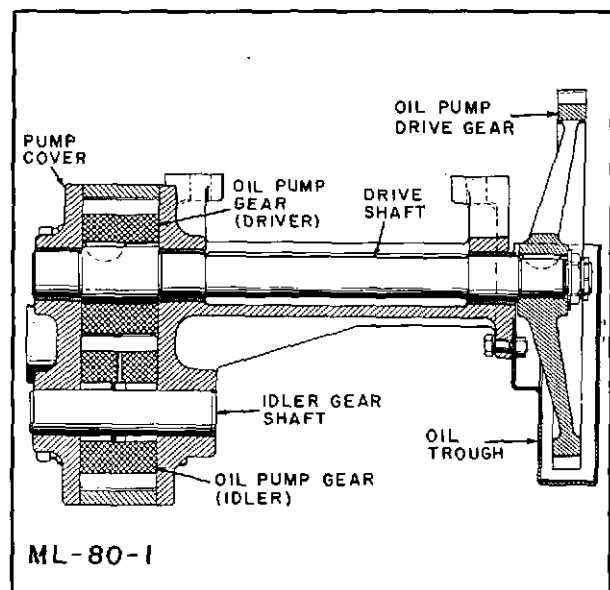
An oil cooler is utilized to assist in maintaining proper oil temperature and viscosity. H1077 and L1616 oil coolers are shell and tube type, while P2154 oil coolers are plate type. Full flow filters with integral by-pass valves are used.

See the lubrication system schematic for oil pressure and return passages and lines. As

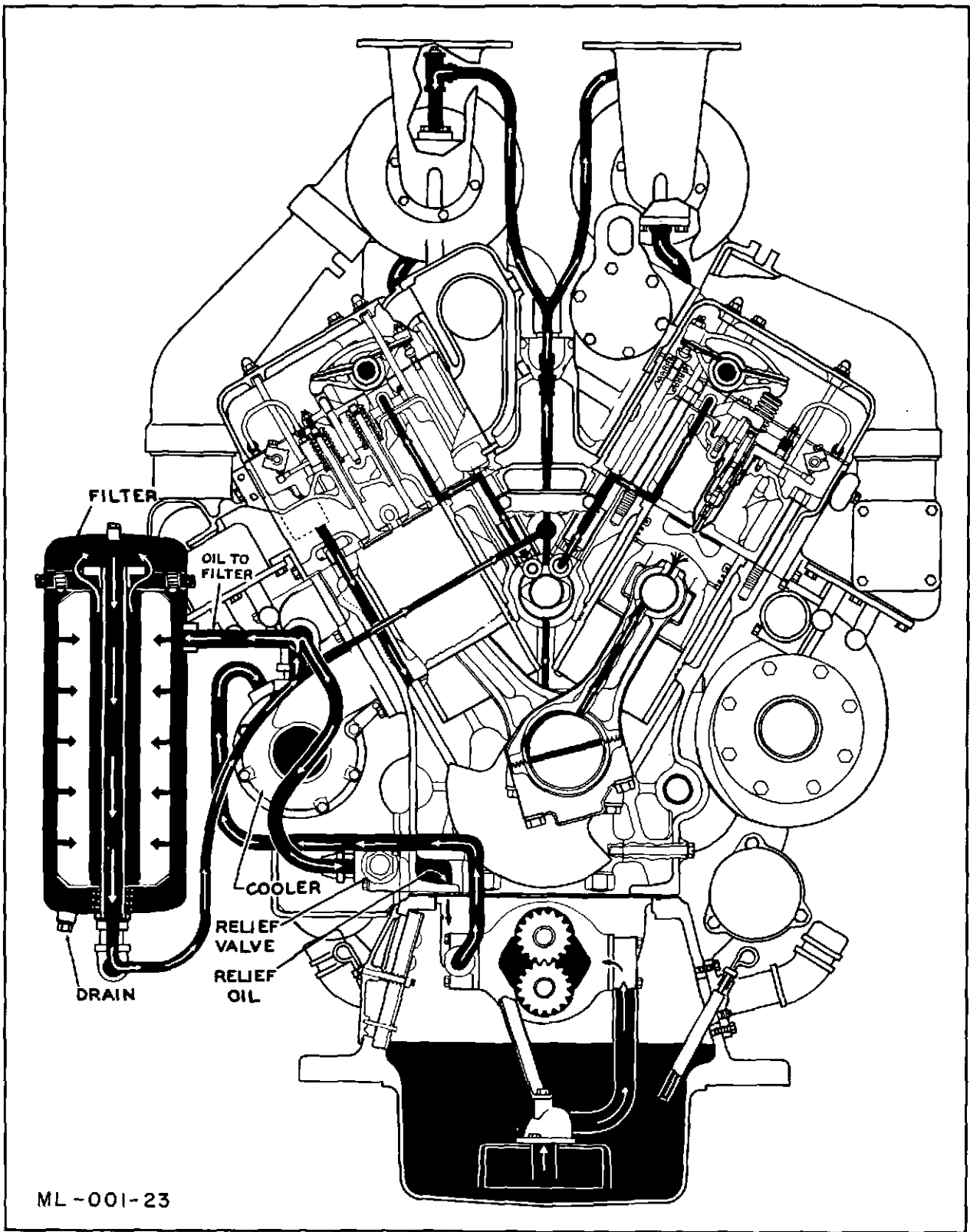
illustrated, the main oil gallery is located directly above the camshaft in the "V" of the crankcase. Pressure oil is supplied to the camshaft journals, main bearing journals, rod bearing journals, piston pin bushings, valve mechanism, hydraulic governor and turbochargers (when applicable), as well as to other engine mounted accessories when required. Both turbocharger oil supply lines are equipped with magnetic plugs as a precautionary measure. Metering orifice fittings in the cylinder heads prevent over-oiling of the valve mechanism. The front and rear gear trains, including the gear driven water pump(s) are spray lubricated via a front oiling plug and the rear idler gear spindles. Oil from the connecting rod journals and from the piston pin bushings sprays on the cylinder walls and is metered by the piston rings for piston and ring lubrication. In addition, pressure oil jets from the upper ends of the connecting rods are directed against the lower sides of the piston crowns, thus providing cooling and preventing heat concentration in this area.

**COOLING SYSTEM**

The right side mounted gear driven water pump operates at engine speed. The water pump ball bearings are lubricated by oil spray from the rear gear train. A spring loaded ceramic water pump seal prevents internal water seepage. Depending upon engine application, a variety of external cooling devices such as radiators,

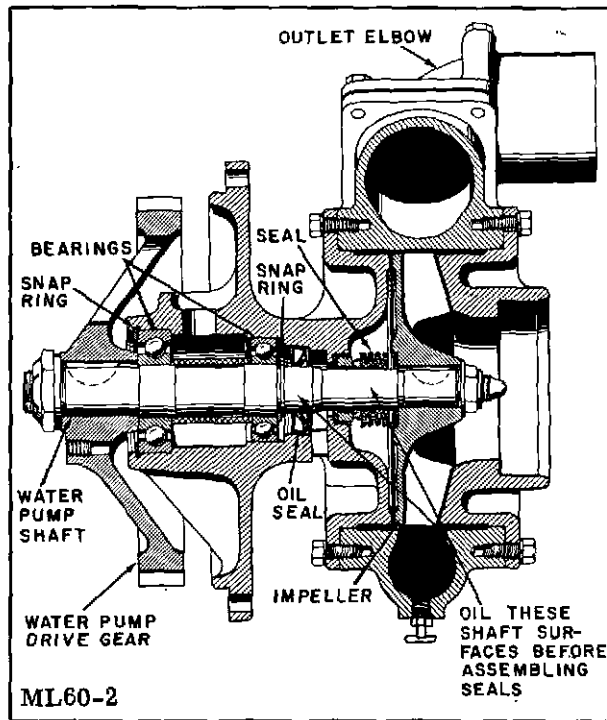


**H1077 OIL PUMP - SECTIONAL VIEW**



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LUBRICATION SYSTEM SCHEMATIC (Turbocharged Marine Diesel)



H1077 WATER PUMP - SECTIONAL VIEW

cooling towers, heat exchangers, keel coolers, etc., are used. Coolant enters through the oil cooler, is pumped into the crankcase water jacket, flows through the cylinder heads and the water cooled exhaust manifolds (when applicable) and into the top water manifold. Previous VC series engines utilized a butterfly type thermostatic control, while current VC series engines utilize a cluster-type thermostat housing.

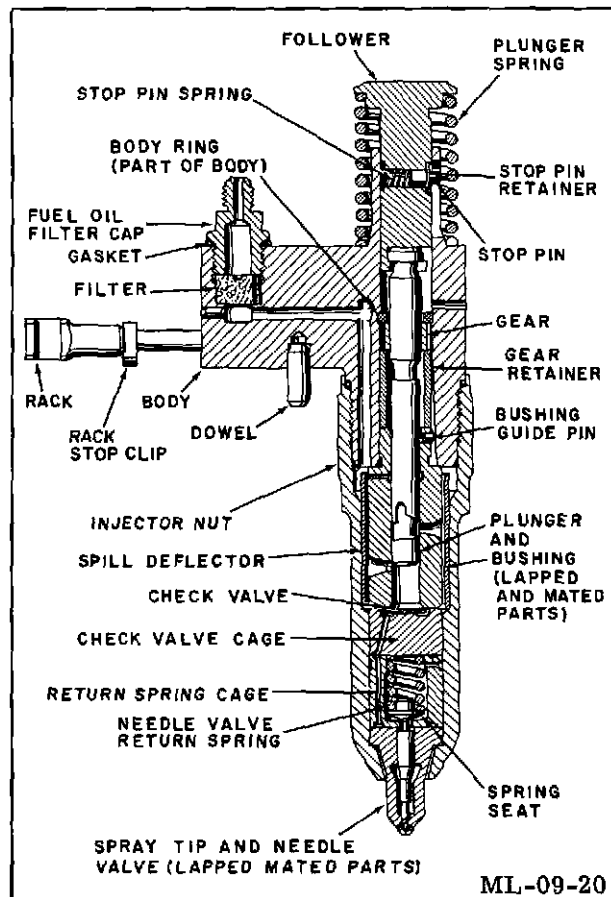
Marine applications, with heat exchanger cooling, include a gear driven sea water pump which is mounted on the left side of the engine. The sea water pump circulates sea water through the tubes of the heat exchanger to cool the engine coolant. The heat exchanger surge tank is equipped with a butterfly type thermostatic control. In marine applications of turbo supercharged diesel engines with a sea water pump, the sea water pump also circulates sea water through the intercoolers, mounted in the intake manifolds, to cool the compressed, heated intake air supplied from the turbochargers. Other turbo supercharged applications require a separate intercooler water pump to circulate coolant from a source other than the engine coolant through the intake manifold intercoolers (diesel engines) or through the externally mounted intercoolers (gas engines).

GAS FUEL SYSTEM

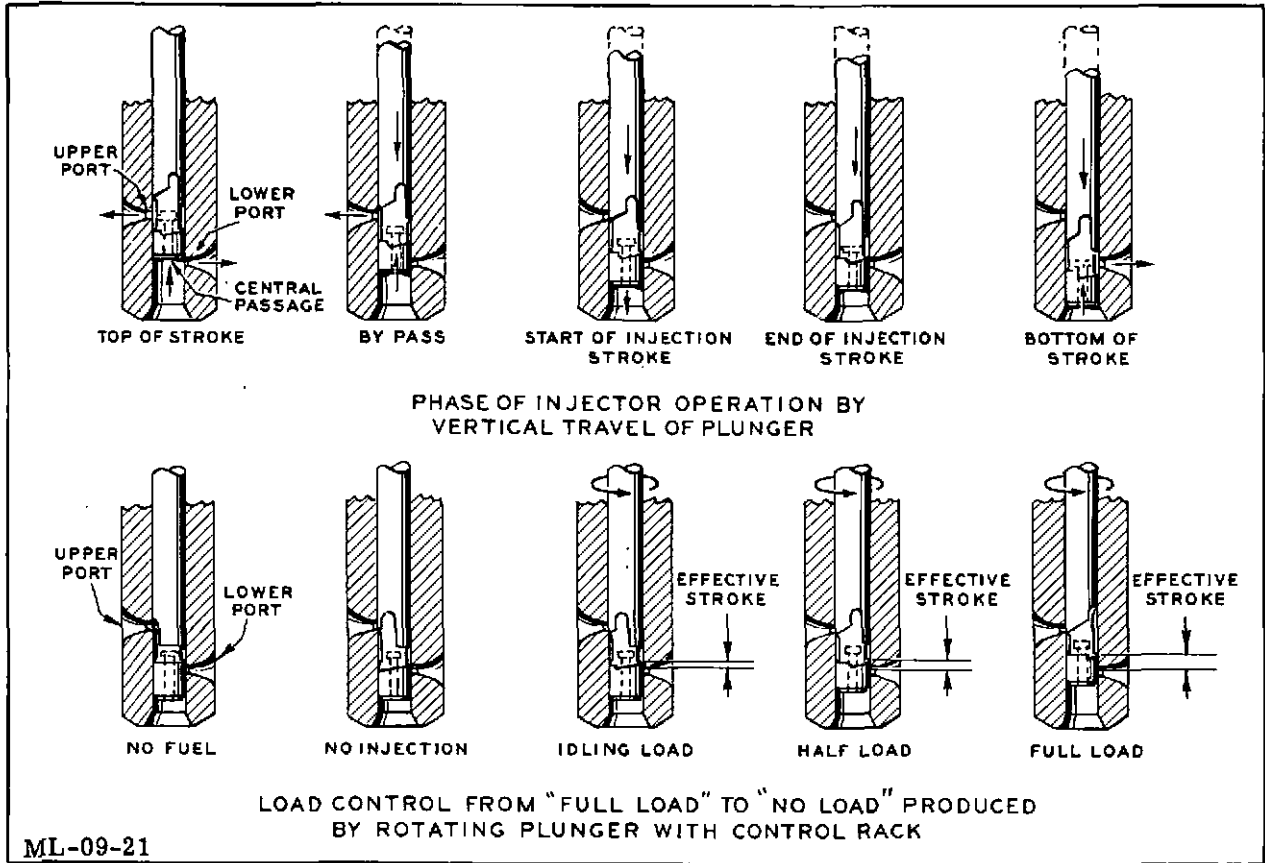
The gas fuel system consists basically of two carburetors (one for each bank) along with two line pressure regulators (for natural gas) or two combination vaporizer regulators (for LPG). Some applications utilize both line pressure regulators and combination vaporizer regulators for operation on natural gas and LPG. With this dual fuel application, changeover is entirely automatic with the engine in operation. Separate load adjustments in the LPG lines allow precise adjustment of the air/fuel ratios for each fuel.

DIESEL FUEL SYSTEM

The diesel fuel system consists basically of a supply tank, supply pump with internal by-pass pressure relief valve, hand primer pump, primary and secondary fuel filters (or dual strainers and filters for marine applications), supply and return manifolds (integral with the intake manifolds), a pressure maintaining return line restriction fitting, unit fuel injectors and the necessary connecting tubing and hoses.



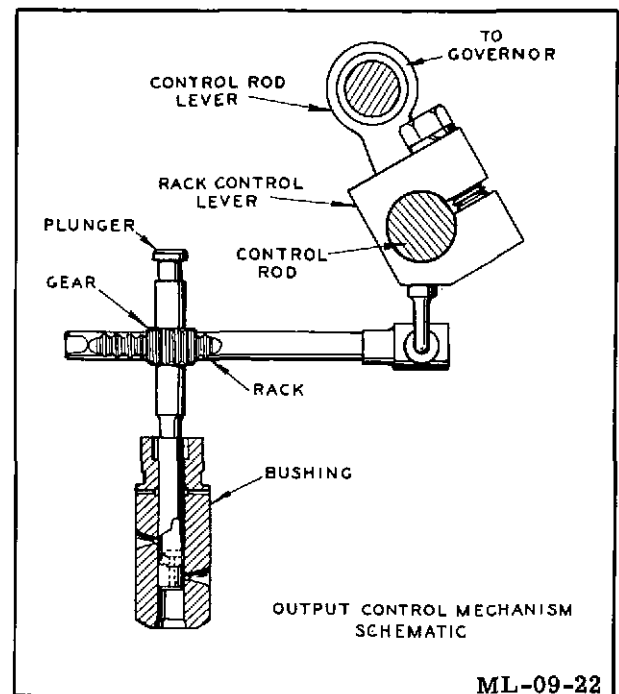
UNIT INJECTOR - SECTIONAL VIEW



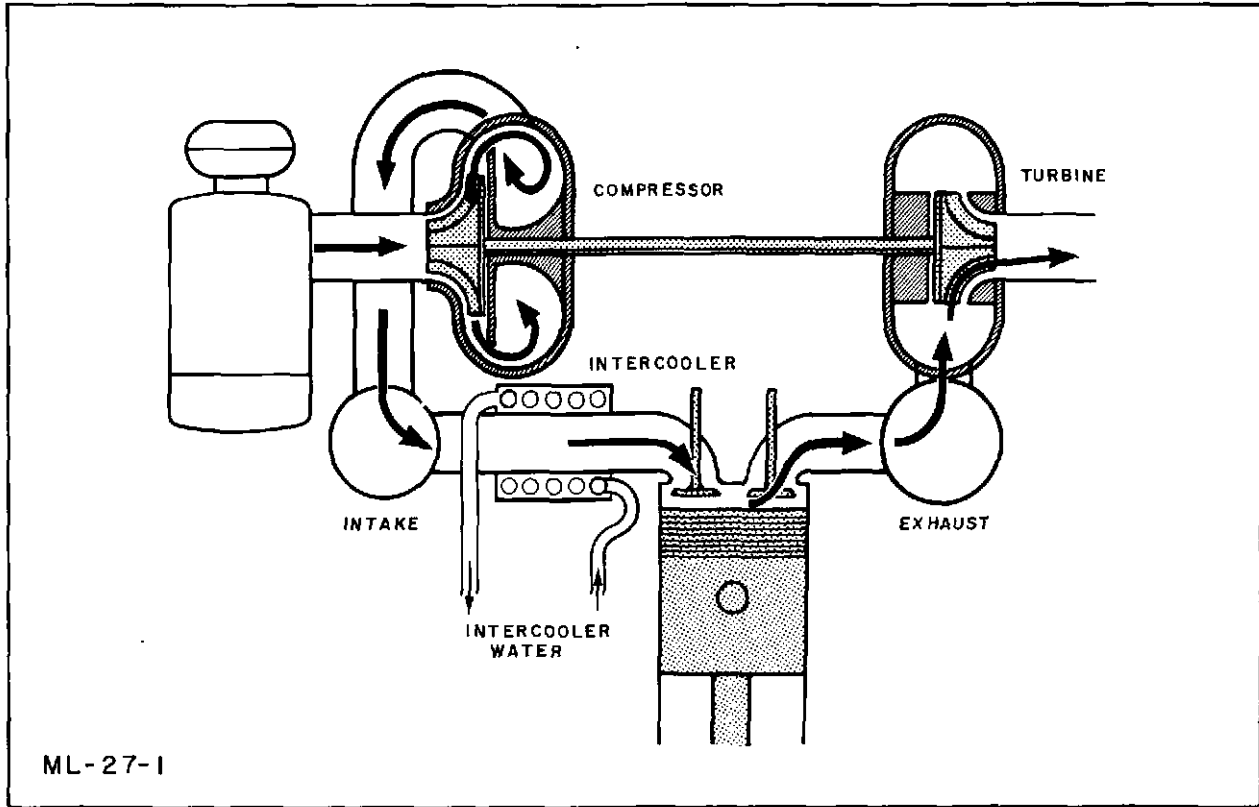
LOAD CONTROL AND STROKE OPERATION

The multiple hole unit injectors, which are actuated via rocker arms and spring-loaded push rods by the engine camshaft, build up the fuel pressure required for injection, as well as meter the fuel according to the engine load requirements as controlled by the governor, and regulate the duration and time of injection. A continuous flow of fuel oil through the filtered inlets and outlets of the injectors furnishes ample fuel for the engine requirements as well as helps cool and purges air from the injectors. See the load control and stroke operation and the unit injector rack control illustrations for operational sequence and output control connections. The sectional view of the unit injector identifies its internal and external components.

Until recently, only certain applications of VC Series diesel engines included injector rack stop clips. All current VC Series diesel engines now include injector rack stop clips, which are designed to limit maximum output of the injectors and thereby limit power output. For further information on the proper use of rack stop clips, refer to Service Bulletin No. 9-1932B.



UNIT INJECTOR RACK CONTROL



TURBOCHARGED AND INTERCOOLED SCHEMATIC

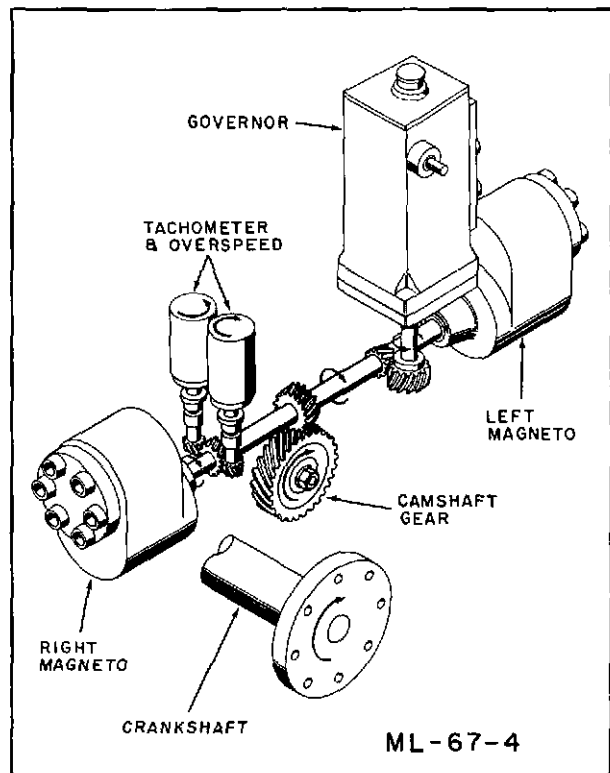
**AIR INDUCTION SYSTEM**

Most VC series engines are equipped with dry panel type air cleaners. Earlier VC series engines were equipped with oil bath type air cleaners. VC series diesel marine engines were previously equipped with flocked screen type air cleaners and are currently equipped with oil-wetted screen type air cleaners.

Turbo supercharged engines utilize two exhaust driven turbochargers (one for each bank), and when intercooled, include either separate water cooled intercoolers in each intake manifold (diesel engines) or a separately mounted box type water cooled intercooler (gas engines). The intercoolers remove heat from the compressed intake air to allow a denser charge of air into the cylinders, which results in increased maximum power output capability of the engine.

**IGNITION SYSTEMS**

VC series gas engines are equipped with either two low tension magnetos (one for each bank) or one breakerless ignition generator, along with individual transformer coils for each



MAGNETO AND GOVERNOR DRIVE

cylinder. The spark plugs mount in tubes in each cylinder head, centered between the four valves of each cylinder. A few applications have utilized distributor ignition or high tension magneto ignition. Ignition drive is through the front accessory drive shaft.

### **GOVERNING SYSTEMS**

VC series engines are equipped with either Woodward SG or PSG hydraulic governors as standard equipment. The governor is either vertically or horizontally mounted and is driven through the front accessory drive shaft. The Woodward SG governor is a speed droop type governor used when isochronous (constant speed) control is not required. The design of the speed droop governor allows the governed system to operate at a slower speed as engine load increases. It is through this characteristic that stability of the governed system is achieved and division of load between paralleled units made possible. The Woodward PSG governor includes buffer type compensation and is normally isochronous, that is, if the engine is not overloaded, the governor maintains the same speed regardless of engine load, except momentarily at the time load change occurs. The PSG governor can be adjusted for speed droop. Both governors use engine supplied oil as a hydraulic medium.

Both governors can be fitted (when required) with speed adjusting motors to enable switchboard operators to match the frequency of an alternator with that of other units or a system before synchronizing and to change load distribution after synchronizing. A manual speed adjusting knob with a friction clutch assembly is included when speed adjusting motors are utilized.

### **SAFETY CONTROLS**

VC series engines are usually equipped with safety controls to shut down the engine in the event of low lubricating oil pressure (below 10 psi), high coolant temperature (above 205° F.) or engine overspeed (usually 10% over high idle speed). Safety controls for marine engines, rather than shutting down the engine, usually activate alarms or similar warning devices.

Gas engines are equipped with an overspeed switch which grounds the ignition for shutdown. The low lube oil pressure and high coolant temperature control for gas engines also grounds the ignition for shutdown. Sometimes dual controls are used with one of the controls activating warning devices prior to reaching shutdown condition.

Diesel engine overspeed is usually controlled by an overspeed governor which allows engine oil pressure to trip air shut-off valves in each intake manifold inlet to shut down the engine. When this system is not used, the air shutoff valves must be either manually or electrically actuated to cut off the engine air supply for emergency shutdown. Some diesel engine applications also include signal micro switches which are actuated when the air shutoff valves are tripped.

Some diesel applications include an overspeed governor which hydraulically over-rides the governor linkage to the injector control shafts to decrease the effective stroke of the injectors until engine speed decreases sufficiently to deactivate it. This slow-down type overspeed governor can also be connected to an air pressure control and utilized as an injector rack shutoff to stop the engine.

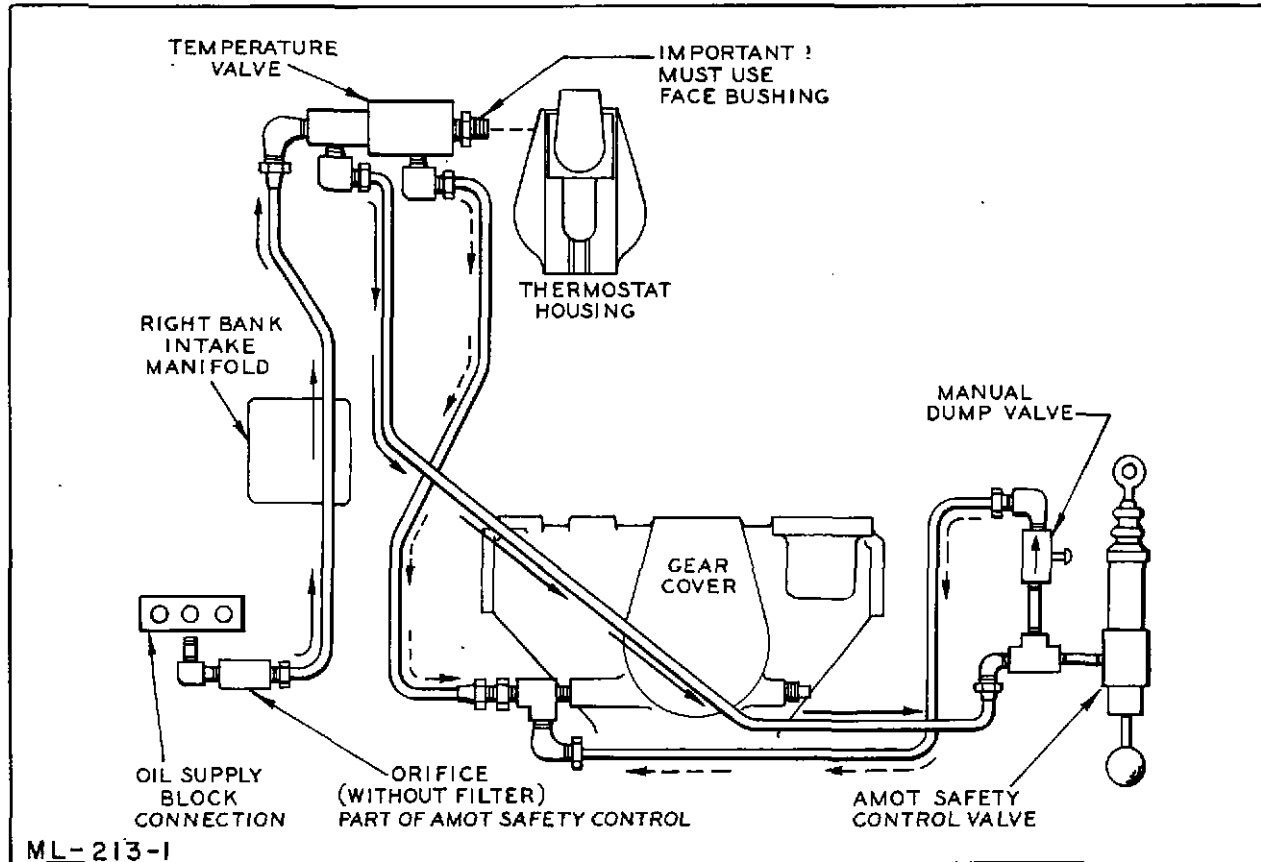
The spring loaded low lube oil pressure and high coolant temperature control used with most diesel engines overrides the governor linkage to the injector control shafts to shut off the injector racks for shutdown. This diesel control system also includes a manually operated push-button (dump) valve to relieve engine oil pressure to the control and thereby effect engine shutdown.

Some off-highway automotive diesels utilize a low lube oil pressure and high coolant temperature idle control which reduces the fuel supply to the fuel manifolds to reduce engine speed to idle instead of shutting down the engine.

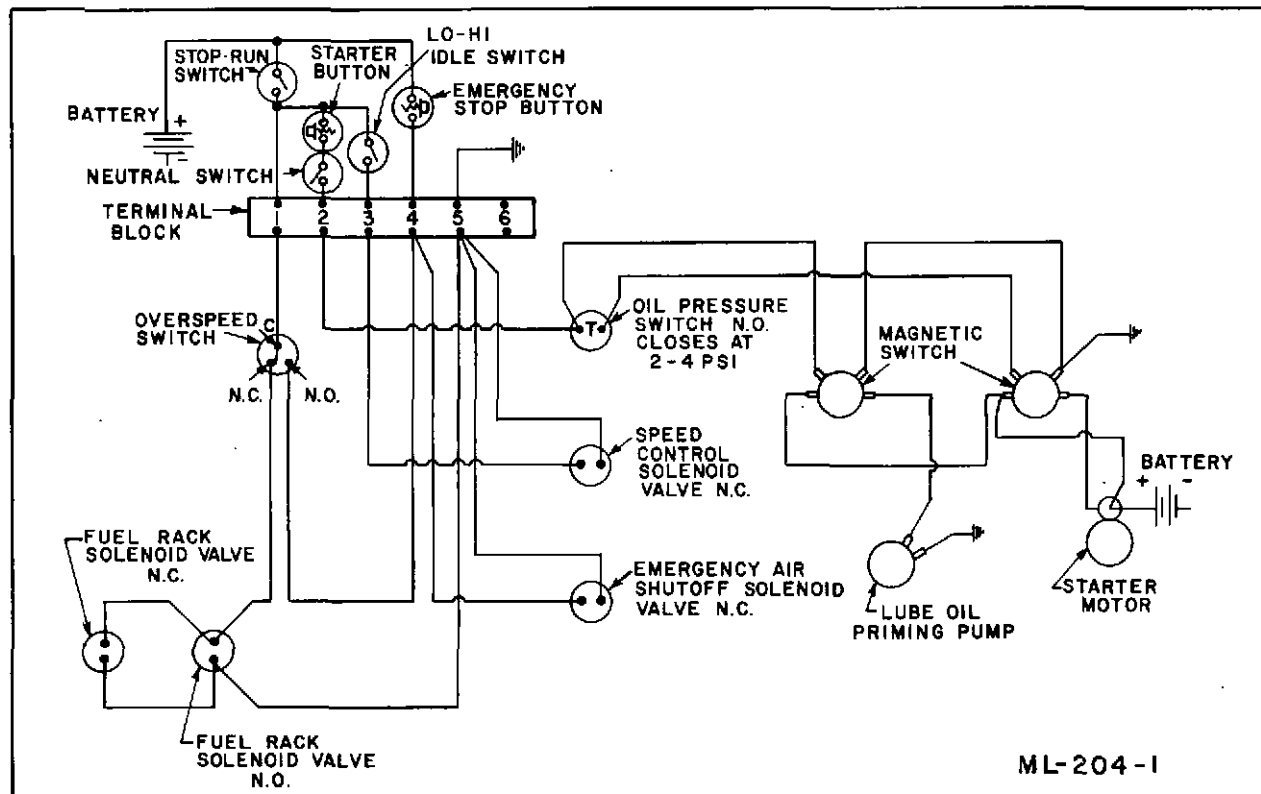
Some applications include an overspeed switch energized solenoid valve which allows engine oil pressure to trip air shutoff valves in each intake manifold inlet to ensure positive shutdown. This solenoid valve, which allows engine oil pressure to trip the air shutoff valve, can also be energized by an emergency stop button. Some off-highway automotive diesels utilize a governor speed control solenoid valve, which is controlled by a manually operated toggle switch, and which allows actuation of an air control cylinder to position the governor control lever for high idle speed. Placing the switch lever in OFF position, or loss of air pressure to the control cylinder, returns the governor control lever to low idle speed position.

When required with surge tank cooling applications, a low coolant level warning switch is included in the safety control system.

WAUKESHA VC SERIES



SCHEMATIC OF TYPICAL DIESEL SAFETY CONTROLS



TYPICAL WIRING DIAGRAM FOR OFF-HIGHWAY AUTOMOTIVE DIESEL

## CHAPTER 2

# GENERAL INSTALLATION REQUIREMENTS

### SCOPE

These are general installation requirements. For more specific and detailed installation requirements, refer to the Waukesha Engine Division Installation Manual or to the Waukesha Engine Division Marine Engine Installation manual.

### AUTOMATIC STARTING

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

The temperature controller for the lube oil heater should be adjusted to open its contacts at 140°F. and close them at 115°F. With the engine shut down, the lube oil temperature at approximately 90°F., and the lube oil circulating pump operating, adjust the relief valve for the circulating pump so the oil pressure in the engine oil header is 3-5 psi. Circulating oil pump pressure in the oil header in excess of 5 psi will flood the turbochargers with oil.

### SPACE REQUIREMENTS

In order to ensure adequate access for engine installation, ventilation and in-service maintenance, engine location must be carefully considered. This is even more important for marine installations, since marine engine overhaul is usually performed with the engine in its operating location.

VC series engines require a minimum of 36" between engines or between engine and wall. End clearance required to remove the camshaft is 48" for the H1077, 66" for the L1616 and 80-1/2" for the P2154. Servicing the front end of the engine requires 38-1/2" from center line of the engine for the H1077, 47-1/2" for the L1616, and 58" for the P2154.

Sufficient overhead clearance is required to permit the use of a chain hoist for removal of heavy engine parts. Cylinder heads weigh 200 lbs. each, H1077 crankcases weigh 1000 lbs., L1616 crankcases weigh 1450 lbs, and P2154 crankcases weigh 2000 lbs. Cylinder head removal requires 34" above the center line of the crankshaft.

### WARNING

Use only engine lifting eyes to position the engine. VC series engines are equipped with two lifting eyes on the rear gear housing and another lifting eye on the front gearcover. **WHEN LIFTING THE ENTIRE ENGINE, SPREADER BARS SHOULD BE USED BETWEEN THE LIFTING POINTS TO AVOID DAMAGING THE ENGINE AND THE LIFTING EYES.** Use adequate cables or chains to easily support the engine. Exercise caution when moving the engine to avoid personnel injury and/or engine damage.

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

### ENGINE FOUNDATIONS, MOUNTING AND ALIGNMENT FOR STATIONARY INSTALLATIONS

#### Engine Foundations

Nearly all stationary VC series engine applications require a foundation or mounting base. This base serves to isolate the engine from the surrounding structure and absorb or inhibit vibration. Equally important, such 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.

#### Trunnion Braces

All VC series diesel engines for off-highway automotive installations and all P2154 gas and diesel engines for industrial installations are equipped with trunnion braces. For detailed information, refer to Service Bulletin No. 14-1992.

## WAUKESHA VC SERIES

### Mounting Box Base Engines

The engine is placed on the sole plates, or skid, and rough aligned with the driven equipment, being sure to keep both the engine and driven equipment level. The engine, and usually the driven equipment, can be leveled by means of the jack screws in the base flange.

### Four Point Mounting

In the case where four point mountings are used, the procedure used to determine the correct thickness of final shims is quite simple. The first step is to bolt the engine down tightly after rough shimming. A dial indicator is then placed near one of the corners. This bolt is then loosened and if the indicator shows a deflection, shims should be added until there is less than .005" dial indicator reading upon loosening and tightening the bolt or bolts. This procedure should be followed for the other three corners, one at a time.

Only one corner should need to be shimmed. All shimming should be rechecked until indicator readings at all four corners in succession give a deflection of less than .005" upon loosening and tightening the bolts.

### Recommended Procedure for Shimming Box Base Engines Mounted on Steel Skids

From time to time, reports of crankshaft, crankcase and bearing damage indicate that improper mounting of box base engines on steel skids has caused definite engine distortion. No installation can be considered complete if a check has not been made for this condition. Obviously, failures resulting from this cause cannot be considered as justifiable warranty claims. This is true even when the engine has been mounted and aligned at the factory since shipping and placement of the engine in position for operation will almost certainly distort the skids.

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 the situation where good alignment would require removing metal from the bottom of the engine or the skid, both approaches being impractical.

We recommend the following procedure for shimming box base engines mounted on steel skids.

#### 1. Attempt To Obtain A True Picture Of The Distortion

Using three indicators, if possible, release all hold down bolts on one side of the engine. If only one instrument is available, take readings at each end and in the middle by loosening and retightening all bolts for each reading. Although involving extra work, this is the only real way to detect a humped skid with one gage. Also, be sure skids are secured to their support and bolts on opposite sides are evenly snugged down. Very deceptive readings will be obtained if engine is rocking laterally with loose bolts on both sides.

#### 2. Be Sure Engine Is Actually Bearing On Skid

Many instances when a skid appears high and the engine appears to be resting on the high point, turn out to be bits of weld spatter, burrs, foreign matter or even scale and paint between the engine base and the skid. It is plainly a waste of time to attempt to shim the rest of the engine base on one side to match a high spot of a "pinpoint" or limited area nature when the proper procedure would be to jack the engine clear (after loosening all bolts) and file or dress the skid or engine base surface clean and flat.

#### 3. Make Up Trial Shims And Recheck

The nature of the shimming procedure is essentially "cut and try". Use easily cut steel or brass shim stock to make up trial shim pads. Remember that the area of the shim pad must be large enough to support the considerable weight and pressure of the engine when the bolts are drawn down. Shims which are too small or not properly stacked tend to shift under load and give false readings. When all trial packs are correct, the tightening or loosening of all bolts on that side of the engine should cause no significant gage reading although a one-half to one thousandth release of shim compression is considered normal.

### 4. Make Up Final Shims

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. If the skid flange is distorted so that the same amount of shim cannot be inserted at both the inner and outer edge of the engine mounting surface on the pan base, install the extra shim needed for the greatest gap under the heavy shim to bring the latter up flush against the engine. Do not lay the heavy shim under the engine and attempt to pack in small bits of shim stock between the heavy shim and the engine base surface. In this type of situation, it is preferable to jack the engine slightly, place the shims needed in a solid and stable stack with the top shim the heaviest and extending the full width of the engine mount surface. The engine should then be lowered onto the shim pack.

### 5. Re-Check All Work on Both Sides

When both sides have been shimmed as recommended, repeat the previous dial indicator checks to be sure that shimmed the second side did not disturb the result initially obtained on the first side.

### Floating Mounts

Where it is necessary to mount either an engine or a skidded unit on flexible mounts, either of the "spring", "cork" or "rubber" type, to isolate vibration from being transmitted to other equipment or the building, it is our suggestion that the supplier of such mounts be consulted. Where mounts are to be supplied with the complete unit, the supplier of such equipment is responsible for the proper selection and placement of the flexible mounts.

Where isolation pads or spring isolators are to be used under an inertia block, the engine should be solidly mounted to the inertia block on sole plates. The isolators should be mounted between the block and the supporting floor. This will give the best vibration dampening for engines and driven equipment installed within buildings. If engines and driven equipment are to be mounted on a common skid, this skid should be mounted solidly to the inertia block.

In many cases, where it is not possible to carry the engine and driven equipment on a floating (spring isolated) "inertia" foundation, the skid mounted unit is isolated from the floor with various spring or vibration absorbing mounts.

### Alignment Procedures

After the engine has been leveled, rough shimmed 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 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.

The correct aligning procedure may vary slightly with different types of driven 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.

### Aligning Single Bearing Generator Couplings

The multiple-disc coupling is widely used to transmit power from an engine flywheel to a single-bearing generator. In this type of coupling, a number of relatively thin steel discs are mounted in a close fitting flywheel counter-bore. The discs provide for a number of important functions as follows:

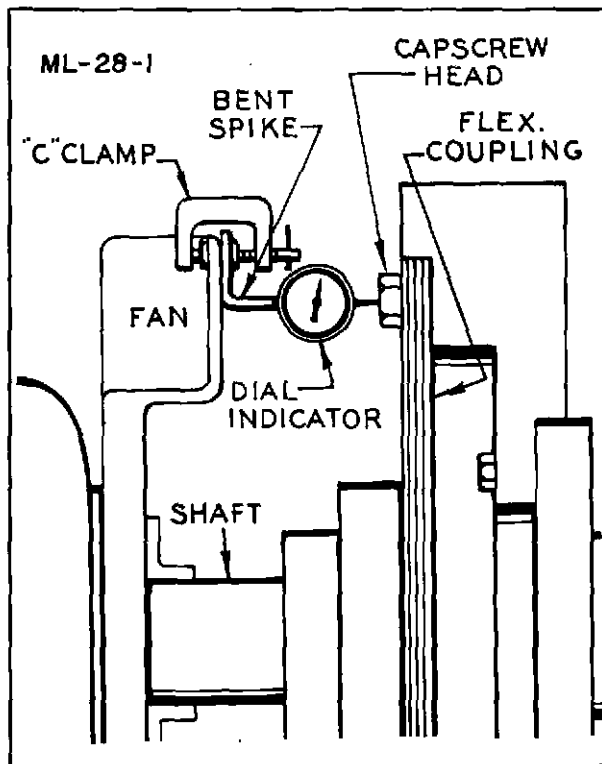
1. Pilot and support the front end of the generator rotor.
2. Eliminate the need for a generator drive end bearing.
3. Permit some minor angular misalignment because of the laminated construction.
4. Permit engine crankshaft end play and some minor longitudinal movement of the rotor.

## WAUKESHA VC SERIES

Misalignment occurs when the center of the generator rear bearing is offset from the center axis of the engine main bearings. If the assembly is allowed to run in this condition, the discs must flex in alternate directions twice for each revolution. This is true for both lateral and vertical misalignment and may be compounded by a combination of both misalignments.

It is important to minimize the amount of disc flexing, since if it is excessive, the assembly will eventually cold fracture, usually near the shaft hub. Also, serious flexing of the discs will cause generator vibration. Perfect bearing alignment, although desirable, is less important than keeping disc deflection to the very minimum possible. Here it is presumed that the pilot bore of the discs is in the exact center and the flywheel counterbore has no practical runout. With these conditions established, perfect bearing alignment will exist when zero deflection of the discs is attained.

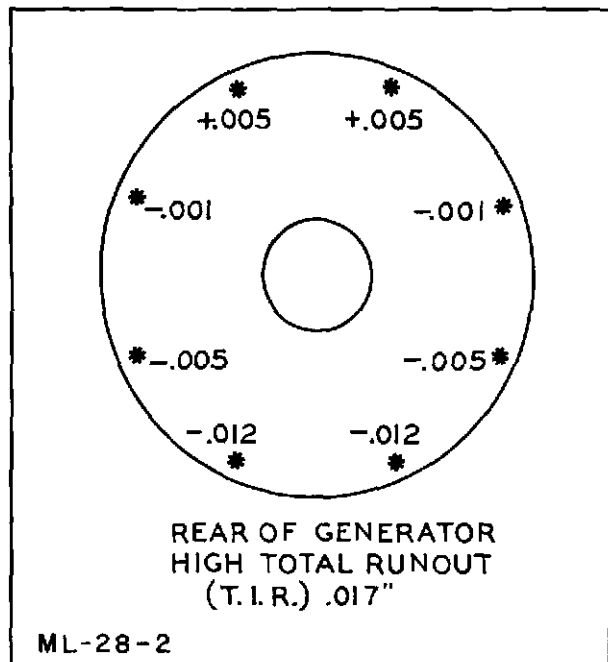
When checking alignment in the field, measurement of disc coupling deflection will demonstrate if misalignment exists. The magnitude of misalignment and the direction of displacement of the generator rear bearing may also be determined from the deflection measurement.



MOUNTING OF GENERATOR COUPLING ALIGNMENT DIAL INDICATOR

To make this check, fasten a dial indicator to either the generator shaft or cooling fan with the point resting on the head of a coupling disc cap screw. This establishes a bridge between the discs and the rotor with the axis of the indicator at a fixed radius from the center of the shaft. The indicator rotates as the engine is turned. Bar the engine over in the normal direction of rotation. Do not allow it to rock back on compression at the end of the travel of each reading. It is unnecessary to zero the indicator since all that is required is a total indicator reading. This will be the sum of the numerical values of the maximum positive and the maximum negative.

Six or eight equally spaced readings will provide a total indicator reading. Half of the total reading will equal the amount of disc bending. A typical example is shown in the illustration.



EXAMPLE OF GENERATOR COUPLING ALIGNMENT RUN-OUT

The example illustrates a total indicated runout (T.I.R.) of .017". This is arrived at by adding plus .005" and minus .012". The indicator appears to be closer to the cap screw head at the top and further from it at the bottom. This indicates that the generator rear bearing is high. Since the side readings are equal, the generator is centered laterally. If shims were removed from under the generator pad to the extent that the .005" plus readings were re-

duced to .0035" minus, the .012" minus would be changed the same amount, to .0035" minus. In brief, one half of the total of .017", .0085", is being added at the top, and the same .0085" is being removed at the bottom.

A simple method for determining the amount of shims to remove is to match the indicator radius against the distance between the support pad shim pack and the indicator. For example, if the radius was 11" and the shims were 33" back, the dimensions relate on a 3 to 1 basis. Three times the correction amount of .0085", or about .025" in shims could be removed to lower the generator.

As a rule of thumb, the T.I.R. should not be more than one thousandth of an inch for each inch of radius (center of shaft to axis of indicator). In the case of the 11" radius used in the example, the T.I.R. allowance would be .011". This would only require a correction of .006" from the T.I.R. of .017". A reading of plus .002" at the top and minus .009" at the bottom would fall within the allowable limit.

After checking alignment, always make a final check of the crankshaft end play!

### **STARTING AIR REQUIREMENTS**

All VC series engines require a one inch diameter pipe to supply compressed air for air starters. Compressed air regulators should be set for 150 psi maximum, with a minimum of 50 psi (gas) or 80 psi (diesel) for H1077s, 75 psi (gas) or 110 psi (diesel) for L1616s, and 100 psi (gas) or 140 psi (diesel) for P2154s required for engine starting.

### **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.

The Waukesha Engine Division 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. Base heat rejection on highest possible load engine will be subjected to. Heat

rejection to jacket water (BTU/HP-Minute) is 55 for naturally aspirated VC gas engines, 44 for turbo supercharged VC gas engines, 43 for naturally aspirated diesel engines, and 40 for turbo supercharged VC diesel engines.

2. Use 185° F. engine water outlet temperature. On compressor applications, use 180° F. engine water outlet temperature to agree with A.P.I. Standard 11K.
3. Base water flow and temperature rise across radiator core or cooler on jacket water pump curve.
4. Pressure drop through radiator core or cooler with full water flow at rated speed must not exceed 3 to 5 psi.
5. 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.
6. 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.
7. 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.
8. Radiators and surge tanks must have 7 psi pressure caps.
9. Provision must be made for de-aeration of coolant, such as divided top tank or separate surge tank.
10. Provision must be made for balance line connection to engine pump suction to prevent pump cavitation.
11. Adequate expansion volume for complete cooling system must be provided in radiator or separate surge tank.
12. Provisions must be made for connecting auxiliary pump to circulate water through oil cooler and/or intercooler where applicable.

## WAUKESHA VC SERIES

13. Maximum back pressure, feeding into radiator or cooler, should not exceed 5 psi at 2000 RPM.
14. Maximum inlet head to jacket water pump is 45 feet of water.

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

Same as for Continuous Duty Operation, except:

2. Use 200° F. (instead of 185° F.) engine outlet temperature.
5. 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 Capacity

The cooling system capacity is 22 gallons for the H1077, 32 gallons for the L1616, and 44 gallons for the P2154 without provision for radiators or other equipment. When adding anti-freeze compounds on a percentage basis remember to include the coolant volume of the radiator and/or other external parts of the cooling system. The following table may be used as a guide.

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

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.

### 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 large access clean-out plugs or plates to permit complete inspection and cleaning of keel coolers or skin coolers at drydocking.
5. Provide readily cleaned sea chests or other arrangements to allow removal of debris from raw water system while underway.

6. Provide easily opened air vents to remove air blocks from cooling system piping and allow immediate priming of system.
7. 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.
8. Keep the system clean!
9. Avoid electrolysis; use zinc anodes or other cathodic protection.

### AIR INTAKE SYSTEM

Huge quantities of combustion air are required for all internal combustion engines. Combustion air requirements for VC series engines may be obtained from your Waukesha 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 or marine engine rooms may upset heating and ventilating 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 and marine

installations. Engine heat radiation is 6 BTU/HP-Minute for naturally aspirated VC series engines and 8 BTU/HP-Minute for turbo supercharged VC series engines. 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. Maximum exhaust back pressure is 18 inches of water for naturally aspirated VC series engines and 12 inches of water for turbo supercharged VC series engines.

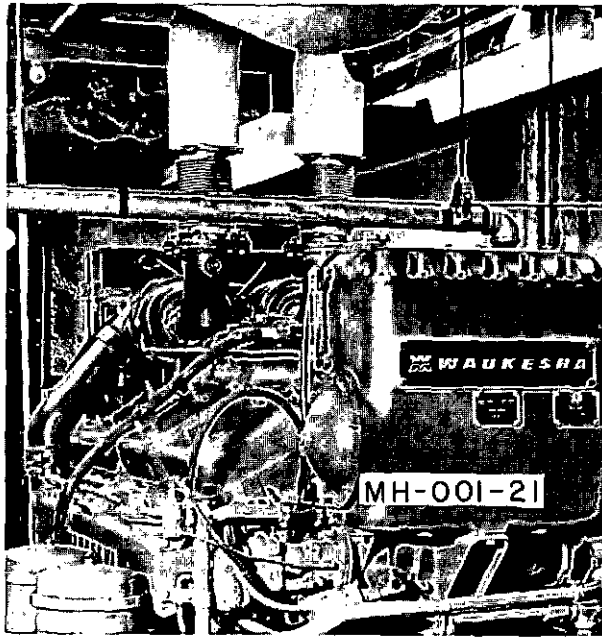
To measure exhaust back pressure, proceed as follows:

1. If the exhaust elbows aren't tapped to measure back pressure, drill and tap a 1/8 inch NPT hole in one side of each exhaust elbow near the inlet to the elbow.
2. Install a tubing connector and a length of copper tubing (to permit dissipation of heat) in each tapped hole and connect a manometer hose and manometer. To ensure accurate measurement, it is important that the manometer line fitting does not protrude beyond the inner surface of the exhaust elbow or pipe. On a turbo supercharged engine, the pipe tap must be located downstream from the turbine.

Measure exhaust back pressure, and for diesel engines record exhaust temperatures, at various speeds up to maximum speed and load conditions.

After the tests are completed, remove the manometer lines and install a pipe plug in each tapped hole.

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.



INDIVIDUAL STACK TYPE INSTALLATION FOR A "V" ENGINE

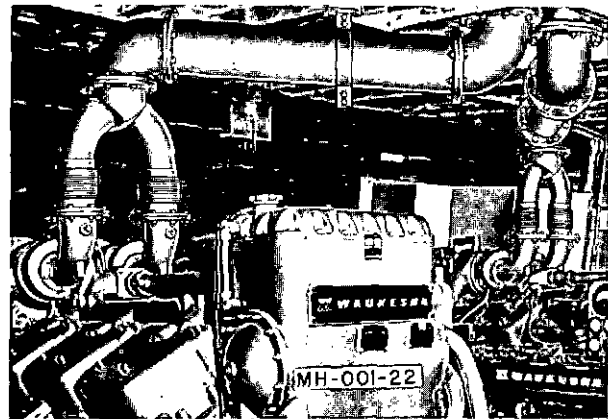
Exhaust pipes must be adequately sized and supported. A condensate trap and drain must be provided at some low point ahead of the engine exhaust manifolds. The back pressures caused by elbows and other pipe bends prohibit their use in a well designed exhaust system. Always use welded tube turns with a radius of four or five diameters.

The best practice with a "V" type engine having two exhaust manifolds is to pipe each separately to individual silencers. If this is not possible, a "Y" connection can be made with the two branches entering the single pipe at approximately 60° angles.

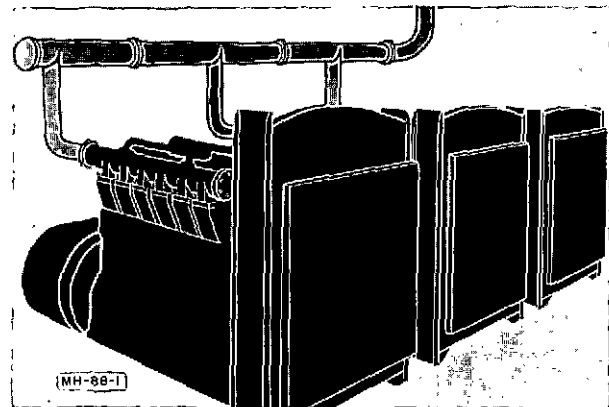
One of the worst exhaust installation practices is to bring two manifold branches into a single pipe by the use of a "T" connection—this condition leads to the pulses of each bank's exhaust interfering with the other and causing surprisingly high back pressure. Multiple exhaust connections to a common 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.



"V" ENGINE "Y" CONNECTION TO SINGLE PIPE



MULTIPLE EXHAUST CONNECTIONS TO A COMMON HEADER ARE VERY POOR PRACTICE

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 VC series engines may be obtained from your Waukesha sales engineer.

Exhaust outlet diameter is six inches for all H1077s and naturally aspirated L1616s, 8 inches for turbo supercharged L1616s and naturally aspirated P2154s, and 10 inches for turbo supercharged P2154s.

Some flexible exhaust connectors can be installed in one direction only as stamped thereon.

## WAUKESHA VC SERIES

Flexible exhaust connectors fail due to excessive distortion. To prevent this type of failure, the following installation caution must be adhered to:

### CAUTION

MAXIMUM DISTORTION OF FLEXIBLE EXHAUST CONNECTOR DUE TO CONNECTED EXHAUST PIPING IS  $\pm 1/4$  INCH OFFSET AND  $\pm 1/4$  INCH AXIAL DEFLECTION.

### GAS FUEL SYSTEM

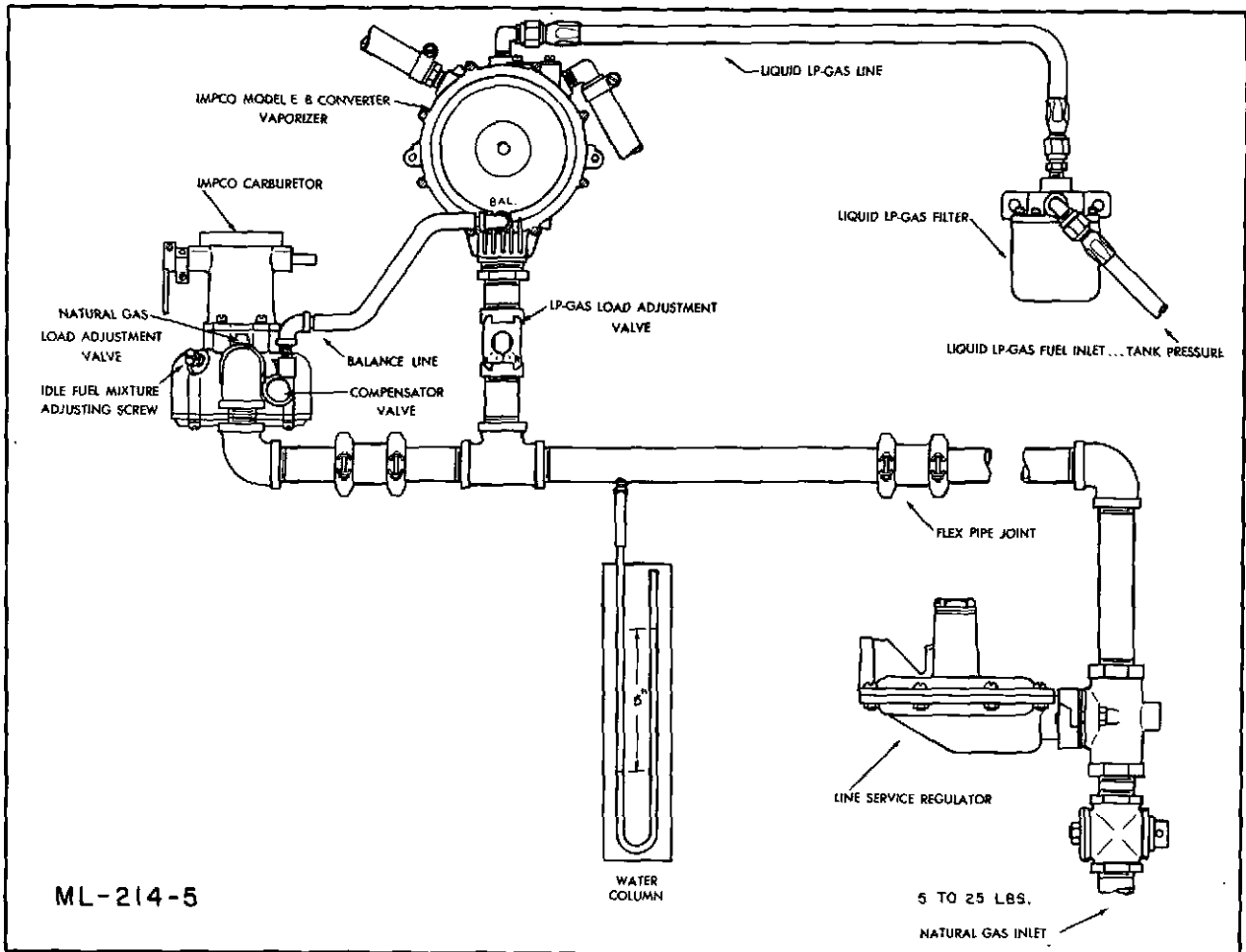
Natural gas inlet pipe size is 1-1/4 inches for the naturally aspirated H1077 and is 1-1/2 inches for all other VC series gas engines. Required natural gas pressure to the line pressure regulators is 20 to 25 psi for turbo supercharged engines and 5 to 25 psi for naturally aspirated engines. One regulator is required for each bank, with an adjustable outlet range of 3-1/2 to 6-1/2 inches of water column (this outlet range is provided when using a red

spring in a Fisher regulator). Line pressure regulators should be equipped with a 3/4 inch orifice for Model H1077G and GSI engines, with a 1 inch orifice for Model L1616G and GSI engines, and with a 1-3/16 inch orifice for Model P2154G and GSI engines.

LPG vaporizer regulators must provide 1-1/2 inches of water column negative pressure to each carburetor of naturally aspirated engines. For turbo supercharged engines the regulators will provide 1-1/2" of water column negative differential pressure. This is provided when using a blue spring in an Impco "EB" vaporizer regulator. The LPG should be filtered before entering the vaporizer.

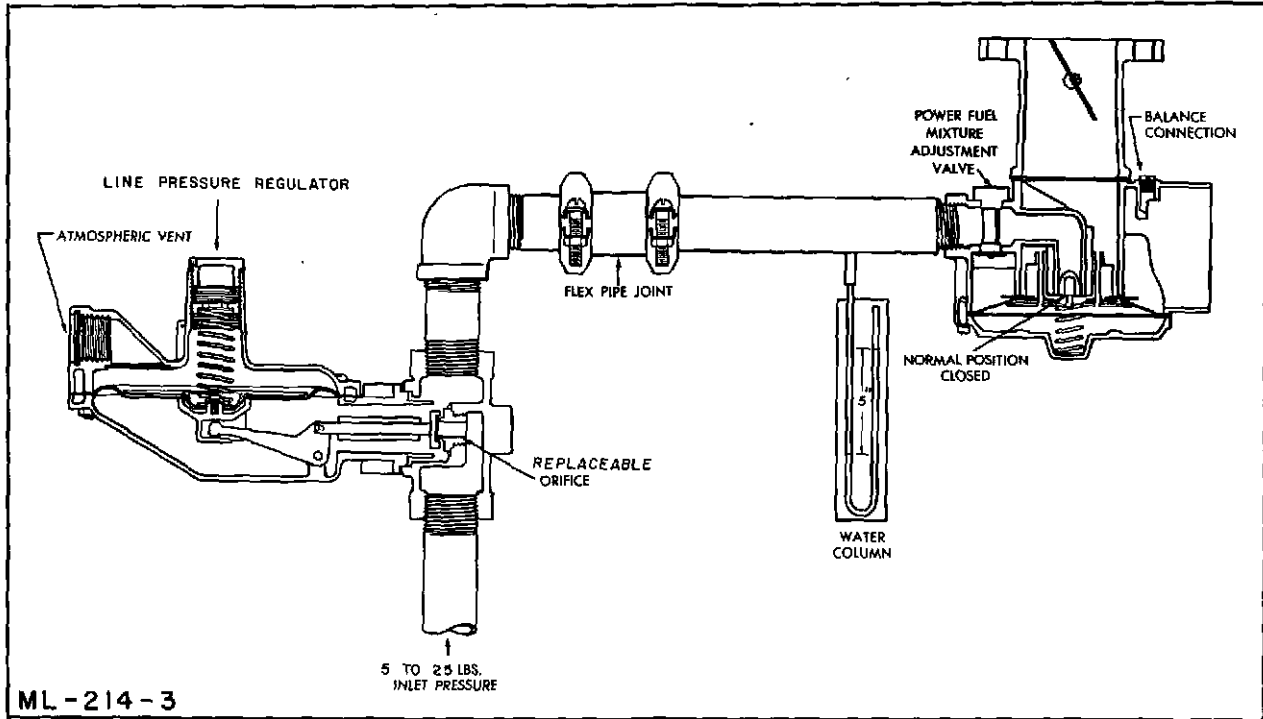
### WARNING

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

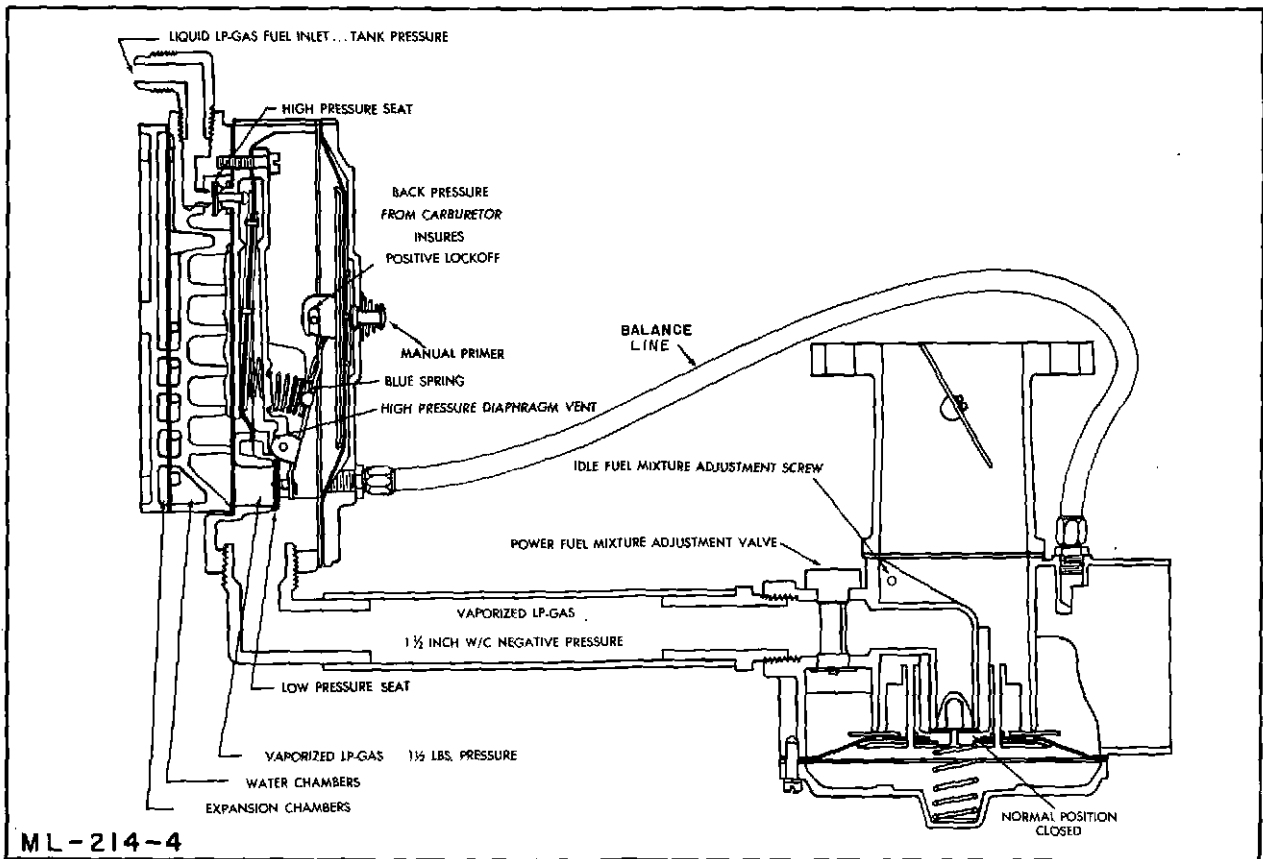


TYPICAL IMPCO COMBINATION LP AND NATURAL GAS INSTALLATION

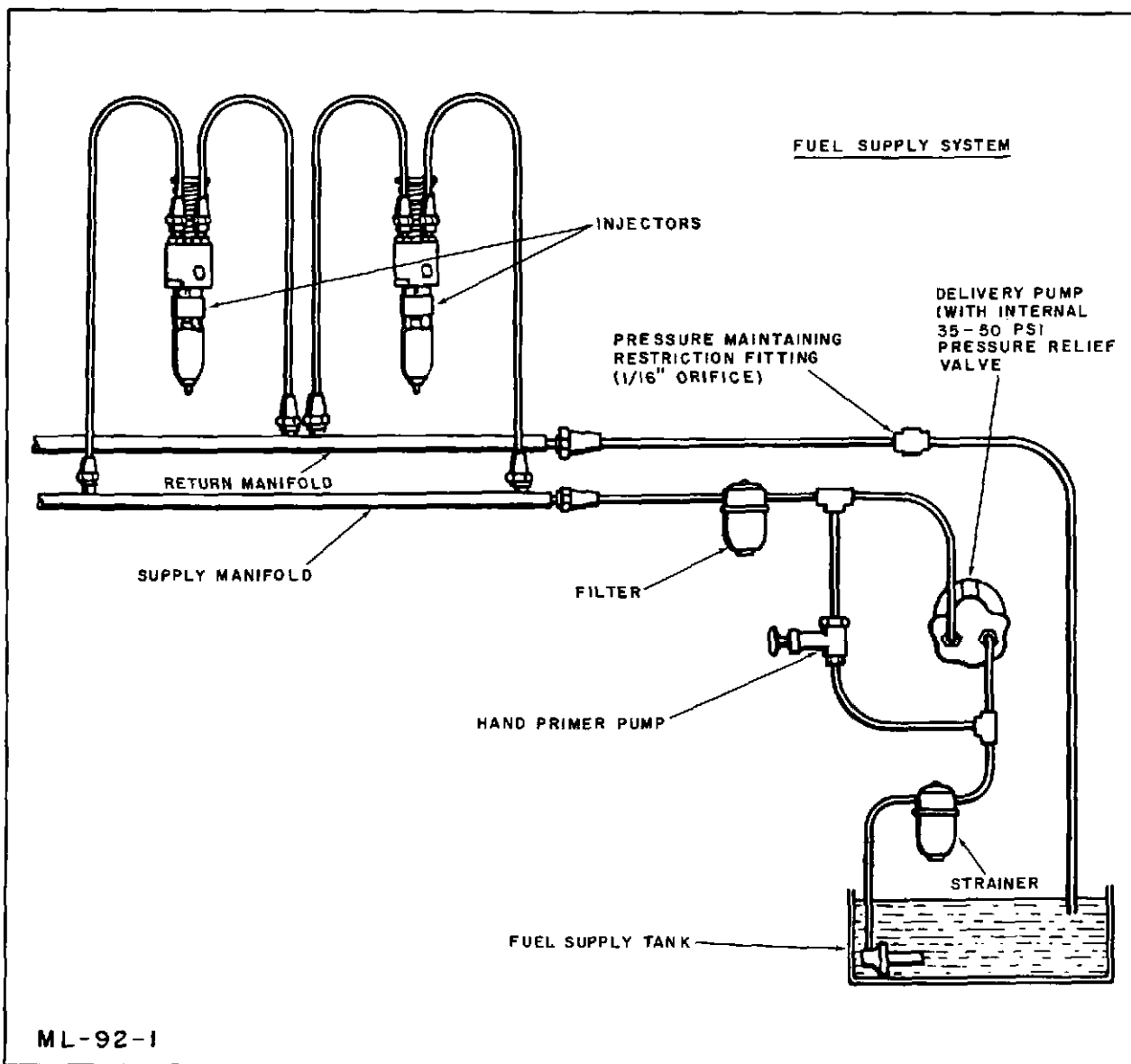
WAUKESHA VC SERIES



TYPICAL IMPCO NATURAL GAS INSTALLATION



TYPICAL IMPCO LP GAS INSTALLATION



ML-92-1

SCHEMATIC OF DIESEL FUEL SYSTEM

On naturally aspirated natural gas applications, the Impco carburetor is somewhat less sensitive than other carburetors to the effects of moderate air cleaner restriction and a balance line may not be needed. When operating on LPG, however, the results of air cleaner restriction may be quite significant and a balance line is important.

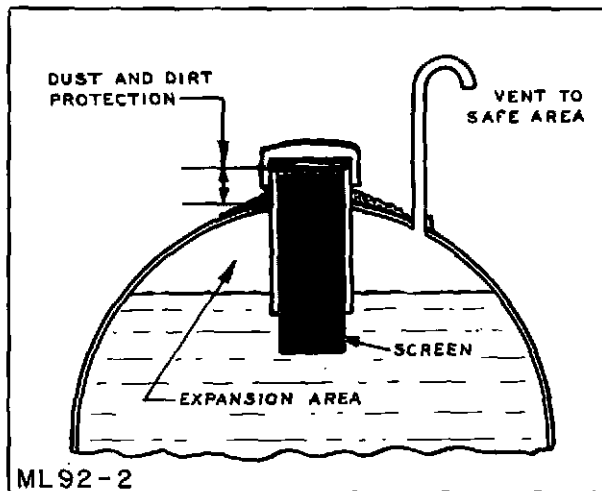
A balance line must also be used on all turbo-charged engines from the pressurized air at the carburetor air horn to the atmospheric vent in the regulator. This will raise gas pressure equal to air pressure rise.

Balance lines may be used on all IMPCO carburetors. Series 200 and 200D carburetors use a 7/16" I.D. balance line.

**DIESEL FUEL SYSTEM**

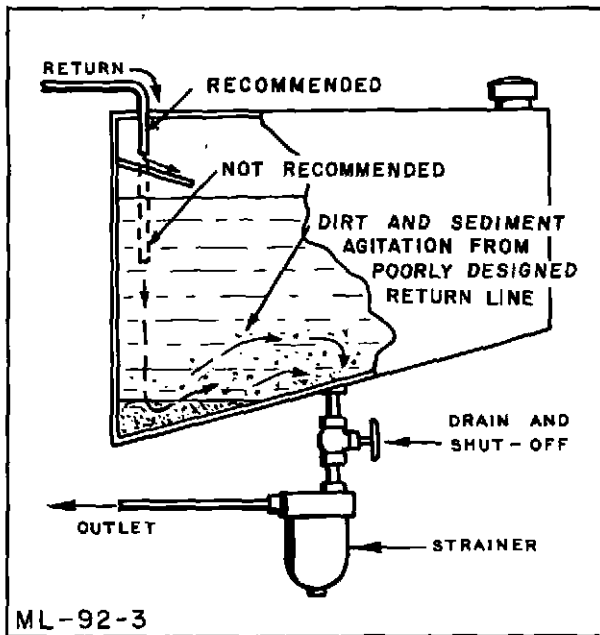
Fuel inlet pipe size for diesels is 1/4" minimum and fuel return pipe size is 1/8" minimum. Maximum lift of the engine mounted fuel supply pump is ten feet. If the engine mounted fuel supply pump is used with a pressurized head due to an overhead tank or outside fuel line pressure, a manual shutoff valve must be installed in the fuel line between the pressure

INSTALLATION



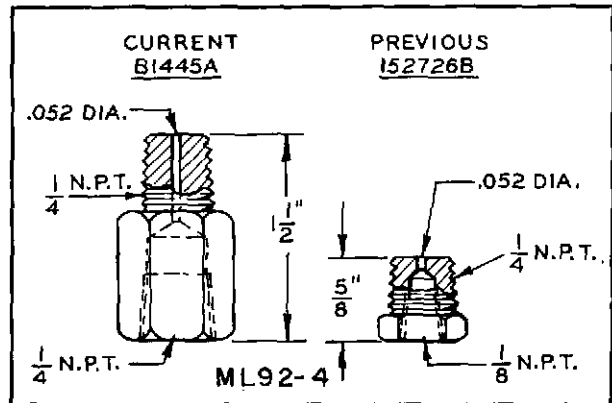
DIESEL FUEL TANK FILLER OPENING

source and the strainer. Fuel oil specification recommendations are contained in Chapter 4. The accompanying illustrations show examples of proper fuel tank design.



DIESEL FUEL TANK RETURN AND OUTLET

Previous VC series diesel engines utilized a Part No. 152726B fuel restriction fitting mounted in the return line tee. Current VC series diesel engines use a Part No. B1445A fuel restriction fitting mounted in the return line tee.



FUEL RESTRICTION FITTINGS

Both fittings provide the same restriction (.052" diameter) in the fuel return system to maintain desired fuel system pressure, but the previously used fitting was often mistaken for a reducing bushing, and was either removed from the engine and not replaced, or was removed and replaced with a conventional reducing bushing—in either instance, this removed the designed restriction from the fuel return system and resulted in insufficient fuel supply pressure.

Depending on the fuel supply system connected to the engine, fuel supply pressure should be 10 to 50 psi with the engine operating at rated speed and load. Fuel supply pressure with the engine operating at idle speed is usually about 10 psi higher than at rated load.

The new fuel restriction fitting, Part No. B1445A, is interchangeable with the previously used fitting, Part No. 152726B, providing that either the customer's connection is changed from 1/8" NPT to 1/4" NPT, or a 1/4" NPT to 1/8" NPT reducing bushing is used to connect the 1/8" NPT tube or hose fitting to the 1/4" NPT tap in the new fuel restriction fitting.

LUBRICATING OIL SYSTEM

Lubricating oil specification recommendations as well as oil sump and filter capacities are contained in Chapter 4. The installation should include adequate provisions for draining lube oil.

Adherence to angular operating limits is very important to successful operation in many engine applications and users should be cautioned when job requirements are such that the engine can be tilted to extreme angles. This sometimes occurs when machines have been

MAXIMUM SAFE TILT ANGLE OPERATION OF VC SERIES ENGINES

MODEL	OIL PAN	OIL PUMP	FRONT DOWN ANGLE	REAR DOWN ANGLE	EITHER SIDE DOWN ANGLE
H1077	Standard	Standard	5°	15°	30°
	Deep Sump	Standard	5°	20°	40°
	Standard	Scavenger	18°	15°	30°
	Deep Sump	Scavenger	25°	20°	40°
	Marine	Standard	15°	25°	45°
L1616	Standard	Standard	4°	8°	30°
	Standard	Scavenger	10°	8°	30°
	Deep Sump	Standard	4°	25°	50°
	Deep Sump	Scavenger	25°	25°	50°
	Base	Standard	8°	10°	30°
	Marine	Standard	15°	25°	45°
P2154	Standard	Standard	3°	3°	25°
	Deep Sump	Standard	10°	15°	40°
	Deep Sump	Scavenger	15°	15°	40°
	Marine	Standard	15°	25°	45°

INSTALLATION

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. The above tabulation lists maximum safe tilt angles for VC series gas and diesel engines.

**PROTECTION OF HOUDAILLE VIBRATION DAMPERS**

It is extremely important that all persons handling, shipping, or installing Houdaille viscous type vibration dampers be aware that they must not be dented or damaged in any manner. 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.

For this reason, extra care is required in handling Houdaille dampers and it is obvious

that they should never be used as a push point for fork lift trucks, wrapped with chains for lifting or pulling, or struck while moving other equipment around the engine.

**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.

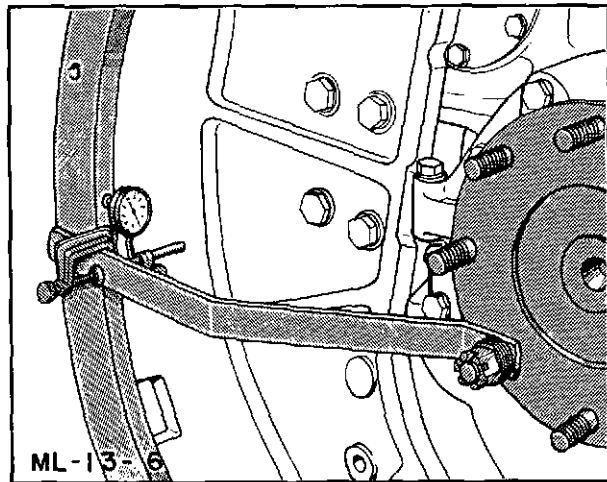
A major factor in obtaining long service life from any engine and clutch or power takeoff assembly is the proper alignment of the fly-

## WAUKESHA VC SERIES

wheel 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 entire drive line from crankshaft bearings 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 run-out of the housing bore all the way around.



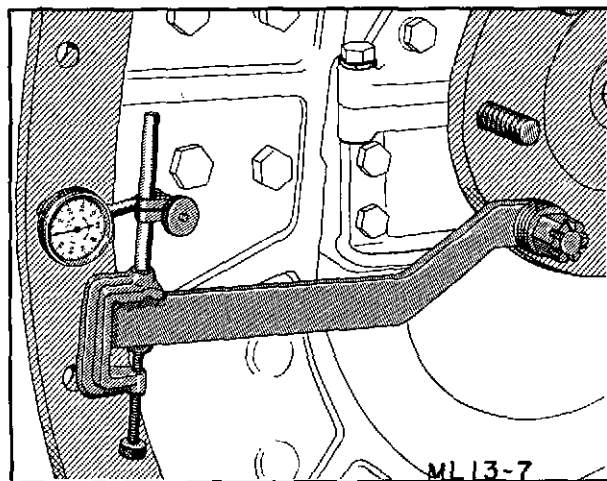
CHECKING HOUSING BORE RUN-OUT

2. If the flywheel housing is out of alignment, loosen all of the flywheel housing bolts, remove the small dowel pin on the right side of the flywheel housing and proceed as follows.
3. Use a small bar inserted in a bolt hole to correct misalignment until the runout does not exceed .010" total indicator reading.
4. Tighten bolts partially, working back and forth across the housing. Recheck bore concentricity with dial indicator.

5. Install appropriate dowel in right side dowel hole.

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

1. Housing face runout should not exceed .010" 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 crankshaft flange.

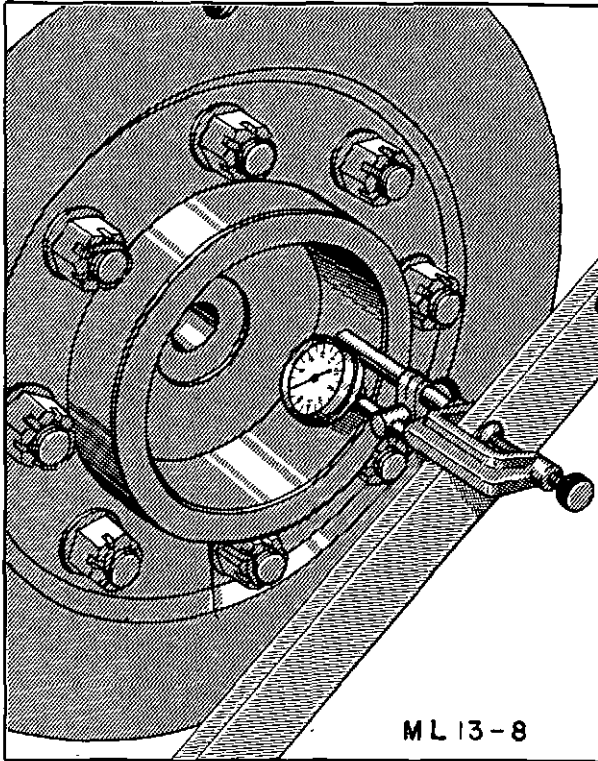


CHECKING HOUSING FACE RUN-OUT

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.

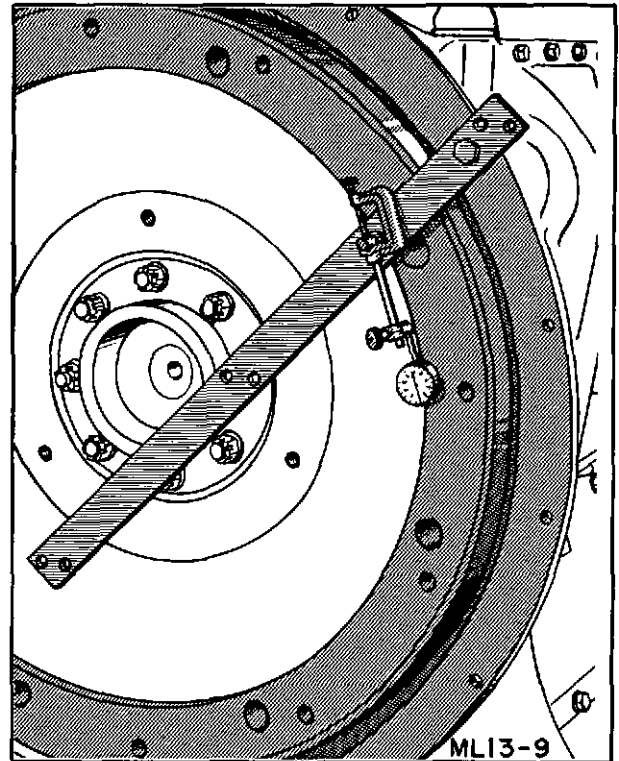
Mount a dial indicator on a bar extending across the flywheel housing and check the run-out of the pilot bearing bore as shown. Runout should not exceed .005" total indicator reading.

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 rough handling has somehow distorted the wheel or crankshaft flange, maximum runout should not exceed .013" total indicator reading.



CHECKING PILOT BEARING BORE

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. Crankshaft endplay must be .005" - .015".



CHECKING FLYWHEEL FACE RUN-OUT

**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.

## CHAPTER 3 OPERATION

### PRE-STARTING PROCEDURES

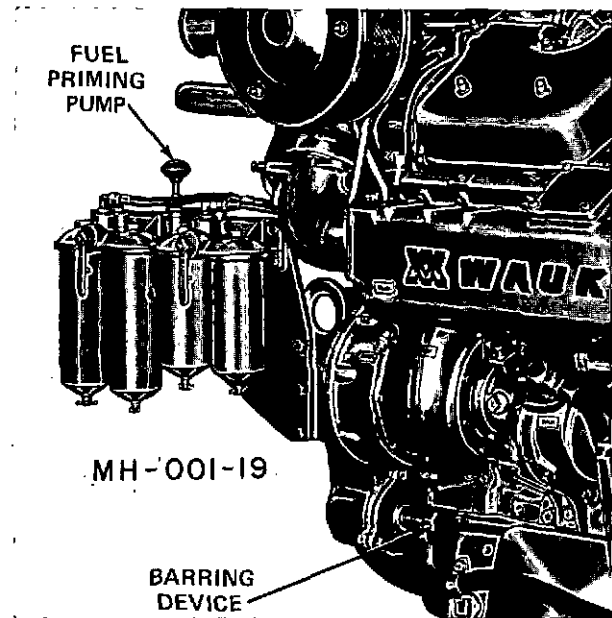
Before starting any engine, there are several things that should be checked to avoid accidents and damage to the engine or other equipment. The following points apply to newly installed engines, but are also applicable with minor and evident variations to any engine.

1. Be sure the main clutch or other power-transmission device is disengaged.
2. Check the oil level as indicated on the dipstick. The hand priming pump should be operated to ensure that the oil cooler and full-flow oil filters are full of oil and that lube oil has filled the passages to the bearings. This procedure precludes the possibility of engine damage due to temporary oil starvation. Adequate priming is assured when the engine oil pressure gauge indicates pressure in the oil header. If VC series engines are not handprimed, they must be cranked for a considerably longer time until sufficient oil pressure is available to the Woodward SG or PSG governor so that the governor can move the fuel control from off position.

#### NOTE

Some off-highway automotive diesels are equipped with starter switch actuated pre-lube pumps. The starter is not actuated until 2 to 4 psi oil pressure has built up.

3. Trace through the external cooling system to make sure all control valves are properly opened and the drain cocks closed. Check the coolant level. If it is necessary to add a large quantity of coolant, be sure to open the thermostat housing and intercooler vents to allow any air trapped in the cooling system to escape.
4. Lubricate all electrical equipment and other accessories in accordance with manufacturer's instructions.
5. If possible, particularly on a new installation, after engine storage, or in freezing weather, bar the engine over through several revolutions to be sure nothing will interfere with operation.



FUEL PRIMING PUMP AND  
BARRING DEVICE

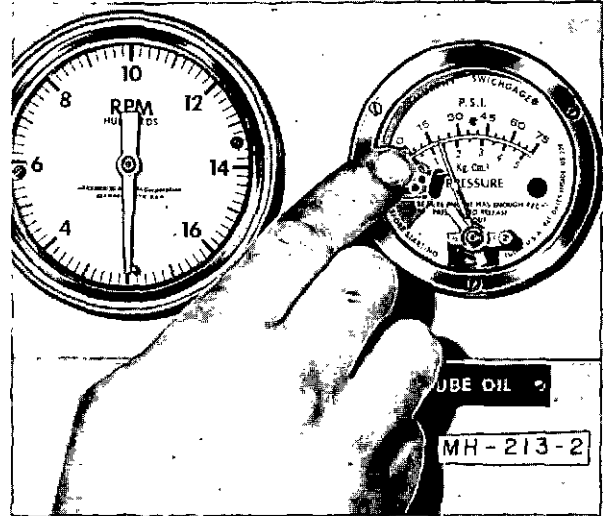
6. Fill diesel engine fuel tank and drain enough fuel from outlet sump trap to remove water or sediment accumulations. If main fuel supply is gravity fed, allow a quantity of fuel to flow into a disposal bucket to clear up any air locks in the line and wash out scale and sediment. Use the hand-primer pump to purge the injectors and filter units of air.
7. If the engine is equipped with air shutoff valves, make sure they are in open position. Never restart an engine which has been stopped by closing the air shutoff valves without first checking the engine; including barring it over by hand to ascertain that the cylinders are clear. Inspect intake manifolds for accumulations of lubricating or fuel oil. Previous VC diesels which utilized an overspeed governor, which allowed engine oil pressure to trip the air shutoff valves in the event of engine overspeed, included a hydraulic relay valve which must be reset along with the air shutoff valves if overspeed shutdown has occurred. Re-setting is accomplished by depressing the relay valve

button. Current VC diesels do not include this relay valve, but instead utilize a mechanical connection between the two air shutoff valves.

8. If a cooling fan is used, be sure its rotation is unobstructed, that the bearing is lubricated. Check that all belt drives are snug and in good condition.
9. Check air cleaner restriction indicator. Clean air filter if indicator shows red.
10. Make certain all guards are in place and secure on engine and driven equipment.

The following procedures must also be accomplished prior to starting the engine.

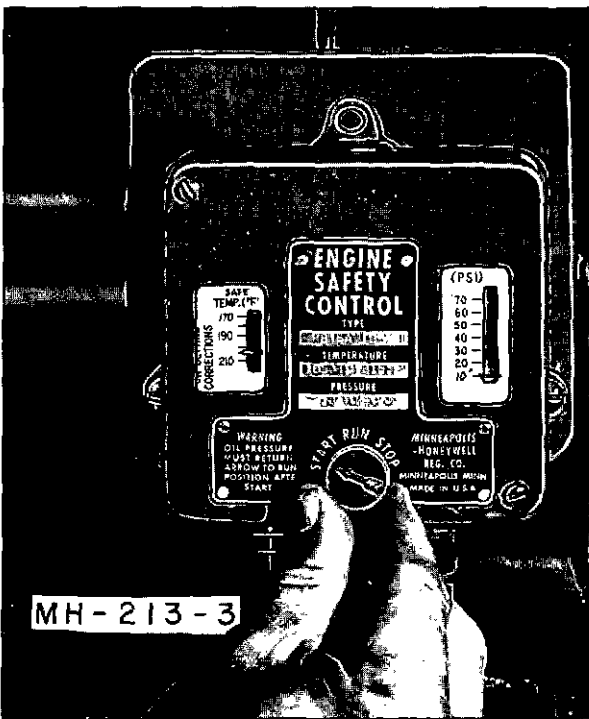
1. Re-set the safety shutdown controls. Diesel and gas engines which utilize the combination low oil pressure and high coolant temperature control switch (Minneapolis-Honeywell) must have the control switch knob turned to the START position. Installations which include dual control switches (one for warning and one for shutdown) must have shutdown control switch knob turned to the START position. Some diesel installations (usually marine engines) use this control switch for warning only. Diesel and gas engines which utilize the oil pressure Murphy Swichgage must have the Swichgage re-set button depressed until



RE-SETTING OIL PRESSURE SWICHGAGE

the lockout latches. Diesel engines which utilize the spring-loaded low oil pressure and high coolant temperature control (Amot) must have the re-set lever lifted up until the plunger latches (latch type only). Diesel and gas engines which utilize an overspeed switch (Synchro-Start) with a re-set button, must have the switch re-set before re-starting after an overspeed shutdown. Some Synchro-Start overspeed switches incorporate an automatic re-set and do not include a re-set button.

2. Diesel and gas engines equipped with stop-run switches must have the switch placed in run position.
3. Diesel engines with a manual shutoff control must have the shutoff control lever pushed towards the engine.
4. Off-highway automotive diesels which include a governor speed low idle-high idle speed control system (toggle switch, solenoid valve, and air control cylinder) must have the switch lever placed in OFF position for starting (places governor control lever in low speed position).
5. Be sure the fuel shutoff valve is opened prior to attempting to start the engine.
6. Never operate a turbo supercharged engine with one turbo blocked off as severe damage of the turbo supercharged bank can result from overload.
7. For gas engines with combination equipment for burning either natural gas or LPG, be sure the main natural gas valve is closed and the liquid LPG shutoff valve is open when the engine is to be started



RE-SETTING MINNEAPOLIS-HONEYWELL SAFETY CONTROL

on LPG. Conversely, when the engine is to be started on natural gas, be sure the natural gas shutoff valve is open and the liquid LPG shutoff valve is closed.

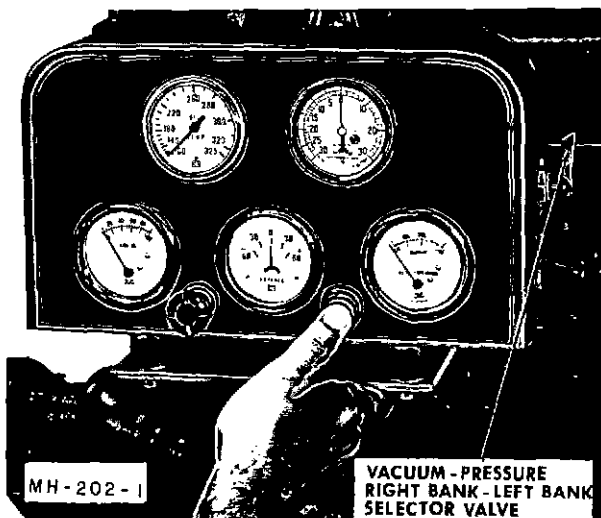
**NOTE**

When an engine utilizes a surge tank and integral heat exchanger, a temperature control manual over-ride is mounted in the front of the surge tank. In the event of thermostatic power unit failure which results in by-passing the jacket coolant around the heat exchanger, rotate the 3/4 inch hex knob of the over-ride clockwise to the OVER-RIDE position to prevent by-passing. This over-ride control is for emergency use only and the failure should be corrected as soon as possible. Rotating the over-ride control knob counter-clockwise returns the control to NORMAL operating position. Unless the thermostatic power unit is known to be malfunctioning, the over-ride control should always be in NORMAL operating position when starting the engine.

**STARTING AND OPERATING PROCEDURES**

To start (after preceding pre-starting procedures are accomplished) and operate VC series engines, proceed as follows:

1. Place throttle control lever in low speed position.



DEPRESSING PANEL MOUNTED STARTER SWITCH BUTTON

2. Actuate starter control to crank engine, while holding Amot re-set lever in "up" position (non-latch type only).
3. After engine starts, check for adequate oil pressure indication and place throttle control lever in medium idle speed position with no load for engine warm-up. Off-highway automotive diesels which include the governor speed low idle-high idle speed control system should be warmed up at low idle (control switch lever in OFF position).

**CAUTION**

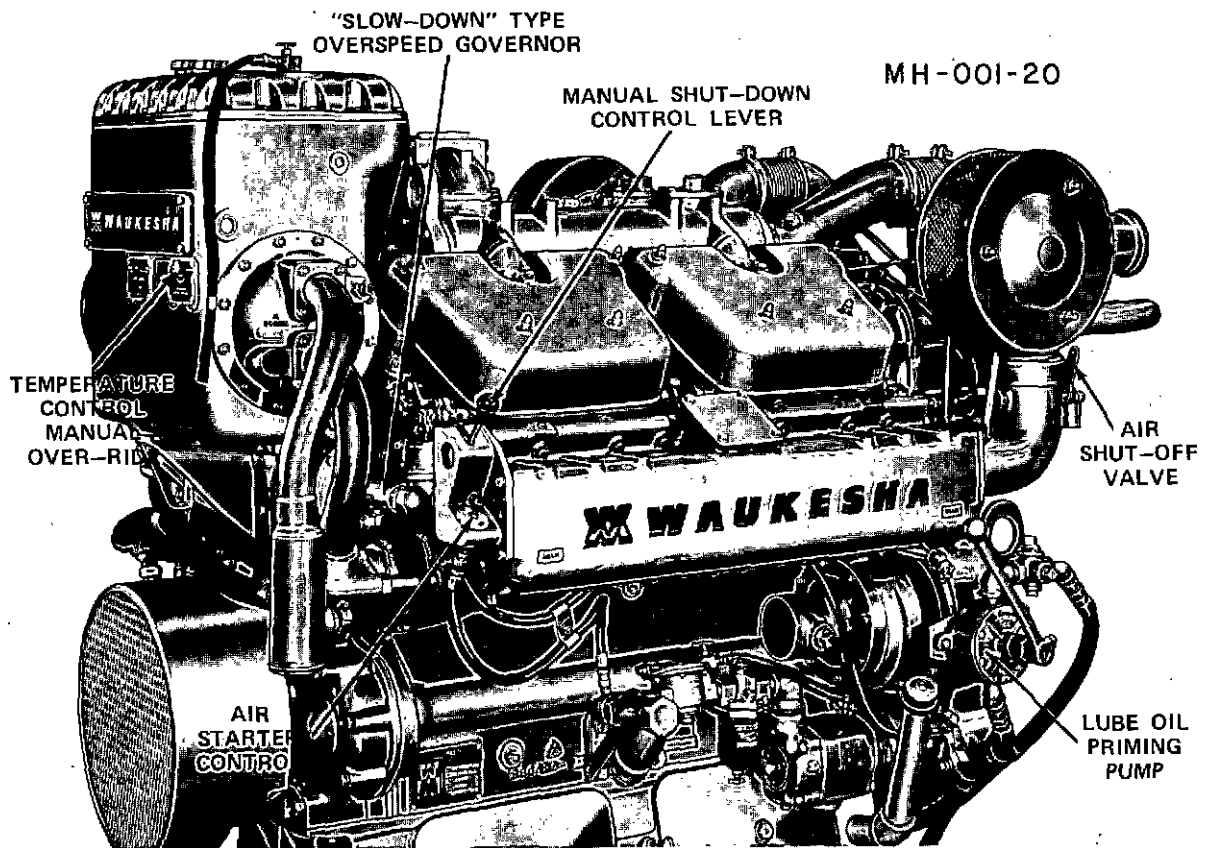
If adequate oil pressure is not indicated within 25 to 30 seconds, shut the engine down at once and correct the cause. Never operate without an adequate oil pressure indication in the hope that a faulty gauge or cold oil is responsible. Check that the safety control oil pressure re-set has released (when applicable) as the engine can continue to operate with low or no oil pressure since the re-set must be released by oil pressure before the low oil pressure safety control is effective. Safety control oil pressure re-set release is effected when the Minneapolis-Honeywell control knob rotates to RUN position, the Amot control re-set latch knob projects slightly from the body, and the Murphy Swichgagelockout releases. Diesel engines equipped with latch type Amot control can be stopped by pulling re-set latch knob, if sufficient oil pressure was not available to unlatch it. Releasing re-set lever of non-latch type Amot control will stop engine if sufficient oil pressure was not available to actuate Amot.

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

**CAUTION**

A turbocharger is intended to increase engine power output. Do not operate turbo supercharged engines at low power more than necessary or for prolonged periods. **DO NOT IDLE TURBO SUPERCHARGED ENGINES FOR**

OPERATION



**DIESEL ENGINE CONTROLS**

**EXTENDED PERIODS!** This type of operation will foul the turbo-charger and make expensive dis-assembly and cleaning necessary.

ings usually indicate troubles which are developing. Also check the air cleaner restriction indicator and listen carefully for unusual operating noises.

5. 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. Off-highway automotive diesels which include a governor speed low idle—high idle speed control system must have the switch lever in ON position for high idle speed before applying the load.

**NOTE**

Be sure white smoke in diesel engine exhaust has "cleaned up" before applying load. Experience and observation of exhaust for minimum smoking will enable operator to determine when diesel engine is warmed up.

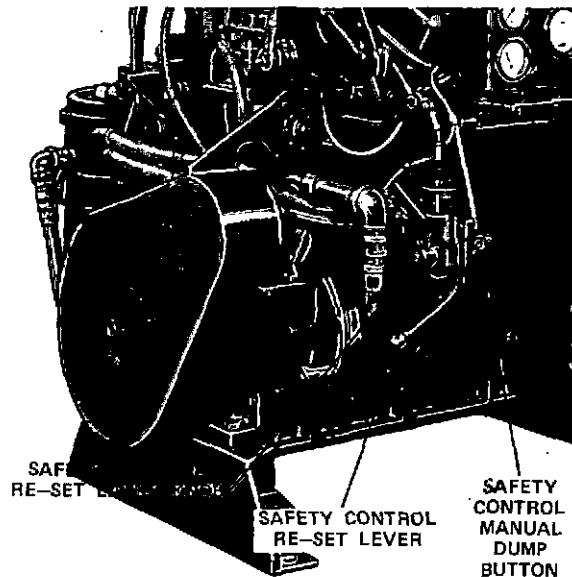
6. Observe and record the normal operating readings. They should be oil pressure 40 - 50 psi, and oil and coolant temperatures 160° - 180°F. Changes from normal read-

**STOPPING PROCEDURES**

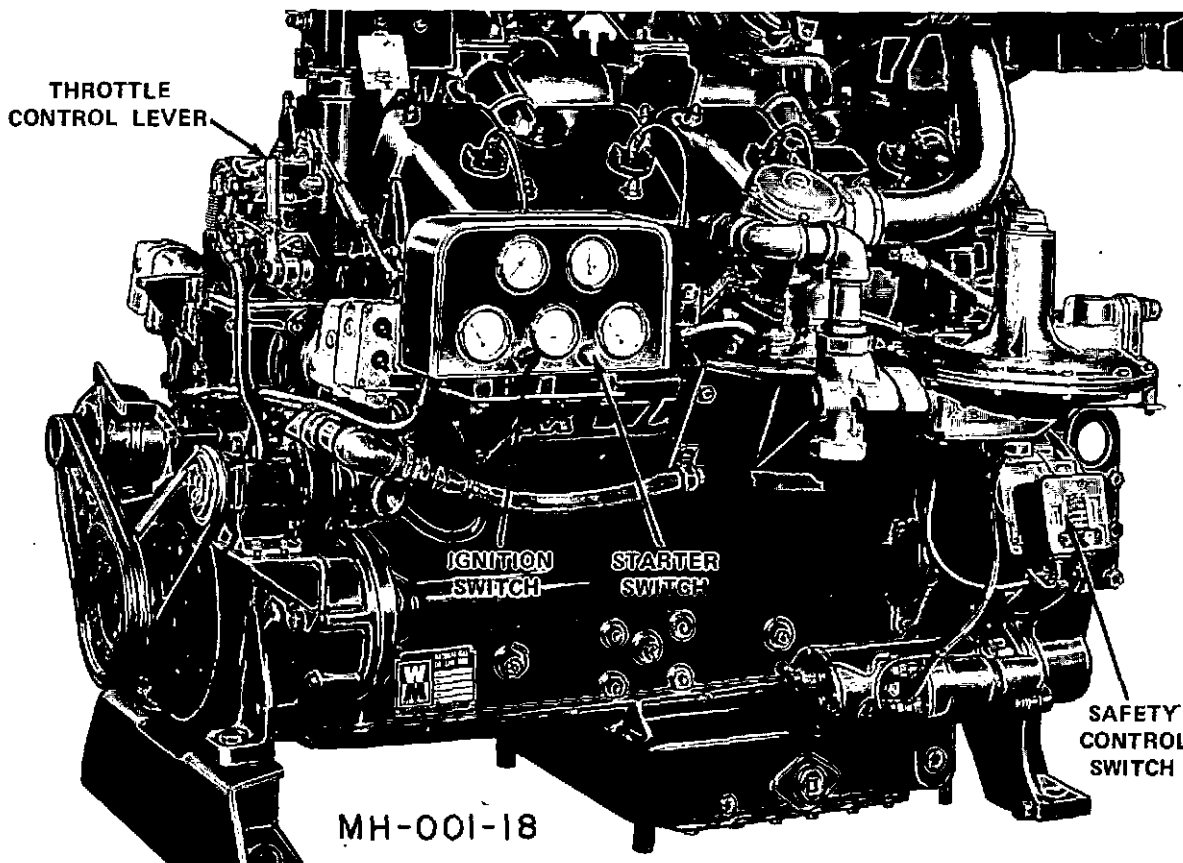
To slow down and stop the engine, proceed as follows:

1. Remove load by disengaging clutch control lever, opening main circuit breaker, etc.
2. Place throttle control lever in medium idle speed position, or high idle—low idle speed control switch lever in OFF position (when applicable with off-highway diesels), and allow engine to idle for a few minutes to reduce and normalize engine temperatures. It's 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. This is especially important for a turbo supercharged engine. If temperature does not begin to recover to normal within one minute, shut the unit down hot.

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. Gas engines equipped with an ignition switch can be stopped by placing the ignition switch in OFF position. Gas engines equipped with Minneapolis-Honeywell control switches can be stopped by rotating the control knob to STOP position.
  - b. Diesel engines equipped with Amot safety controls can be stopped by depressing the manual dump button. Diesel engines equipped with Minneapolis-Honeywell control switches can be stopped by rotating the control knob to STOP position. Diesel engines with the "slow-down" type overspeed governor can be stopped by applying 25-100 psi air pressure to the overspeed governor. Diesel applications which are equipped with a stop-run switch can be



DIESEL ENGINE SAFETY CONTROL



GAS ENGINE CONTROLS

OPERATION

stopped by placing the stop-run switch in stop position which, depending upon the application, will either apply air pressure to the overspeed governor or de-energize governor oil supply solenoids. Diesel engines equipped with a manual shutoff control can be stopped by pulling the shutoff control lever away from the engine.

- c. For emergency shutdowns, diesel engines equipped with manually, electrically, or hydraulically actuated air shutoff valves can be stopped by closing these air shutoff valves. Depressing the emergency stop button on off-highway automotive diesels results in actuation of the air shutoff valves.

### CAUTION

Never restart an engine which was stopped by closing the air shutoff valves without first checking the engine, including barring it over by hand to ascertain that the cylinders are clear. Inspect intake manifolds for accumulations of lube or fuel oil.

4. Unless otherwise protected, the exhaust pipe should be capped upon shutting down the engine for long periods of time to prevent condensation, rain, or snow from getting into the engine if it is exposed to the elements. A pail or bucket inverted over the exhaust pipe will be sufficient.
5. Test the coolant solution for adequate anti-freeze to protect the engine from freezing during shutdown periods. The immediate and anticipated air temperature will govern the amount of anti-freeze needed.

### 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. Priming of the lubricating oil system is especially important before attempting to start in cold weather, and is even more important for turbo supercharged engines to ensure adequate lubrication of the turbochargers. The engine should not be started if lube oil pressure cannot be generated by the priming system.

### NOTE

Some off-highway automotive diesels are equipped with starter switch actuated pre-lube pumps. The starter is not actuated until 2-4 psi oil pressure has built up.

### ENGINE BREAK-IN

#### General

Various installations will require minor variations of the following schedules for break-in of new and rebuilt engines due to the individual characteristics of the installations; however, this should not lessen the importance to perform a program as outlined, or equal.

A program whereby a medium to heavy load is applied for a short period of time, as described in these schedules, with five minute cooling periods, repeated until four to six hours of operating time is accumulated, will usually be sufficient for a break-in period.

Do not allow engines with new power parts to idle no load for periods exceeding ten minutes until the engine has operated for approximately 100 hours.

An oil and filter change after the first 100 hours of operation is recommended to remove any metal particles which might have accumulated in the oil during the break-in period. The normal operating oil specification recommended in Chapter 4 should be used during the break-in period.

#### VC Diesel Off-Highway Installations

Perform normal start-up installation and engine checks.

Start engine and operate at low idle, no load, until engine temperature stabilizes, but not to exceed twenty minutes.

Operate vehicle with no load for one hour, operating controls, roading vehicle, etc. Operate at low idle for five minutes with no load.

Operate vehicle with medium to heavy load for 15 minutes; then at low idle for five minutes with no load.

Continue cycling 15 minutes with load, five minutes with no load at low idle, until four operating hours have accumulated.

Place engine in normal service.

## WAUKESHA VC SERIES

Do not idle engine in excess of ten minute periods until it has operated for 100 hours.

Change oil and filter after 100 hours operation, using the Waukesha recommended SAE and specification oil.

### 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 and turbocharger problems by creating excessive coke and ash deposits.

### VC Marine Diesel Main Propulsion Installations

OPERATING SPEED	OPERATING INSTRUCTIONS PERFORM NORMAL START-UP INSTALLATION & ENGINE CHECKS
800 RPM	Starting and warm-up (30 min.)
1000 RPM	Operate 10 minutes 25% load
700 RPM	Idle engine five minutes (No Load)
1400 RPM	Operate 15 minutes 50% load
700 RPM	Idle engine five minutes (No Load)
(Note: Repeat 50% load and idle cycling 3 times)	

Continue cycling 30 minutes with rated load at governed RPM, five minutes with no load at low idle, until six operating hours have accumulated.

Place engine in normal service, sea trials, etc.

Do not idle engine in excess of ten minute periods until it has operated for 100 hours.

Change oil and filter after 100 hours operation, using the Waukesha recommended SAE and specification oil.

### 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 and turbocharger problems by creating excessive coke and ash deposits.

### VC Stand-By and Continuous Service Generator Installations

An engine powering an AC generator is restricted to loaded RPM because of the generator's performance characteristics.

To perform a break-in schedule, it is necessary to cycle the engine through a sequence of idling and loading to accelerate piston ring seating.

OPERATING SPEED	OPERATING INSTRUCTIONS PERFORM NORMAL START-UP INSTALLATION & ENGINE CHECKS
Governed RPM	Starting and warm-up (30 min.)
Governed RPM	Operate 15 minutes 25% load
Governed RPM	Idle engine five minutes (No Load)
Governed RPM	Operate 15 minutes 50% load
Governed RPM	Idle engine five minutes (No Load)
(Note: Repeat 50% load and idle cycling 3 times)	

### CAUTION

Do not operate generator at less than 100 RPM below synchronous speed, unless the voltage regulator is disabled.

Continue cycling (75% load for 30 minutes, idle for five minutes) until six operating hours have accumulated.

Do not idle engine in excess of 10 minute periods until it has operated for 100 hours.

Change oil and filter after 100 hours operation, using the Waukesha recommended SAE and specification oil.

### CAUTION

Avoid prolonged idling—in excess of 20 to 30 minutes at a time without bringing the engine up to normal operating tem-

peratures near full-load. Excessive idling periods tend to cause cylinder and turbocharger problems by creating excessive coke and ash deposits.

#### 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 on the line". Examples are hospital generators in some types of switching configurations; 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, check out 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.

# CHAPTER 4

## LUBRICATION, SERVICE, AND PREVENTIVE MAINTENANCE

### SECTION I - LUBRICATION

#### LUBRICATION GUIDE

Lubricants are listed in the accompanying Lubrication Guide. Intervals listed are for normal operation and should coincide with other preventive maintenance services; however, under unusual conditions, intervals should be changed if indicated by 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 OIL RECOMMENDATIONS

##### General

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 he is the one who must make decisions on oil changes, filter changes, loads, general maintenance, and operating conditions. A tabulation of lubricant producers and marketers, together with the performance grades for which the producers have indicated their products are qualified, is available from the Engine Manufacturers Association (EMA), 111 East Wacker Drive, Chicago, Illinois - 60601.

This tabulation (EMA LO Form 6-12/72) is entitled "Lubricating Oils Data Book for Heavy Duty Automotive and Industrial Engines". The Waukesha Engine Division has made it a practice not to recommend oil by brand name.

##### NOTE

All Waukesha industrial engines are considered to be in heavy-duty service. They are classified "A" or "B" according to displacement: Class A, engines up to 1000 cubic inches and Class B, engines above 1000 cubic inches.

##### Gas Engines

For Class B engines operating on gaseous fuels, Waukesha Engine Division recommends oils compounded for gas engine operation. In addition, the oil shall have 5,000 PPM of barium, calcium, or combination of both with a maximum of .03 percent zinc. In addition, the sulfated ash level should be .5 to 1.5% by weight.

##### NOTE

Refer to EMA LO Form 6-12/72, columns headed "Nat. Gas/LPG - High ASH" and "Ash Content % by Wt." to assist in selection of oils to this specification.

This recommendation is based on many years of actual operating experience that conclusively verifies that high ash lubricating oils substantially reduce valve face and seat erosion because the ash oxidizes and provides a dry lubricant on the valve face and seat. However, we also recognize that due to extensive research and testing, several oil companies have now successfully formulated low ash lubricating oils that also reduce valve face and seat recession and/or erosion.

Waukesha Engine Division's warranty is limited to the repair or replacement of parts that fail due to defective material or workmanship during the warranty period and as such,

## LUBRICATION GUIDE

Location	Interval	Lubricant	Service
Air starter	Weekly	As specified in AIR STARTER LUBRICATION.	Fill lubricator or remove plug in housing cover and fill sump with oil (as applicable).
Oil can points (linkages, etc.)	50 hrs.	Engine oil.	Clean and lubricate linkages.
Air actuator	200 hrs.	Lithium soap bearing grease.	Apply with grease gun to two fittings.
Crankcase	250 hrs.	As specified in LUBRICATING OIL RECOMMENDATIONS.	Drain and refill. Install new filter elements.
Electric starter and alternator	300 hrs.	Light engine oil.	Apply five drops to bearings.
Air starter	3 months	Grease, No. 2 cup.	Remove gear case plug (and housing cover plug when applicable). Insert lubrication fitting and use two strokes of grease gun to add lubricant.
Governor synchronizing motor bearings	6 months	Gulferest A or Stanoil No. 18.	Apply through oil cup.
Synchro-start overspeed switch (only pre-1972 models)	6 months	Aero Shell 7A MIL-G-23827 or equivalent grease.	Check and replenish grease reservoir between bearings (3/4 full).
Air starter	Annually	SAE 20 engine oil.	Remove plug from drive housing and saturate oil wick.
Governor synchronizing motor speed reduction gears	Annually	Below 32 °F. use Bodine LG2 or Beacon No. 325; above 32 °F. use D.A. Stuart H.M.P. No. 1 or Hodson No. 2-1000; above 212 ° F. or with motor mounted so gear housing is up, apply Dow Corning No. 44 grease directly to gears.	Clean out old grease; re-fill gear housing 3/4 full.
Fan hub	Annually or 2000 hrs.	Lithium soap type ball bearing grease.	Clean out old grease; repack bearings and fill housing 1/2 full.
Power take-offs	(At intervals and per instructions of manufacturer)		

## WAUKESHA VC SERIES

the compliance or non-compliance of lubricating oil recommendations in no way alters the Standard Warranty.

Waukesha Engine Division's warranty does not include responsibility for satisfactory performance of the lubricating oil whether it is high ash or low ash, this being the responsibility of the oil supplier.

Simply stated this means the owner may use the lubricating oil of his choosing without concern for the engine warranty status since the warranty is not affected by the type or brand of lubricating oil used in the engine.

### Diesel Engines

Oil is designated several ways, including the API, which is usually stamped on the container, the military, and the engine manufacturers. For Class B engines operating on Diesel fuel, Waukesha Engine Division recommends lubricating oils designated by the API as CD, by the military as MIL-L-45199B or MIL-L-2104C, and by the manufacturer as S-3.

### OIL CAPACITY

The oil capacity of VC series engines is as specified in the accompanying table. If additional filters or other engine lubricated equipment is used, the capacity should be determined and the correct amount added. Be sure to drain the oil cooler when changing oil. Replacing the cooler drain pipe plug with a drain cock will simplify this draining operation. Engines operating with full-flow type oil filters must have the filters prefilled. Prefilling the filters is necessary because the engine will be starved for oil until the filters and lines are filled.

After prefiling the filters, refill the oil pan to the proper level and operate the engine 10 or 15 minutes without load. Shut the engine down to determine how much, if any, additional oil is needed to bring the level to "full" on the dipstick. This will establish the total amount required for future oil changes. On future oil

changes the entire amount of oil may be placed in the crankcase at once. However, if this extra oil is put in, and the external equipment requiring it is not completely drained of the old oil, then the engine will have an excessive oil supply which is undesirable. In addition, dirt and sludge from the old oil will contaminate the fresh oil.

### 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 and maintenance. Where oil performance problems arise or are anticipated, the oil supplier should be consulted. For VC series engines, an oil change period of 250 hours of normal service can be used as a guide, unless monitoring by analysis, such as available in the Waukesha Oil Analysis Program, indicates the requirement for a shorter change period. Extended drain periods may cause varnish deposits, oil oxidation, or sludge conditions to appear in the engine, which an oil analysis cannot detect.

Extended 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

OIL CAPACITY (Gallons)

Model	Standard Oil Pan	Deep Sump Oil Pan	Base Type Oil Pan	Marine Oil Pan	Full-Flow Oil Filters	Oil Cooler
H1077	9	15	—	18	4	1
L1616	13	18	22	27	8	2
P2154	18	24	—	36	8	2

"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 internal condition for the first year's usage. This procedure will help in determining if the new oil is compatible to your type of operation. The Waukesha Oil Analysis Program can be useful in supplementing physical inspections for this evaluation.

**SELECTING OIL VISCOSITY**

All other things such as oil type and quality being equal, the principal factor in choosing the proper oil viscosity is the operating temperature of the oil. It is this temperature that establishes the running viscosity of the oil.

1. Make one or more check runs under actual operating conditions of speed and load. Use SAE 40 oil for this test. Note the temperature range of the oil in the oil pan or oil header by means of an accurate oil temperature gauge.
2. Find the temperature range noted in the preceding test in the following tabulation. The proper oil viscosity for these operating conditions will be found directly to the right. If different kinds of service cause the loads and operating conditions to vary, re-check the oil temperature as above and select an oil of lighter or heavier viscosity as required by the new conditions.

CLASS "B" ENGINES  
OIL TEMPERATURE METHOD

Oil Header Operating Temperatures	Oil Pan Operating Temperatures	SAE Viscosity Numbers
190° - 210° F.	210° - 230° F.	40
150° - 190° F.	180° - 210° F.	30
130° - 150° F.	150° - 180° F.	20

Multi-viscosity oil should be used only where cold starting conditions make it absolutely necessary. Oil change periods should be reduced to

25 hours. At the present state of development, multi-viscosity oils are normally not recommended for use in heavy duty industrial engines. The viscosity improvers presently used may tend to deteriorate in continuous service, allowing the oil to revert to its original low viscosity base. In this state, the oil may not supply sufficient film strength and/or oil pressure.

**OPERATING TEMPERATURES**

Engines operated with low oil temperatures (below 160° F.) can be expected to show excessive sludging and wear. Engines operated with high oil temperatures (above 220° F.) may experience lacquering and ring sticking. The undesirable effects of operating at abnormally low or high oil temperatures can be alleviated to some extent by the use of additive type oils.

**LOW TEMPERATURE OPERATION**

At low ambient temperatures an oil must be used which will provide proper lubrication when the engine is hot and working. If special heaters are needed to warm oil or coolant for starting, they should be used. Waukesha Engine Division will supply information on these devices upon request. Such heating systems permit the use of the recommended oil grades for the operating loads and temperatures involved.

**SPECIAL INDUSTRIAL SERVICE**

Extra precautions are necessary to provide adequate lubrication of industrial engines that must be started after long periods at rest or after standing in a cold place. They should be filled with fresh warm oil and run idle for a few minutes to permit the lubrication system to fill and ensure oil reaching all parts of the engine.

**OIL CONSUMPTION**

Acceptable oil consumption should range from 0.0005 to 0.004 pounds per horsepower-hour. To figure use-

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

**OIL FILTERS**

Although some variations may appear in the oil-filter installations used on the VC 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 filters, even temporarily, and run the engine. **ALL OIL GOING TO THE ENGINE MUST PASS THROUGH THE FILTERS.** For this reason it is doubly important when changing oil that the elements be changed and the filter parts thoroughly washed to prevent clogging or blocking of the oil flow to the engine. When changing full-flow filter elements, be sure to prefill the filters. When a condition arises where neglect of the filters or an unusually rapid accumulation of sludge tends to bring about filter element clogging, the engine will not be starved of oil because of this condition, 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, and may reduce engine life materially.

Engine lubricating oil is used in the governor. Dirty oil causes many governor troubles and any dirt present in the engine oil because of clogged filters will eventually be deposited in the governor.

No particular difficulties are involved in replacing the cartridges, although for the sake of cleanliness it is suggested that the filters be drained of the accumulation of sludge and oil before removing the elements of those filters with replaceable cartridge type elements. About once a year it is good practice to remove the filter plugs and flush out the entire units with mineral spirits, kerosene, benzol, or similar solvent. At the same time, the by-pass valves should be examined for freedom and proper operation. To ensure a clean job without leaks, it is important that the filter seal gaskets be handled carefully and renewed at the same time as the elements.

### FAN HUB LUBRICATION

Use lithium soap type ball bearing grease for lubrication of VC series engine fan hubs. When assembling these fan hubs, be sure to handpack both ball bearings by completely filling the clearances between the balls and fill the space in the hub between the bearings full to diameter of the smaller bearing. Don't overfill the fan hub as excess grease will cause the bearings to burn out.

Once a year or at 2000 hours, repack the bearings and fill the housing with lithium soap type ball bearing grease to the one-half full level. If grease should need to be added during interim periods, rotate the fan hub so the two pipe plugs are horizontal, remove the pipe plugs and add grease as required (till grease begins coming out of the pipe plug vent opening). Replace the two pipe plugs.

### NOTE

As a general recommendation, Waukesha Engine Division recommends the use of lithium soap type ball bearing grease for all grease lubricated ball bearings used in Waukesha engines.

### OVERSPEED SWITCH LUBRICATION (Only Pre-1972 Models)

Once every six months, or as experience dictates, check and replenish the grease reservoir between the bearings (3/4 full) with Aero Shell 7A MIL-G-23827 or equivalent grease. For access to the grease reservoir, remove the cap and switch assembly and the weights and shaft assembly. After greasing, reassemble and re-adjust trip speed as covered under SHUT-DOWN AND SPEED CONTROL ADJUSTMENTS in this chapter.

### AIR STARTER LUBRICATION

Check the oil level before starting the air motor by opening the oil level plug in the motor housing cover. The oil level should be checked weekly and oil added as required to fill the oil reservoir. On systems equipped with line lubricators, maintain the proper oil level as marked on the "Lubricator" bowl. Use SAE 10 oil above 32° F. and No. 2 Diesel oil below 32° F. Line lubricators should be adjusted to produce a light oil vapor at the starter exhaust.

The drain plug below the oil level plug should be removed occasionally to allow any water or condensate in the bottom of the housing cover to drain off. This should be done before adding new oil and after the motor has been idle long enough to permit the oil and water to separate.

Once every three months, or as experience dictates, remove the pipe plug from the gear case (and the housing cover when applicable), and insert a grease fitting to apply a good quality No. 2 cup grease. Two or three strokes from a grease gun are sufficient. Do not pack the gear case full.

Either annually, or whenever the air starting motor is removed from the engine, unscrew the

bushing oiler plug at the end of the drive housing and saturate the felt bushing oiler with SAE 20 motor oil.

Do not adjust the built-in lubricator of starters without line lubricators unless the starter exhaust is either oil-free or contains an excessive amount of oil. Turn either or both of the oiler adjusting screws in to decrease the oil flow; back them out to increase the oil flow. Both of the oiling adjusting screws are located in the housing cover. They are accessible through the air inlet.

**ACCESSORY LUBRICATION**

Those accessories not directly involved in the operation of the engine are generally selected to fill the specific needs of the engine operator. For this reason the variety of types and models of accessory devices becomes so

large that the engine manufacturer must necessarily refer the operator to the recommendations of the accessory manufacturer for service data. Commonly, however, the lubrication of accessories follows certain basic rules that may be used as a guide, but should not be construed as over-riding or substituting for exact instructions from the accessory manufacturer.

Lubricate power take-off units according to the instructions of their manufacturers. Apply a lithium soap type ball bearing grease to the pilot bearing with a pressure gun capable of forcing the grease the length of the hollow shaft and into the pilot hole. Remember, however, that these shafts are filled before installation at the factory and should also be filled when installed in the field; hence great quantities of grease are not desirable. Many modern units will be equipped with permanently sealed pilot bearings and require no greasing at this point.

**SECTION II - SERVICE AND PREVENTIVE MAINTENANCE**

**GENERAL**

Periodic inspection and maintenance must be performed by qualified maintenance personnel to maintain performance and prolong the service life of the engine.

The operator's inspection and maintenance are important in a regular and complete maintenance program and should be considered as a

part of these instructions. Periodic inspections by maintenance personnel should include a check or performance of operator's inspection and maintenance.

**PREVENTIVE MAINTENANCE SERVICES**

Preventive maintenance procedures and time schedules are listed in the accompanying table.

**SERVICE AND PREVENTIVE MAINTENANCE SCHEDULE**

Interval	Procedure
As Required	<p><b>AIR CLEANERS.</b> Check that the air cleaners are securely mounted and that all connections are air tight. Clean air cleaner elements. Replace air cleaner elements if necessary.</p> <p><b>OIL SCREENS.</b> If any indications of low or fluctuating oil pressure become evident, clean the oil screen(s).</p>

SERVICE AND PREVENTIVE MAINTENANCE SCHEDULE (Cont.)

Interval	Procedure
Daily or at each Shift Change	<p>FUEL FILTERS and STRAINERS. Drain a small quantity of fuel. Turn handle of edge type strainer 2-1/4 turns to clean it.</p> <p>LUBRICATING OIL LEVEL. Check oil level and add as required to maintain FULL level.</p> <p>COOLANT LEVEL. Check coolant level and add as required.</p> <p>OPERATING TEMPERATURES and PRESSURES. Check and record all operating temperatures and pressures.</p>
50 Hours	<p>NOISE AND VIBRATION. Check for unusual engine noises or excessive vibration.</p> <p>LUBRICATION. Inspect the entire unit for damaged oil lines or lubrication fittings and for indications of insufficient lubrication and oil leaks. Replace damaged lines or fittings.</p> <p>BATTERY. Check electrolyte level and inspect cables and terminals.</p> <p>BELT DRIVES. Check belt tension and adjust if necessary. Check condition of belts and replace if necessary.</p> <p>COOLING SYSTEM. Inspect for coolant leaks and correct as required.</p> <p>FUEL LINES. Inspect fuel lines for leaks or damage. Repair or replace any damaged lines.</p> <p>GENERATOR or ALTERNATOR. Check for vibration, moisture, unusual amount of dirt, dust, oil, or grease, scorched odor indicating excessive temperature and possible insulation damage, and hot bearings.</p>
150 Hours	<p>Perform 50 hours inspection.</p> <p>FUEL STRAINERS. Clean fuel strainer elements.</p>
250 Hours	<p>Perform 50 hours inspection.</p> <p>MAGNETIC PLUGS. Remove and clean magnetic plugs at lubricating oil inlets to turbochargers.</p> <p>MANIFOLDS and GASKETS. Inspect the intake manifolds and exhaust manifolds for leaks, loose bolts, and defective gaskets. Check the condition of the air and exhaust lines. Tighten any loose bolts to specified torque values. Replace defective gaskets.</p> <p>WATER PUMPS. Inspect the water pumps for leaks and for loose mounting bolts. Tighten or replace loose or missing bolts and cap screws. If water pump leaks, replace it with a new or reconditioned one. Check condition of clamps and check hoses for damage and deterioration.</p>

SERVICE

SERVICE AND PREVENTIVE MAINTENANCE SCHEDULE (Cont.)

Interval	Procedure
250 Hours (Cont.)	<p>GOVERNOR and LINKAGE. Inspect governor for correct operation. Inspect governor linkage for excessive wear or damage. Replace the governor if defective. Adjust or replace governor linkage.</p> <p>FUEL SUPPLY and PRIMER PUMPS. Examine fuel supply pump for leaks at seal leakage drain and at connections. Check operation of primer pump. Replace supply pump and/or primer pump if necessary.</p> <p>AIR ACTUATORS. Check operation of air actuators. Engine speed should respond to controls with no hesitation. Check linkages and air actuators for binding and smooth travel. Lubricate linkage. Repair or replace air actuators if necessary.</p>
500 Hours	<p>Perform 250 hour inspection.</p> <p>VALVE MECHANISM. Check and adjust the valve clearance as required while the engine is cold.</p> <p>UNIT INJECTORS. Inspect all lines and connections for leaks. Check and adjust injector timing as required. Check operation of injector control linkage. Adjust as required.</p> <p>IGNITION. Check points and adjust or replace as required. Check timing. Inspect and re-gap spark plugs—replace if necessary. Inspect ignition wiring. Check magneto drive coupling.</p> <p>FUEL FILTERS. Change fuel filter elements.</p> <p>EXHAUST SYSTEM. Check exhaust back pressure.</p> <p>OIL COOLER. Clean and inspect for clogging or corrosion.</p>
Monthly	<p>BREATHING SYSTEM. Service breather and check operation of crankcase ventilation system. Check crankcase pressure and adjust breather valve if required (if applicable).</p> <p>SAFETY CONTROLS. Check for proper operation.</p>
3 Months	<p>If operating on digester gas, remove carburetor air-gas valve assemblies and wash in water and detergent.</p> <p>GENERATOR or ALTERNATOR. Check all attaching parts and connections, alignment of flexible couplings, and condition and operation of brushes.</p> <p>SWITCHGEAR. Vacuum and clean compartments. File relay points as necessary. Review meter setpoints. Check batteries.</p>
6 Months	<p>INTERCOOLERS. Remove and clean.</p> <p>ENGINE MOUNTING. Check for secure engine mounting.</p>

SERVICE AND PREVENTIVE MAINTENANCE SCHEDULE (Cont.)

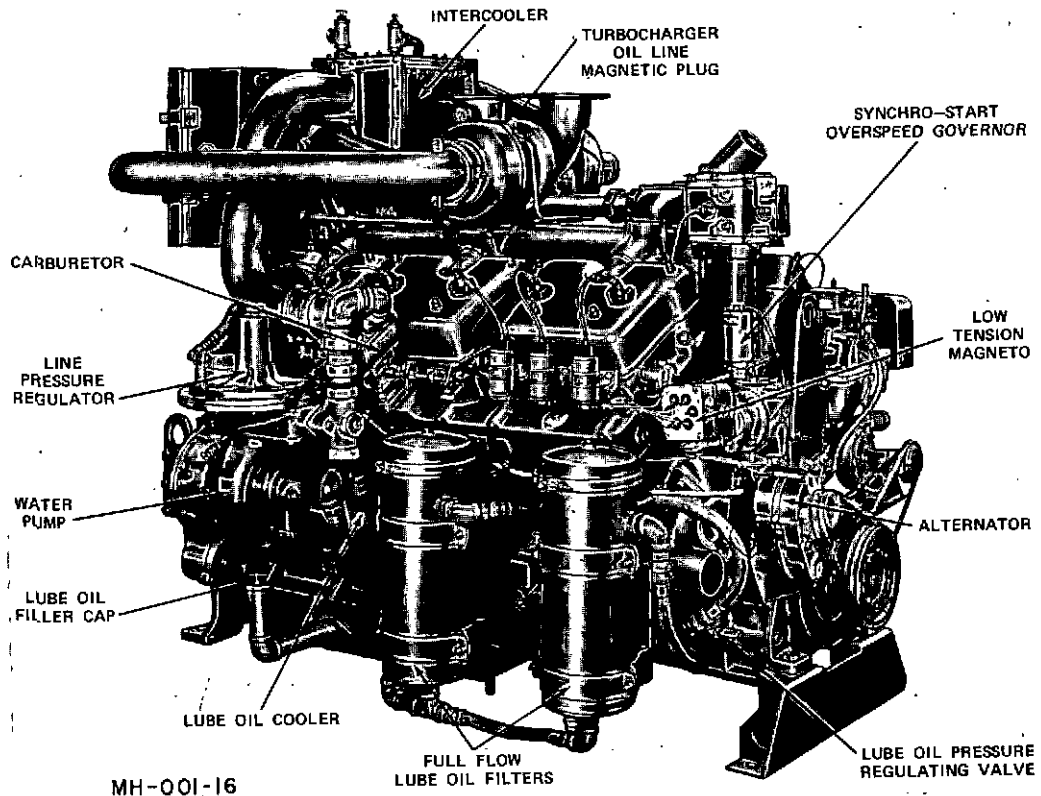
Interval	Procedure
6 Months (Cont.)	<p><b>TURBOCHARGERS.</b> Clean and inspect for damage and excessive seal and bearing wear. Check for adequate lubrication.</p> <p><b>COMPRESSION.</b> Perform compression test.</p> <p><b>MANIFOLD VACUUM.</b> Perform intake manifold vacuum test (gas engines only).</p> <p><b>CARBURETORS.</b> Check gas pressure and carburetor adjustment.</p> <p><b>COOLING SYSTEM.</b> Clean and refill cooling system. Check operation of thermostats. Test pressure cap. Service water filter. Change zinc anodes when applicable.</p>
Annually	<p><b>GENERATOR or ALTERNATOR.</b> Check air gap (4 points at each end-- should be within <math>\pm 5\%</math> of each other), insulation resistance with a megger, coils, and commutators. Clean as required.</p> <p><b>SWITCHGEAR.</b> Inspect and tighten connections. Clean and inspect relays and circuit breakers. Check relay contacts.</p> <p><b>CARBURETORS.</b> Inspect diaphragms annually and replace if cracked or damaged.</p> <p><b>INJECTORS.</b> Test as detailed in Chapter 7 and repair or replace as required.</p>
2 Years	<p><b>GENERATOR or ALTERNATOR.</b> Disassemble, clean, inspect, and repair as required. Dip and bake rotors, revolving armatures, field coils, and stators which can be so handled. Stators and rotors which are too large for dipping should be given a good spray of air drying varnish.</p>
Engine Overhaul	<p>Replace vibration damper to ensure satisfactory performance until next engine overhaul.</p>

SERVICE

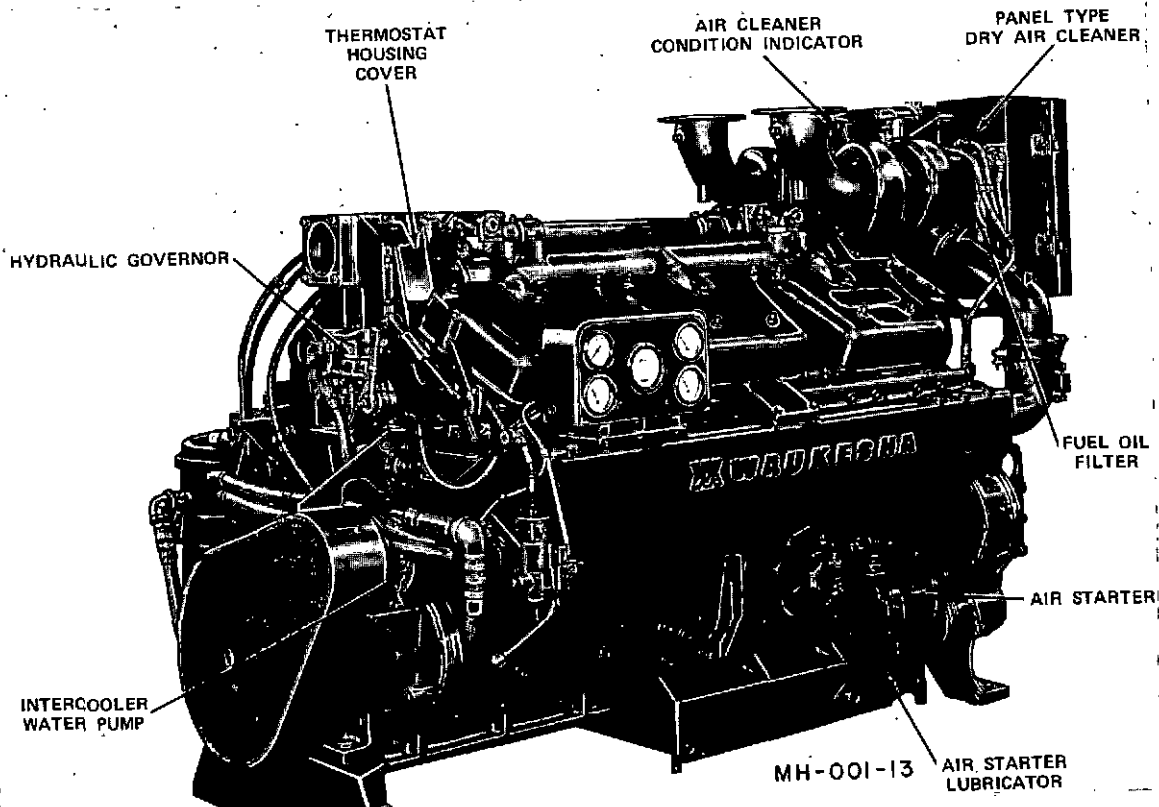
**OIL COOLER**

Maintenance of the oil cooler unit on VC series engines consists largely of periodic cleaning and inspection for clogging or corrosion. Lubrication problems such as 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 entire cooler unit (or element of Model P2154 coolers) with a new unit. All rust and lime deposits should be removed from the

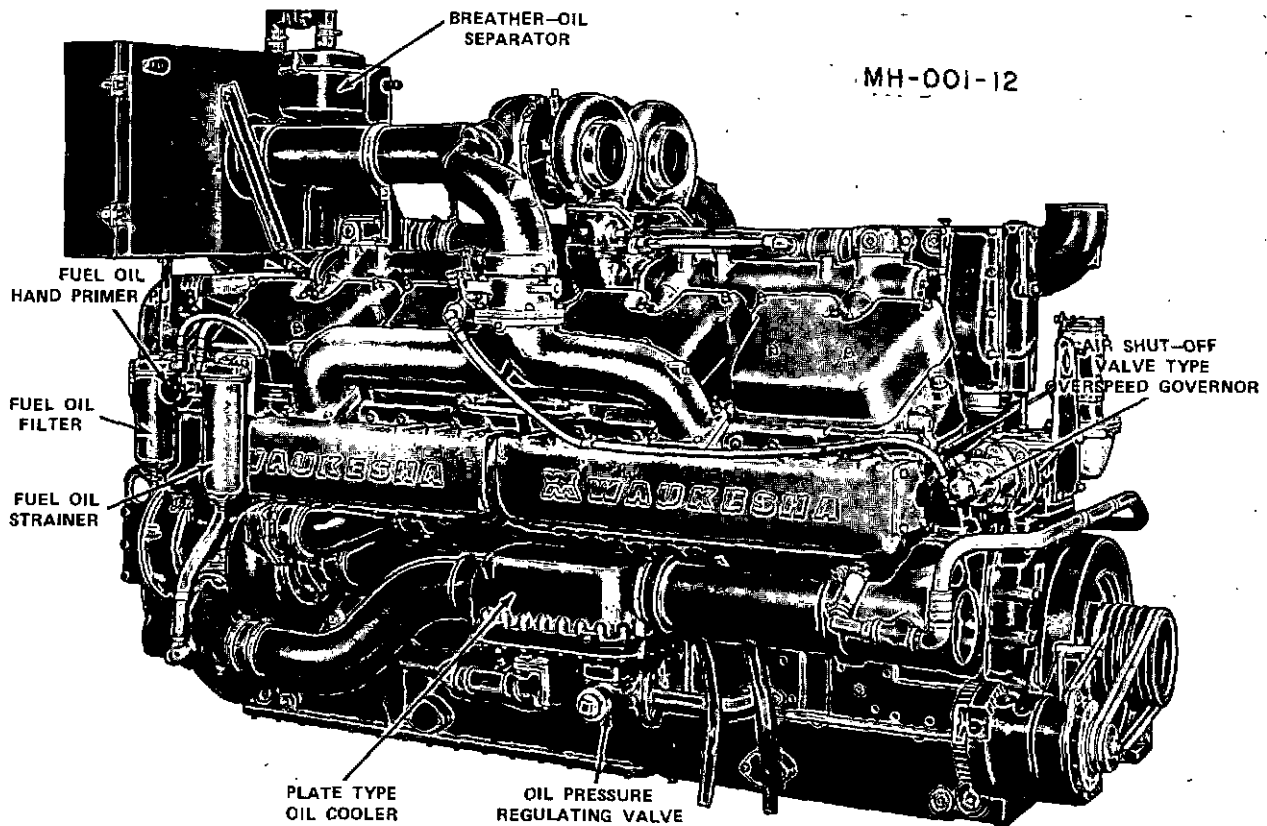
water passage tubes (or element plates) of the cooler at this time. The sludge deposits within the cooler body (or element) may be cleaned out by several solvents and methods, but in all cases, it is recommended that cleaning take place as quickly as possible after removing the cooler from the engine to prevent hardening of sludge and carbon deposits. Circulate the cleaning agent in reverse direction of the normal oil flow through the element of Model P2154 coolers. Ordinarily, a commercial sludge and carbon remover will be effective if pumped vigorously through the cooler body (or element). Soak the cover and the base of Model P2154 coolers in a suitable cleaning solvent. Observe fire and safety precautions.



RIGHT SIDE OF L1616 GAS ENGINE



LEFT SIDE OF L1616 DIESEL ENGINE



MH-001-12

RIGHT SIDE OF P2154 DIESEL ENGINE

SERVICE

**OIL SCREEN(S)**

If any indications of low or fluctuating oil pressure become evident, we recommend the removal and cleaning of the screen mesh strainer(s) below the oil-level equalizers in the oil sump. To remove any accumulation of sludge and carbon gum from the screen mesh, it is recommended that the screen be soaked in a suitable solvent. Soaking should continue until softening of the deposit permits easy removal without damage to the screen.

**TURBOCHARGER AND INLET MAGNETIC PLUGS**

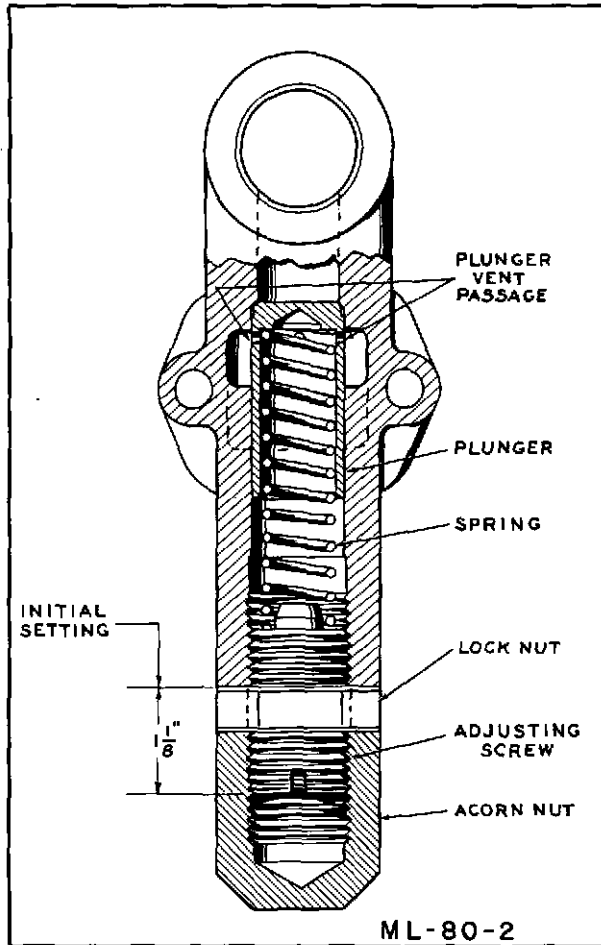
Remove and clean the magnetic plugs at the lubricating oil inlets to the turbochargers at each oil change.

The turbocharger should be inspected for cleanliness and general condition approximately once every six months. Dirt on the impeller must be removed by careful washing with solvent. Check for free rotation and excessive bearing clearances manually.

**OIL PRESSURE CONTROL**

Under all normal operating conditions, the high-capacity lubricating oil pumps used on the VC series engines will maintain the oil pressure within the specified limits of 40-50 psi. A cold engine, or the addition of cold oil to the crankcase of a warm engine, will cause high oil pressure until the oil temperature stabilizes in the proper range. A warm engine will normally carry a low oil pressure at idle speeds and no alarm should be felt under these circumstances if it does not fall below 15 psi. Moreover, the oil pressure gauge of an engine started under cold conditions may fail to register pressure immediately because of congealed oil in the gauge line. If pressure still fails to register after the engine has run for 25 to 30 seconds, the engine should be shut down immediately and the cause of the lack of pressure determined and corrected.

Adjustment of the oil system pressure regulating valve is seldom necessary. This operation should always be done AFTER the engine and oil temperatures have stabilized at normal levels. It is equally important that all other

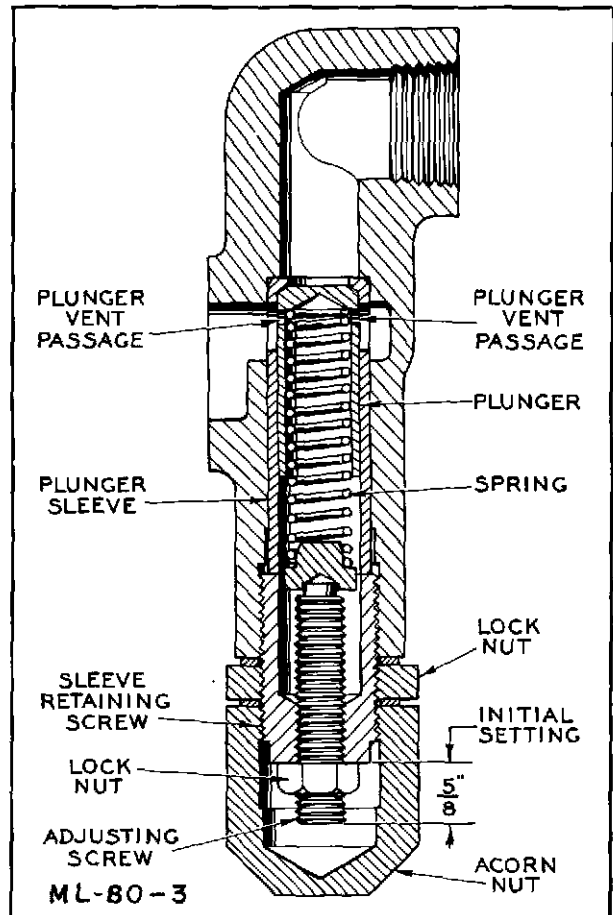


PREVIOUS H1077 AND L1616 OIL PRESSURE REGULATING VALVE - SECTIONAL

factors—proper grade of clean oil, bearing clearances, no leakage, and so on—be satisfactory before attempting to adjust the oil pressure. Adjustment of the pressure regulating valve is not proper compensation for diluted or broken-down lubricating oil. When adjustment is necessary, the pressure adjusting screw should be turned in to raise or out to lower oil pressure as required.

As illustrated, current H1077 and L1616 engines utilize a regulating valve including a plunger sleeve and sleeve retaining screw. The pressure adjusting screw threads into the sleeve retaining screw. Never attempt to adjust oil pressure by loosening the large lock nut which retains and locks the sleeve retaining screw—this results in violent movement of the plunger and causes rapid and severe wear. The plunger sleeve should be bottomed with the sleeve retaining screw drawn down snugly and locked in place with the large lock nut.

Oil pressure fluctuations may sometimes be caused by erratic operation of the pressure regulating valve. If this occurs, it is recommended that the pressure regulating valve adjusting screw and the spring be removed. It is then possible to check the valve plunger itself for freedom of movement. Small particles of carbon or other material may have jammed the plunger or clogged the vent passage in the plunger. In both cases, both the plunger and the control valve body passages should be cleaned thoroughly. If burring or nicking of the plunger seat is found, it may be beneficial to polish the damaged surface carefully with a hone and crocus cloth dipped in fuel oil.

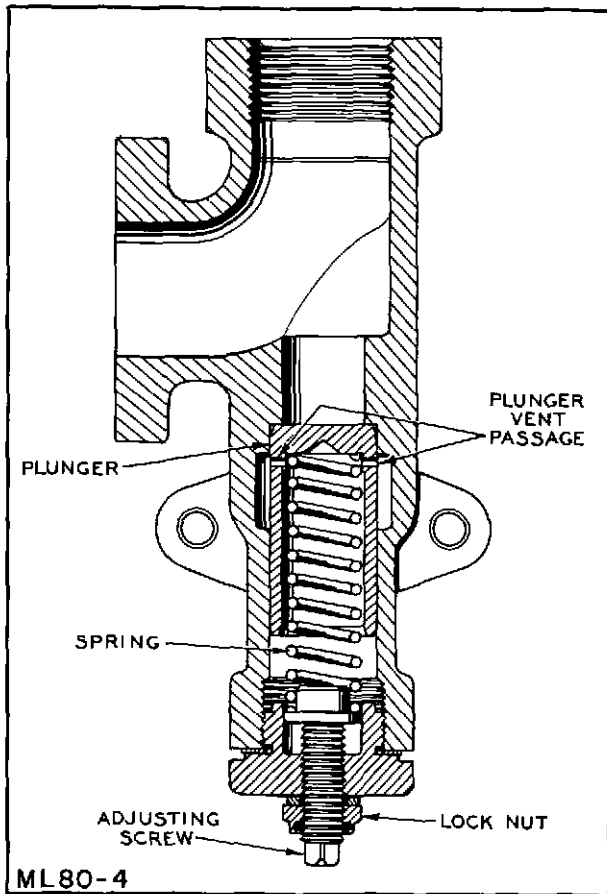


CURRENT H1077 AND L1616 OIL PRESSURE REGULATING VALVE - SECTIONAL

## AIR CLEANER SERVICING

### General

Although various types of engine installations will have differences in air cleaner types and arrangements, it is important for the opera-



P2154 OIL PRESSURE REGULATING VALVE - SECTIONAL

tor to appreciate that the common purpose of all air cleaners is to collect dirt and grit and so keep it out of the engine working parts. As a result, the cleaner units must themselves be cleaned, sometimes several times each day, if operating conditions are particularly bad.

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

#### Oil Bath Air Cleaners

In principle, the intake air passes over a pool of oil located at the bottom of the filter shell. Some of the dust particles are simply caught by the oil and settle at the bottom of the pool; other particles adhere to the oil vapor and droplets that leave the surface of the oil pool. The latter are prevented from entering the engine by a wire-screen element.

To clean filters of the type described above, flush out the oil in the lower part whenever an

obvious accumulation of sediment, or thickening of the oil, makes itself apparent. Scrape away any accumulation, then refill the unit with fresh, clean engine oil. A bead pressed in the metal or an oil level stamping in some types indicates the proper oil level. The screen filter is easily washed out in solvent.

#### Panel Type Dry Air Cleaners

A heavy-duty panel type dry air cleaner is standard equipment.

An air cleaner condition indicator gauge mounted in the air duct serves as positive evidence when air cleaner service is necessary.

### WARNING

The air cleaner condition indicator communicates directly with the intake manifold and is subject to occasional high pressure if gas engines backfire. A restrictor is normally installed in the air passage to dampen momentary high pressure which might damage the indicator and project broken pieces with possible danger to persons nearby. A check should be made to be certain this restrictor is actually in place.

As dirt trapped by the air cleaner gradually restricts the flow of air, the condition indicator signal, which is pre-set for a maximum restriction, rises within the gauge. When the maximum restriction is reached, the signal locks into full view indicating the need for servicing the air cleaner element. After servicing, re-set indicator by depressing indicator button.

### CAUTION

Unless the signal is locked in view indicating a clogged element, 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.

Prior to cleaning, inspect element with a bright light for large or noticeable ruptures, cracks, or tears. Replace if necessary.

To properly clean panel type dry air cleaner elements when required, proceed as follows:

1. Water wash (Preferred method)
  - a. Soak element in lukewarm water and non-foaming detergent solution for ap-

proximately ten minutes. Air inlet side should be submerged and air outlet side held above water level.

- b. Rinse element in clean water with air inlet side down.
- c. Shake excess water from element by hand.
- d. Allow element to dry thoroughly in dust-free area with outlet side down.
- e. When element is completely dry, examine it carefully from outlet side for breaks or ruptures. If any breaks or ruptures are apparent, element must be discarded.

## 2. Air wash

- a. Use soft, open jet of compressed air from outlet side. To avoid rupturing element, never use air pressure over 20 psi.
- b. Shake loosened contaminants from element, holding inlet side down.
- c. Examine element for damage as in step 1.e.

The flow arrows on the edges of the element point towards the air outlet side. Always store elements with the air outlet side down to prevent dust and dirt from accumulating on the outlet side and being passed into the engine when the element is installed.

### CAUTION

A panel type dry air cleaner element should never be cleaned and reused more than three (3) times regardless of its apparent condition.

## Marine Engine Air Cleaners

VC series diesel marine engines were previously equipped with flocked screen-type air cleaner elements, and are currently equipped with oil-wetted screen-type air cleaner elements. These elements are reusable unless they become damaged, or if extended use or improper servicing remove the flocked coating from the previously used elements.

These air cleaner elements should be inspected daily and serviced whenever a substantial dirt build-up can be observed on the surface. If a differential pressure indicator is used, the element should be cleaned at fifteen inches of water restriction.

## Cleaning (Both Types)

Where hot water, compressed air and drainage facilities are available, immerse filter in boiling solution of water and suitable grease solvent (Oakite No. 20; 3 pounds to 5 gallons of water, Tri-Sodium Phosphate, 2 pounds to 5 gallons water). Boil 20 to 30 minutes. Rinse in plain hot water and allow to dry.

Where hot water is available at normal tap pressure of 65 to 90 lbs., immerse filter in hot solution (150° to 180°F.) of water and grease solvent. Agitate filter with outlet side down. Rinse in hot water and allow to dry.

Where hot water and compressed air are not available, immerse filter in Oakite Saturol or Oakite No. 9 and agitate. It may be necessary to use a scrub brush. Rinse thoroughly in plain water and allow to dry.

### WARNING

Use rubber gloves for protection of hands.

Inspect element by holding it up to a light. When element is thoroughly clean, no cloudy areas should be seen.

### NOTE

While the entire media can be cleaned bright, it is not necessary to wash off blackened oil coating on wire element.

## Wetting

Immerse filter element in SAE 30W-50W engine oil. Place filter in heated chamber (20° to 39° F. above working ambient). Allow to drain for a minimum of 8 hours. Wipe surplus oil from frame.

Where only compressed air is available, immerse element in SAE 30W-50W engine oil. Allow surplus to drain off. Using compressed air (85 - 100 psi) start at top of element and work down blowing off heavy oil deposits. Use air on both sides and wipe surplus oil from frame.

Where compressed air and a spray gun are available, use SAE 30W-50W engine oil. Use minimum pressure required to emit oil from spray gun. Traverse both sides of filter with nozzle 3 to 5 inches from element. It normally requires 1/2 pint oil per square foot of filter area. After filter element has been coated thoroughly, allow to drain, face down, or on edge. A receptacle should be used to catch excess oil.

Wipe element base and cover with cloth dipped in solvent before re-installation of element.

Replace element gaskets if necessary. Make sure cover fasteners are in good condition and hold element securely in position and that base is securely fastened to air cleaner adapter.

### COOLING SYSTEM SERVICE

#### General Recommendations

The following suggestions will help to keep an engine cooling system in good condition:

1. Use clean, soft water, free from silt and not contaminated by organic acids or sulphur.
2. Use proper head gaskets and properly torqued head bolts. Retorque replaced heads after running the engine either idle or after load testing. Be sure to follow the head bolt torquing sequence diagram.
3. Keep hoses, pump seals, and other points where air can be picked up, well sealed and free of turbulence or low water conditions which trap air.
4. Maintain oil coolers and rubber hoses to prevent the build-up of adhesive materials and greases.
5. Avoid "trick" and unknown brands of cleaners and inhibitors. Clean and flush thoroughly as follows, whenever anti-freeze changeovers are made, more often if necessary.
  - a. Run engine until hot. Stop engine and open all cooling system vent and drain cocks. Remove pressure cap and allow system to drain.
  - b. After system has completely drained, close all drain cocks and fill cooling system with solvent that will not harm engine parts. Close vent cocks after cooling system is filled.
  - c. Run engine with solvent solution in it for about an hour. Drain system as above.
  - d. If water under pressure is available, leave drain cocks open and place end of water hose in filler opening. Flush system with clean clear water at no more than 30 psi for 15 to 20 minutes.
  - e. Close drain cocks and open vent cocks, and fill cooling system with one ounce of soluble oil per gallon of water or a recommended corrosion preventive or inhibitor and clean water, or glycol type anti-freeze solution if required for cold weather operation. Periodic additions of anti-freeze will be required to compensate for evaporation.

Use a hydrometer type test gauge to ensure that the anti-freeze solution is maintained at its proper strength. Close vent cocks after cooling system is filled.

6. When using soluble oil or other inhibitors, make sure the material is not breaking down to form gummy deposits. The use of soluble oil is definitely worthwhile, particularly with respect to water pump seal lubrication.

#### 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 covers and adapter plates at the forward end of the water manifold. Current surge tanks for keel cooling include two thermostats, which are accessible by removing the surge tank cover and thermostat adapter plate. 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 sufficient water to cover the thermostats and fitted with a good quality thermometer suspended in the water so that the sensitive bulb portion does not rest directly on the bucket bottom or side. A stove or burner 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 167° - 172° range, the thermostat should start to open and should be completely open when the temperature has risen to about 192°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. Previously used thermostats started to open at about 180°F. and were fully open at about 202° F. All thermostats must be tested in this way. Use care when replacing the thermostats to seat them squarely and concentrically to avoid interference with the thermostatic action.

#### Butterfly Type Thermostatic Control

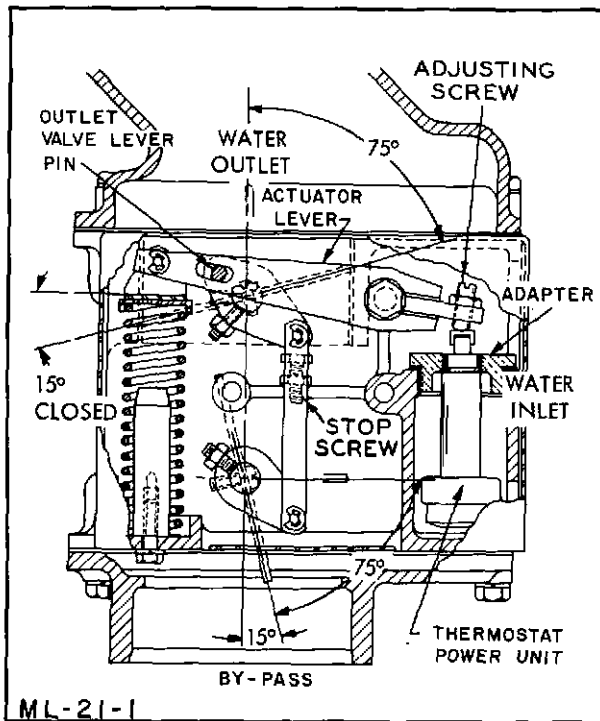
Thermostat power units may be tested in hot water of known temperature. Thermostat power units are assembled into their adapter with Loctite, and should be removed as an assembly with the adapter.

The temperature range of previously used thermostat power units is 160° - 178° F. The temperature range of currently used thermostat power units is 170° - 185° F.

On reassembly, check all linkage for condition and free movement. The power unit should be cooled to room temperature and checked for "cold" position by pressing firmly on end that contacts adjusting screw.

To adjust butterfly type thermostatic control, proceed as follows (see illustration):

1. With water outlet valve in closed position as illustrated, adjust stop screw until outlet valve lever pin is free in slot of actuator lever. Movement of actuator lever must open and close valves freely, with valves not jamming in their bores.

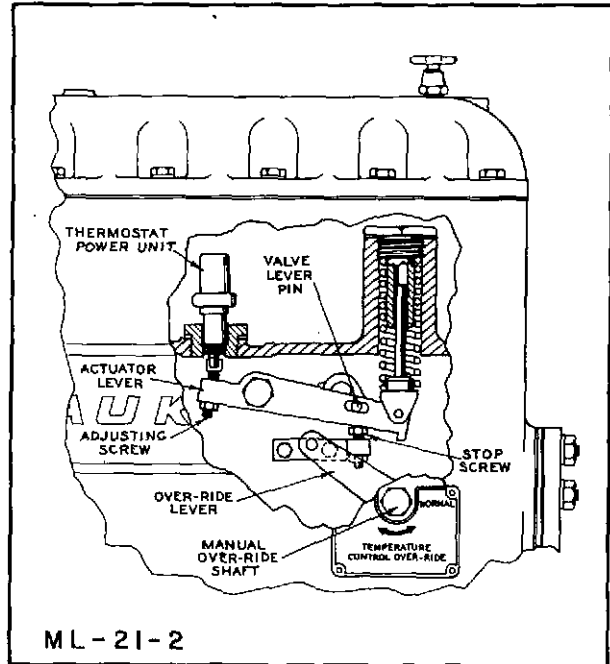


BUTTERFLY TYPE THERMOSTATIC CONTROL

2. Tighten adjusting screw until outlet valve lever starts to raise off stop screw, and then back adjusting screw off 1/2 turn so outlet valve lever rests on stop screw. Hold and lock adjusting screw and stop screw.

If replacing valve shaft seals, install them with lips toward valves.

When butterfly type thermostatic control is used in surge tanks, all of the foregoing information is also applicable, except that the adjustment procedure differs slightly.



BUTTERFLY TYPE THERMOSTATIC CONTROL IN SURGE TANK

To adjust butterfly type thermostatic control when used in a surge tank, proceed as follows (see illustration):

1. With outlet valve in closed position, adjust stop screw until valve lever pin is free in slot of actuator lever. Movement of actuator lever must open and close valves freely, with valves not jamming in their bores.
2. Tighten adjusting screw until actuator lever starts to raise off stop screw, and then back adjusting screw off 1/2 turn so actuator lever rests on stop screw. Hold and lock adjusting screw and stop screw.

Adjust manual over-ride shaft when surge tank cooling is utilized until wave washer drag prevents shaft from turning due to weight of over-ride lever. Setscrew in over-ride lever allows positioning of lever on shaft to adjust drag.

#### Cooling Fans

About the only maintenance work encountered in connection with cooling fans will be the occasional replacement of a blade damaged in some manner and the replacement of fan belts. In the case of slightly bent blades, it is important to remember that inaccurate blade alignment can

cause considerable roughness, vibration and noise as well as inefficient cooling and bearing wear. Hence, fan blades should be examined for security of the hub attachment and possible cracks in the spider area.

### Fan Belts

Periodic replacement of fan belts is good insurance against damaged radiators and inopportune shut-downs. Provision has been made to reduce the stretch between the fan pulley and the drive pulley on the engine and this adjustment should be used to install the belts. Attempting to force the belts over the pulley while they are under tension is almost certain to damage the belts.

To install new fan belts, (all three should be replaced at the same time), proceed as follows:

1. Loosen fan hub nut.
2. Loosen fan adjustment screw on top of fan-support bracket and lower fan hub and pulley until belt tension is completely relieved and old belts can be slipped free.
3. Slip new belts over pulley and take up on adjusting screw until belts show some tension but are not so tight as to prevent movement with thumb and forefinger for about one-half an inch to either side. If available, a belt tensioning gauge should be used.
4. Retighten fan hub nut.

### Intercoolers

Usually the raw water flowage rate is sufficient in providing a turbulent action which will keep mineral or salt accumulation in the intercooler tubes to a minimum for long periods of time. It is recommended, however, that the intercoolers be removed from the manifolds (diesel engines) or disassembled (gas engines) periodically (approximately every six months) for thorough cleaning. This is accomplished by "rodding-out" the tubes of gas engine intercoolers with a soft wire brush or by circulating a commercially available solvent such as Oakite through the tubes of gas or diesel intercoolers. Intercooler gaskets and grommets should be replaced whenever the intercooler is removed for cleaning. For further gasket replacement information, refer to Service Bulletin Nos. 2-1976 and 2-1988B.

### CAUTION

When using a chemical solvent, be sure it does not corrode the tubes or aluminum cooling fins. If an acid solution is used, the residue in the intercooler must be neutralized.

Normally the air or fin side of the intercooler can be cleaned by blowing steam over the fins.

### CAUTION

Do not bend or damage cooling fins while cleaning. This will reduce cooling efficiency.

Zinc anodes are pressed into the two pipe plugs in the gas engine intercoolers. These are provided to minimize galvanic corrosion caused by the salt content in some water supplies. If salt content is high, these anodes will require occasional replacement.

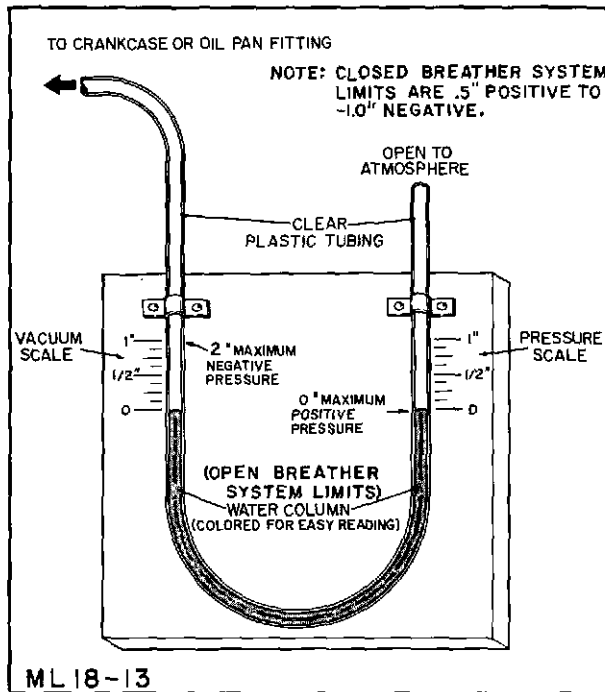
Visually inspect the intercoolers for damage. Test for leaks by plugging the outlet connection, applying 75 psi air pressure to the inlet connection, and immersing the intercooler in water.

### Surge Tank Heat Exchanger

Use a suitable round, soft wire brush to clean scale and corrosion from the heat exchanger tubes. Flush the assembly thoroughly with Oakite or an equivalent cleaning solvent. Flush the surge tank thoroughly.

### CRANKCASE VENTILATION

Regular maintenance of the crankcase ventilation system is very important. Excessive crankcase pressure caused by a poorly maintained system can result in severe lubricating oil leakage, especially around the crankshaft oil seal areas. On the other hand, excessive vacuum or negative pressures can cause small dirt particles to be drawn into the crankcase around these seals. Crankcase pressure should, therefore, be kept within the proper limits as measured in inches of water at rated horsepower. Bend a clear plastic tube into a "U" shape and clip to a section of wood to make a manometer with negative and positive pressure



MANOMETER USED TO CHECK CRANKCASE PRESSURE

scales, as shown in the illustration. Water added to the manometer tube should just reach the zero mark on both positive and negative pressure scales. A dye or ink added to the water aids in reading the manometer when the engine is in operation.

Components of the ventilation system should be serviced on a monthly basis or more often if unusual conditions are encountered. Inspect the ventilation system each time the oil is changed. Don't allow dirt to accumulate.

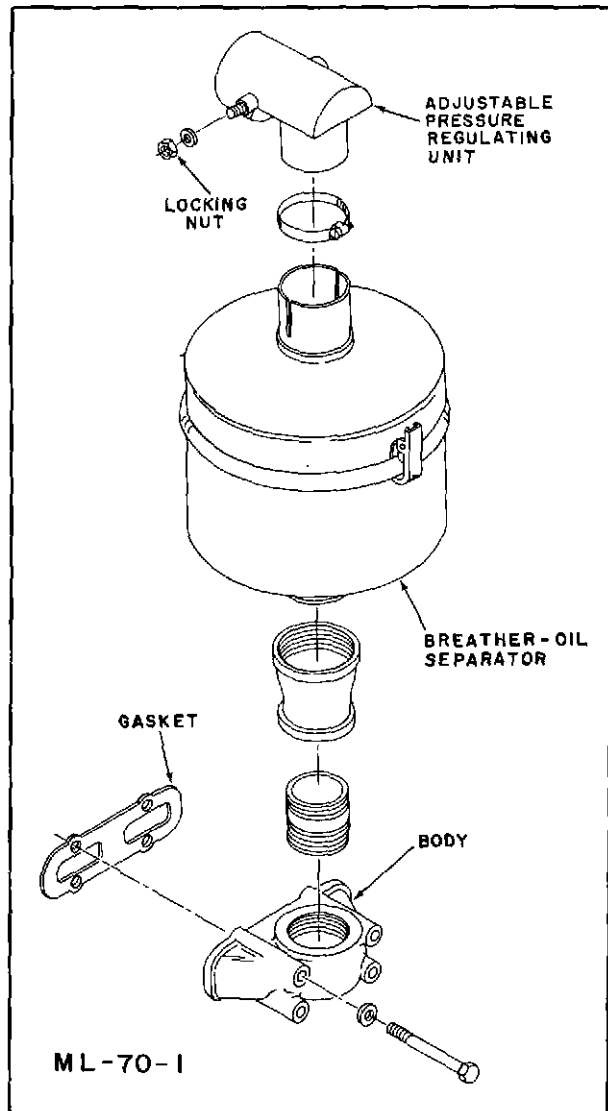
The basic crankcase ventilation system consists of a cylindrical type breather-oil separator and an adjustable pressure regulating unit, with the system vented to the air cleaner plenum. Variations include the use of two plate type breather-oil separators mounted in the rear of the flywheel housing, not using a pressure regulating unit, using a restriction disc instead of a pressure regulating unit, using an automatic pressure regulating unit along with a venturi in the exhaust outlet, venting the system to the outside of the air cleaners, and venting the system to the atmosphere through a down-draft road tube. If the adjustable pressure regulating unit is supplied, it should be adjusted for  $-.25''$  to  $-1.0''$  pressure.

The breather-oil separator(s) filter oil mist from the vented crankcase air by means of metal elements, condense it, and allow the con-

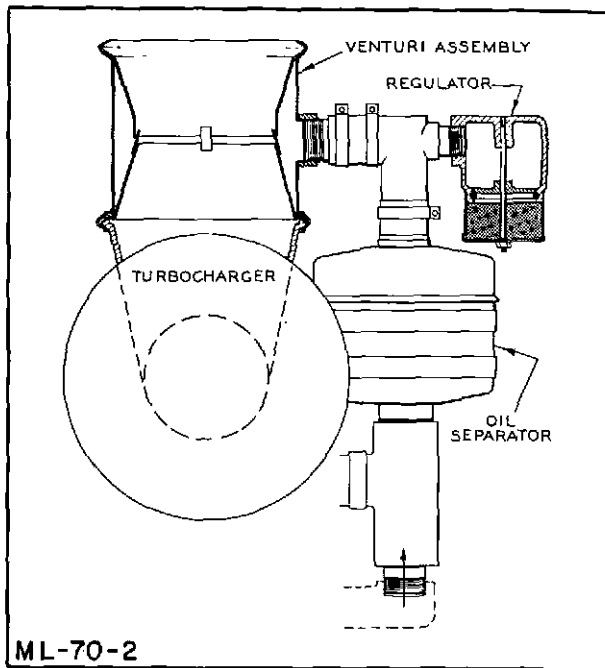
densed oil droplets to drain back into the crankcase.

When used, the adjustable pressure regulating unit must be adjusted to maintain desired crankcase pressure with the engine operating at its rated speed and load. The adjustable pressure regulating unit consists of the breather-oil separator outlet elbow with an adjustable butterfly valve assembled into it. The threaded end of the butterfly valve shaft is slotted to indicate the relative position of the butterfly valve—the slot is parallel to the valve. When the butterfly valve is properly positioned, a locking nut secures the butterfly valve shaft.

When used, the exhaust venturi creates a pressure drop drawing the filtered air from the



TYPICAL BREATHER SYSTEM - EXPLODED VIEW



VENTURI TYPE BREATHER SYSTEM - SECTIONAL

breather. In order to prevent the venturi breather system from pulling excess vapor into the exhaust (as well as creating excess negative crankcase pressure), the automatic pressure regulating unit admits outside air to the system to regulate the breather flow to maintain .5 positive to 1 negative inches of water crankcase pressure.

The automatic pressure regulating unit characteristics have been carefully worked out and no adjustment of this regulator is required in maintaining correct crankcase pressures. If the venturi assembly is not functioning properly due to carbon deposits, it must be disassembled and cleaned. If crankcase pressures continue to build even after careful cleaning of the system, make sure that the exhaust venturi is properly installed and that the regulating unit is working properly.

Maintenance of the breather system consists of cleaning of the breather-oil separator at monthly intervals or more often on engines operated under unusual conditions. To service the cylindrical breather-oil separator, it must be disconnected and removed from the engine. Remove the lid and lift out the removable top element. Wash both the top element and the body which includes the permanent filter in kerosene or some other non-volatile cleaning solution. After washing, dry these parts thoroughly with low pressure compressed air. High-pressure

air could damage the easily crushed light metal filter maze and eventually cause breather system restriction and the resultant excessive crankcase pressure condition.

To service the plate type breather-oil separators, they must also be removed from the engine and have their screens cleaned in kerosene or some other non-volatile cleaning solution, and then dried with low pressure compressed air.

Breather systems venting through downdraft road tubes should have the tube cleaned and examined carefully for kinks which could create a venturi effect and cause excess negative crankcase pressure.

After the breather system components are properly serviced and the engine is again placed in operation, re-check crankcase pressures to make sure that the system is functioning properly.

#### FUEL OIL

VC series diesel engines will operate on any good domestic commercial #2 Diesel fuel oil of 40 Cetane or above (see accompanying table). The fuel must be free from water, foreign material, and deterioration products from prolonged storage. Storage periods of one year should be considered maximum, after which fuel tanks should be drained, inspected, and fresh fuel provided. When fuel oil from sources other than the usual reputable refiners may be considered, the Engineering Department of the Waukesha Motor Company should be consulted.

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

1. Although two major refineries state that their Jet "A" fuel is always above 45 cetane, 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 in approximately the percentage by which the Jet "A" is lighter than No. 2 diesel fuel.

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
SU 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.

FUEL FILTERS AND STRAINERS

Although some variations in filter and strainer equipment will be encountered, depending upon the engine service application, the following service schedules should be observed:

1. Drain small quantity of fuel daily from lower area of each strainer and filter with drain cock at bottom.
2. Turn handle of edge type strainer 2-1/4 turns to clean it.
3. Disassemble, clean, and wash strainer elements at approximately 150 hour intervals.
4. Replace filter elements at 500 hours with original equipment elements.

CALIBRATION FLUID SPECIFICATION

The following calibration fluid specification covers one grade of calibration and flushing fluid for use by Waukesha Engine Division manufacturing, laboratory, and field personnel for flow bench testing, leakage tests, and flushing injection pumps.

The calibration fluid shall be formulated from a straight run deodorized stock containing the necessary additives to meet the requirements of this specification.

An approved source of supply is the Viscosity Oil Company, 3200 South Western Avenue, Chicago, Illinois 60608.

This fluid is recommended for use in all bench testing of unit injectors, especially when such injectors are stored or unused for indefinite periods of time before being placed in service.

VALVE CLEARANCE SETTINGS

General

Accurate valve clearance settings materially prolong engine life and aid performance. In addition to impairing performance, excessive clearances are detrimental to cams and tappets as well as the rest of the valve mechanism. On the other hand, when clearances are too low, valve timing is again disturbed and the possibility of burned valves becomes much greater.

Never attempt to adjust valve clearances without loosening the adjusting screw lock nuts and re-tightening them when completed.

PROPERTY REQUIREMENTS OF CALIBRATION FLUID

Property	Specification Limit	Test Method
Viscosity at 100°F. SUS	34-35	ASTM D-2161
Gravity, API	37-41	ASTM D-287
Color, ASTM	2-1/2 maximum	ASTM D-1500
Color, after storage 6 months at 110°F. ±5°F., ASTM	4 maximum	ASTM D-1500
Humidity Corrosion, hours	45 minimum	
Galvanic Corrosion, 10 days	Pass	FTMS 5322.1
Sulfur, percent weight	0.4 maximum	ASTM D-129 or ASTM D-1552
Distillation, 90 percent BP, °F.	560-580	ASTM D-86
Flash, °F.	160 minimum	ASTM D-93
Water and Sediment, percent volume	0.005 maximum	ASTM D-1796
Foaming Tendency at 75°F., ML after 5 minutes blowing	50 maximum	ASTM D-892
Foam Stability at 75°F., ML after 2 minutes settling	0 maximum	ASTM D-892
Gum	Anti-Gumming	

SERVICE

Whenever the rocker covers are removed, the valve and spring mechanism should be examined for evidence of inadequate lubrication due to sludging or plugged oil lines. Excessive sludge in the rocker arm area is an indication of too low oil operating temperatures, poor filtering action, or an oil that breaks down and is unsuited for the operation involved.

**Valve Clearance Adjustment**

The following adjustment procedure should be followed at all times as normal service procedure (about every 500 hours) and after replacing a cylinder head or rocker arm assembly. Diesel cylinder head or rocker arm assembly replacement also require injector re-timing and injector rack operating lever readjustment.

**CAUTION**

When replacing rocker arm assemblies, be sure that injector push rod spring is centered in rocker arm support. Failure to do this may cause spring, rocker arm, or push rod breakage when spring is compressed.

This procedure must be carried out in sequence in each cylinder in firing order with each piston brought into approximate top center position, compression stroke, as in any conventional valve adjustment.

The valve actuator bridges must be adjusted prior to adjusting clearance between the rocker arms and the rocker arm contact surfaces of the bridges. This valve bridge adjustment compensates for any variation in dimensional tolerances between the two valves actuated by each bridge.

**CAUTION**

If the valve bridges have been removed, be sure to lubricate both the bridge guide pin and the pilot in the bridge with engine lubricating oil prior to installing the bridges.

To properly adjust valve bridges proceed as follows:

1. Back off adjusting screws on rocker arms to allow valve bridges to move freely.

## WAUKESHA VC SERIES

2. Loosen adjusting screw locknuts on valve bridges and back off the valve bridge adjusting screws.
3. Using two fingers, press the valve bridge firmly down on the guide pin and turn the adjusting screw down until it seats against the top of the valve stem (see illustration). Snug down the locking nut after each adjustment to prevent loosening during checking.



ADJUSTING VALVE BRIDGE

4. Check the valve bridge to make sure it is properly centered by holding down each end of the valve bridge and rocking the opposite end (see illustration). Using 1/8 turn increments, clockwise or counter-clockwise as required, adjust the valve bridge screw until the clearance felt by the rocking procedure is equal on both sides of the bridge.

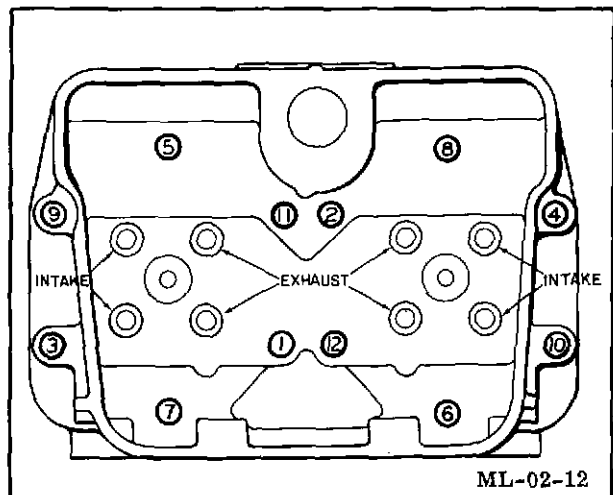


CHECKING VALVE BRIDGE  
ADJUSTMENT

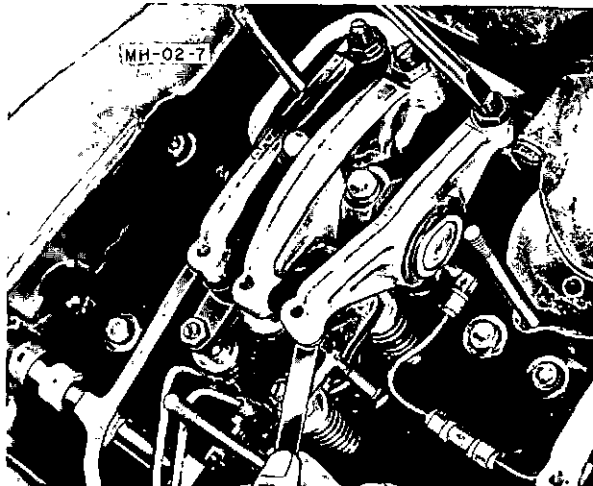
### CAUTION

When checking valve bridge, be sure that the rocking motion is completely vertical. Bridges are capable of moving sideways thus giving a false indication of clearance.

5. Tighten down the adjusting screw locknut while holding the adjusting screw in posi-



VALVE LOCATION AND CYLINDER  
HEAD BOLT TIGHTENING DIAGRAM



**VALVE CLEARANCE ADJUSTMENT**

tion. Adjust the other valve bridge for that cylinder and proceed to valve clearance adjustments.

To make valve clearance adjustment, follow procedure given below:

1. Insert feeler between rocker arm tip and upper end of number one exhaust valve bridge. Drag should be definite but not a forcing fit. Loosen adjusting screw locknut a few turns and rotate adjusting screw as needed until correct clearance is felt on feeler. Tighten locknut again—do not permit adjusting screw to turn with the nut. Check clearance after tightening.
2. Repeat step one for number one intake valve bridge.
3. Repeat valve bridge and valve clearance adjustments on each cylinder in firing order.
4. When completed, rotate engine two revolutions and check valve clearance again.

Rocker arm to bridge clearance, as specified on the engine timing plates, is .011" to .013" for intake valves (both gas and diesel) and .019" to .021" (diesel) or .024" to .026" (gas) for exhaust valves. These clearances are for engines at normal ambient temperatures, NOT FOR HOT ENGINES.

Before starting the engine, after adjusting valve clearance, rotate the crankshaft manually with the barring device to be certain no oversights have occurred which might cause valve and piston interference. After starting and before installing the rocker covers, observe the action and oiling of each set of rocker arms.

**IGNITION SYSTEM MAINTENANCE**

For top engine performance, each unit of the ignition system must be in good condition and properly adjusted. Normal maintenance consists of replacing defective units at periods determined by experience with the type of service involved. Adjustment several times during the service life will extend the usefulness and help benefit engine life.

The following tabulation will be found useful when checking through the ignition system. **DO NOT SLIGHT MINOR POINTS, THEY ARE ALL IMPORTANT.**

**SPARK PLUGS** Check for correct heat range in plug manufacturer's chart. Examine for cracked porcelain, leakage, burned electrodes, deposits on center insulator, correct gap, good washers, and clean threads and seating surface.

**PLUG GAP**

18 mm . . . . .	.025"
14 mm . . . . .	.014"

**LEAD WIRES** Check for sound, unburned, insulation without cracks, breaks, or oil contamination. Terminals at each end should seat firmly on clean, uncorroded contacts.

**COIL** If a transformer coil is suspected to be defective, test by replacing with one known to be good.

**LOW TENSION MAGNETO MAINTENANCE**

**BREAKER POINTS** Check for wear on fiber cam follower; secure mounting; tight, clean, well-insulated low-tension wire; correct spring breaker tension (40 oz. min. for FM-LTR, 21 to 28 oz. for MSB8A); point contacts meeting squarely and not excessively pitted; point gap .016" - .018" for FM-LTR, .020" for MSB8A.

**CONDENSER** Check for secure ground to breaker plate, freedom from oil and grease, wire connection solid. Try new condenser if in doubt.

**LUBRICATION** The ball bearings of the magneto are packed in grease and require no lubrication except at overhaul time. Then the grease should be washed out and replaced with high temperature bearing grease.

Be sure that the felt attached to the cam follower is replaced at overhaul.

**DISTRIBUTOR BLOCK BRUSHES** Brushes should move freely in brush holders and be under slight spring tension. Replace worn or damaged brush assemblies.

**DISTRIBUTOR DISC** Replace distributor discs that are pitted, corroded or have enlarged hub bore. If replacing distributor disc, also replace brush and spring assemblies. Serviceable discs should be cleaned with petroleum solvent and polished with fine emery paper.

### PERIODIC INSPECTION OF BREAKERLESS IGNITION SYSTEMS

Breakerless ignition systems are designed to operate from one engine overhaul period to the next without requiring any intermediate inspection or maintenance procedures. This has been accomplished through the solid state design of its circuitry and by the elimination of many of the normal magneto parts which make rubbing or intermediate contact.

If the engine should develop trouble which appears to be definitely associated with its ignition system, inspect wiring, spark plugs, and transformer coils for the difficulty. If the trouble appears definitely related to the ignition generator, remove it from the engine and replace it with a unit known to be good. It is suggested that a spare ignition generator be kept on hand at the facility for these emergency situations. A defective ignition generator should be sent to a qualified service station for overhaul.

The ignition generator and transformer coils will benefit from periodic cleaning with a cloth dampened with solvent. Inspect the primary terminals and harness plug for security and make certain that the ignition cable is inserted all the way into the high tension well. If corona appears to have affected the high tension terminals, they may be cleaned with a fine,

brass wire brush. Periodic inspection of the mounting bolts is also recommended.

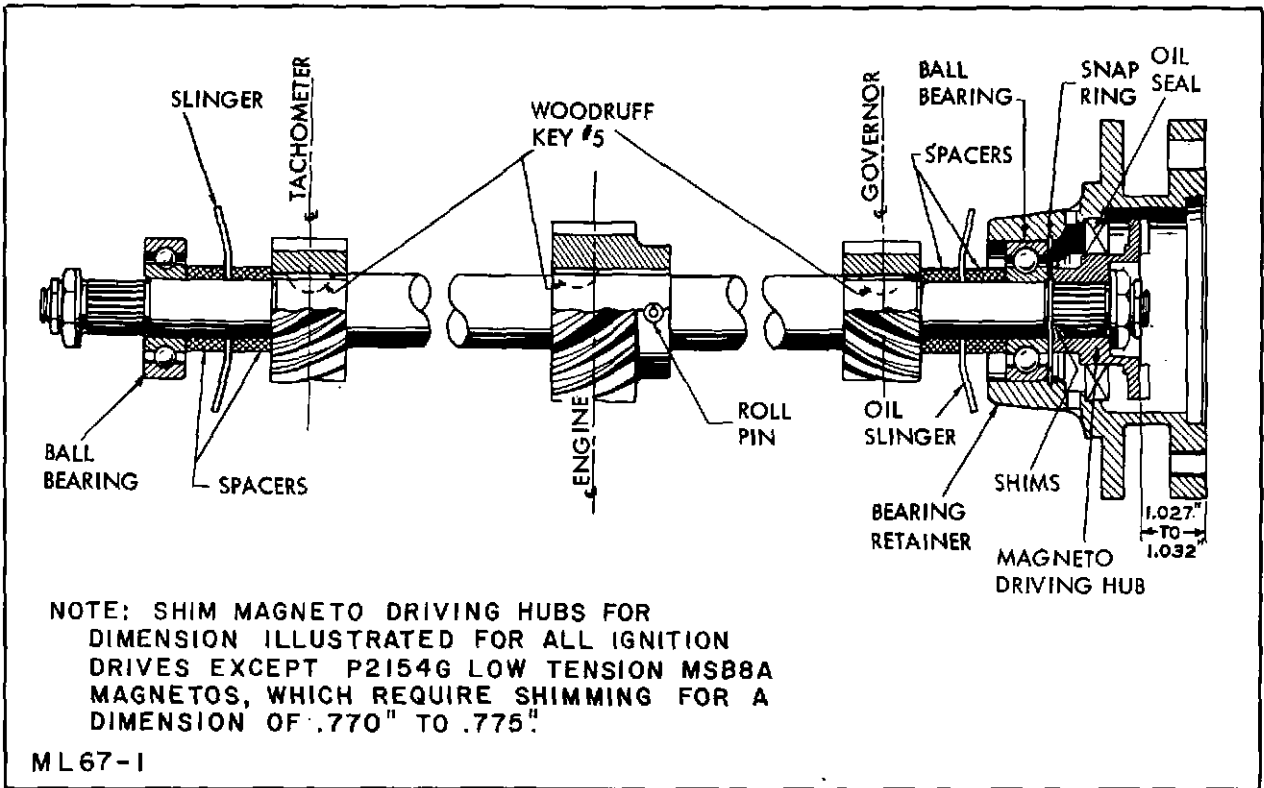
It is not necessary to open the ignition generator for periodic inspection. Opening of the unit will only permit dirt to enter.

### LOW TENSION MAGNETOS

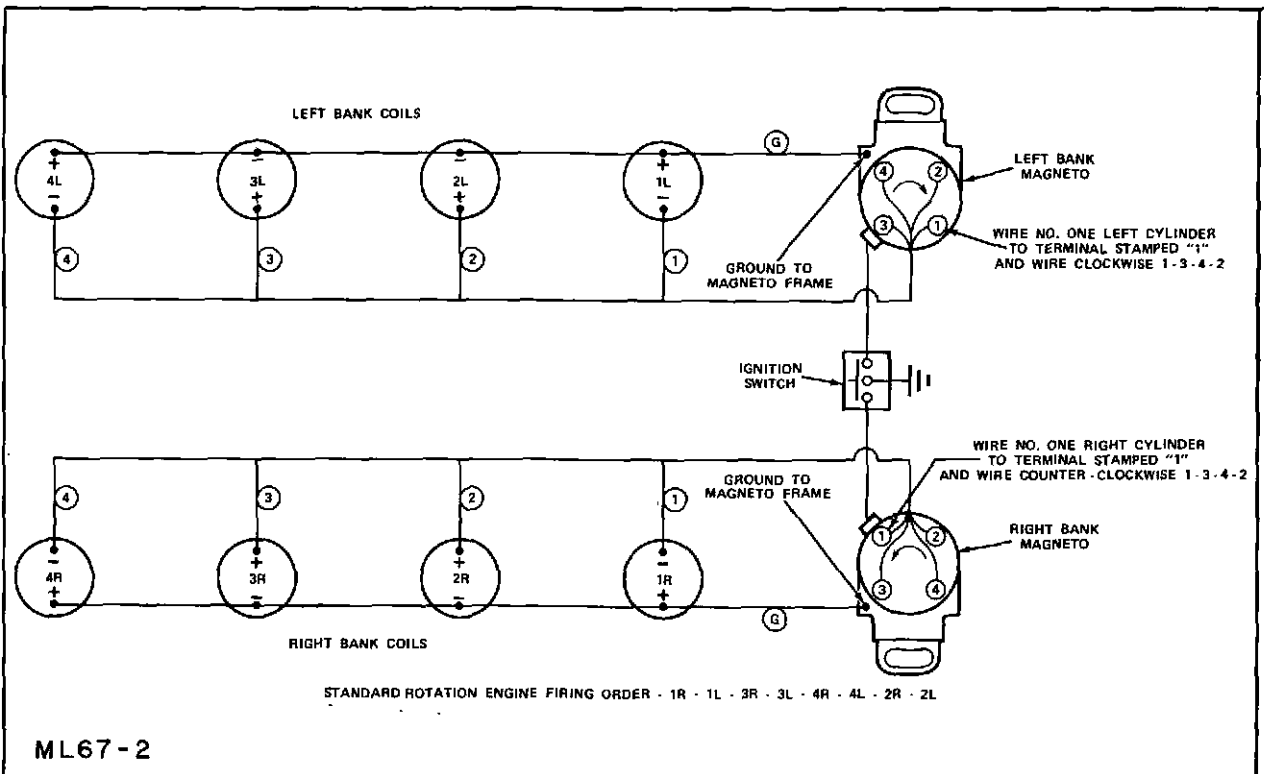
Low tension magnetos generate only low tension or primary current. The magneto distributes this primary current to individual transformer coils, one for each cylinder, where primary current is transformed into high voltage current and is delivered to the spark plug through a short high tension lead.

### LOW TENSION MAGNETO TIMING

1. Bar engine flywheel so correct degree mark on timing tape for bank being timed is centered in right bank timing hole (left bank timing hole is never used) and first piston of that bank in firing order (either 1R or 6L for L1616; 1R or 1L for H1077; 1R or 8L for P2154) is approaching top center, compression stroke. The first pistons in firing order for opposite (left hand) rotation engines are 1L or 6R for L1616, 1L or 1R for H1077, and 1L or 8R for P2154. This is the point at which firing occurs when engine is running and impulse coupling has disengaged.
2. Remove timing plug from top of magneto end cap. Turn magnetic rotor shaft in opposite direction of rotation until yellow timing mark, on edge of distributor disc, is centered in timing window. This mark denotes that end cap cover terminal stamped No. 1 is approximately ready to fire No. 1 cylinder in firing order.
3. Check that engine drive hub is correctly shimmed as illustrated. Install magnetos on engine. If it is impossible to engage slot and tongue drive within range of mounting slots, remove hub nut and hub from accessory drive shaft, and relocate hub on serrations as necessary.
4. Replace magneto timing plug.
5. After magnetos are installed on engine, connect transformer coil lead wires to magneto end cap terminals. Starting with No. 1 terminal, connect wires to agree with engine firing order. When facing end



FRONT ACCESSORY DRIVE



LOW TENSION MAGNETO WIRING DIAGRAM - STANDARD ROTATION H1077G ENGINE

SERVICE

cap cover, No. 1 terminal is at upper left. Connect wires in counterclockwise rotation for right bank, and in clockwise rotation for left bank, as viewed from terminal end of magneto. As illustrated, the No. 1 magneto terminal connects to the negative (-) terminal of the transformer coil for the first cylinder in the firing order; the No. 2 magneto terminal connects to the positive (+) terminal of the transformer coil for the second cylinder in the firing order; the No. 3 magneto terminal connects to the negative (-) terminal of the transformer coil for the third cylinder in the firing order, etc., with connections continuing in the firing order to alternate negative (-) and positive (+) terminals of the transformer coils. Right and left bank magneto rotation for reverse rotation engines is just opposite of that for standard rotation engines. Ground terminals of the transformer coils connect through jumper wires to the magneto end cap screws. The primary terminals on the magneto housings connect to the ignition switch.

ting at governed RPM. If timing is not correct, tap magneto by hand enough to rotate it on mounting flange. With careful tapping, one direction or the other as required, exact timing is readily determined and flange mounting screws must then be tightened.

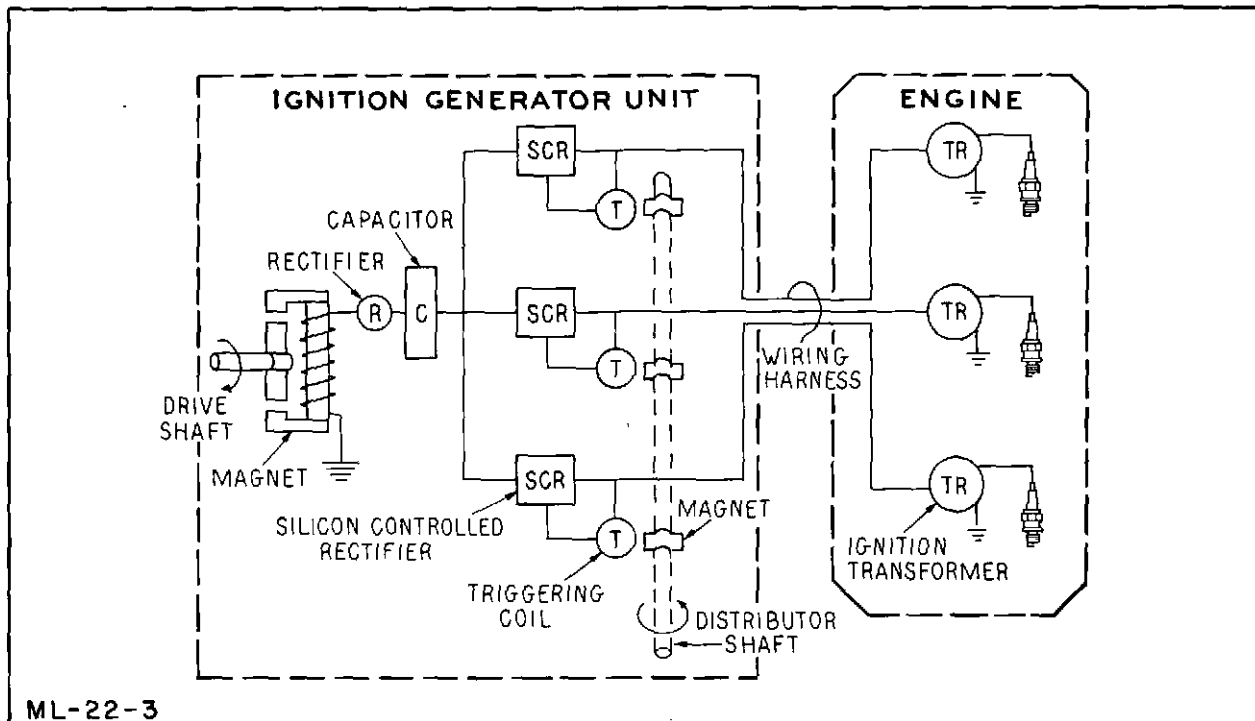
**BREAKERLESS IGNITION SYSTEMS**

Breakerless (capacitor discharge) ignition systems consist basically of an ignition generator, transformer coils, and an interconnecting wire harness with a plug attaching to the ignition generator.

The absence of breaker points and high tension distributor contacts makes the ignition generator completely free of internal arcing. Also, mechanical reliability is greatly enhanced.

The ignition generator includes extensive use of pulse activated solid state electronic components. Alternating current is rectified and stored in the storage capacitors. Silicon controlled rectifiers (SCR) function as switches to release the stored energy to the transformer coils. The switching or turning on of the SCR's is accomplished by a trigger coil arrangement which produces the small SCR turn-on voltage.

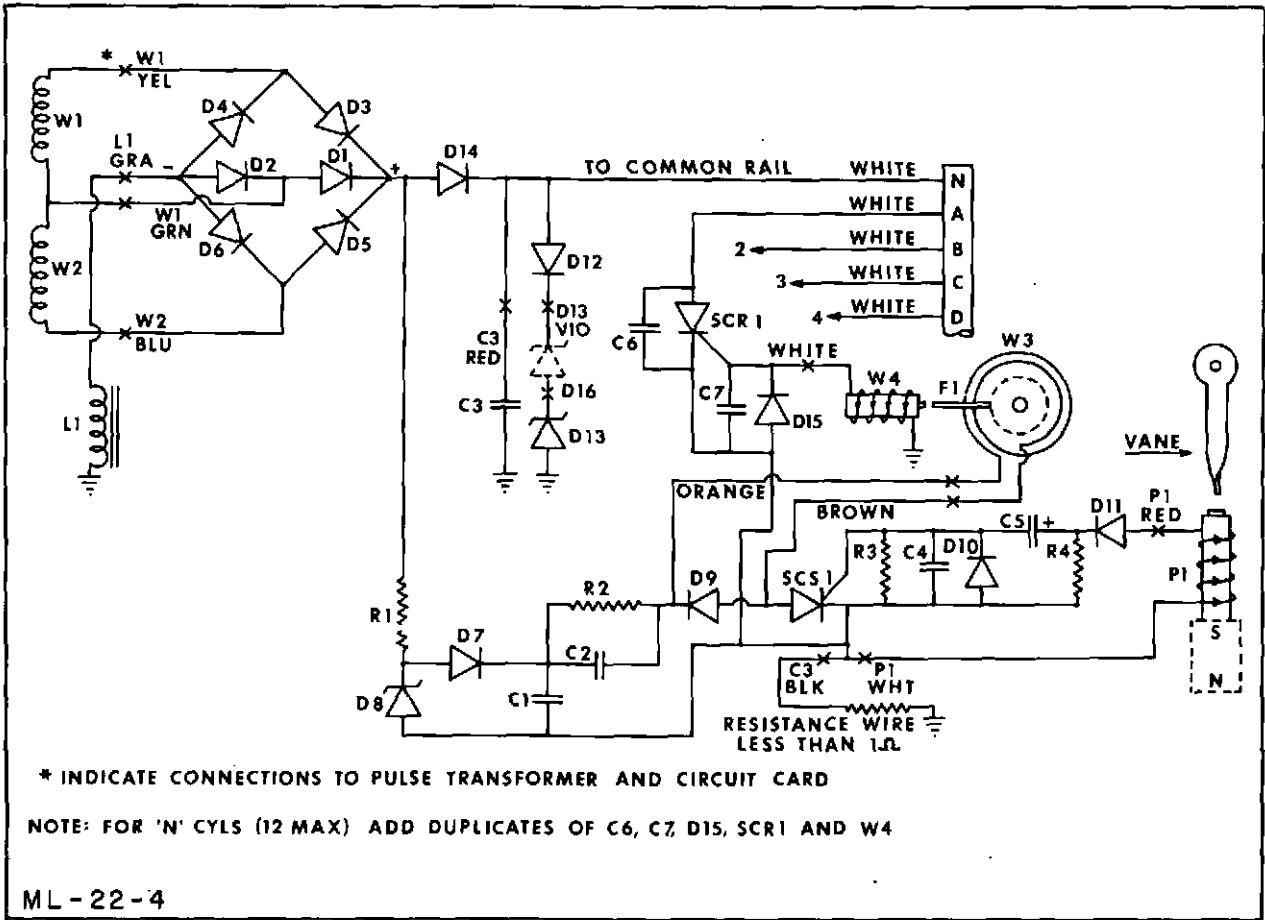
- Final timing is done with flange mounting screws snug. Connect battery powered timing light to spark plug lead of first cylinder in firing order for bank being timed and check timing with engine opera-



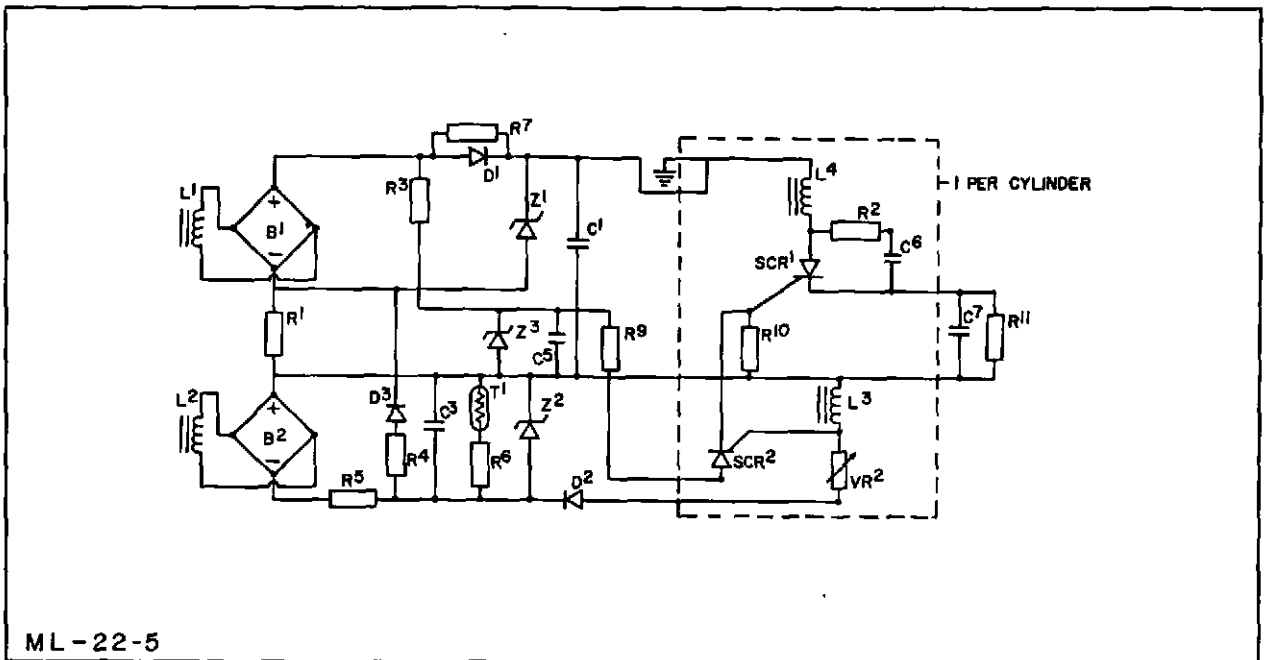
ML-22-3

MAGTRONIC IGNITION SCHEMATIC

WAUKESHA VC SERIES

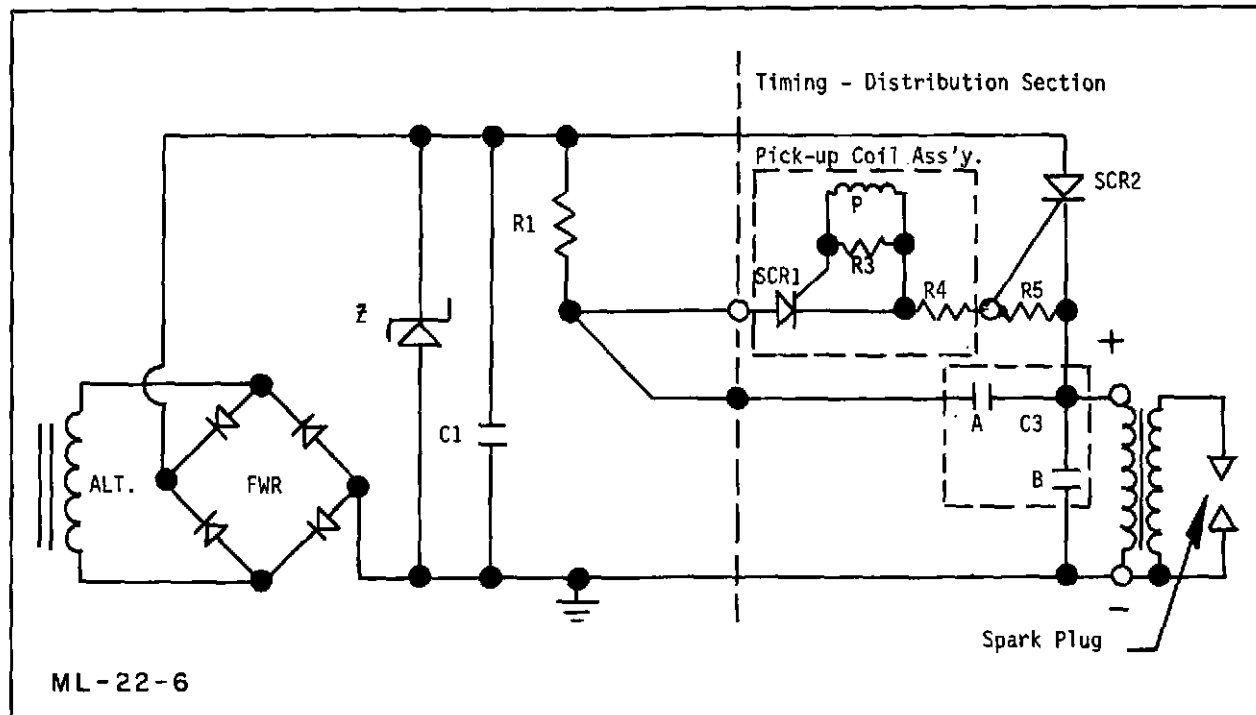


BENDIX S1800 IGNITION SCHEMATIC



FAIRBANKS MORSE SCSA IGNITION SCHEMATIC

SERVICE



ALTRONIC III IGNITION SCHEMATIC

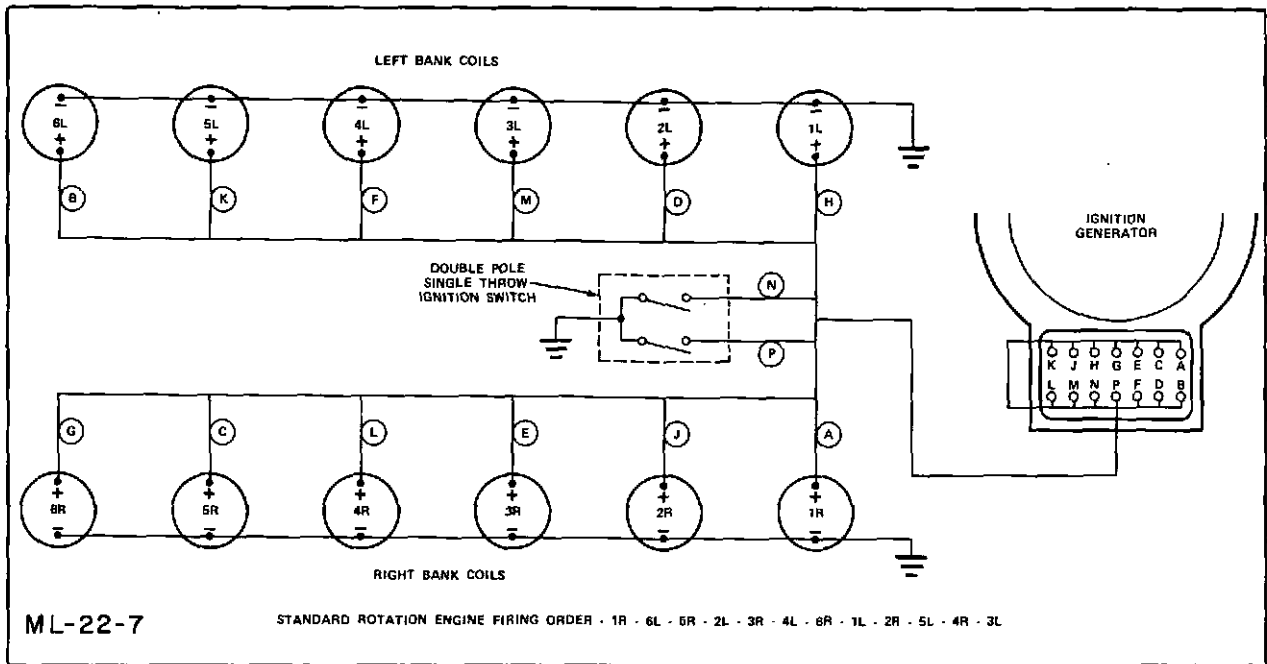
**MAGTRONIC IGNITION TIMING**

When timing ignition generator to engine, proceed as follows:

1. Bar flywheel to No. 1 right cylinder compression stroke, (1L for opposite rotation engines) and align correct timing mark on flywheel in right bank timing hole (left bank timing hole is never used).
2. Rotate drive shaft coupling on generator in direction of rotation, until leading edge of longest (red) finger of distributor rotor is approximately in center of timing window in cover.
3. Check engine drive hub for correct shimming as illustrated.
4. Assemble drive disc to drive plate and connect unit to engine drive. Check to be certain that internal timing has not been disturbed. If it's impossible to engage slot and tongue drive within range of mounting slots, remove hub nut and hub from accessory drive shaft, and relocate hub on serrations as necessary. Flange mounting screws should only be tightened enough to hold unit in place. Make certain that flange gasket is in place.
5. The wiring harness is fitted with a molded terminal plug that mates with receptacle in ignition generator. Each lead in each harness is identified by a letter stamped into insulation at plug end which corresponds with similarly identified terminal in harness receptacle. Regardless of direction of rotation, or number of cylinders served, firing order of ignition generator at receptacle terminals is always in alphabetical sequence, beginning with letter "A". All of harness leads, excepting harness leads "N" and "P", are connected to positive terminals of transformer coils in accordance with engine firing order. Harness leads are also identified with cylinder designation they are to be connected to. Negative terminals of transformer coils connect through jumper wires to engine ground connections.

**CAUTION**

Harness leads "N" and "P" require a double pole switch. A single pole switch is used with "P" harness leads. Never connect "N" and "P" leads to a single pole switch. Doing so will ground system.



MAGTRONIC WIRING DIAGRAM - STANDARD ROTATION L1616 ENGINE

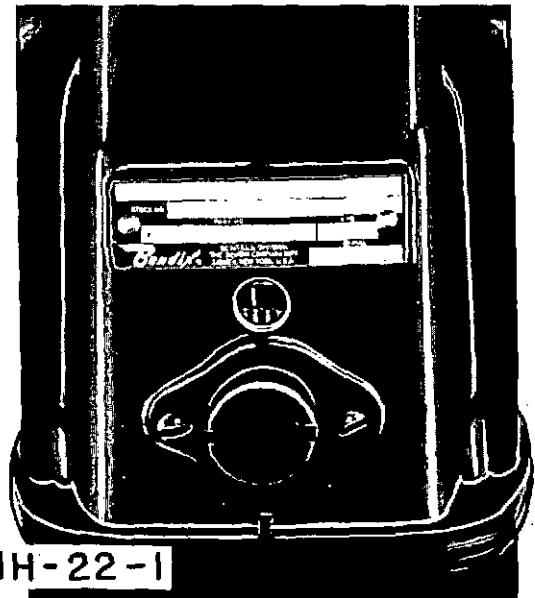
- Timing must be checked with timing light with engine operating at governed RPM. Use temporary high tension lead between plug and transformer coil to connect timing light. If timing is not correct, tap ignition generator by hand enough to rotate it on mounting flange. With careful tapping, one direction or the other as required, exact timing is readily determined and flange mounting screws must then be tightened.

- Install intermediate drive disc on engine drive hub. Note position of slot in intermediate drive disc.
- Keeping timing pointer in center of timing window, install ignition generator on engine. Drive lugs on drive hub should en-

**BENDIX BREAKERLESS IGNITION TIMING**

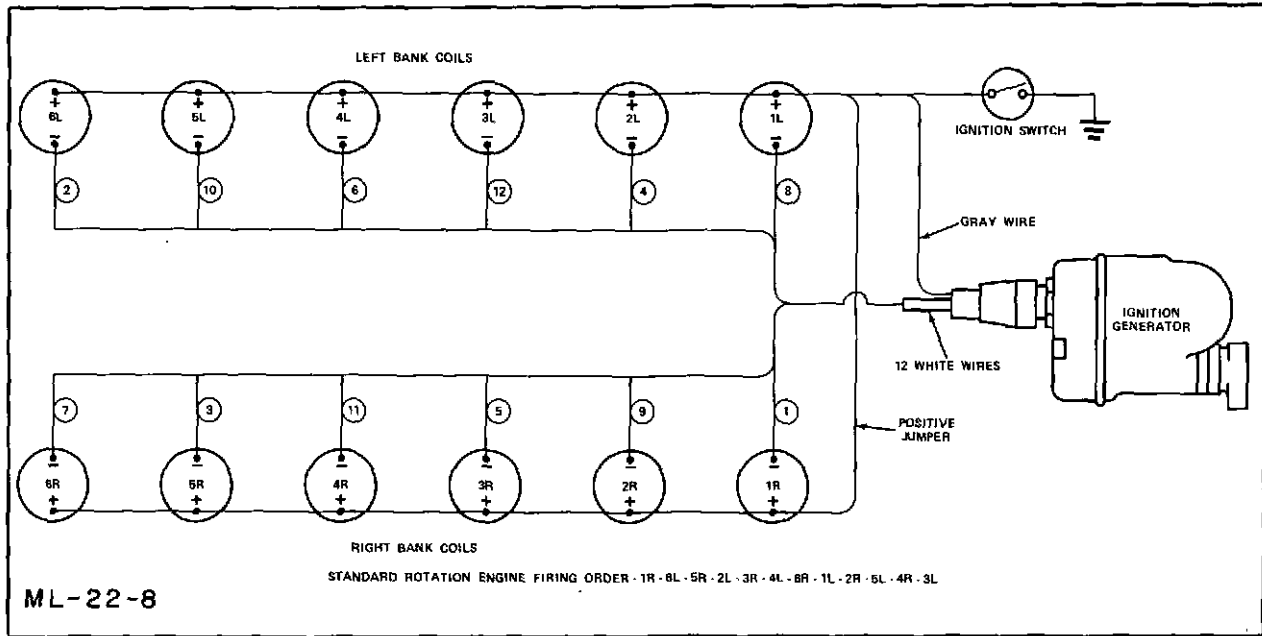
When timing ignition generator to engine, proceed as follows:

- Bar flywheel to number one right cylinder firing position on compression stroke (1L for opposite rotation engines).
- Check ignition generator for proper rotation, remove plug from timing window in top, and turn drive shaft of unit in direction of rotation until timing pointer on large distributor gear is centered in timing window.
- Check that engine drive hub is correctly shimmed as illustrated.



MH-22-1

BENDIX S1800 INTERNAL TIMING



BENDIX S1800 WIRING DIAGRAM - STANDARD ROTATION L1616G ENGINE

gage slots in intermediate drive disc without moving ignition generator drive shaft. If it's impossible to engage slot and tongue drive within range of mounting slots, remove hub nut and hub from accessory drive shaft, and relocate hub on serrations as necessary.

- Secure ignition generator to engine mounting pad with mounting clamps. Replace timing window plug.

**NOTE**

This is not final timing adjustment, but is sufficient to permit installation of unit on engine.

- Connect wiring harness terminal plug to receptacle on ignition generator. To either connect or check wiring, refer to wiring diagram. White wires of wiring harness are identified in numerical sequence in firing order of ignition generator (for both standard and reverse rotation engines) and are also identified with cylinder designation they are to be connected to. They connect to negative terminals of transformer coils. Gray wire of wiring harness is common ground wire which connects through jumpers to positive terminals of all transformer coils and to ignition switch.

- Connect lead of stroboscopic type timing light to spark plug lead of No. 1 right cylinder (1L for reverse rotation engines). Operate engine at governed RPM and observe timing marks on engine flywheel. If timing is not correct, adjust by loosening mounting clamp bolts and rotating ignition unit in applicable direction. Tighten mounting clamp bolts when timing is correct.

**FAIRBANKS MORSE SCSA BREAKERLESS IGNITION TIMING**

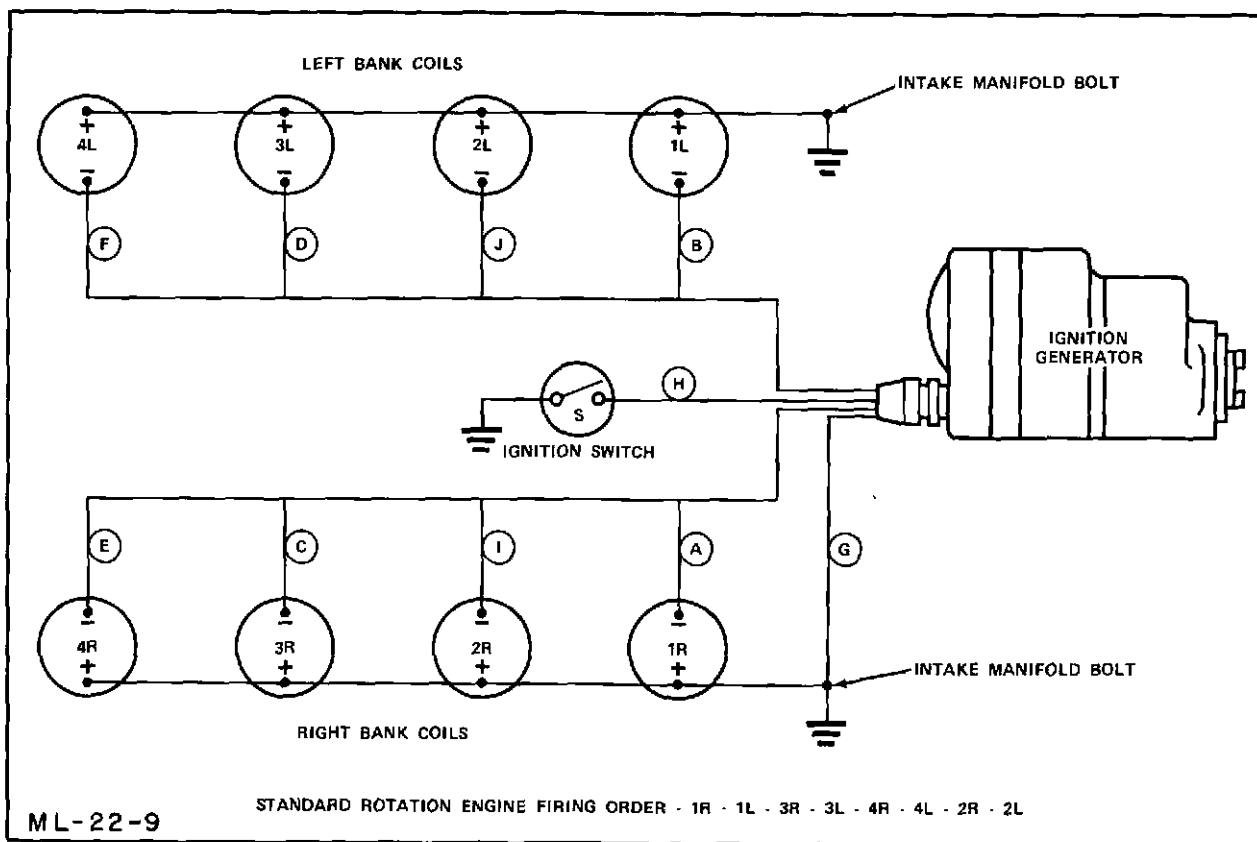
When timing ignition generator to engine, proceed as follows:

- Bar flywheel to number one right cylinder firing position ("STOPPED" timing) on compression stroke (1L for opposite rotation engines). This is 4° BTC for engines operating on natural gas, and TDC for engines operating on LPG.
- Check ignition generator for proper rotation, remove plug from timing opening in top, and turn drive shaft of ignition generator in direction of rotation until yellow timing mark on pulser shaft gear is centered in timing opening.
- Check that engine drive hub is correctly shimmed as illustrated.

4. Install intermediate drive disc on engine drive hub. Note position of slot in intermediate drive disc.
5. Keeping yellow timing mark centered in timing opening, install ignition generator on engine. If it's impossible to engage slot and tongue drive within range of mounting slots, remove hub nut and hub from accessory drive shaft, and relocate hub on serrations as necessary.
6. Check to ensure that internal timing of ignition generator has not been disturbed. Flange mounting screws should only be tightened enough to hold ignition generator in place.
7. Replace timing opening plug in ignition generator.
8. Connect wiring harness terminal plug to receptacle on ignition generator. To either connect or check wiring, refer to wiring diagram. Firing order of ignition generator at receptacle terminals is in alphabetical sequence for standard rotation engines, and is in reverse alphabetical sequence for reverse rotation en-

gines (except that "A" is always first in firing order). All harness leads except "G" and "H" are connected to negative terminals of transformer coils in accordance with engine firing order. Harness leads are also identified with cylinder designation they are to be connected to. Harness wire "G" is ground wire for common connections from positive terminals of transformers. Harness wire "H" connects to ignition switch.

9. Timing must be checked with timing light with engine operating at governed RPM. Use temporary high tension lead between plug and transformer coil to connect timing light. If timing is not correct, tap ignition generator by hand enough to rotate it on mounting flange. With careful tapping, one direction or the other as required, exact "RUNNING" timing is readily determined and flange mounting screws must then be tightened. "RUNNING" timing is 34° BTC for engines operating on natural gas, and 30° BTC for engines operating on LPG. The 30° variation between "RUNNING" and "STOPPED" timing is due to the automatic spark advance built into the ignition generator.



FAIRBANKS MORSE SCSA WIRING DIAGRAM - STANDARD ROTATION H1077G ENGINE

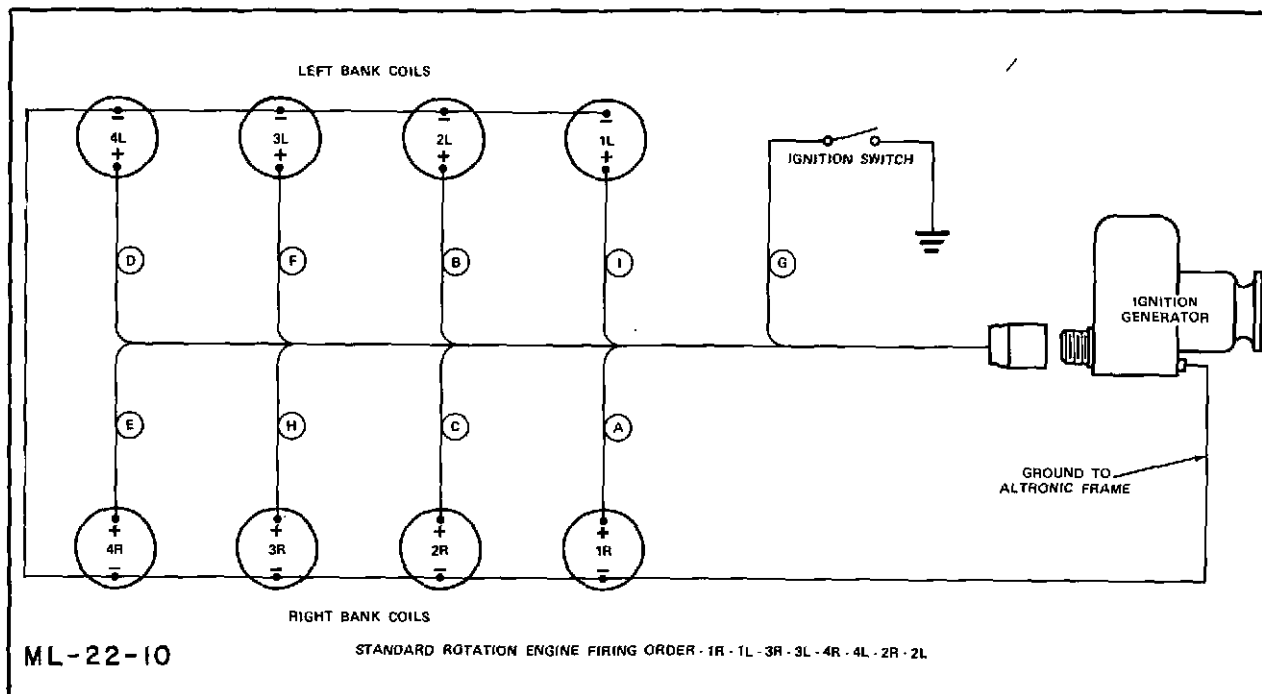
**ALTRONIC III BREAKERLESS IGNITION TIMING**

When timing ignition generator to engine, proceed as follows:

1. Bar flywheel to number one right cylinder firing position on compression stroke (1L for opposite rotation engines).
2. Remove top screw and loosen bottom screw of timing cover on rear of ignition generator, so timing cover can be pivoted to reveal timing marks. Determine correct rotation of ignition generator (as viewed from drive end) and rotate drive coupling until red mark on distributor shaft aligns with proper mark (CW for clockwise rotation or CCW for counter-clockwise rotation) on housing. Standard rotation VC series engines utilize clockwise (CW) ignition generator drive.
3. Check that engine drive hub is correctly shimmed as illustrated.
4. Install intermediate drive disc on engine drive hub. Note position of slot in intermediate drive disc.
5. Keeping red timing marks aligned, install ignition generator on engine. If it's impossible to engage slot and tongue drive with-

in range of mounting slots, remove hub nut and hub from accessory drive shaft, and relocate hub on serrations as necessary.

6. Check to ensure that internal timing of ignition generator has not been disturbed. Flange mounting screws should only be tightened enough to hold ignition generator in place.
7. Replace top screw and tighten bottom screw of timing cover on rear of ignition generator.
8. Connect wiring harness terminal plug to receptacle on ignition generator. To either connect or check wiring, refer to wiring diagram. Firing order of ignition generator at receptacle terminals is in reverse alphabetical sequence for clockwise rotation ignition generators (standard rotation engines), and is in alphabetical sequence for counter-clockwise rotation ignition generators (reverse rotation engines), except that "A" is always first in firing order. All harness leads except "G" are connected to positive terminals of transformer coils in accordance with engine firing order. Harness wire "G" connects to ignition switch. Negative terminals of transformer coils connect through jumper wires to ignition generator frame.



ALTRONIC III WIRING DIAGRAM - STANDARD ROTATION H1077G ENGINE

- Timing must be checked with timing light with engine operating at governed RPM. Use temporary high tension lead between plug and transformer coil to connect timing light. If timing is not correct, tap ignition generator by hand enough to rotate it on mounting flange. With careful tapping, one direction or the other as required, exact timing is readily determined and flange mounting screws must then be tightened.

### ADJUSTMENT OF IMPCO CARBURETORS (1000 BTU LHV NATURAL GAS)

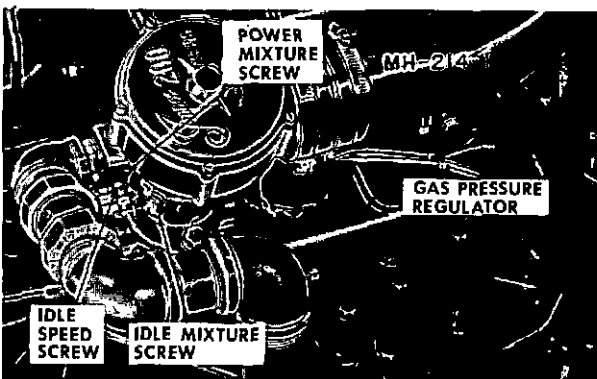
Prior to making any adjustments to the fuel system, it is very important that the linkage from the engine governor to each carburetor is adjusted so that both carburetor butterflies are synchronized—that is, both butterflies are simultaneously fully open and simultaneously fully closed. Refer to Service Bulletin No. 9-2063 for adjustment of carburetor and governor linkage.

After the above check and/or adjustment, proceed as follows:

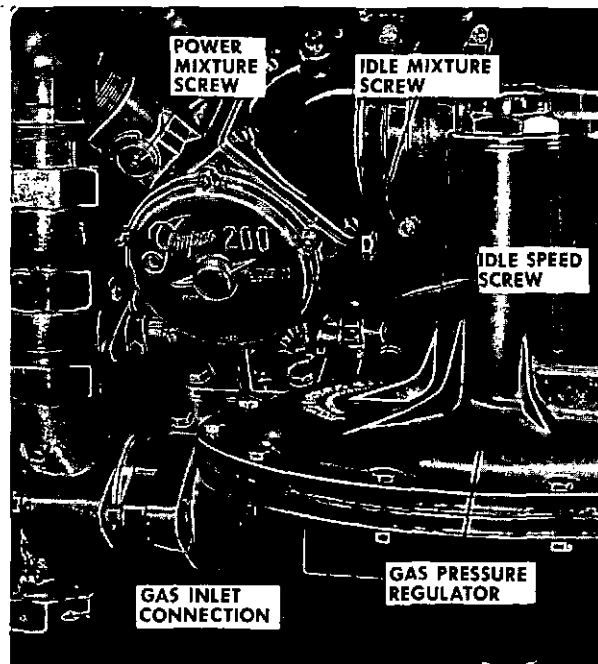
#### Naturally Aspirated Engines

##### Low Idle Preliminary Adjustment

Adjust line pressure regulators, which should be mounted as close to carburetors as possible, to provide 5 inches water column, plus or minus 1/4 inch, gas pressure at each carburetor fuel inlet with engine at low idle, carburetor idle fuel adjustment screws backed out 3 full turns, and carburetor load adjustments turned to rich (R) position.



H1077G CARBURETOR ADJUSTMENTS



L1616G CARBURETOR ADJUSTMENTS

##### Load Adjustment

- Apply full load at maximum governed speed with warm engine. Turn load adjustment toward lean (L) until highest intake manifold vacuum reading is obtained (both carburetors).

#### NOTE

It is important that the fuel supply is adequate to permit the carburetors to be set "over-rich". This can be determined by moving the load adjustment from rich (R) to lean (L) and back again. Between these two points, there should be a position where highest intake manifold vacuum is obtained. If carburetors cannot be set "over-rich", it indicates deficiencies in the fuel system. The carburetors should not be set "over-rich" for actual operational adjustment; this is only a check that should be made to insure the adequacy of the fuel supply.

- Fuel economy can be improved by adjustment to leaner mixture. Turn load adjustment of one carburetor toward lean (L) until intake manifold vacuum drops 1/2 inch mercury column. Turn load adjustment of other carburetor toward lean

(L) until vacuum drops 1/2 inch mercury column.

3. Recheck gas pressure at each carburetor. Under full load, steady state and transient, gas pressure at carburetor ideally should not drop more than 2 inches water column, although this is not critical, if at full load, carburetors can be set over-rich. If full load pressure drop is more than this, it indicates undersize piping and/or gas regulators, or incorrect orifice or spring in regulators, or insufficient line pressure. For gas fuel system requirements, see Chapter 2.
4. Recheck intake manifold vacuum--both banks. If differential between banks is greater than 1/2 inch mercury column, recheck governor to carburetor butterfly linkage and re-adjust as required. Do not lean fuel mixture any further to balance banks.

#### Low Idle Final Adjustment

1. Reduce governor speed setting to bring carburetor butterfly levers against low idle stops.
2. Adjust carburetor idle stop screws to obtain desired engine RPM.
3. Adjust carburetor idle fuel adjustment screws to obtain highest engine RPM (both carburetors).
4. Repeat Step 3 until RPM does not change more than 25 RPM.
5. Re-adjust idle stop screws to obtain desired engine RPM.

### Turbocharged Engines

#### Low Idle Preliminary Adjustment

Adjust line pressure regulators, which should be mounted as close to carburetors as possible, to provide "gas-over-air" pressure at each carburetor of 5 inches water column, plus or minus 1/4 inch, at each carburetor fuel inlet with engine at low idle, carburetor idle fuel adjustment screws backed out 3 full turns, and carburetor load adjustments turned to rich (R) position.

#### NOTE

"Gas-over-air" is defined as the increment of gas pressure at the carburetor inlet over air pressure at the carburetor air horn. It is measured by connecting a water manometer to the carburetor fuel inlet and to the carburetor air horn.

#### Load Adjustment

1. Apply full load at maximum governed speed with warm engine. Turn load adjustment toward lean (L) until lowest intake manifold pressure reading is obtained (both carburetors).

#### NOTE

It is important that the fuel supply is adequate to permit the carburetors to be set "over-rich". This can be determined by moving the load adjustment from rich (R) to lean (L) and back again. Between these two points, there should be a position where lowest intake manifold pressure is obtained. If carburetors cannot be set "over-rich", it indicates deficiencies in the fuel system. The carburetors should not be set "over-rich" for actual operational adjustment; this is only a check that should be made to insure the adequacy of the fuel supply.

2. Fuel economy can be improved by adjusting to leaner mixture. Turn load adjustment of one carburetor toward lean (L) until intake manifold pressure increases 1/4 inch mercury column. Turn load adjustment of other carburetor toward lean (L) until pressure increases 1/4 inch mercury column.
3. Recheck "gas-over-air" pressure at each carburetor. Under full load, steady state and transient, "gas-over-air" pressure ideally should not drop more than 2 inches water column, although this is not critical, if at full load, carburetors can be set over-rich. If full load pressure drop is more than this, it indicates undersize piping and/or gas regulators, or incorrect orifice or spring in regulators, or insufficient line pressure. For gas fuel system requirements, see Chapter 2.

4. Recheck intake manifold pressure--both banks. If differential between banks is greater than 1/4 inch mercury column, recheck governor to carburetor butterfly linkage and re-adjust as required. Do not lean fuel mixture any further to balance banks.

Low Idle Final Adjustment

1. Reduce governor speed setting to bring carburetor butterfly levers against low idle stops.
2. Adjust carburetor idle stop screws to obtain desired engine RPM.
3. Adjust carburetor idle fuel adjustment screws to obtain highest engine RPM (both carburetors).
4. Repeat Step 3 until RPM does not change more than 25 RPM.
5. Re-adjust idle stop screws to obtain desired engine RPM.

**ADJUSTMENT OF IMPCO CARBURETORS (LPG)**

The adjustment sequence for Impeco carburetors when operated on liquid or vaporized LPG, either as the only fuel source or as a dual fuel source along with natural gas, is very similar to the adjustment sequence for natural gas, with the following exceptions:

1. The Impeco "EB" vaporizer-regulators with blue spring provide 1-1/2" water column negative pressure to the carburetor fuel inlets.
2. If vaporized LPG is used, the Impeco pressure reducing valves (with regulator spring removed and valve mounted upside down) provide 1" water column negative pressure to the carburetor fuel inlets.

Line pressure regulators utilized with vaporized LPG are adjusted the same as for natural gas to supply 5" water column gas pressure to the pressure reducing valves.

3. The idle fuel adjustment for dual fuel engines need not be repeated for LPG after it has been set for natural gas.
4. Dual fuel installations require load adjustment for both fuels, since they utilize separate load adjustment controls.

**ADJUSTMENT OF IMPCO CARBURETORS (DIGESTER GAS)**

The adjustment sequence for Impeco carburetors when operated on digester gas, either as the only fuel source or as a dual fuel source along with natural gas, is very similar to the adjustment sequence for natural gas, with the following exceptions:

1. Digester gas is furnished at 6" water column pressure to the carburetor fuel inlets. If used as a dual fuel installation along with natural gas, Impeco pressure reducing valves (with regulator spring removed and valve mounted upside down) are used in the natural gas supply lines to provide 1" water column negative pressure to the carburetor fuel inlets.
2. The idle fuel adjustment for dual fuel engines need not be repeated for digester gas after it has been set for natural gas.
3. Dual fuel installations require load adjustment for both fuels, since they utilize separate load adjustment controls.

**GAS ENGINE MANIFOLD VACUUM TEST**

Operate engine until it is at normal operating temperature.

Connect vacuum gauge to intake manifold and test with engine operating at idle speed, with no load condition (see table at bottom and on page 4-36).

Gauge Readings	Engine Condition
High and Steady (Approx. 18-19 inches at Idle Speed)	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 piston rings.
Very Low	Manifold, carburetor or cylinder head gasket leak.

## WAUKESHA VC SERIES

Gauge Readings	Engine Condition
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 or intake manifold gasket leak.

### UNIT INJECTOR TIMING

VC series diesel engines produced prior to 1968 were equipped with a flywheel marked only for TDC number 1 cylinder right bank (number 1 cylinder left bank for left hand rotation) and injectors for these engines were timed with the injector lifter roller on the injector cam base (with the exhaust valve just closing and the intake valve just opening for the cylinder whose injector is being adjusted). The timing gages for adjusting these injectors were 167079 (1.928" - 1.930" between injector body shoulder and injector spring follower) for all H1077D and lower speed L1616D engines timed at 28° BTC and 167079A (1.905" - 1.907" between injector body shoulder and injector spring follower) for higher speed L1616D engines timed at 32° BTC.

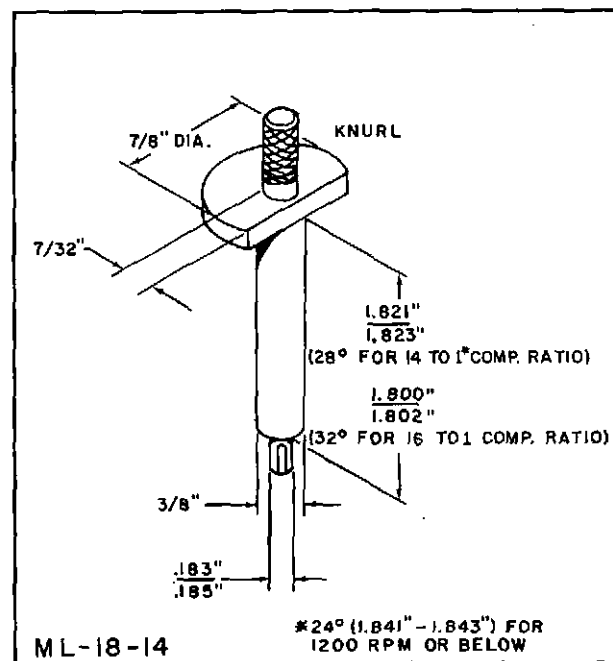
#### NOTE

When timing injectors, use the crankshaft barring device to rotate the crankshaft in the direction of normal rotation. Injectors must be timed in the engine firing order. Adjust injector rocker arm adjusting screw for correct timing dimension and lock in this position.

VC series diesel engines produced since 1968 are equipped with a flywheel which is marked for the firing point of each cylinder (see illustration), and injectors for these engines are timed with the injector lifter roller on the injector cam ramp (with the timing pointer aligned with the timing mark for the cylinder whose injector is being adjusted with that cylinder on its compression stroke). The timing gage for adjusting these injectors is 167079B (1.821"-1.823" between injector body shoulder and injec-

tor spring follower) for the entire speed range of H1077D, L1616D, and P2154D engines timed at 28° BTC.

Current production VC series naturally aspirated diesel engines are equipped with 16 to 1 compression ratio pistons, and are timed at 32° BTC, with timing gauge 167079C (1.800" - 1.802" between injector body shoulder and injector spring follower). Current production VC series turbo supercharged diesel engines, as well as all previous VC series diesel engines, are equipped with 14 to 1 compression ratio



INJECTOR TIMING GAUGE



ADJUSTING INJECTOR TIMING WITH GAUGE

pistons, and are timed at 28° BTC, as covered in the preceding paragraph, except for current turbo supercharged diesel engines, which operate at 1200 rpm or below and are timed at 24° BTC. For 24° BTC timing, use timing gauge 167079D (1.841"-1.843" between injector body shoulder and injector spring follower).

A lesser dimension is utilized when adjusting timing of ramp adjusted injectors since the injector plunger has already been partly depressed because of the position of the injector lifter roller on the injector cam ramp.

Gauges 167079B and 167079C are adequate for service work; however, a dial indicator type gauge, Waukesha Motor Company Kit No. 903-149, is available which assures the most accurate settings in the least time.

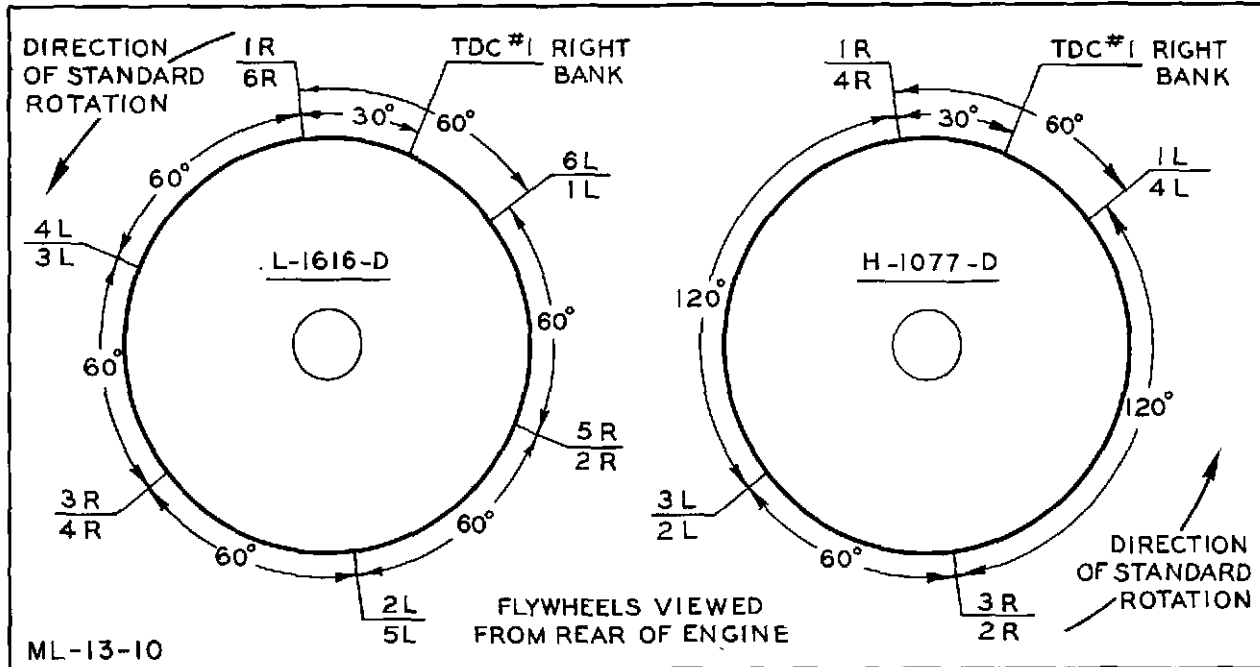
The gauge block of the dial indicator type gauge is 1.799" - 1.801" thick. To adjust in-

jector timing using the dial indicator type gauge, proceed as follows:

1. Set the dial indicator gauge to minus .022" for 28° BTC timing, to minus .001" for 32° BTC timing, or to minus .042" for 24° BTC timing, with the gauge cap contacting the gauge block.
2. Place the gauge block on the injector body shoulder with the block locating pin inserted in the locating pin hole in the injector body shoulder. The gauge cap will be contacting the injector spring follower.
3. Hold the gauge block firmly in position, and with its lock nut loosened, turn the injector rocker arm adjusting screw in or out as required to zero the gauge.
4. Hold the injector rocker arm adjusting screw and tighten its lock nut.
5. Check that the gauge is still zeroed and readjust if required.



ADJUSTING INJECTOR TIMING WITH DIAL INDICATOR TYPE GAUGE



LOCATION OF H1077D AND L1616D FLYWHEEL TIMING MARKS

**CAUTION**

When aligning the timing pointer with the timing mark on the flywheel for the cylinder whose injector is being adjusted, be sure to use the timing pointer located beneath the timing hole cover on the right side of the flywheel housing. There is also an unused timing hole in the left side of the flywheel housing which is covered with a timing hole cover but does not include a timing pointer. Timing must always be set using the right side timing pointer--never attempt to set timing using the timing hole in the left side of the flywheel housing as this will obviously result in completely mis-timing the engine. Flywheel housings on current production engines do not have a left side timing hole.

Each VC series diesel engine shipped includes the proper timing gage to be used for its designated timing (as stamped on its timing and valve clearance plate) and adjusting procedure.

To "ramp time" engines produced prior to 1968 whose flywheels are marked only for TDC number 1 cylinder right or left bank, the flywheel must first be correctly marked for the firing point of each cylinder. These engines included a timing tape for number 1 cylinder right or left bank affixed to the flywheel,

so locating 30° BTC for that cylinder is simple. The locations for the other cylinder firing points can be readily determined. If desired, flywheels can be removed from the engine for marking firing points.

The following measurements are for all VC flywheels:

- 30° = 6.444" or 6-7/16"
- 60° = 12.888" or 12-29/32"
- 120° = 25.776" or 25-25/32"

The flywheel should be permanently marked with a chisel for the timing lines, and cylinder numbers and letters should be stamped with 1/2" stamps.

Since "ramp timing" is more accurate than "base timing", and to standardize on one timing method to avoid confusion and mis-timed engines, we recommend marking early VC series diesel engine flywheels (which were marked for number 1 cylinder TDC only) for the firing point of each cylinder. This will also necessitate remarking the timing and valve clearance plate for 28° BTC (if necessary), and using the "ramp timing" procedure as previously described, using timing gage 167079B with piston of cylinder whose injector is being adjusted on its compression stroke with timing mark for that cylinder aligned with timing pointer.

NOTE

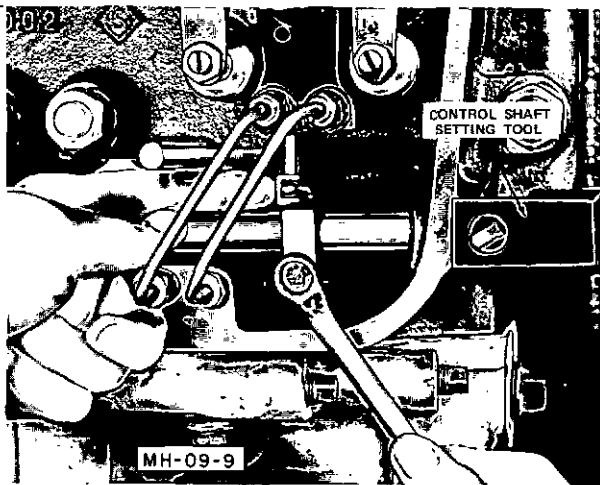
Any VC series naturally aspirated diesel engines which have pistons changed for 16 to 1 instead of 14 to 1 compression ratio must have the timing and valve clearance plate remarked for 32° BTC (if necessary) and must use timing gauge 167069C for "ramp timing".

Injector timing should be checked and re-adjusted as required about every 500 hours, and an injector requires re-timing whenever it is removed and reinstalled or replaced—re-timing is also obviously required if a rocker arm assembly or cylinder head is removed and re-installed or replaced. Rocker arm assembly or cylinder head replacement also require valve clearance re-adjustment. Re-timing because of injector, rocker arm assembly, or cylinder head removal also requires injector rack operating lever re-adjustment as described and illustrated in ADJUSTMENT OF DIESEL FUEL CONTROLS AND LINKAGE, as follows.

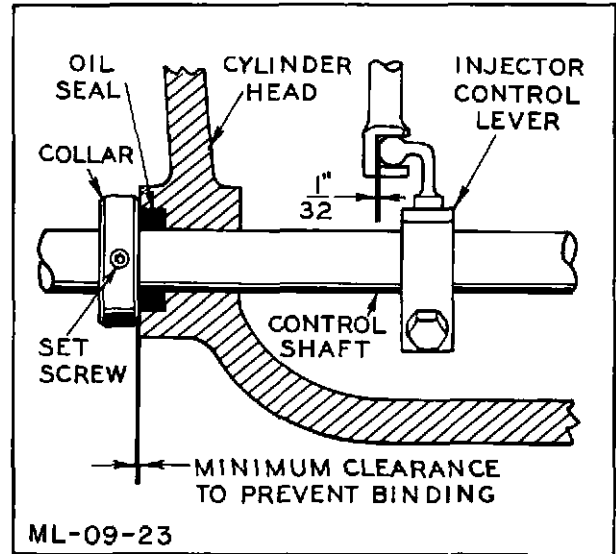
ADJUSTMENT OF DIESEL FUEL CONTROLS AND LINKAGE

NOTE

The "control shaft setting tool", part number A167672, referred to in the following adjustment procedures is supplied with each engine. However, due to a recent revision to control levers and reorientation of the control shaft, an additional number 3 keyway, identical



ADJUSTING INJECTOR CONTROL LEVERS



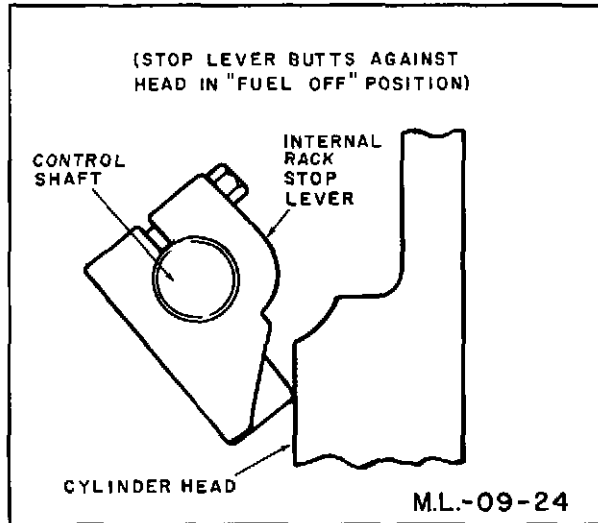
POSITIONING INJECTOR CONTROL LEVERS

to and 180° opposite from the original single keyway, must be cut into tools with only one keyway in order to use them with currently produced engines. The clamping tools furnished with currently produced engines do include the two keyways.

To adjust injector control levers for engines which do not utilize rack stop clips, proceed as follows:

1. Back out full load stop screw in external rack lever stop bracket assembly (if applicable). Disconnect cross rod and remove control shaft lever from front of control shaft (left bank or right bank, as applicable). On engines with vertically mounted governors, install control shaft setting tool (A167672) on front extension of left bank control shaft—on engines with horizontally mounted governors, install control shaft setting tool on front extension of right bank control shaft. Control shaft setting tool must be installed to secure control shaft in "full fuel" position.
2. Adjust individual injector control levers on control shaft with setting tool installed so they are engaged with injector rack "C" opening (with rack in full "in" position) and with flexible coupling free (not forced in either direction) so lever end has a slight clearance in either direction with approximately 1/32" clearance at inner surface of "C" opening (see illustration). Remove control shaft setting tool.

3. If engine is equipped with internal rack stop lever, rotate control shaft to static off position and lock stop in place with stop boss in contact with cylinder head, but with the injectors just slightly in.



ADJUSTING INTERNAL RACK STOP LEVER

NOTE

Check and adjust the cross shaft length if necessary. This dimension should be  $30\text{-}1/2" \pm 1/64"$  between centers of the ball ends. This dimension should not be changed during any of the subsequent adjustment procedures.

4. Re-install control shaft lever on front of control shaft and re-connect cross rod between right and left bank control shaft levers. With control shaft of first adjusted bank rotated so its injector racks are in full "in" position, adjust injector control levers on opposite bank so their injector racks are in full "in" position. Re-adjust full load stop and off-position stop screws in external rack lever stop bracket assembly (if applicable) to absorb force of governor thrust without allowing injector control levers to force racks and linkage.
5. Check for free rotation of entire assembly.

To adjust injector control levers for engines utilizing rack stop clips, proceed as follows:

1. Disconnect cross rod and remove control shaft lever from front of control shaft (left bank or right bank, as applicable). On engine with vertically mounted gov-

ernors, install control shaft setting tool (A167672) on front extension of left bank control shaft—on engines with horizontally mounted governors, install control shaft setting tool on front extension of right bank control shaft. Control shaft setting tool must be installed to secure control shaft in "full fuel" position with rack stop clips removed from all injectors on this bank.

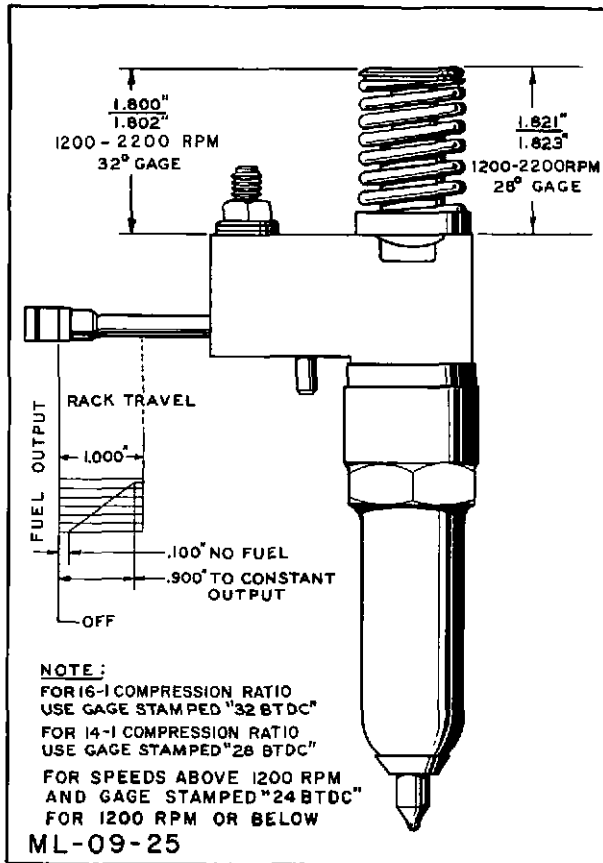
2. Adjust injector control lever of number one injector for control shaft with setting tool installed so injector control rack is in full "in" position.

NOTE

Adjust individual injector control levers so they are engaged with injector rack "C" opening and with flexible coupling free (not forced in either direction) so lever end has a slight clearance in either direction with approximately  $1/32"$  clearance at inner surface of "C" opening (see illustration).

3. Remove control shaft setting tool.
4. Reinstall rack stop clips on all injectors for this bank. Adjust injector control levers for injectors other than number one injector so their stop clips are all firmly contacting their injector bodies simultaneously with stop clip on number one injector. It may be necessary to disconnect rack return spring from rear head injector control lever until this adjustment sequence is completed for all other injectors on this bank, and then reconnect spring and adjust its injector control lever.
5. Reinstall control shaft lever on front extension of control shaft of bank which has been adjusted. This is positioned with a woodruff key and locked with a setscrew.
6. Install cross shaft without disturbing its previous length adjustment ( $30\text{-}1/2" \pm 1/64"$  between centers of ball ends).
7. With control shaft of first adjusted bank rotated so its injector rack stop clips are firmly contacting injector bodies, adjust injector control levers for opposite bank so their injector stop clips are firmly contacting their injector bodies.

- Connect control linkage from governor and check for travel from "off" position to "full-fuel" position (injector rack stop clips against injector bodies). Adjust length of governor rod so injector control racks are not quite in their fully extended position when governor lever is in "off" position. This assures that racks will not be forced tightly against their travel limit in injectors when governor lever returns to its "off" position. Fuel delivery does not commence until racks have moved .100" from extreme shut-off end of their travel.

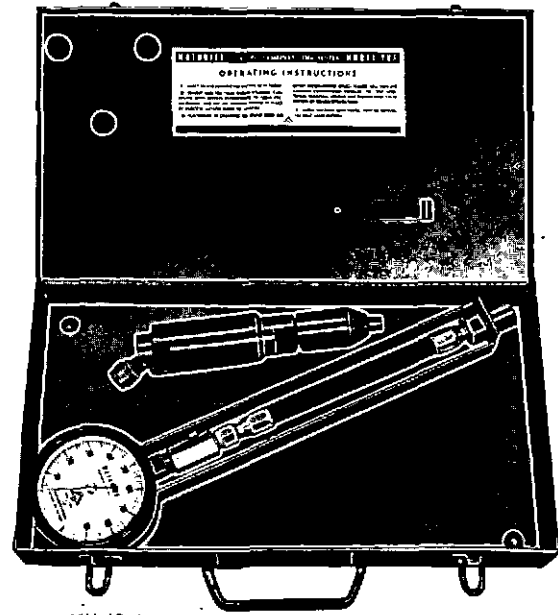


INJECTOR RACK TRAVEL AND TIMING

**NOTE**

Engines equipped with rack stop clips do not require either the external rack lever stop bracket assembly or the internal rack stop lever.

- Check for free rotation of entire assembly.

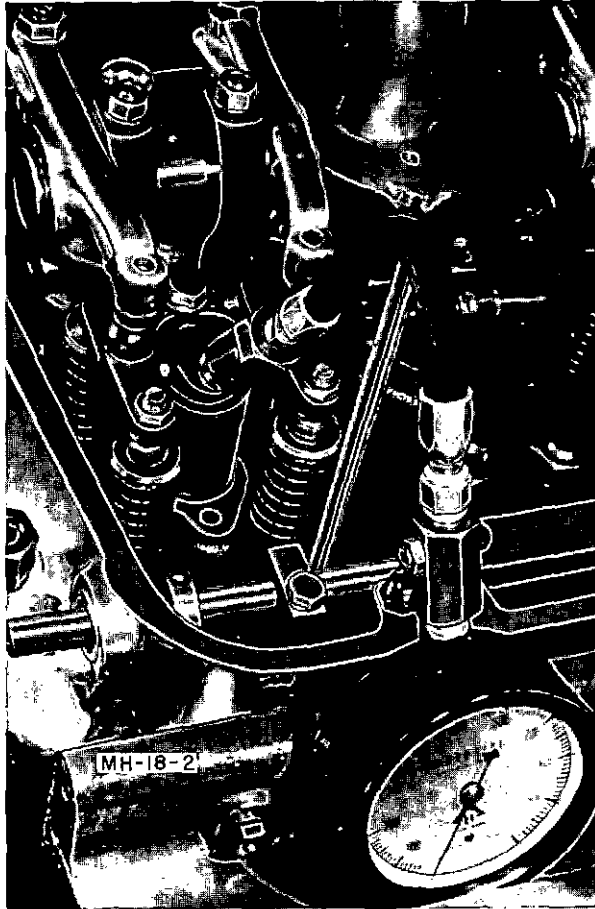


DIESEL ENGINE COMPRESSION TESTER AND ADAPTOR

**COMPRESSION TESTING**

To check compression of VC series diesel engines, a special compression test adaptor, Part No. 499946, is required along with a standard compression gauge and hose assembly, Part No. 499940. The rocker arm assembly and injector must be removed and the adaptor (along with an injector sealing washer) and a special rocker arm assembly without the injector rocker must be installed. When installing rocker arm supports, be sure that injector push rod spring is centered in rocker arm support. Failure to do this may cause spring, rocker arm, or push rod breakage when spring is compressed. The injector hold-down clamp must be used to hold the adaptor in position. Then connect the gauge and hose assembly to the adaptor. The injector push rod is left in position during the compression test. The engine should be warmed up to normal operating temperature and make sure the fuel control rod is in "no fuel" position. Crank the engine several times until gauge indication stabilizes.

To check compression of VC series gas engines, a standard automotive type compression tester with threaded adaptors should be used. Current gas engines utilize 14 mm spark plugs, while previous gas engines utilized 18 mm spark plugs. Before checking compression, be sure the engine has been warmed up to operating temperature, the throttle is held in open position, and the ignition is grounded so



USING ADAPTOR TO CHECK DIESEL ENGINE COMPRESSION

the engine can't start while cranking for the compression test. Maintain engine cranking speed for approximately 20 seconds—repeat compression testing for each cylinder.

Normal compression pressures at cranking speed are listed in FITS AND CLEARANCES, Chapter 8. Uneven compression or pressures lower than normal call for further investigation. It may indicate the need for valve re-grinding, piston ring replacement, or other overhaul procedures.

### SHUT-DOWN AND SPEED CONTROL ADJUSTMENTS

#### Slow-Down Type Overspeed Governor (Diesel Engines)

To adjust the "slow-down" type overspeed governor linkage, proceed as follows (see illustration):

1. Apply air pressure (25 to 100 PSI) to remote shut-down connection of overspeed governor to extend overspeed governor rod to its shut-off position.
2. Adjust overspeed governor adjusting nut (if necessary) so overspeed shut-down lever is firmly against contact surface of left bank control shaft lever.
3. Remove and apply air pressure to overspeed governor a few times to check for proper operation. The application of air pressure must cause the shut-down lever to rotate the control lever to shut-off position, thereby withdrawing injector racks to their off position. Re-adjust overspeed governor adjusting nut if necessary.

#### CAUTION

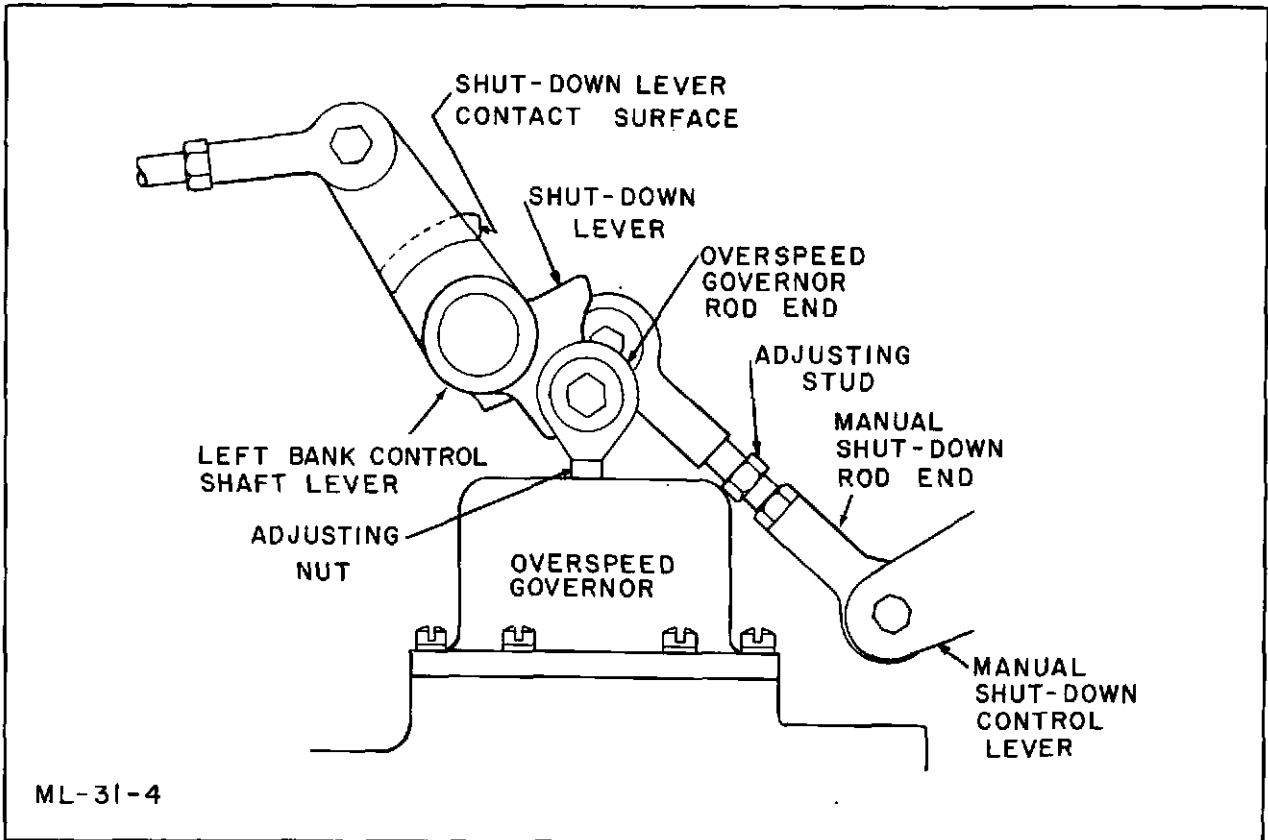
Avoid imposing excessive force against the control shaft lever, as this will result in unnecessary strain of the control linkage and the off-position stop (when applicable). Check for interference by holding the engine governor lever in full fuel position; the shut-down lever, when in run position, must not prevent the left bank control shaft lever from rotating to full fuel position.

To adjust the overspeed setting of the "slow-down" type overspeed governor, remove the acorn nut, loosen the adjusting screw lock nut, and turn the adjusting screw in to raise or out to lower the maximum RPM setting. The overspeed governor is usually set for 10% above engine high idle speed. When properly adjusted, hold the adjusting screw, tighten the lock nut, and replace the acorn nut.

#### Manual Shut-Down Control (Diesel Engines)

To adjust manual shut-down control, proceed as follows (see illustration):

1. Place control handle in shut-down position (pulled away from engine).
2. Adjust manual shut-down adjusting stud (if necessary) so manual shut-down control lever is directly in line with manual shut-down rod and manual shut-down lever is firmly against contact surface of left bank control shaft lever.



ML-31-4

SLOW-DOWN TYPE OVERSPEED GOVERNOR AND MANUAL SHUT-DOWN ADJUSTMENT

**NOTE**

When the manual shut-down control is mounted on the right bank of the engine, the adjustment is identical, except that the manual shut-down lever is of a different configuration and includes a pin which bears against the right bank control shaft lever to effect shut-down.

3. Adjust over center stop setscrew in manual shut-down control bracket to permit manual shut-down control lever to toggle over center far enough to hold in shut-down position; check by placing control handle in shut-down position while holding engine governor lever in full fuel position.

**CAUTION**

Avoid imposing excessive force against the control shaft lever, as this will result in unnecessary strain of the control linkage and the off-position stop (when applic-

able). Check for interference by holding the engine governor lever in full fuel position; the shut-down lever, when in run position, must not prevent the control shaft lever from rotating to full fuel position.

**Synchro-Start Overspeed Switch**

To adjust the overspeed setting of a Synchro-Start overspeed switch, loosen the cap lock screw and rotate the cap clockwise to lower or counter-clockwise to raise the maximum RPM setting. The overspeed switch is usually set for 10% above engine high idle speed. When properly adjusted, hold the cap and tighten the cap lock screw.

**Air Shut-Off Valve Type Overspeed Governor (Diesel Engines)**

To adjust the overspeed setting of the "air shut-off valve" type overspeed governor, remove the cap nut, loosen the adjusting screw lock nut, and turn the adjusting screw in to raise or out to lower the maximum RPM set-

ting. The overspeed governor is usually set for 10% above engine high idle speed. When properly adjusted, hold the adjusting screw, tighten the lock nut, and replace the cap nut.

### Minneapolis-Honeywell Safety Control Switch

The high coolant temperature and the low oil pressure settings as indicated by the pointers on the scales inside the case are the most desirable and normally should not be tampered with. However, in case of extreme conditions, these settings may require adjustment. The Waukesha Engine Division is willing to assist in any special engineering problems, and should always be consulted before changing these settings.

If adjustment of these settings is required, the adjusting screws and lock nuts are accessible after removing the operating knob and front cover. Loosen the lock nut inside the case and adjust the screw from the top of the case until the pointer on the scale indicates the desired setting. Hold the adjusting screw and tighten the lock nut to secure the new setting. Replace the front cover and the operating knob.

### Murphy Safety Control Switches

These high coolant temperature, low oil pressure, and low coolant level switches do not normally require adjustment; however, in case of extreme conditions, their settings may be adjusted. The Waukesha Engine Division is willing to assist in any special engineering problems, and should always be consulted before changing these settings.

If adjustment of these settings is required, the coolant temperature and oil pressure switch contacts are adjusted by means of an external Allen head adjustment, while the coolant level switch is adjusted by loosening the external lock nut and adjusting the movable contact screw.

### Idle Control Sentinel (Diesel Engines)

The high coolant temperature and low oil pressure settings of the idle control sentinel are not adjustable, but the idle fuel quantity allowed to pass through the idle control when it is activated can be adjusted, if necessary.

To adjust idle fuel quantity, proceed as follows:

1. Disconnect lubricating oil inlet line from idle control. Cap end of line to prevent loss of oil with engine operating.
2. Remove knurled cap near fuel outlet of idle control, and turn adjustable fuel plunger counter-clockwise a few turns.
3. Rotate re-set lever at bottom of idle control completely clockwise to simulate engine oil pressure.
4. Start engine and operate at normal speed with load applied, if possible.
5. Simulate oil pressure failure by rotating idle control re-set lever completely counter-clockwise.
6. Adjust idle control fuel plunger to obtain desired idle RPM. Clockwise rotation decreases idle fuel flow while counter-clockwise rotation increases idle fuel flow. If load is not applied while adjusting idle fuel flow for desired RPM, idle RPM fuel setting must be increased to compensate for load which would be applied during normal operation when idle control is expected to operate.
7. When adjustment is correct, shut down engine, replace knurled cap, and un-cap and re-connect lubricating oil inlet line to idle control.

### Air Shut-Off Valves (Diesel Engines)

Both center inlet and rear inlet air shut-off valves which are interconnected must have the connecting linkage adjusted so that both air shut-off valves close tightly simultaneously. The connecting linkage for center inlet air shut-off valves is a rod with a clevis at the right bank connection and a rod end bearing at the left bank connection—always adjust the left bank rod end bearing of this linkage. With center inlet air shut-off valves open (latch pawl engaging left bank lever), the left bank valve may be slightly beyond center while the right bank valve may be just short of center. If the right bank valve is more than 1/4" short of center, re-adjust the connecting linkage to bring it within 1/4" of center, but be sure both valves still close tightly when tripped for shut-off.

## WAUKESHA VC SERIES

### Low Idle - High Idle Speed Control (Diesel Engines)

To adjust the low idle - high idle speed control linkage, proceed as follows:

1. Operate engine with idle speed control switch lever in OFF position.
2. Adjust low speed stop screw in governor for 1000 RPM and lock in this position.
3. Place idle speed control switch lever in ON position.
4. Adjust high speed stop screw in governor for 2200 RPM and lock in this position.
5. Check that governor speed control lever travel from low idle to high idle position is about equal above and below horizontal position of lever, and if necessary, reposition lever on governor speed control shaft serrations to obtain equal travel.
6. With governor speed control lever in high idle position, shorten or lengthen actuating rod of air cylinder, if required, so it is in fully extended position from air cylinder, with speed control switch lever in ON position so air pressure is applied to air cylinder.
7. With speed control switch lever in OFF position so air pressure is not applied to air cylinder, air cylinder actuating rod must return governor speed control lever to low idle position.

### Amot Safety Control (Diesel Engines)

The spring-loaded Amot low oil pressure and high water temperature controls cannot be adjusted to alter the pressure and temperature settings. However, the linkage from the spring-loaded Amot control to the left bank control shaft shut-down lever must be properly adjusted so the injector racks are moved to off position, but not to the end of their strokes, when the Amot control is in shut-down position. When the Amot control is in run position, the shut-down lever must not prevent the left bank control shaft lever from rotating to full fuel position.

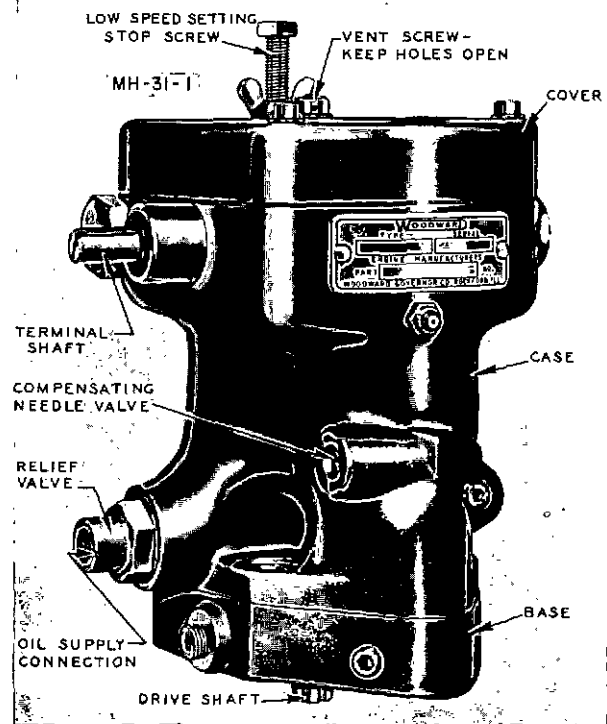
#### CAUTION

The spring-loaded Amot control linkage must not impose excessive force

against the left bank control shaft lever, as this will result in unnecessary strain of the control linkage and the off-position stop (if applicable).

### INITIAL ADJUSTMENT OF PSG GOVERNOR

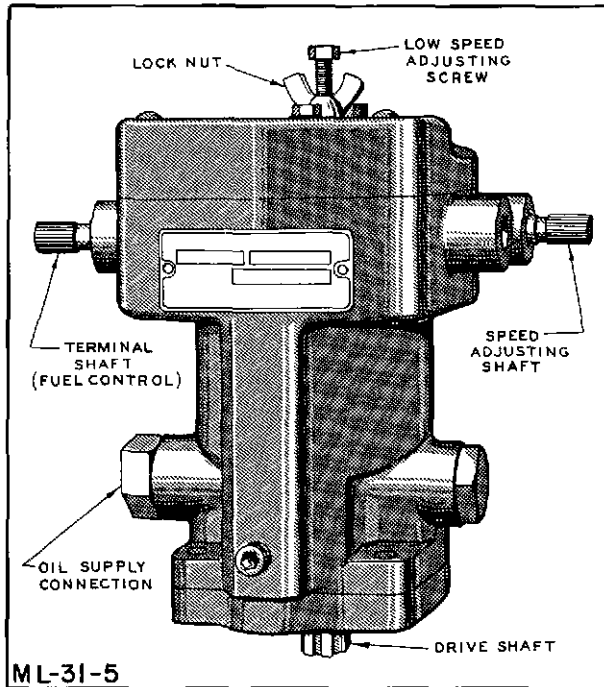
Start the engine and position the speed adjusting shaft for desired running speed. Allow the engine to warm up. Open the compensating needle valve two or three turns and allow the engine to hunt or surge for about one-half minute to bleed trapped air from the governor oil passages. Gradually close the needle valve until hunting just stops. Closing the needle valve farther than necessary will make the governor slow to return to normal speed after a load change. Test action by manually disturbing engine speed. Engine should return promptly to original steady speed with only a small overshoot.



WOODWARD PSG GOVERNOR -  
EXTERNAL VIEW

### INITIAL ADJUSTMENT OF SG GOVERNOR

Start the engine and position the speed adjusting shaft for the desired running speed. Allow the engine to warm up.



WOODWARD SG GOVERNOR -  
EXTERNAL VIEW

If the engine surges during warm-up, remove the governor cover while the engine is running and adjust the speed droop bracket and pin towards maximum position (i.e., away from governor ballhead).

When the engine is warmed up, adjust the speed droop bracket and pin as much towards minimum as possible while maintaining steady speed. Manually move the engine fuel linkage to cause a temporary engine speed increase. If the engine returns to the original steady speed, the adjustment is satisfactory for most single engine installations. If the engine speed does not settle out, increase droop slightly (approx. 1/16" movement of bracket) and test again. Continue to increase the droop until the operation is satisfactory.

**SPEED ADJUSTMENT**

The speed adjusting shaft is used to set the governor for the desired running speed. Low speed and high speed stop screws are provided to limit the speed range of variable speed governors. If the engine is to be operated at one speed setting, the stop screws may be used to lock the position of the speed adjusting shaft.

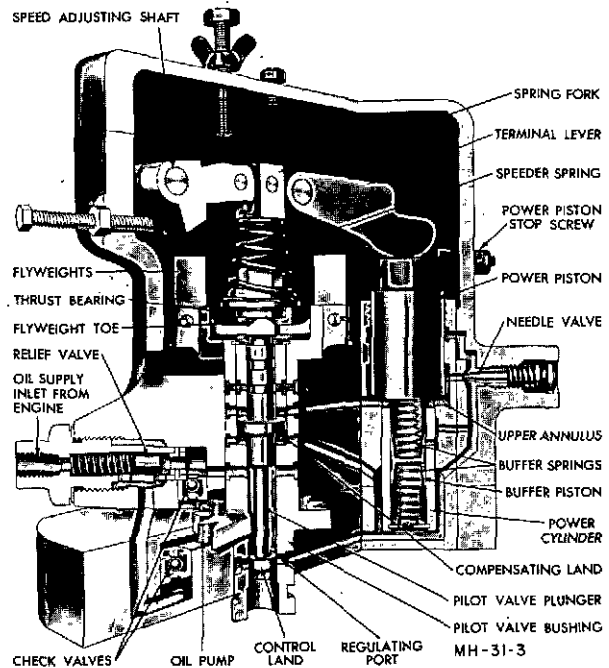
Shut-down of the engine can be accomplished by turning the speed adjusting shaft below the idle speed setting position.

When used, a synchronizing motor drives the speed adjusting shaft through a worm and gear with a friction clutch to protect the motor if the adjustment is run against the stops. If the friction clutch is disassembled, adjust it to slip at 4-1/2 lbs. in. and lock with setscrew. Synchronizing motor must be mounted so as to center motor shaft in clutch. Full travel of the motor shaft in each direction should produce no binding.

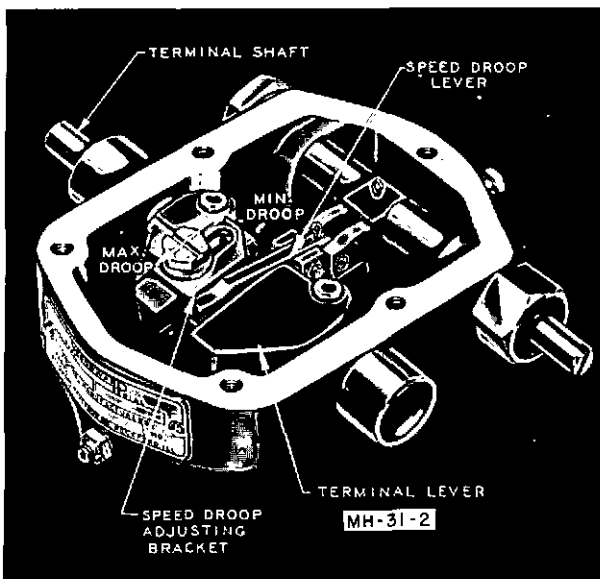
A manual speed adjusting knob is included on units fitted with a speed adjusting motor. Turning the manual speed adjusting knob in the direction of its arrow increases speed.

**SPEED DROOP ADJUSTMENT**

A PSG governor is illustrated with the top cover removed to expose the speed droop mechanism. The speed droop bracket is clamped to the terminal lever by the slotted hexagonal head screw. When loosened, it can be moved radially to the terminal shaft. The bracket carries a pivot pin for the speed droop lever and this pin can be adjusted from a position on the terminal shaft centerline to a location and a radius of about one-half inch. When the



WOODWARD PSG GOVERNOR -  
SECTIONAL VIEW



PSG GOVERNOR - COVER REMOVED

pin is at the shaft center, rotation produces no vertical movement of the pin and, therefore, no movement of the speed droop lever. As the pin is moved out away from the shaft center, rotation produces movement of the end of the speed droop lever which is pivoted on the speed droop pin. This speed droop lever movement thus produces a speed setting which is a function of terminal shaft position with speed decreasing as fuel flow increases. This is speed droop.

Speed droop is increased by moving the bracket outward and is reduced to its minimum when the pivot pin is at the shaft center. Since there is no calibration for the droop adjustment, the minimum droop position may be set only by trial and error on the engine or by use of a dial indicator on the speed droop lever during manual rotation of the terminal shaft. Speed droop must be set by operation on the engine, re-adjusting the slides to obtain the desired speed droop between full load and no load.

#### FINAL SPEED DROOP ADJUSTMENT OF PSG GOVERNOR

Speed droop may be used to permit load division between two or more engines operating in parallel on an alternating current system or connected to a single shaft. If the engine is operated alone or on a DC system with proper generator compounding, the PSG governor may be set for zero droop (isochronous operation).

AC generating units tied in with other units should have droop set sufficiently high to prevent interchange of load between units. If one unit in the plant or system has enough capacity, its governor may be set on zero droop and it will regulate the frequency of the entire system. This unit will take all load changes within the limits of its capacity and will control frequency if its capacity is not exceeded.

The system frequency is adjusted by changing the speed setting of the governor having zero droop. The distribution of load between units is accomplished by changing the speed setting of the governors having speed droop.

#### FINAL SPEED DROOP ADJUSTMENT OF SG GOVERNOR

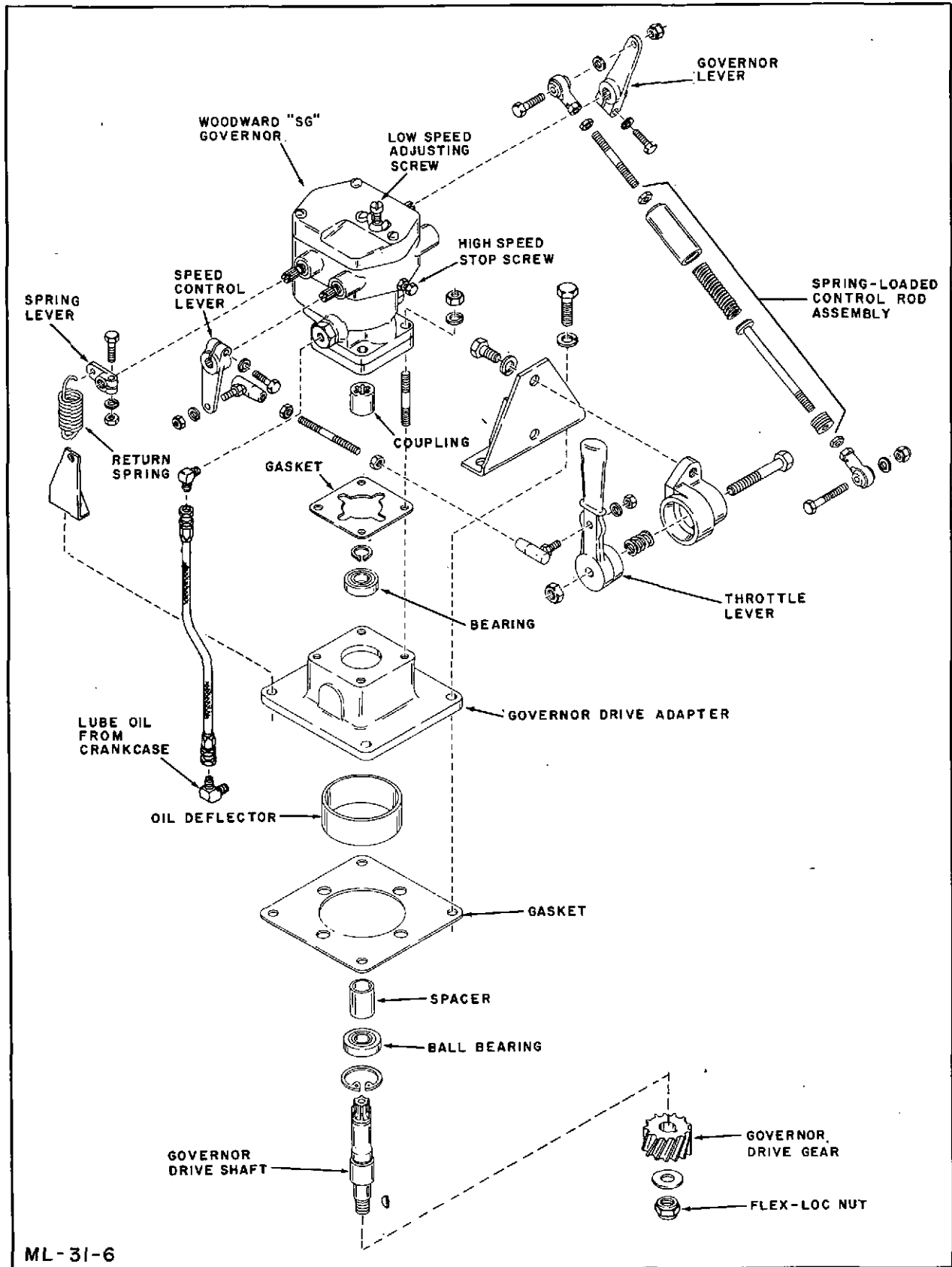
The droop setting required to gain stability varies with each installation; in most instances it must be set to increase unit speed two or three percent over the terminal shaft rotation used from rated power output at rated speed to zero power output. The range of adjustment is from one-half of one percent to approximately seven percent over the full 36° available travel of the governor terminal shaft.

**SINGLE ENGINE OPERATION:** Set the speed droop bracket as near minimum as possible (consistent with satisfactory performance) to have the least decrease in speed as load is added to the unit.

**OPERATING IN PARALLEL WITH OTHER ALTERNATORS:** The SG type speed droop governor will maintain system frequency. An isochronous (constant speed) PSG governor, installed on one of the units having sufficient capacity to absorb all load changes, is needed to maintain system frequency. The other units may then be equipped with SG governors. Set the droop sufficiently high (towards maximum) to secure satisfactory load division between units. If load does not divide properly, increase droop on units taking too great a portion of the load. Increasing the droop setting will also prevent interchange of load between units.

The distribution of load between synchronized units is accomplished by adjusting the speed setting of the SG governors or other governors with speed droop.

**DC GENERATING UNITS ELECTRICALLY INTERCONNECTED:** Set the droop as near minimum as possible consistent with satisfac-



GOVERNOR, DRIVE, AND LINKAGE - EXPLODED VIEW

tory operation. If load does not divide as desired, increase droop on units taking too much of the load.

### SPECIAL SERVICE TOOLS AND TEST EQUIPMENT

#### General

Other special tools for both gas and diesel engines are referred to in SPECIAL TOOLS FOR REMOVAL AND REPLACEMENT PROCEDURES in Chapter 7.

#### For Servicing Diesel Engines

In addition to the timing gauge referred to in UNIT INJECTOR TIMING, the control shaft setting tool referred to in ADJUSTMENT OF DIESEL FUEL CONTROLS AND LINKAGE and the compression tester adaptor referred to in COMPRESSION TESTING (all in this chapter), the following special service tools and test equipment are also desirable for servicing VC series diesel engines.

For servicing VC series diesel engines with aluminum injector rocker arms, an injector depressor (cut-out) tool, Part No. 499901, is

available to check for malfunctioning injector(s). The injector depressor is used to hold an injector follower depressed to prevent the injector from functioning and thereby determine which injector is responsible for rough running of the engine (similar to shorting out spark plugs of a gas-gasoline engine). Current VC series diesel engines utilize steel injector rocker arms, which do not have a drilled opening in the upper end of the rocker arm. For this reason, the injector depressor tool can not be used with steel injector rocker arms.

Other special tools and test equipment referred to in CARE AND OVERHAUL OF UNIT INJECTORS in Chapter 7 include an injector flow comparator, an injector cleaning kit, an injector service tool kit, and a nozzle and injector tester, which includes the injector needle valve test adaptor.

#### For Servicing Gas Engines

The only special tool required for servicing VC series gas engines is a spark plug wrench with a long extension, Part No. 167164 (for the currently used 14 mm plugs) or Part No. 167164A (for the previously used 18 mm plugs).

## CHAPTER 5 TROUBLE SHOOTING

### GENERAL

This chapter provides information useful in diagnosing and correcting unsatisfactory operation or failure of the engine and its components.

### TROUBLE SHOOTING TABLE

Trouble shooting procedures are listed in the accompanying table. Each symptom stated is followed by a list of probable causes of the trouble. The remedy is described for each probable cause.

### COMPILATION OF NORMAL OPERATING DATA

The "logging" of the basic engine temperatures and pressures, on a regular basis, is helpful in tracing past problems and analyzing present malfunctions. An abnormal rise or fall in temperature, pressure or liquid levels will immediately alert the operator that a malfunction is occurring. Corrective action, taken by the operator, before a serious malfunction develops, will save many hours of unnecessary work and may prevent serious injury to personnel.

### TROUBLE SHOOTING TECHNIQUES

Trouble shooting ranges from such elementary problems as locating a grounded wire or closed valve to complex installation engineering decisions. A certain amount of common sense and ordinary reasoning can eliminate many false starts and much wasted time in attempting to correct symptoms rather than the trouble source. Troubles may arise generally from the following sources:

#### 1. Misapplication or Improper Installation of the Engine

Under this heading may be considered the problems associated with incorrect gear ratios, extensive idling at low temperatures, constant overloads, inadequate cooling, unusual exposure to weather, dirt, or other elements, and innumerable other situations which may sometimes benefit from the help of the Waukesha Engine Di-

vision Service Division or its authorized dealers. The Waukesha Engine Division is always ready to make available the experience of over 60 years of industrial engine building and application.

#### 2. Normal Wear in Service

In the course of normal service, any engine will lose the precise adjustments it had when new. Normal adjustment and maintenance will prevent most troubles caused by normal wear, and careful thought about any symptom that does appear will usually lead to its immediate repair.

#### 3. Inadequate or Improper Maintenance

Sometimes operating difficulties occur from such sources as poorly serviced oil or air filters, bad cooling water, failure to make regular inspection and maintenance checks, and even the use of unsatisfactory fuels or lubricants. Analysis and understanding of such problems will often point the way to more satisfactory operation in the future, sometimes with only a minor change in the operating or maintenance techniques.

### ISOLATING TROUBLES

Engine troubles may be considered general troubles or local troubles. For example, an inadequate fuel supply, partially closed fuel valve, grounded magneto, or clogged radiator would affect the entire operation of the engine; no one cylinder or group of cylinders being distinctly better or worse than others. This is a general trouble and sources of trouble capable of producing this effect should receive first consideration. On the other hand, a valve tappet with insufficient clearance, a fouled spark plug, a faulty injector, or a leaking intake manifold gasket might affect one cylinder very noticeably without reflecting in the operation of the others. This is a local trouble and normal good judgment would suggest that the correction is not likely to be found in adjustment of the governor, changing the fuel mixture, or other general remedies.

**WAUKESHA VC SERIES**

The essence of successful trouble shooting is the location and isolation of an unsatisfactory condition without bringing several other equally bad troubles into existence by unsystematic "tinkering". When an engine is operating

improperly, take time to define the difficulty clearly. Visualize the system involved and attempt to picture the most likely point where a condition might exist that would give the observed symptoms.

**TROUBLE SHOOTING**

SYMPTOM	PROBABLE CAUSE	REMEDY
<p>Crankshaft cannot be barred over using barring device.</p>	<p>Load not disengaged from engine.</p> <p>Coolant or obstruction in cylinder:</p> <p>a. Leaking spark plug tube or injector tube.</p> <p>b. Blown head gasket.</p> <p>c. Blown water cooled exhaust manifold gasket.</p> <p>d. Cracked head.</p> <p>e. Cracked sleeve.</p> <p>f. Cracked crankcase.</p> <p>Fuel in cylinder from leaking injector (diesels).</p> <p>Seized piston.</p> <p>Bearings too tight:</p> <p>a. Main bearing caps installed backwards or out of location.</p> <p>b. Improper torque.</p> <p>c. High spots on bearings.</p>	<p style="text-align: center;"><b>CAUTION</b></p> <p>DO NOT ATTEMPT TO ROTATE CRANKSHAFT WITH STARTER.</p> <p>Disengage load.</p> <p style="text-align: center;">NOTE</p> <p>REMOVE SPARK PLUGS OR INJECTORS TO VENT CYLINDERS OF ACCUMULATED COOLANT.</p> <p>a. Replace spark plug tube or injector tube.</p> <p>b. Replace head gasket.</p> <p>c. Replace exhaust manifold gasket.</p> <p>d. Replace head.</p> <p>e. Replace sleeve.</p> <p>f. Replace crankcase.</p> <p style="text-align: center;">NOTE</p> <p>REMOVE INJECTORS TO VENT CYLINDERS OF ACCUMULATED FUEL.</p> <p>Replace or overhaul injector.</p> <p>Replace piston assembly and possibly sleeve. Determine cause of seizure—insufficient ring gap, insufficient lubrication, inadequate cooling, overload.</p> <p>a. Check each bearing cap, place in proper position and location.</p> <p>b. Loosen bearing caps and re-torque.</p> <p>c. Replace bearings.</p>

TROUBLE SHOOTING — Continued

SYMPTOM	PROBABLE CAUSE	REMEDY
<p>Engine will crank but will not start.</p>	<p>Stop-run switch in stop position or defective.</p> <p>Fuel throttle or manual shutoff control in off position.</p> <p>Safety shut-down control not re-set.</p> <p>Insufficient cranking speed:</p> <ul style="list-style-type: none"> <li>a. Low starting air pressure.</li> <li>b. Run-down battery or electric starter system malfunction.</li> <li>c. Lube oil viscosity too high.</li> </ul> <p>Fuel system inoperative:</p> <ul style="list-style-type: none"> <li>a. Insufficient fuel supply.</li> <li>b. Air bound (diesels).</li> <li>c. Water in fuel (diesels).</li> <li>d. Clogged fuel filters and strainers (diesels or LPG engines).</li> <li>e. Inoperative fuel supply pump (diesels).</li> <li>f. Improper control rack setting (diesels).</li> <li>g. Improper timing of injectors (diesels).</li> <li>h. Malfunctioning injectors.</li> <li>i. Stiff carburetor diaphragm (gas engines).</li> <li>j. Worn carburetor air-gas valve assembly (gas engines).</li> <li>k. Ruptured line pressure regulator diaphragm (gas engines).</li> <li>l. Bent line pressure regulator control rod (gas engines).</li> </ul> <p>Mistimed ignition system (gas engines).</p>	<p>Place switch in run position—replace defective switch.</p> <p>Place fuel throttle or manual shutoff control in on position.</p> <p>Re-set safety shut-down control.</p> <ul style="list-style-type: none"> <li>a. Build up air pressure.</li> <li>b. Charge or replace battery; check starter system.</li> <li>c. Change to lower viscosity as recommended in Chapter 4.</li> </ul> <ul style="list-style-type: none"> <li>a. Fill fuel tank (diesels)—check gas pressure and carburetor adjustments (gas engines).</li> <li>b. Operate hand primer pump until air is expelled. Repair source of air entering into system.</li> <li>c. Drain water at strainers, filters, and fuel tanks. Replace filter elements.</li> <li>d. Clean strainers and replace fuel filter elements.</li> <li>e. Rebuild or replace pump.</li> <li>f. Re-set control rack linkage.</li> <li>g. Re-time injectors.</li> <li>h. Repair or replace injectors.</li> <li>i. Replace air-gas valve assembly.</li> <li>j. Replace air-gas valve assembly.</li> <li>k. Replace diaphragm.</li> <li>l. Replace control rod.</li> </ul> <p>Re-time.</p>

TROUBLE SHOOTING

TRUBLE SHOOTING — Continued

SYMPTOM	PROBABLE CAUSE	REMEDY
<p>Engine will crank but will not start (continued).</p>	<p>Faulty ignition system (gas engines):</p> <ul style="list-style-type: none"> <li>a. Low tension magneto breaker points stuck open.</li> <li>b. Low tension magneto distributor brushes stuck or damaged.</li> <li>c. Low tension magneto distributor disc loose or broken.</li> <li>d. Breakerless ignition generator power board faulty.</li> <li>e. Breakerless ignition generator distributor pulser faulty.</li> <li>f. Broken leads.</li> <li>g. Drive disc broken.</li> </ul> <p>Insufficient or no intake air:</p> <ul style="list-style-type: none"> <li>a. Intake air shutoff valve (s) closed (diesels).</li> </ul> <ul style="list-style-type: none"> <li>b. Clogged intake air filters.</li> <li>c. Clogged intercoolers (air side).</li> </ul> <p>Governor inoperative:</p> <ul style="list-style-type: none"> <li>a. Insufficient oil:                             <ul style="list-style-type: none"> <li>(1) Defective safety shut-down control solenoid (s) in governor supply and/or drain lines (diesels).</li> <li>(2) Supply hose blocked/collapsed.</li> <li>(3) Gasket blocks off oil supply hole (after repair).</li> <li>(4) Carbon/sludge in oil passages.</li> </ul> </li> <li>b. Binding control linkage:                             <ul style="list-style-type: none"> <li>(1) Linkage dirty.</li> <li>(2) Linkage broken.</li> <li>(3) Linkage pivot points.</li> </ul> </li> <li>(4) Slow-down type overspeed governor linkage stuck in fuel off position (diesels).</li> </ul>	<ul style="list-style-type: none"> <li>a. Replace breaker assembly.</li> <li>b. Free or replace brushes.</li> <li>c. Replace distributor disc and secure.</li> <li>d. Replace power board.</li> <li>e. Replace distributor pulser.</li> <li>f. Replace leads.</li> <li>g. Replace disc—check timing.</li> </ul> <ul style="list-style-type: none"> <li>a. Open valve (s).</li> </ul> <p style="text-align: center;">NOTE</p> <p>BAR ENGINE OVER BY HAND TO ASCERTAIN THAT CYLINDERS ARE CLEAR. INSPECT INTAKE MANIFOLDS FOR ACCUMULATIONS OF LUBE OR FUEL OIL.</p> <ul style="list-style-type: none"> <li>b. Remove and clean.</li> <li>c. Remove and clean.</li> </ul> <ul style="list-style-type: none"> <li>(1) Replace solenoid (s).</li> <li>(2) Replace hose.</li> <li>(3) Re-position or replace gasket.</li> <li>(4) Clean or replace governor.</li> </ul> <ul style="list-style-type: none"> <li>(1) Clean.</li> <li>(2) Repair linkage.</li> <li>(3) Re-adjust or replace pivot point bearing surfaces.</li> <li>(4) Determine cause, repair or replace linkage.</li> </ul>

TROUBLE SHOOTING — Continued

SYMPTOM	PROBABLE CAUSE	REMEDY
<p>Engine will crank but will not start (continued).</p>	<p>Poor compression:</p> <ul style="list-style-type: none"> <li>a. Worn rings.</li> <li>b. Leaking valves.</li> <li>c. Leaking head gaskets.</li> </ul> <p>Camshaft gear not in time with crankshaft gear.</p>	<ul style="list-style-type: none"> <li>a. Renew rings.</li> <li>b. Recondition heads and valves.</li> <li>c. Replace head gaskets.</li> </ul> <p>Set crankshaft at T.D.C. #1 R.B. (#1 L.B. for reverse rotation engines.) Align camshaft, idler and crankshaft gear match marks.</p>
<p>Engine stops suddenly.</p>	<p>Fuel:</p> <ul style="list-style-type: none"> <li>a. Insufficient fuel supply.</li> <li>b. Air in fuel (diesels).</li> <li>c. Water in fuel (diesels).</li> <li>d. Clogged fuel strainers and filters (diesels).</li> <li>e. Clogged fuel supply hose (diesels).</li> <li>f. Fuel supply pump failure (diesels).</li> <li>g. Loose fuel control linkage.</li> </ul> <p>Low oil pressure causes safety control to shut down engine.</p> <p>High coolant temperature causes safety control to shut down engine.</p> <p>Faulty ignition system (gas engines).</p> <p>Engine overspeed causes safety control to shut down engine.</p> <p>Excessive load causes engine to stall.</p> <p>Insufficient intake air:</p> <ul style="list-style-type: none"> <li>a. Intake air shutoff valves closed (diesels).</li> </ul>	<ul style="list-style-type: none"> <li>a. Fill tank (diesels) — Check gas pressure (gas engines).</li> <li>b. Operate hand primer pump until air is expelled. Repair source of air entering into system.</li> <li>c. Drain water at strainers, filters and fuel tank. Replace filter elements.</li> <li>d. Clean strainers and replace fuel filter elements.</li> <li>e. Replace hose.</li> <li>f. Repair or replace pump.</li> <li>g. Readjust and tighten.</li> </ul> <p>Inspect lubricating oil system and components—correct cause.</p> <p>Inspect cooling system and components—correct cause.</p> <p>Repair or replace components as required.</p> <p>Determine and correct cause of overspeed.</p> <p>Determine and correct cause of overload.</p> <ul style="list-style-type: none"> <li>a. Open valves, determine cause of closing.</li> </ul>

TRUBLE SHOOTING — Continued

SYMPTOM	PROBABLE CAUSE	REMEDY
<p>Engine stops suddenly (continued).</p>	<p>b. Clogged intake air filter (s).</p> <p>c. Clogged intercoolers (air side).</p> <p>Obstructed exhaust manifold.</p> <p>Piston seizure:</p> <p>a. Insufficient cooling.</p> <p>b. Insufficient lubrication.</p> <p>c. Insufficient ring gap (applicable only immediately after overhaul).</p> <p>Obstruction in cylinder.</p> <p>Seizure of bearings—main, connecting rod, piston pin or camshaft.</p> <p>a. Lack of lubrication.</p> <p>b. Dirt in lube oil.</p>	<p style="text-align: center;"><b>CAUTION</b></p> <p>NEVER RESTART AN ENGINE WHICH WAS STOPPED BY CLOSING THE AIR SHUTOFF VALVES WITHOUT FIRST CHECKING THE ENGINE, INCLUDING BARRING IT OVER BY HAND TO ASCERTAIN THAT THE CYLINDERS ARE CLEAR. INSPECT INTAKE MANIFOLDS FOR ACCUMULATIONS OF LUBE OR FUEL OIL.</p> <p>b. Remove and clean.</p> <p>c. Remove and clean.</p> <p>Determine obstruction and remedy cause.</p> <p>a. Replace scored piston, sleeve and rings. Clean and/or fill cooling system, including heat exchangers.</p> <p>b. Replace scored piston, sleeve and rings. Clean oil passages, and/or determine cause of lack of lubrication.</p> <p>c. Replace scored piston, sleeve and rings. Adjust ring gap in accordance with Fits and Clearances (Chapter 8).</p> <p>Replace all parts that failed.</p> <p>Replace bearings—clean up or replace crankshaft, camshaft, or piston pins as required.</p> <p>a. Check lube oil system—correct cause.</p> <p>b. Check lube oil filters.</p>
<p>Engine power loss.</p>	<p>Insufficient fuel:</p> <p>a. Dirty fuel filters or strainers (diesels).</p> <p>b. Low gas pressure (gas engines).</p>	<p>a. Clean strainer and replace fuel filter elements.</p> <p>b. Check gas fuel system.</p>

TRUBLE SHOOTING — Continued

SYMPTOM	PROBABLE CAUSE	REMEDY
<p>Engine power loss (continued).</p>	<ul style="list-style-type: none"> <li>c. Cracked fuel lines/filters (diesels).</li> <li>d. Worn fuel supply pump (diesels).</li> <li>e. Worn fuel injectors (diesels).</li> <li>f. Return fuel back pressure restriction missing (diesels).</li> </ul> <p>Air in fuel (diesels).</p> <p>Air intake system malfunction:</p> <ul style="list-style-type: none"> <li>a. Dirty intake air filters.</li> <li>b. Clogged intercoolers.</li> <li>c. Air shutoff closed on one bank (diesels).</li> </ul> <p>Injectors malfunction (diesels):</p> <ul style="list-style-type: none"> <li>a. Clogged spray tip.</li> <li>b. Dirty.</li> <li>c. Misadjusted fuel control rack.</li> <li>d. Unbalanced cylinders.</li> <li>e. Worn plunger and bushing.</li> <li>f. Rack and gear out-of-time (check if recently rebuilt).</li> </ul> <p>Air leaks in intake system (turbo supercharged gas engines).</p> <p>Turbocharger malfunction or failure:</p> <ul style="list-style-type: none"> <li>a. Lack of lubrication.</li> <li>b. Foreign material.</li> <li>c. Excessive back pressure.</li> </ul>	<ul style="list-style-type: none"> <li>c. Replace cracked line/filters.</li> <li>d. Overhaul or replace.</li> <li>e. Overhaul or replace.</li> <li>f. Replace fuel back pressure orifice fitting.</li> </ul> <p>Operate hand primer pumps until air is expelled. Repair source of air entering system.</p> <ul style="list-style-type: none"> <li>a. Remove and clean.</li> <li>b. Remove and clean.</li> <li>c. Open valve.</li> </ul> <div style="border: 1px solid black; padding: 5px; text-align: center; width: fit-content; margin: 10px auto;"> <p><b>CAUTION</b></p> </div> <p>BAR ENGINE OVER BY HAND TO ASCERTAIN THAT CYLINDERS ARE CLEAR. INSPECT INTAKE MANIFOLDS FOR ACCUMULATIONS OF LUBE OR FUEL OIL.</p> <ul style="list-style-type: none"> <li>a. Overhaul injector, clean tip or replace.</li> <li>b. Overhaul and clean.</li> <li>c. Adjust per Chapter 4.</li> <li>d. Re-adjust fuel and governor control linkages.</li> <li>e. Overhaul injector/replace plunger and bushing.</li> <li>f. Re-time.</li> </ul> <p>Correct as required.</p> <ul style="list-style-type: none"> <li>a. Determine cause; repair or replace turbocharger.</li> <li>b. Repair or replace turbocharger.</li> <li>c. Determine cause and correct.</li> </ul>

TRUBLE SHOOTING

TROUBLE SHOOTING — Continued

SYMPTOM	PROBABLE CAUSE	REMEDY
<p>Engine power loss (continued).</p>	<p>Engine misfiring (gas engines):</p> <ul style="list-style-type: none"> <li>a. Incorrect carburetor or regulator adjustment.</li> <li>b. Faulty ignition system.</li> </ul> <p>Ignition or injection system out-of-time.</p> <p>Low compression pressure:</p> <ul style="list-style-type: none"> <li>a. Leaking head gasket.</li> <li>b. Leaking exhaust; intake valves.</li> <li>c. Misadjusted intake and exhaust valves (if recently overhauled).</li> <li>d. Worn rings (excessive blow-by).</li> <li>e. Worn pistons/liner.</li> <li>f. Cracked piston.</li> <li>g. Cracked cylinder head.</li> </ul> <p>Excessive exhaust system back pressure.</p>	<ul style="list-style-type: none"> <li>a. Readjust.</li> <li>b. Repair or replace components as required.</li> </ul> <p>Re-time.</p> <ul style="list-style-type: none"> <li>a. Replace head gasket—inspect for warped cylinder head and/or crankcase—replace if necessary.</li> <li>b. Recondition head and valves.</li> <li>c. Adjust valves.</li> <li>d. Replace rings.</li> <li>e. Replace as necessary.</li> <li>f. Replace.</li> <li>g. Replace</li> </ul> <p>Correct as required.</p>
<p>Engine will not shut down when using normal stopping procedures.</p>	<p>Defective stop-run switch.</p>	<p>NOTE</p> <p>CLOSE AIR SHUTOFF VALVES FOR POSITIVE SHUTDOWN OF DIESELS OR SHUT OFF GAS SUPPLY FOR POSITIVE SHUTDOWN OF GAS ENGINES. NEVER RESTART A DIESEL ENGINE WHICH WAS STOPPED BY CLOSING THE AIR SHUTOFF VALVES WITHOUT FIRST CHECKING THE ENGINE, INCLUDING BARRING IT OVER BY HAND TO ASCERTAIN THAT THE CYLINDERS ARE CLEAR. INSPECT INTAKE MANIFOLDS FOR ACCUMULATIONS OF LUBE OR FUEL OIL.</p> <p>Replace.</p>

TROUBLE SHOOTING — Continued

SYMPTOM	PROBABLE CAUSE	REMEDY
<p>Engine will not shut down when using normal stopping procedures (continued).</p>	<p>Injector rack and gear out-of-time (diesels—check if injectors recently rebuilt).</p> <p>Governor control linkage mis-adjusted (diesels).</p> <p>Lubricating oil entering cylinder through valve guides (diesels).</p> <p>Overheated combustion chamber deposits allow gas engine to "diesel".</p>	<p>Disassemble and re-time.</p> <p>Adjust linkage.</p> <p>Replace valve guides/recondition heads.</p> <p>Allow engine to cool down before attempting to stop.</p>
<p>Engine will not reach rated speed.</p>	<p>Engine overloaded.</p> <p>Insufficient fuel supply.</p> <p>Restricted air intake.</p> <p>Governor misadjusted.</p> <p>Fuel control rack linkage not properly adjusted (diesels).</p> <p>Injectors or ignition not properly timed.</p> <p>Injector rack and gear out-of-time (diesels—check if injectors recently rebuilt).</p> <p>One or more injector plungers stuck (diesels).</p> <p>Tachometer inaccurate.</p> <p>Low idle—hi idle switch left in OFF position, or defective—or defective solenoid or loss of air pressure to control cylinder (diesels).</p>	<p>Determine and correct cause of overload.</p> <p>Check fuel supply system.</p> <p>Correct cause.</p> <p>Readjust.</p> <p>Readjust linkage.</p> <p>Re-time.</p> <p>Re-time.</p> <p>Replace or overhaul injectors.</p> <p>Calibrate or replace tachometer.</p> <p>Repair as required.</p>
<p>Engine hunts or surges.</p>	<p>Governor and fuel linkage sticky or sloppy.</p> <p>Misadjusted governor compensating needle valve (PSG governor only).</p> <p>Dirty governor.</p>	<p>Remove all dirt and burrs from linkage. Realign and re-set.</p> <p>Adjust compensating needle valve. Slow reaction—open needle valve. Fast (overshooting) reaction—close needle valve.</p> <p>Clean or replace governor.</p>

TROUBLE SHOOTING

TROUBLE SHOOTING — Continued

SYMPTOM	PROBABLE CAUSE	REMEDY
Engine hunts or surges (continued).	<p>Slow-down type overspeed governor malfunction (diesels).</p> <p>Speed droop adjustment incorrect.</p>	<p>Adjust overspeed governor linkage or replace overspeed governor.</p> <p>Increase speed droop.</p>
Low or fluctuating lubricating oil pressure.	<p>Insufficient oil.</p> <p>Gauge inaccurate.</p> <p>Oil gauge line plugged or valve shut.</p> <p>Lube oil filters plugged.</p> <p>Lubricating oil pressure regulating valve stuck in open position.</p> <p>Oil pressure regulating valve set too low.</p> <p>Lubricating oil dilution.</p> <p>Lubricating oil of low viscosity.</p> <p>Lubricating oil foaming.</p> <p>Clogged oil inlet screen (s).</p> <p>Engine operated at angles in excess of maximum safe tilt angles.</p> <p>Dirty oil cooler.</p> <p>Worn lubricating oil pump.</p> <p>Worn bearings (connecting rod, main, and camshaft).</p> <p>Cracked or leaking lubricating oil piping.</p>	<p style="text-align: center;"><b>CAUTION</b></p> <p style="text-align: center;">SHUT DOWN ENGINE IMMEDIATELY.</p> <p>Add oil as required.</p> <p>Compare to master gauge—replace gauge.</p> <p>Renew gauge line/open valve.</p> <p>Change elements. Clean filter.</p> <p>Free valve.</p> <p>Readjust oil pressure regulating valve for 40-50 psi at governed speed.</p> <p>Change oil and filter elements. Determine and correct source of dilution.</p> <p>Change to higher viscosity oil as recommended in Chapter 4.</p> <p>Use oil grade recommended in Chapter 4. Check for water leaks into oil.</p> <p>Remove and clean screen (s).</p> <p>Operate within maximum safe tilt angles—see Chapter 2.</p> <p>Clean.</p> <p>Repair or replace pump.</p> <p>Replace worn bearings.</p> <p>Repair or replace piping.</p>

TROUBLE SHOOTING — Continued

SYMPTOM	PROBABLE CAUSE	REMEDY
<p>High lubricating oil pressure.</p>	<p>Misadjusted oil pressure regulating valve.</p> <p>Lubricating oil temperature too low.</p> <p>Lubricating oil of high viscosity.</p> <p>Lubricating oil pressure regulating valve stuck in closed position.</p> <p>Gauge inaccurate.</p>	<p>Readjust oil pressure regulating valve for 40-50 psi at governed speed.</p> <p>Raise temperature.</p> <p>Change to lower viscosity oil as recommended in Chapter 4.</p> <p>Free valve.</p> <p>Compare to master gauge—replace gauge.</p>
<p>High fuel oil pressure (diesels).</p>	<p>Clogged return fuel back pressure orifice fitting.</p> <p>Defective fuel supply pump relief valve.</p> <p>Clogged or collapsed fuel return hose.</p> <p>Gauge inaccurate.</p>	<p>Clean or replace orifice fitting.</p> <p>Free relief valve or replace pump.</p> <p>Replace hose.</p> <p>Compare to master gauge—replace gauge.</p>
<p>Low fuel oil pressure (diesels).</p>	<p>Gauge inaccurate.</p> <p>Gauge line clogged or line valve shut.</p> <p>Fuel filters and strainers clogged.</p> <p>Clogged or collapsed fuel supply hose.</p> <p>Air leak on suction side of pump.</p> <p>Return fuel back pressure orifice fitting not in return line or of wrong size.</p> <p>Defective fuel supply pump.</p> <p>Defective check valves in hand primer pump which allow fuel to re-circulate through hand primer and back to supply pump.</p>	<p>Compare to master gauge—replace gauge.</p> <p>Replace line or open valve.</p> <p>Clean strainers and replace filter elements.</p> <p>Replace hose.</p> <p>Locate and repair leak.</p> <p>Install orifice fitting of correct size.</p> <p>Replace pump.</p> <p>Replace check valves.</p>

TROUBLE SHOOTING

TROUBLE SHOOTING — Continued

SYMPTOM	PROBABLE CAUSE	REMEDY
<p>Low gas pressure (gas engines).</p>	<p>Incorrectly adjusted gas regulators.</p> <p>Insufficient line pressure.</p> <p>Incorrect orifice and/or spring in gas regulators.</p> <p>Undersize gas regulators.</p> <p>Undersize piping.</p> <p>Gas regulators mounted too far from engine.</p>	<p>Readjust.</p> <p>Increase line pressure.</p> <p>Replace orifice and/or spring.</p> <p>Replace with gas regulators of adequate size.</p> <p>Replace with piping of adequate size.</p> <p>Remount gas regulators as close to carburetors as possible.</p>
<p>High gas pressure (gas engines).</p>	<p>Incorrectly adjusted gas regulators.</p> <p>Incorrect spring in gas regulators.</p> <p>Excessive line pressure.</p>	<p>Readjust.</p> <p>Replace spring.</p> <p>Reduce line pressure.</p>
<p>Low jacket water pressure.</p>	<p>Low water level.</p> <p>Clogged jacket water heat exchanger or radiator.</p> <p>Air entering system through suction side of jacket water pump.</p> <p>Wrong pressure cap.</p> <p>Gauge inaccurate.</p> <p>Gauge line clogged or valve shut.</p> <p>Worn pump.</p> <p>Leaking pump seals.</p> <p>Blown water cooled exhaust manifold end gasket.</p> <p>Cracked water cooled exhaust manifold.</p>	<p>Fill cooling system.</p> <p>Clean.</p> <p>Repair leak—purge air from system.</p> <p>Replace.</p> <p>Compare to master gauge—replace gauge.</p> <p>Replace line—open valve.</p> <p>Replace or overhaul pump.</p> <p>Repair pump.</p> <p>Replace gasket.</p> <p>Replace manifold</p>

TROUBLE SHOOTING - Continued

SYMPTOM	PROBABLE CAUSE	REMEDY
<p>Low raw water pressure (marine diesels).</p>	<p>Clogged sea inlet strainer.</p> <p>Gauge inaccurate.</p> <p>Clogged gauge line/gauge line valve shut.</p> <p>Air entering system through suction side of pump.</p> <p>Valve closed in sea system.</p> <p>Worn sea water pump.</p> <p>Clogged heat exchanger/intercooler.</p>	<p>Clean.</p> <p>Compare to master gauge—replace gauge.</p> <p>Replace line/open valve.</p> <p>Repair leak—purge air from system.</p> <p>Trace system—open valve.</p> <p>Replace or overhaul pump.</p> <p>Clean heat exchanger/intercooler.</p>
<p>Low jacket water temperature.</p>	<p>Gauge inaccurate.</p> <p>Inoperative/malfunction thermostat (s).</p> <p>Surge tank temperature control manual over-ride engaged.</p>	<p>Compare to master gauge/replace gauge.</p> <p>Replace thermostatic element or thermostats (as applicable).</p> <p>Disengage over-ride.</p>
<p>High jacket water temperature.</p>	<p>Gauge inaccurate.</p> <p>Low coolant level.</p> <p>Inoperative/malfunction thermostat (s).</p> <p>Cooling system is air bound.</p> <p>Insufficient raw water pressure (marine diesels).</p> <p>Engine overloaded.</p> <p>Insufficient circulation of air (radiator cooling).</p> <p>Poor coolant circulation.</p>	<div style="text-align: center;"> <p><b>CAUTION</b></p> <p>COOL ENGINE SLOWLY.</p> </div> <p>Compare to master gauge/replace gauge.</p> <p>Fill cooling system.</p> <p>Engage temperature control manual over-ride (surge tank cooling). Replace thermostatic elements or thermostats (as applicable).</p> <p>Purge air from cooling system.</p> <p>See Low Raw Water Pressure causes.</p> <p>Determine and correct cause of overload.</p> <p>Correct as required.</p> <p>Check entire cooling system.</p>

TROUBLE SHOOTING

TROUBLE SHOOTING — Continued

SYMPTOM	PROBABLE CAUSE	REMEDY
<p>High jacket water temperature (continued).</p>	<p>Worn jacket water pump or seals.</p> <p>Frozen coolant.</p> <p>Blown head gasket.</p> <p>Late ignition or injection timing.</p> <p>Cracked head.</p> <p>Cracked sleeve.</p>	<p>Replace or overhaul pump.</p> <p>Completely thaw cooling system before re-starting engine.</p> <p>Replace head gasket.</p> <p>Re-time ignition or injectors.</p> <p>Replace head.</p> <p>Replace sleeve</p>
<p>High lubricating oil consumption.</p>	<p>Oil leaks in lubricating oil system.</p> <p>Improper viscosity.</p> <p>Leaking oil seal (s)—rear and/or front.</p> <p>O-rings leaking in flywheel housing.</p> <p>Worn intake valve guides.</p> <p>Stuck/worn piston rings.</p> <p>One or more pistons with rings upside down.</p> <p>Excessive connecting rod bearing running clearance.</p>	<p>Locate and repair leaks.</p> <p>Change to recommended viscosity for operating temperatures (see Chapter 4).</p> <p>Change seal (s).</p> <p>Replace o-rings and flat washers.</p> <p>Change head/renew guides, or valve stem seals if used.</p> <p>Renew rings.</p> <p>Remove piston—correct position of rings.</p> <p>Replace bearings.</p>
<p>Lubricating oil contaminated.</p>	<p>Lubricating oil diluted with diesel fuel:</p> <p>a. Injector (s) leaking.</p> <p>b. Injector inlet and outlet tubing leaking.</p> <p>c. Supply pump seal leaking.</p>	<p>NOTE CHANGE OIL.</p> <p>a. Replace or overhaul injector (s).</p> <p>b. Tighten or replace tubing.</p> <p>c. Replace or repair pump.</p>

TRUBLE SHOOTING - Continued

SYMPTOM	PROBABLE CAUSE	REMEDY
Lubricating oil contaminated (continued).	<p>Lubricating oil contaminated with water:</p> <ul style="list-style-type: none"> <li>a. Sleeve seals leaking/or sleeve cracked.</li> <li>b. Injector tube upper seal or spark plug tube seal leaking.</li> <li>c. Oil cooler leaking.</li> <li>d. Cracked crankcase.</li> </ul> <p>Lubricating oil contaminated with dirt:</p> <ul style="list-style-type: none"> <li>a. Lube oil filter by-pass valves opening because elements are plugged.</li> <li>b. Lube oil filter elements punctured.</li> <li>c. Air intake filters punctured.</li> </ul>	<ul style="list-style-type: none"> <li>a. Replace sleeve and/or o-rings.</li> <li>b. Replace seal and tube.</li> <li>c. Replace oil cooler.</li> <li>d. Replace crankcase.</li> </ul> <ul style="list-style-type: none"> <li>a. Replace elements.</li> <li>b. Replace elements.</li> <li>c. Replace air intake filters.</li> </ul>
Excessive vibration.	<p>Foundation bolts:</p> <ul style="list-style-type: none"> <li>a. Loose.</li> <li>b. Cracked.</li> </ul> <p>Unbalanced cylinders:</p> <ul style="list-style-type: none"> <li>a. Injectors improperly set (diesels).</li> <li>b. One or more injectors in-operative (diesels).</li> <li>c. Misfiring ignition system (gas engines).</li> </ul> <p>Vibration damper:</p> <ul style="list-style-type: none"> <li>a. Loose.</li> <li>b. Malfunctioning.</li> </ul> <p>Balancing system failure (H1077 only).</p> <p>Balancing system out-of-time (H1077 after overhaul only).</p>	<div style="border: 1px solid black; padding: 5px; text-align: center; width: fit-content; margin: 0 auto;"> <b>CAUTION</b> </div> <p>STOP ENGINE AT ONCE - INVESTIGATE CAUSE.</p> <ul style="list-style-type: none"> <li>a. Torque.</li> <li>b. Replace bolts—torque all bolts.</li> </ul> <ul style="list-style-type: none"> <li>a. Re-set all injector control racks.</li> <li>b. Replace all defective injectors.</li> <li>c. Repair or replace components as required.</li> </ul> <ul style="list-style-type: none"> <li>a. Replace all securing bolts. Torque bolts to specifications.</li> <li>b. Replace damper.</li> </ul> <p>Replace balancing system.</p> <p>Re-time balancing system.</p>

TRUBLE SHOOTING

TRUBLE SHOOTING - Continued

SYMPTOM	PROBABLE CAUSE	REMEDY
Excessive vibration (continued).	Crankshaft: a. Cracked.  b. Main bearing nuts loose.  Loose flywheel.	a. Conduct a complete investigation of entire engine for damage. b. Determine reason for loosening, investigate the entire lower crankcase before torquing and subjecting engine to use.  Determine cause and correct.
Blue-white exhaust (diesel).	Worn or stuck piston rings, worn sleeves.  Worn valve guides.  Cracked piston.  Wrong compression ratio pistons (after overhaul).  Thermostats not maintaining engine temperature (particularly on naturally aspirated engines at start-up).	Replace rings and/or sleeves.  Replace guides.  Replace piston.  Replace pistons.  Test and replace thermostats as required.
Black exhaust (diesels).	Insufficient intake air: a. Intake air filters clogged. b. Malfunctioning turbocharger.  Engine overloaded.  Inoperative injector.  Late injector timing.  Cylinders not balanced.  Low compression: a. Insufficient valve clearance. b. Burned valves. c. Worn/stuck rings and sleeves.	a. Clean. b. Replace turbocharger.  Determine and correct cause of overload.  Replace or repair defective injector.  Re-time.  Re-set all fuel racks.  a. Re-set valves. b. Replace or overhaul head. c. Overhaul.
High lubricating oil temperature.	Gauge inaccurate.	Compare to master gauge/replace gauge.

TROUBLE SHOOTING — Continued

SYMPTOM	PROBABLE CAUSE	REMEDY
<p>High lubricating oil temperature (continued).</p>	<p>Engine overloaded.</p> <p>Insufficient cooling:</p> <ul style="list-style-type: none"> <li>a. Low jacket water pressure.</li> <li>b. Low raw water pressure.</li> <li>c. High jacket water temperature.</li> <li>d. Dirty lube oil cooler.</li> <li>e. Dirty jacket water heat exchanger or radiator.</li> </ul> <p>Low lubricating oil pressure.</p>	<p>Determine and correct cause of overload.</p> <ul style="list-style-type: none"> <li>a. See Low Jacket Water Pressure causes.</li> <li>b. See Low Raw Water Pressure causes.</li> <li>c. See High Jacket Water Temperature causes.</li> <li>d. Clean or replace.</li> <li>e. Clean or replace.</li> </ul> <p>See Low Lubricating Oil Pressure causes.</p>
<p>Knocking or unusual noises.</p>	<p>Low octane fuel (gas engines) or low cetane fuel (diesels).</p> <p>Engine overloaded.</p> <p>Overly advanced ignition or injection timing.</p> <p>Excessive valve clearance.</p> <p>Sticking valves or rocker arms.</p> <p>Damaged or excessively worn accessory drives.</p> <p>Loose bearings (failed).</p> <p>Loose piston pins (failed).</p> <p>Excessive crankshaft end play.</p> <p>Misfitted or excessively worn timing gears.</p>	<p>Adjust timing for fuel being used (gas). Replace fuel with better grade (diesel).</p> <p>Determine and correct cause of overload.</p> <p>Re-time.</p> <p>Readjust valve clearance.</p> <p>Free up or replace.</p> <p>Repair or replace components as required.</p> <p>Replace bearings.</p> <p>Replace piston pins and/or pin bushings as required.</p> <p>Replace main bearing thrust rings.</p> <p>Replace.</p>
<p>Excessive fuel consumption.</p>	<p>Carburetors adjusted over-rich (gas engines).</p> <p>Leaks in fuel system.</p> <p>Excessively worn fuel injectors (diesels).</p>	<p>Readjust.</p> <p>Repair as required.</p> <p>Repair or replace.</p>

TROUBLE SHOOTING

TRUBLE SHOOTING — Continued

SYMPTOM	PROBABLE CAUSE	REMEDY
<p>Excessive fuel consumption (continued).</p>	<p>Faulty ignition system (gas engines).</p> <p>Late ignition or injection timing.</p> <p>Engine overloaded.</p> <p>Poor synchronization of multi-engine installations.</p> <p>Improper matching of torque convertor to engine and load.</p> <p>Poor compression.</p>	<p>Repair or replace components as required.</p> <p>Re-time.</p> <p>Determine and correct cause of overload.</p> <p>Balance loads.</p> <p>Replace torque convertor.</p> <p>Determine cause (s) and effect repair.</p>

## CHAPTER 6 STORAGE

### BASIC REQUIREMENTS

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 kraft paper will serve this purpose. Where these openings are in the form of screened or louvered guards or cover 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 judgment 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.

**NUCLE-OIL STORAGE**  
(Recommended Storage Procedure)



For many years the Waukesha Engine Division has felt obliged to offer the best available advice on engine storage procedures for use by OEM accounts, distributors, and engine owners. One great difficulty, however, has always been the lack of sources for suitable preservative compound oils in practical quantities at the field level. Moreover, when using conventional storage oils, many larger engines would require a rather large amount of this expensive material which would later have to be discarded when the engine was again placed in service. Other objections to the procedures offered involved the difficulty of introducing a suitable coating of preservative oil into the cylinder wall and combustion chamber area and sustaining a film which did not break down or drain off after a time.

Nucle-Oil, a product of the Daubert Chemical Company, is offered in one gallon cans through Waukesha Engine Division under Part No. 166709-A and offers a practical and economical solution to the problems summarized above. This product is similar in appearance to a conventional lubricating oil of about SAE No. 10 viscosity. As its description suggests, however, it contains volatile-corrosion-inhibiting chemicals which vaporize slowly and diffuse throughout any closed void such as the interior of an engine or gear housing. These chemicals form an invisible protective layer on the exposed surfaces even though the surfaces were not originally coated with the oil. Obviously, absolute sealing of an engine may not be 100% practical in the field but reasonable blockage of the escape paths for the vaporized chemicals is not difficult and ordinary storage times present no problem.

Nucle-Oil contains Petroleum Distillate. Harmful or fatal if swallowed. Avoid contact with skin. Vapor is harmful. Causes irritation of eyes, nose, throat and skin. Use only with adequate ventilation. Avoid prolonged or repeated breathing of vapor. Avoid contact with skin, eyes, and clothing. Do not take internally. Keep container closed and away from heat. In case of contact, immediately flush skin or eyes with plenty of water for at least 15 minutes; for eyes, get medical attention. Remove and wash clothing before reuse. If affected by exposure, move to fresh air. If swallowed, do not induce vomiting. Remove ingested material by gastric lavage with 2 to 4 quarts or liters of tap water or milk. Follow with fruit juice or vinegar to neutralize the alkali.

Equally important, especially when large engines are involved, the Nucle-Oil may simply be added to the existing crankcase oil in the amount of 2% without concern for future removal. It is stressed that Nucle-Oil cannot and will not protect engine surfaces in intimate contact with highly corrosive used engine oil. In other words, Nucle-Oil will do an effective job if added to engine oil in normal clean condition. If high sulfur fuel or improper control of oil condition from whatever cause, has left highly corrosive oil in the bearings and close contact surfaces, it is self evident that the protective vapors cannot be expected to force the oil from the bearing clearances and substitute a protective layer. Such engines should have an oil change and be run long enough to circulate the clean oil.

NUCLE-OIL APPLICATION CHART

Engine Model	Upper Cylinder		Crankcase		Fuel Tank	Oil Bath Air Filter	Injectors	Total Ounces
	Ozs. of Nucle-Oil Per Cyl.	Ozs. of Nucle-Oil All Cyls.	Std. Oil Pan* Cap. Qts.	Ozs. Nucle-Oil	Ozs. Nucle-Oil	Ozs. Nucle-Oil	Ozs. Nucle-Oil	Nucle-Oil Required
H1077	1	8	36	23	43	3	4	81
L1616	1	12	52	34	64	4	6	120
P2154	1	16	72	46	86	6	8	162

\*Proportionately greater quantities of Nucle-Oil must be added to deep sump and marine oil pans.

## WAUKESHA VC SERIES

Nucle-Oil is not intended as an external surface coating protective measure since it would be about the same in effectiveness as coating the surface with conventional lubricating oil. Other excellent products are available for polished or machined surfaces and should be used when needed.

The Waukesha Engine Division is offering this oil as a service so that Waukesha users may be able to purchase an effective engine preservative on an over-the-counter basis.

Although basic instructions for the use of Nucle-Oil are offered on each can label, the following material taken directly from our correspondence with Daubert Chemical is highly explanatory and should be read carefully.

One ounce of Nucle-Oil per cubic foot of air space will provide good VCI protection in sealed systems. In considering the amount required for each upper cylinder, approximately ten times this amount was used for calculating the Nucle-Oil requirement for each cylinder. The recommended amounts of Nucle-Oil should be added through the spark plug or injector opening. The amounts recommended will provide safe VCI protection allowing for possible leakage of the VCI inhibitors.

2% Nucle-Oil added to the crankcase oil is recommended to customers for VCI protection in this area. The amounts recommended in the table are based on this approximate concentration.

Generally, Nucle-Oil is recommended for use in fuel tanks at the rate of 1 oz. Nucle-Oil per 20 gallons of air space plus enough additional Nucle-Oil to flush through the fuel lines.

The following procedure for preservation is suggested:

1. Start with a cold engine (below 100° F.) containing clean oil and filter elements.
2. Add the required amounts of Nucle-Oil to the crankcase, oil bath type air filters, and fuel tanks.
3. Crank engine for 20 seconds, if possible, to help disperse Nucle-Oil, with fuel supply line picking up Nucle-Oil to protect injectors.
4. Add the required amounts of Nucle-Oil to each cylinder through the spark plug or injector openings and replace plugs or injectors. Apply to rocker area by light brushing or pouring. Replace rocker covers.
5. Store engine up to one year. If storing for more than one year, inspect and re-preserve annually, as necessary.

## 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. Circumstances may compel omitting some steps and, on the other hand, special conditions may point to greater emphasis on other steps.

### CAUTION

All VC Series engines shipped by Waukesha Engine Division receive storage measures internally which prepare the engine for a storage period of up to one year, 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 represervation.

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 re-install.
- 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 six months 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 mechanically 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 judgment 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 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 judgment of the operator and storage conditions warrant, the engine should be disassembled, thoroughly cleaned, and reassembled 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 inaccessible 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 anti-freeze, 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 startup. 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 insulation 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  $\div$  1000 + 1 (i.e., machine voltage of 480 V.A.C.  $\div$  1000 = .480 + 1 = 1.480 megohms). If any circuit to ground measures less than calculated value, consult the Waukesha Motor Company 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)
Nucle-Oil #120 Mil Spec. MIL-L-46002 Grade 2	Army Ordnance 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 rather than Nucle-Oil storage, 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 racks in off position. Purge by operating hand priming pump.

**PRESERVATIVE OIL**

In addition to Nucle-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.	#800 Regal Oil A (R & O)

**NOTE**

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

## CHAPTER 7 REPAIR AND REPLACEMENT PROCEDURES

### SECTION I - GENERAL INSTRUCTIONS

#### SCOPE

The instructions contained in this section cover general and multi-use items. They are a definite part of the repair and replacement procedures where applicable.

#### 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 such as oil coolers and intercoolers 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.

#### INSPECTION

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

#### CLEANING

##### General

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 and then 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 brass 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 washed 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.

#### General

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 non-flammable cleaning solution 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.

#### Removal

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

#### Installation

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

#### Removal

Oil seals should not be removed unless absolutely necessary for gaining access to another item or 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.

#### Inspection

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 and replaced.

#### Installation

When possible, soak new rawhide seals in warm 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 part 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 in gear with keyway in shaft before installing. Lubricate mating surfaces of gear and shaft when pressing gear on shaft.

### 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 ones whenever possible. Never use cork or felt gaskets a second time. Be sure holes in gaskets correspond with lubricant passages in mating parts. If 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 or 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.

### 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 possibility that 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 tapered splines are always very tight. If they are not tight when disassembled, inspect tapered splines and discard part if splines are worn. Before assembling shafts with tapered splines, be sure splines are clean, dry, and free from burrs. Press mating parts together tightly.

### FLEXIBLE HOSE LINES

The large oil lines are flexible hoses, incorporating swivel fittings.

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.

## SECTION II - REPAIR AND REPLACEMENT PROCEDURES

### SPECIAL TOOLS FOR REMOVAL AND REPLACEMENT PROCEDURES

A valve lifter guide puller kit, Part No. 947-4, is used to remove guide and lifter assemblies from the crankcase. The top of the valve and injector lifter guides have two 1/4" puller holes opposite each other, and can frequently be removed with a hooked bar. However, if they become tightly lodged, the puller kit is a necessity. This kit includes two special expandable collets, which are each equipped with a 1/4" pin to fit into one of the two puller holes. The smaller collet is for all valve lifter guides and recently used reduced diameter injector lifter guides, while the larger collet is for the previously used larger diameter injector lifter guides. Usually, use of the slide hammer will free the lifter and guide assembly, but occasionally, the puller bridge must be used. The lifter cannot be removed without removing it along with the guide, since the lifter guide pin, which engages a vertical slot in the lifter, becomes locked in place when the lifter and guide are inserted into the crankcase. Current VC Series engines use completely different valve lifters and guides and this puller kit is not useable with these engines.

The piston rings, cylinder wall, and ring compressor must all be oiled with clean engine oil when installing the piston and rod assembly, using the tapered sleeve type ring compressor, Part No. 494000.

Because of the two cam bushings used per journal (installed with an annular oiling space between them) and the limited access to remove and install them, the cam bushing removal and insertion tool, Part No. 499989, is necessary to remove and install cam bushings when required. Service only cam bushings should be used for replacement purposes, since they are pre-sized to preclude line reaming. The cam bushing tool consists of a driving rod, a removal and insertion driver, and two driving rod pilots (one pilot to fit bore with bushings out and one pilot to fit bore with bushings in).

A pilot sleeve, Part No. 494017, is used to facilitate camshaft removal and installation.

Proper use of an injector tube removal and installation tool set is covered in **INJECTOR TUBE REMOVAL AND INSTALLATION** in this chapter.

A puller set for removing valve seat inserts, consisting of an extractor, Part No. 499943, an adaptor, Part No. 499944, and a depth collar, Part No. 499945, removes the inserts quite quickly. Once the tool is properly set, removal is accomplished in approximately 10 seconds per insert, without damage to the surrounding cylinder head metal.

Proper use of special tools for the installation of Teflon sleeve seal rings is covered in **INSTALLATION OF SPRING-LOADED TEFLON SLEEVE SEAL RINGS** in this chapter.

Proper use of a spreader bar tool, Part No. 494021, which is used for press fitted main bearing cap installation is covered in **MAIN BEARING CAP TORQUING PROCEDURES** in this chapter.

### PROPER SELECTION OF VALVE MECHANISM SERVICE PARTS

Because of a rocker arm support stud size increase, changes in oiling passages, a cylinder head stud size increase, a spark plug tube and spark plug size change, the use of steel rocker arms in the current design, valve spring and injector push rod spring changes, and other related changes, the proper selection of service parts is important. Refer to Service Bulletin No. 7-1940A for detailed interchangeability information.

### VALVES AND MECHANISM

#### General

When replacing valves, valve guides, or valve seat inserts, exercise caution to use service parts of the correct material. Stellite seat facings are employed on the valves and the valve seat are stellite inserts. The stellite inserts are installed and retained by shrinking and driving into the cylinder head. Intake and exhaust guides are pressed into the cylinder head but may be pulled and replaced if necessary.

Injector valve lifters, valve lifter guides, and push rods are not interchangeable with intake and exhaust valve lifters, valve lifter guides, and push rods.

Make sure expansion plugs in ends of rocker arm shafts are tight. If not tight or if they are being replaced, stake expansion plug at three equally spaced points, taking care to prevent distortion of shaft outer diameter and retaining ring groove. Current rocker arm shafts utilize cup plugs which do not require staking.

### Replacing Rocker Arm Bushings

When replacing rocker arm bushings, they must be installed as follows:

1. Bushings in aluminum rocker arms must be flush with the side of the rocker arm which contacts the retaining snap ring.
2. Bushings in steel rocker arms must be flush with the side of the rocker arm which contacts the rocker arm support.
3. The oil holes in the bushing must be aligned with the oil holes in the rocker arm. The notch in bushings in aluminum rocker arms must be towards the valve end and on the horizontal centerline, while the notch in bushings in steel rocker arms must be towards the top and on the vertical centerline.
4. Aluminum rocker arms which include roll pins as oiling tubes must have the bushing drilled through  $3/32$ " after it is installed. When reinstalling the roll pin, it should be clear of the bushing bore by  $1/16$ ".
5. The bushings are a press fit in the rocker arms and are reamed to size after installation (see Chapter 8).

### Replacing Valve Seat Inserts

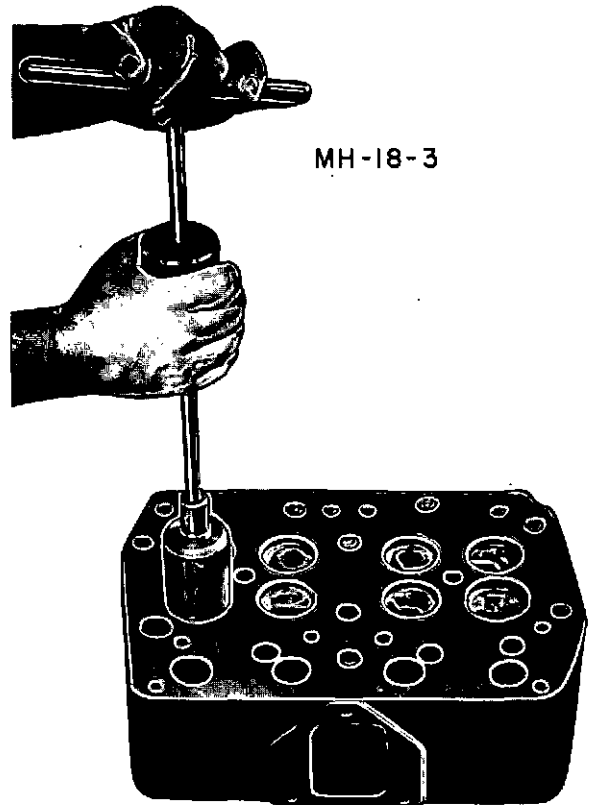
Since valve seat inserts must resist severe and repeated contacts with the valve, the action of hot gases and the reverse stresses of rapid heating and cooling, the proper replacement of the inserts is of utmost importance. Make certain that proper tools are available before proceeding with replacement. Remove and replace the insert as follows:

#### NOTE

Insert failure may be a result of poor valve grinding in previous overhauls, lack of coolant during operation, uneven torquing of head bolts, etc. Any conditions contributing to insert failure should be corrected.

1. If inserts require replacement, remove defective inserts with a puller made for this purpose or follow this procedure:

Position cylinder head on work bench with inserts up and place asbestos cloth into valve ports to protect against weld spatter. Adjust welding machine to 80-85 amps and lay bead of  $1/8$ " stainless steel weld rod around seat of insert. Quench insert with rag soaked with cold water; insert should crack. Remove insert by lightly tapping with hammer and chisel; taking care not to drive chisel between insert and counterbore. Clean counterbore with wire brush and allow head to return to ambient temperature.



USING SPECIAL PULLER SET TO REMOVE VALVE SEAT INSERTS

2. Check insert counterbore. Counterbore must be free of distortion, cracks and chips so that good metal-to-metal contact between insert heat conducting surfaces and head is attained.
3. A counterbore cutter will provide light cutting action for cleaning up counterbore

after insert removal. The piloting of the cutter must permit cutting to micrometer dimensions as required. If new valve guides are required, they should be installed first so that counterbore cutting operations will pilot true in the guide.

4. Use counterbore cutter if required to re-size insert counterbore for oversize insert. Refer to Chapter 8 for counterbore diameter for oversize insert.

**CAUTION**

The shrink fit of the insert in the cylinder head is very critical. The insert will loosen in service if the insert is installed in the counterbore with too tight a fit. This is the result of a metallurgical condition whereby the expanded metal takes a permanent set while hot and thereafter never returns to its original position.

5. Shrink insert before installing to prevent scuffing counterbore walls. Shrink by placing the insert in a container of alcohol in which several pieces of dry ice have been immersed.
6. Check counterbores for cleanliness and freedom from burr edges. Support cylinder head solidly and place in convenient position for driving in insert.
7. The insert tool must be piloted in the valve guide to ensure proper fit in the counterbore. If necessary, use valve guide installing mandrel and slip sturdy, washer-like driving plate somewhat larger than insert over mandrel pilot.

**WARNING**

The insert must be handled with forceps or a hooked wire after being chilled. Use care not to drop inserts as they are extremely fragile when chilled.

8. Lift chilled insert from dry-ice bath with pair of forceps or hooked wire and locate it over counterbore so that chamfer on insert lower edge is centered squarely.

Start driving mandrel pilot in valve guide, bring driving face accurately against insert upper surface and tap mandrel firmly with medium weight hammer. If insert will not seat without severe hammering, counterbore size is incorrect, insert is not chilled enough, or it was not started into counterbore straight and true.

**Grinding Valves and Valve Seats**

If the valve seat insert or the valve guide have been replaced, the valve seat must be re-ground concentric with the new guide. To assure smooth, accurate seats, the valve guide must be in good condition and the pilot must fit properly in the guide and at the hub of the grinder stone. Make certain that the pilot is a proper fit in the valve guide and will not wobble at the upper end. Excessively worn valve guides must be replaced before grinding is attempted. The grinding wheel must be dressed according to the manufacturer's instructions for proper grinding of valve seats.

If inspection of the valves indicates the need for grinding the faces, this should be done on a valve grinding machine. The valve stems and guides must be a good fit without wobble to ensure a concentric seat and a tight valve. Only grind enough Stellite material from the valve face to insure good sealing. The Stellite is .030" thick—do not re-use the valve if more than .015" is ground off. Hand lap the valves after machine grinding as follows:

1. Apply medium to fine grinding compound sparingly over entire valve face and dip in water.
2. Slip light lifting spring over stem, lubricate stem, and insert valve in cylinder head. Spring should just lift valve off its seat.
3. Attach lapping tool to valve head with suitable suction cup. Press down until valve is seated and turn valve a quarter turn, first in one direction, then in other direction. Repeat three or four times.
4. Release pressure on valve, turn 10 to 15 degrees to another position and repeat lapping. Continue until all compound is rubbed from valve seat.
5. Remove valve and wipe both valve and seat clean.

6. Check valve and seat for gray, frosty seating surface located either in center of valve face or somewhat towards head to indicate proper lapping. The lapped surface must extend evenly and completely around the face and will neither appear as a sharp line contact nor as a wide band on the valve contact face. Clean valve seat and surrounding area.

**CORRECT USAGE OF CYLINDER HEADS, GASKETS, AND SLEEVES**

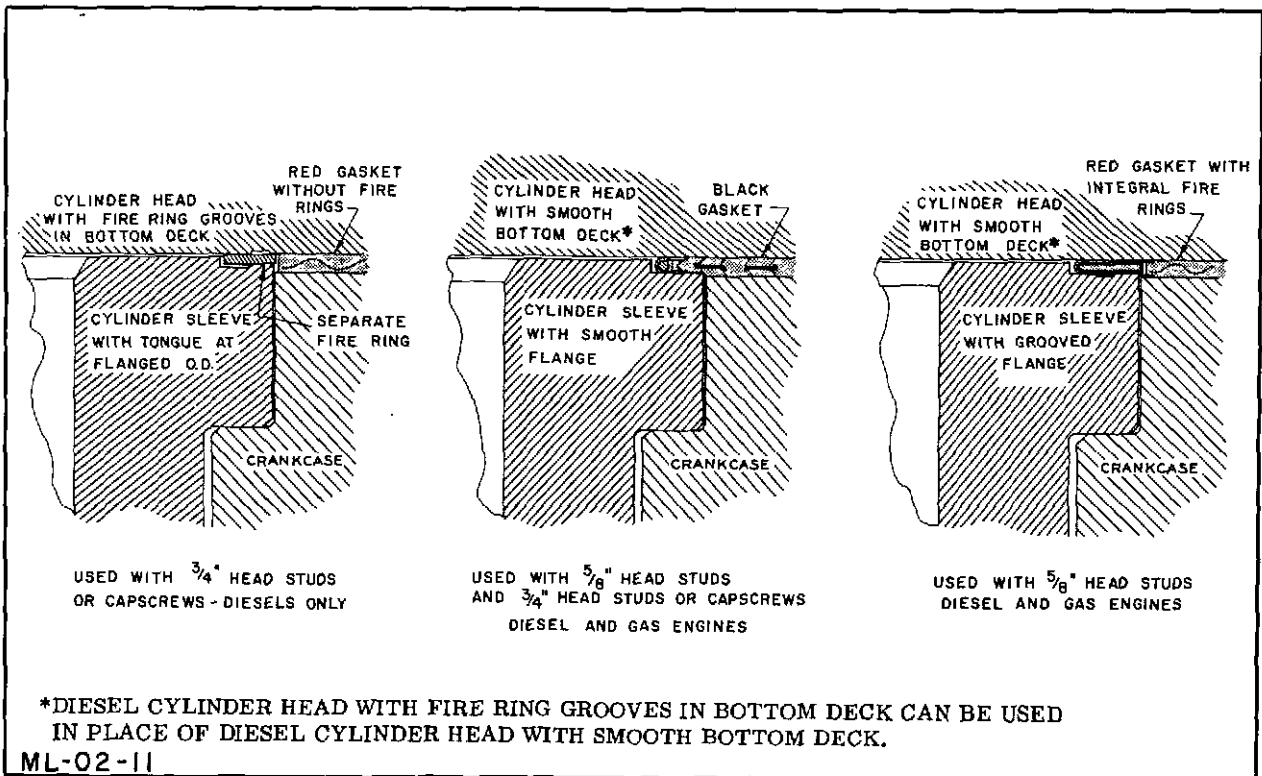
**CAUTION**

Since the cylinder heads clamp the cylinder sleeves in place, removal of the heads will permit the sleeves to move slightly from piston friction when crankshaft is turned. This will damage the sleeve lower seal rings. If repair of only one cylinder head is anticipated without removal of piston and sleeve, install a suitable length of pipe over one head stud and secure with a nut and washer to hold the top flange of the sleeve in place. When resting cylinder head assembly on work bench, protect valve side by placing it on wooden blocks.

**Replacing Valve Guides**

Replace valve guides that are excessively worn. The guides are a press fit in the head casting and replacement guides must be reamed in place (see Chapter 8) to provide proper valve stem clearance. The valve seat inserts in the head must be re-ground concentric with the new guides whenever new guides are installed. Remove worn guides with a suitable press or by reaming to a thin shell and collapsing them. Press new guides into place on an arbor press with a mandrel of the proper size to prevent damage. End of guide with 15° chamfer enters cylinder head. Check each guide to make sure that it extends 1-1/16 in. above the cylinder counterbore. Exhaust valve guides must not protrude into the exhaust ports, but should be slightly recessed instead (1/16 to 3/32 inch).

Various combinations of cylinder heads, gaskets, and sleeves have been utilized on VC series engines. The accompanying illustration includes the three basic combinations in which heads, gaskets, and sleeves must be used to ensure effective sealing between the top of the sleeve and the head.



REPAIR AND REPLACEMENT

**PROPER COMBINATIONS OF CYLINDER HEADS, GASKETS, AND SLEEVES**

## WAUKESHA VC SERIES

The basic combination illustrated on the left is for VC diesels only with 3/4" head studs or cap screws. As illustrated, the sleeve is machined with a tongue at its flange OD, the cylinder head includes machined fire ring grooves in its bottom deck, and a red gasket, plus separate fire rings, is used.

The basic combination illustrated in the center is for VC diesel and gas engines with 5/8" head studs and 3/4" head studs or cap screws. As illustrated, the sleeve has a smooth flange, the cylinder head has a smooth bottom deck, and a black gasket is used.

The basic combination illustrated on the right is for VC diesel and gas engines with 5/8" head studs. As illustrated, the sleeve has a grooved flange, the cylinder head has a smooth bottom deck, and a red gasket (with integral fire rings) is used.

### NOTE

Always install cylinder head gaskets with the side marked "TOP" towards the cylinder head.

Refer to Service Bulletin No. 7-1940A to clarify interchangeability requirements of cylinder heads, gaskets, and sleeves, along with interchangeability requirements of rocker arms, shafts, supports, and related components. As noted in this service bulletin, the red head gasket and separate fire rings and the cylinder head with machined fire ring grooves must always be used on diesel engines which use the cylinder sleeve machined with a tongue at its flange OD.

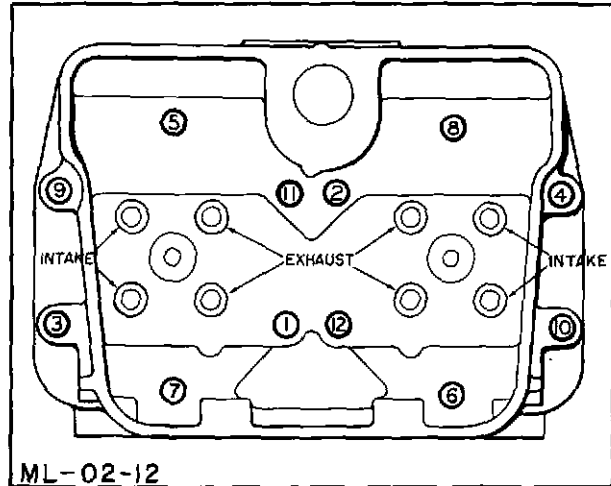
### CAUTION

The cylinder sleeve flange projects a few thousandths above the deck to ensure a tight crush at the gasket joint. Whenever sleeves are installed, a check should be made to be sure that this projection (see Chapter 8) is present.

## CYLINDER HEAD TORQUING PROCEDURES

Original VC series engines utilized 5/8" cylinder head studs. Later VC series engines utilized 3/4" cylinder head studs. Current VC series engines utilize 3/4" cap screws.

The torquing sequence (see illustration) is the same for all three variations, but the torquing procedures and torque values differ.



CYLINDER HEAD TORQUING SEQUENCE AND VALVE LOCATION DIAGRAM

### NOTE

All of these torque values are for oiled threads.

To torque cylinder heads on VC series engines with 5/8" cylinder head studs, proceed as follows:

1. Torque cylinder head stud nuts in proper sequence to 1200 in. lbs. (100 ft. lbs.).
2. Repeat torquing sequence to 1800 in. lbs. (150 ft. lbs.).
3. Repeat torquing sequence to final value of 2230 to 2280 in. lbs. (186 to 190 ft. lbs.).
4. After running the engine either idle or after load testing, retorquing as follows:
  - a. If engine is equipped with grooved flange cylinder sleeves and red cylinder head gaskets, retorquing all cylinder head stud nuts to 2230-2280 in. lbs. (186 - 190 ft. lbs.).
  - b. If engine is equipped with smooth flange cylinder sleeves and black cylinder head gaskets, check accessible cylinder head stud nuts for torque loss. If any of these nuts are looser than 2160 in. lbs. (180 ft. lbs.), all cylinder head stud nuts must be retorqued to 2230-2280 in. lbs. (186 - 190 ft. lbs.).

To torque cylinder heads on VC series engines with 3/4" cylinder head studs, proceed as follows:

1. Torque cylinder head stud nuts in proper sequence to 2400 in. lbs. (200 ft. lbs.).
2. Repeat torquing sequence to 3000 in. lbs. (250 ft. lbs.).
3. Repeat torquing sequence to final value of 3550-3600 in. lbs. (296-300 ft. lbs.).
4. After running the engine either idle or after load testing, check accessible cylinder head stud nuts for torque loss. If any of these nuts are looser than 3420 in. lbs. (285 ft. lbs.), all cylinder head stud nuts must be retorqued to 3550-3600 in. lbs. (296-300 ft. lbs.).

To torque cylinder heads on VC series engines with 3/4" cylinder head cap screws, proceed as follows:

**NOTE**

A 3/4" drive, 3/4 inch, 12 point flank drive socket is required to torque these 3/4" cylinder head cap screws. Hardened flat washers should be used with these cap screws.

1. Torque cylinder head cap screws in proper sequence to 2400 in. lbs. (200 ft. lbs.).
2. Repeat torquing sequence to 3300 in. lbs. (275 ft. lbs.).
3. Repeat torquing sequence to final value of 3840-3900 in. lbs. (320-325 ft. lbs.).
4. After running the engine either idle or after load testing, check accessible cylinder head cap screws for torque loss. If any of these cap screws are looser than 3720 in. lbs. (310 ft. lbs.), all cylinder head cap screws must be retorqued to 3840-3900 in. lbs. (320-325 ft. lbs.).

**PROPER INSTALLATION OF DIESEL PISTONS AND CYLINDER SLEEVES WHICH ARE CLASSIFIED BY SIZE (A, B, OR C)**

Pistons and cylinder sleeves previously used in some VC series diesel engines were stamped with an "A", "B", or "C", to indicate the size classification. A replacement piston may be installed in a sleeve of the same size classification as the piston, or in a sleeve of one size classification larger. A replacement piston may not be installed in a sleeve of a size classification smaller, nor in a sleeve of a size classification two steps larger than the piston size classification.

The size classification of these pistons is stamped in the piston head near the part number stamping while the size classification of these sleeves is stamped on the fire dam. Sleeves which have been in service may have this size mark obliterated and measurement of the sleeve ID is then necessary to determine the size classification.

**NOTE**

Do not confuse piston size "B" with piston symbol 230104B, or vice versa. The size stamp is considerably larger than the part number.

CYLINDER SLEEVE	
Size Classification	I.D.
"A"	5.750" - 5.7503"
"B"	5.7503+ - 5.7506"
"C"	5.7506+ - 5.7510"

For more detailed information on sized pistons and sleeves, refer to Service Bulletin No. 6-1891.

**SELECTION OF SERVICE PISTONS AND CONNECTING RODS**

Current production VC series diesel engines are now built with pistons which are not classified by size and may be used with cylinder sleeves of size classifications A, B, or C and in place of sized pistons, for either single piston or piston set replacement. However, sized pistons cannot be used in place of current production pistons which are not classified by size, unless installed in accordance with Service Bulletin No. 6-1891 in size classified cylinder sleeves.

Both the current production diesel and gas pistons are not presently marked red or blue for red or blue marked piston pins. Also, piston pins are not presently marked red or blue. Neither the pin bore in the piston nor the piston pin O.D. have been changed and previously red or blue marked piston pins can be used in previously marked red or blue marked pistons—that is, a red marked pin can be used with a blue marked piston and vice versa. Also, unmarked pins can be used in marked pistons and vice versa.

Current production engines use hardened steel washers with hex head, grade 8 connecting rod bolts. The Waukesha Engine Division recommends the addition of these washers to rods

**REPAIR AND REPLACEMENT**

which did not include them, to prevent possible bottoming of bolt threads in the rod. The currently used bolt is interchangeable with the previously used place type bolt.

Future production rods will utilize ferry head rod bolts without washers, which are interchangeable with both the place type and the hex head, grade 8 bolts.

All currently used connecting rods have the sides of the pin end tapered to mate with the tapered sides of the piston pin bosses in diesel pistons. Previously used connecting rods have straight pin end sides and previously used diesel pistons have straight side piston pin bosses.

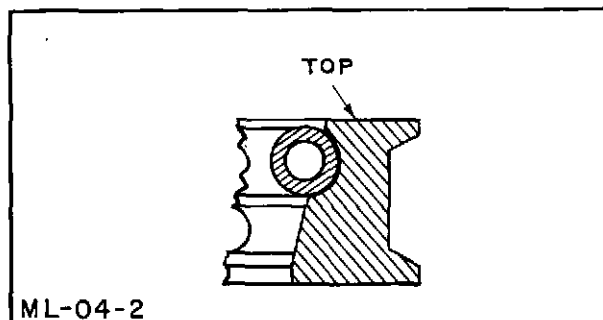
The tapered pin end rods cannot be used in diesel engines with the straight side pin boss pistons and the straight pin end rods cannot be used in diesel engines with the tapered pin boss pistons. The gas engine piston has adequate space between its straight piston pin bosses and can be used with either the tapered or straight pin end rods. The straight pin end rods require straight end pin bushings, while the tapered pin end rods require tapered end pin bushings.

Currently used connecting rods have a narrow crankpin end and are used only with the currently used crankshaft which has wide intermediate main bearing journals and narrow crankpin bearing journals. This crankshaft can be used in either the narrow or the wide intermediate main bearing crankcase.

For more detailed information on selection of service rods, and rod bolts, refer to Service Bulletin No. 5-1941-A.

## INSTALLATION OF OIL RINGS

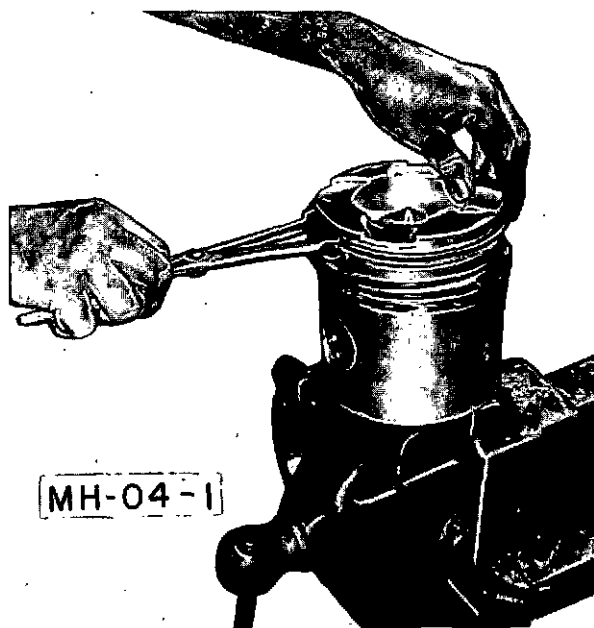
The type of oil ring previously used in VC series diesel engines may be installed with the spring towards either the top or bottom of the



PROPER INSTALLATION OF OFFSET SPRING OIL RING

piston. However, for purposes of standardization, the Waukesha Engine Division Engineering Department recommends installing this type oil ring with the spring towards the top of the piston (see illustration). Engines have been built with this type oil ring installed in both directions with no resultant ill effects. Early applications of this type oil ring incorporated a nylon scuff sleeve over the spring which was assembled across the ring gap. Field experience has proven this sleeve to be unnecessary and it has been omitted.

All VC series gas engines and current VC series diesel engines utilize a symmetrical oil ring, that is, the spring is centered in the oil ring, and either side of the ring may be towards the top of the piston. This oil ring supersedes and is interchangeable with the previously used diesel oil ring.



INSTALLING PISTON RINGS

### 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. The spring gap should be 180° from the ring gap on both types of oil rings.

**INSTALLATION OF SPRING-LOADED  
TEFLON SLEEVE SEAL RINGS**

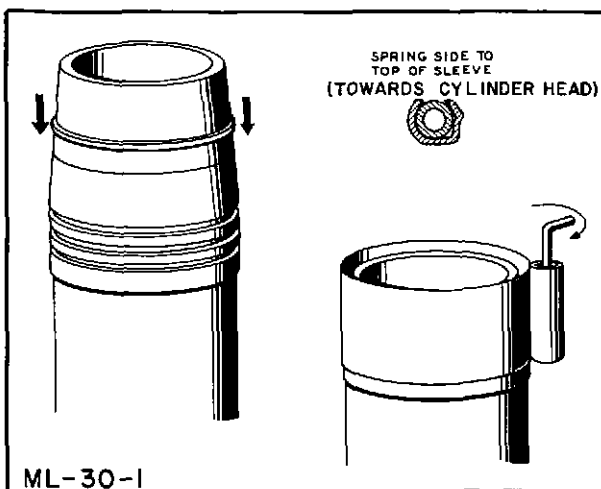
Teflon sleeve seal rings can be used in the lower sleeve groove during repair and rebuilding of VC series engines. This seal consists of a machined Teflon ring with a flat-wound stainless steel inner spring. The materials used make this seal extremely resistant to temperature variables and attack by crankcase or cooling water chemicals. The Teflon seal is employed in the lower groove only and standard sealing rings are used in the upper (water side) grooves. Current VC series engines use standard sealing rings in all three grooves. The proper sealing rings to use in the two upper grooves are marked with a white dot, while the sealing ring used in the lower groove is marked with a red dot.

Certain installation procedures must be followed to ensure success with the Teflon seal...

1. All seating surfaces and all surfaces over which the seal must pass on the sleeve and within the crankcase must be absolutely free of burrs and nicks. The crankcase bore must be smooth and the upper edge entering portion must be blended so the seal can slip into it freely without catching.
2. The seal ring should not be stretched by hand to slip over the lower end of the sleeve. A tapered sleeve is required and its use is illustrated. Lubricate the exterior of the installation tool and the lower

end of the sleeve with Parker O-Lube or equivalent. After aligning and starting the ring on the taper, it should be thrust down to the groove smartly with hand pressure. Current sleeves include a large chamfer on the lower end and do not require use of the tapered sleeve.

3. The above procedure stretches the ring and if installed in this condition, it is probable that excess Teflon will be sheared off and the seal ruined. A compressor tool such as the clamp or band commonly used to install piston rings may be used to re-size the seal ring. A scrap of thin material such as Mylar or heavy cellophane should be used at the clamp slip joint to protect the seal against notching at this point, or the inside end of the compression tool must be feathered to a fine edge. Torque the lock nut of the compression tool to 10-15 ft. lbs. to re-size the ring. After removing the compression tool, the sleeve is ready for installation in the crankcase.
4. The compression tool can be purchased from Waukesha as Part No. 494089.
5. If a compressor is not available, it is preferable to allow the seals to set overnight by which time they will regain approximately their former dimensions. Also, the sleeve with the Teflon seal only installed may be submerged in boiling water for 15 minutes to re-size it. A No. 105 rubber band is another good substitute when only a few sleeves are involved. Using the rubber band, the seals must set from a few hours to overnight.
6. Lubricate the seal with liquid soap or other lubricant in the conventional manner and install and inspect the sleeve as usual. Check for leakage and bore roundness.



**INSTALLING TEFLON SEAL RINGS**

**RE-USE OF CHROME PLATED CYLINDER SLEEVES**

VC series diesel engines are equipped with chrome plated cylinder sleeves. These chrome plated sleeves should not be honed or have a glaze breaking operation performed at the time of overhaul or repair. When these chrome plated sleeves are reusable and new piston rings are installed, no special preparation of the sleeve

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REPLACEMENT**

I.D. is necessary or desirable. New piston rings will seat and establish oil control successfully on the chrome surface of a used sleeve.

### **CRANKCASE ASSEMBLY AND COMPONENTS INTERCHANGEABILITY**

Changes to crankcase assemblies and components consist mainly of a revised balancing system (H1077 series only), use of 3/4" in place of 5/8" head studs (and subsequently, use of longer 3/4" head studs with increased thread engagement in the crankcase, and then use of 3/4" cap screws instead of studs), use of reduced diameter injector cam followers and injector cam follower guides (diesels only), the addition of an oil inlet line connection to replace a pipe tap in the crankcase, the use of longer main bearing studs with increased thread engagement in the crankcase along with doweled instead of piloted main bearing caps (and subsequently, the use of press fitted and piloted main bearing caps along with wider intermediate main bearings), and the use of different crankcases for gas and diesel engines (crankcases for gas engines do not include the reamed holes for injector cam followers and guides). Current VC series engines use completely different cam followers and guides. Refer to Service Bulletin No. 6-1949A for detailed interchangeability information.

### **CLEANING AND PRELUBRICATION OF CAM FOLLOWERS USED FOR SERVICE REPLACEMENT**

Cam followers used for service replacement are shipped from the factory coated with Cosmoline. We have received reports of followers being dipped or immersed in cleaning solvent to remove the Cosmoline. This practice not only removes the Cosmoline, but also removes the Molycote from the follower roller bushing and pin which can result in follower failure.

The Cosmoline should be removed from the followers by wiping them with either a dry cloth or a cloth dampened with cleaning solvent. After the Cosmoline has been removed, we recommend immersing the followers in clean engine lubricating oil for 4 to 5 minutes to insure adequate roller bushing and pin lubrication. Don't wipe the oil from the followers before installing them in the engine.

These prelubrication procedures also apply to reinstallation of removed cam followers which are being reused.

MH-23-3.



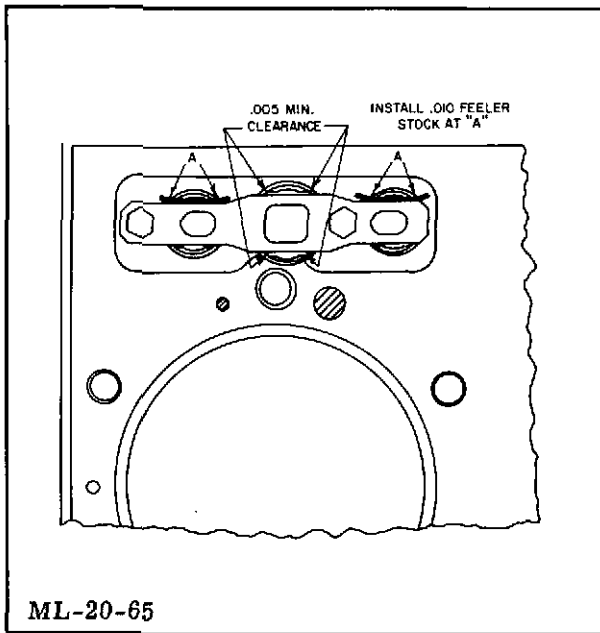
**INSTALLING CAM FOLLOWER GUIDE PINS**

### **REMOVAL AND INSTALLATION OF CAM FOLLOWERS AND GUIDES**

Remove cam followers and guides together by using special cam follower and guide removal tools (Kit No. 947-4). Mark each unit as it is removed to assure that they are reinstalled in their original positions. Push guide pin out from inside using hooked end of scribe and slide follower out of guide. These tools are not useable with current crankcases which use completely different cam followers and guides. Current cam followers use bracket type guides rather than sleeve type guides. When the bracket type guides are removed, the cam followers can be easily removed from the crankcase.

To install previously used cam followers, insert follower assembly into guide so that guide pin hole and slot are aligned. Install guide pins as illustrated. Slide follower up and down a few times to assure smooth operation.

Note that cam follower guide counterbore in crankcase has a locating pin. Align slot in flange of guide with pin when installing. Make sure that followers and guides are installed in their original locations.



CURRENT CAM FOLLOWER  
INSTALLATION

To install currently used cam followers, proceed as follows:

1. Insert all three followers (only two for gas engines) for each cylinder.
2. Install cam follower guide and hand tighten two retaining capscrews.
3. Insert .010" feeler stock as illustrated.
4. Hold the follower guide firmly against the feeler stock and tighten the retaining capscrews to 23-25 ft. lbs.
5. On diesel engines, check for .005" minimum clearance between the injector cam follower and the follower guide as illustrated, before removing the .010" feeler stock. If .005" minimum clearance is not obtained, remove follower guide and cam followers and reassemble per steps 1 through 4 with injector cam follower rotated 180° from originally installed position.

NOTE

Due to the special assembly methods used for these roller type cam follow-

ers, only complete follower assemblies can be used for service replacement purposes.

CRANKSHAFT AND CRANKSHAFT GEAR  
REMOVAL AND REPLACEMENT

Current engine crankshafts with narrow connecting rod journals include pipe plugs which plug oil passage drill openings. Service crankshafts have oil passage openings covered with tape to prevent dirt or debris from entering oil passages. If a crankshaft of this type is removed and reinstalled, remove the pipe plugs, clean the oil passages, and then reinsert the pipe plugs. Tape oil passage openings if crankshaft is not reinstalled immediately after cleaning.

**CAUTION**

Always install new main and rod bearings when installing a new or reground crankshaft. Crankshaft oil passage pipe plugs should be installed 3 threads below surface and staked securely.

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 a soft face hammer or driving tool if slight cocking or binding causes it to stick.

CAMSHAFT AND CAMSHAFT GEAR  
REMOVAL AND REPLACEMENT

Push rods and cam followers must be removed before camshaft is removed. To remove camshaft, remove screws and lock washers which secure camshaft thrust plate to crank-

REPAIR AND  
REPLACEMENT

case. Remove front accessory drive gear and support end of camshaft with pilot sleeve, Part No. 494017, and withdraw it slowly and carefully straight out of crankcase. Be careful to prevent damaging bushing running surfaces with camshaft lobes. If necessary to remove cam gear to replace either it or thrust plate, bend ears of lock plate and remove bolts, lock plate, and washer. Use heavy duty puller to remove cam gear from camshaft. Never apply heat to remove gear as this may damage camshaft. Remove key and thrust plate. Measure thrust plate thickness for wear and replace it if necessary prior to installation of cam gear.

When installing gear on camshaft, gear must be heated to maximum of 400° F. in an oven or other even source of heat. Allow gear to remain in source of heat long enough to be heated evenly. Do **NOT** use torch to heat gear.

### WARNING

Use asbestos gloves when handling a hot gear.

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

### CAUTION

When a new camshaft is installed to replace a failed or worn camshaft, an entire set of new valve and injector cam followers must also be installed. Wear patterns on the old cam followers can result in early failure of the new camshaft.

Use pilot sleeve, Part No. 494017, to reinstall camshaft. Coat cam journals with moly-cote bonded lubricant and coat cam lobes with clean engine oil. Be careful to prevent damaging bushing running surfaces with camshaft lobes. Install thrust plate retaining cap screws with lock washers through holes in web of gear. Replace front accessory drive gear on camshaft.

## TIMING GEARS

When installing timing gears, crankshaft gear keyway should be at top dead center with "W" or "B" marks on idler gears matching "W" or "B" marks on crankshaft gear. "C" mark on camshaft gear must match "C" mark on camshaft idler gear. H1077 engines also require matching "X" marks on balance weight drive gears with "X" marks on idler gears. To prevent confusion and to assure correct alignment of timing marks, current crankshaft gears are stamped with a "B" on the left side of the keyway and a "W" on the right side of the keyway. The left side idler gears are now stamped with a "B" instead of a "W", and this "B" mark must be aligned with the "B" mark on the crankshaft gear. The right side idler gears are still stamped with a "W", which must be aligned with the "W" mark on the crankshaft gear. Left side and/or top idler gears are used on current engines only when required.

## CAM BUSHING REMOVAL AND INSTALLATION

To remove cam bushings when they require replacement, drive them out with a portable hydraulic power unit or other means. Use a flange sufficiently smaller than the outer diameter of the bushing to allow it to pass freely through the bushing bore in the crankcase. Use a driving bar long enough to permit working from the front of the crankcase. The Waukesha Engine Division has a special tool available, Part No. 499989, which is used to remove and install cam bushings.

When cam bushings have been removed, clean up the crankcase bore surfaces and remove any sheared metal. Check all oil passages in the crankcase to and from the cam bushing bores to make sure they are open and absolutely clean.

### CAUTION

Use a driving tool with an accurate pilot in the bushing bore to ensure correct placement. As mentioned above, a special cam bushing removal and installation tool is available from the Waukesha Engine Division. If a good installation tool is not available, a threaded puller type tool may be fabricated to pull the bushing into place. The puller

plate must bear squarely against the bushing.

Position the bushings in the crankcase very carefully so that oil passages are not covered by any part of the bushings. When driving the bushings, work slowly and carefully to prevent cocking and scraping or distortion. To prevent bushings from obstructing oil passages, relieve them prior to installing them in the case, if necessary to match bushings they are replacing. The oil passages from the cam bushing bores to the cylinder heads must be open at least 1/16". The oil passages to the cam bushing bores from the oil header and from the cam bushing bores to the main bearing bores must be open at least 1/4". Use steel wire to check for minimum size openings.

### 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.

### MAIN AND CONNECTING ROD BEARINGS

Upper and lower main bearings and upper and lower connecting rod bearings are not interchangeable. The backs of the main bearings are stamped CASE and CAP, and the back of the rod bearings are stamped ROD and CAP, to identify their proper location. Also, upper main bearings include an oil groove, while the lower main bearings do not, and lower rod bearings include an oil groove, while the upper rod bearings do not.

Current VC crankcases with press fitted main bearing caps have wider intermediate main bearings than previous crankcases. Front and rear main bearings remain the same.

### CONNECTING RODS

Piston pin bushings are diamond bored for precise size and alignment. For this reason, connecting rods are never bent for alignment, neither at the factory nor in the field. Replacement piston pin bushings are pressed flush with

rod tapered side surfaces. Use a press plug faced at a matching 15° angle to press in bushings, aligning narrow side of bushing with top of rod. Finish bore bushings to tolerances specified in Chapter 8.

Connecting rods are stamped 1, 2, 3, etc., starting at the front of the engine, so they can be replaced in their original location whenever they are removed. Therefore, left bank connecting rods are odd numbered as 1, 3, 5, etc., while right bank connecting rods are even numbered as 2, 4, 6, etc. Connecting rods must be installed with the chamfered side of the large end towards the crankshaft fillet.

### MAIN BEARING CAP TORQUING PROCEDURES

In order to position and torque main bearing caps in the same sequence as when they are line-bored when manufactured, the following torquing sequences (as applicable) must be adhered to whenever main bearing caps are removed and reinstalled.

In order to simplify these procedures and to use only one illustration for the crankcases for all three VC models (H1077, L1616, and P2154), the illustration includes a numbering sequence for the P2154 with nine bearing caps. Since the H1077 has only five bearing caps, ignore sequence numbers 6 through 9, 20 through 27, and 33 through 36, when using these procedures for an H1077 crankcase. Also, since the L1616 has only seven bearing caps, ignore sequence numbers 8 and 9, 24 through 27, and 35 and 36, when using these procedures for an L1616 crankcase. The dowel pin side is also identified as the left side of each cap, since most crankcases do not utilize dowel pins to locate the bearing caps.

### NOTE

To prevent possible oil leaks, the use of 3M sealer (Scotch Grip Industrial Adhesive 847) on both faces of the cross-tie bolt washers is recommended. Make sure all bearing cap and crankcase mating surfaces are clean and free of burrs. All of these torque values are for oiled cross-tie bolt and stud and nut threads (SAE30 engine oil), and especially all studs and nuts must be saturated with oil. Apply oil just before torquing procedure is initiated.

## WAUKESHA VC SERIES

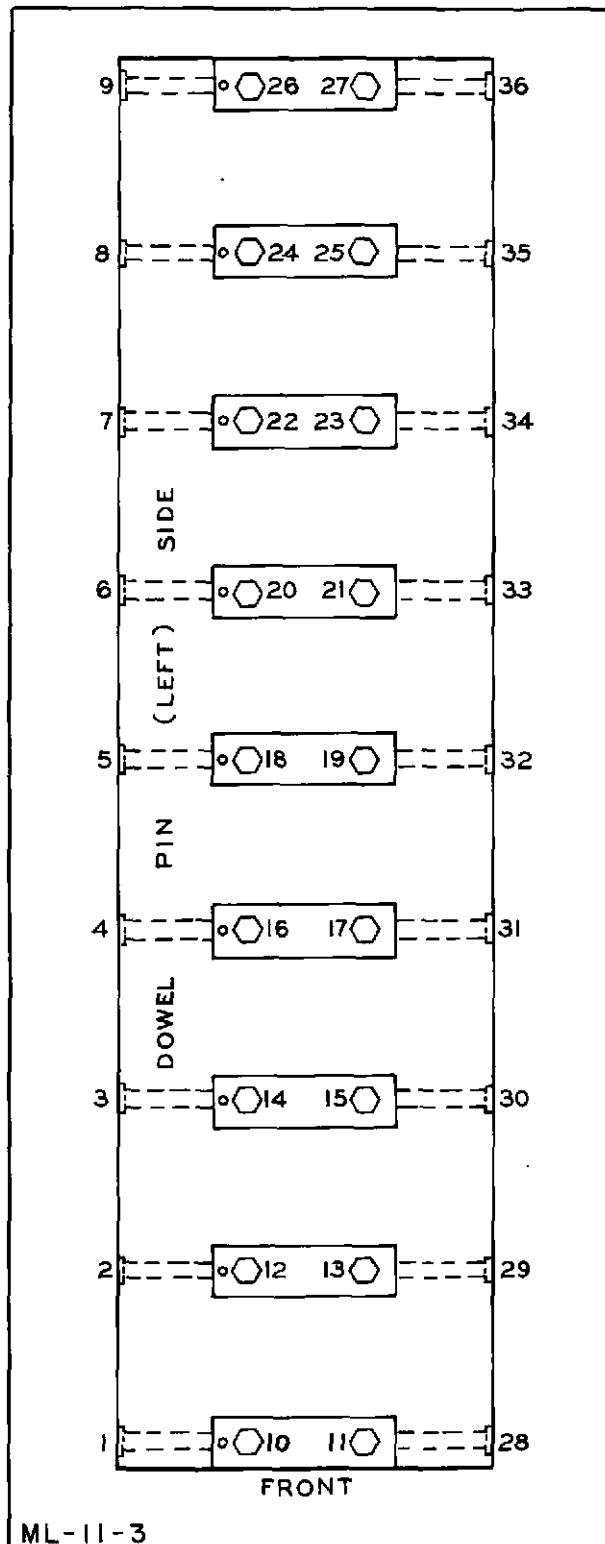
Original VC series engines utilized piloted studs to locate the main bearing caps. A few later VC series engines utilized dowels to locate the main bearing caps. Current VC series engines utilize a press fit along with piloted studs to locate the main bearing caps.

To torque main bearing caps located by piloted studs only, proceed as follows:

1. Tighten 18 cap nuts hand tight (not over 50 in. lbs.), working from front to rear of engine, first left side of each cap, and then opposite side of each cap (numerical sequence 10 through 27 in illustration).
2. Tighten 9 cross-tie bolts hand tight (not over 25 in. lbs.), working from front to rear of engine, on left side of each cap (numerical sequence 1 through 9 in illustration).
3. Tighten 9 cross-tie bolts hand tight (not over 25 in. lbs.), working from front to rear of engine, on opposite side of each cap (numerical sequence 28 through 36 in illustration).
4. Torque 9 cross-tie bolts in not less than two increments to 950-1000 in. lbs., working from front to rear of engine, on left side of each cap (numerical sequence 1 through 9 in illustration).
5. Torque 18 cap nuts to 7200-7250 in. lbs., in 25% increments, alternating the nuts on a cap as each increment is accomplished, working from front to rear of engine, first left side of each cap, and then opposite side of each cap (numerical sequence 10 through 27 in illustration).
6. Torque 9 cross-tie bolts in not less than two increments to 950-1000 in. lbs., working from front to rear of engine, on opposite side of each cap (numerical sequence 28 through 36 in illustration).

### NOTE

Whenever one or more but not all of the caps are removed and reinstalled, follow the same sequence, but by-pass the cross-tie bolts and cap nuts of the caps which were not removed. However, the cross-tie bolts of the two adjacent caps must be loosened before one or more caps are removed, and then retorqued in sequence along with the cross-tie bolts of the removed cap(s).



MAIN BEARING CAP TORQUING SEQUENCE

To torque main bearing caps located by dowels, proceed as follows:

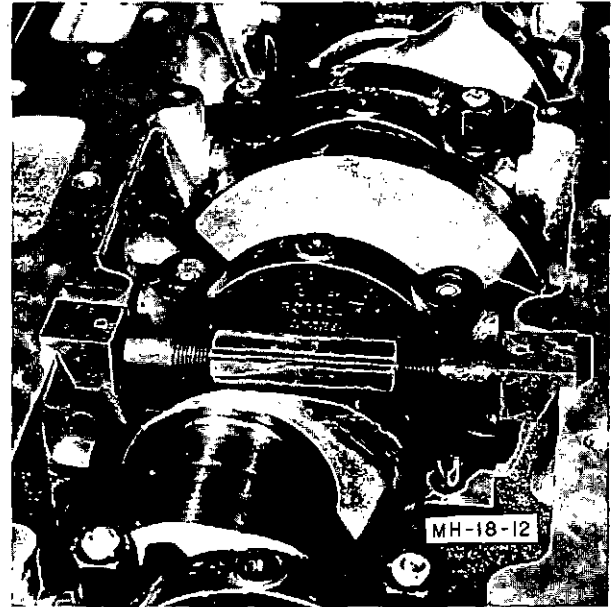
1. Tighten 18 cap nuts hand-tight (not over 50 in. lbs.), working from front to rear of engine, first dowel pin side of each cap, and then opposite side of each cap (numerical sequence 10 through 27 in illustration). Be sure caps are pulled into case.
2. Torque 9 cross-tie bolts to 200-250 in. lbs., working from front to rear of engine, on dowel pin side of each cap (numerical sequence 1 through 9 in illustration).
3. Tighten 9 cross-tie bolts hand-tight (not over 25 in. lbs.), working from front to rear of engine, on opposite side of each cap (numerical sequence 28 through 36 in illustration).
4. Torque 18 cap nuts to 7200-7250 in. lbs., in 25% increments, alternating the nuts on a cap as each increment is accomplished, working from front to rear of engine, first dowel pin side of each cap, and then opposite side of each cap (numerical sequence 10 through 27 in illustration).
5. Torque 9 cross-tie bolts in not less than two increments to 950-1000 in. lbs., working from front to rear of engine, on dowel pin side of each cap (numerical sequence 1 through 9 in illustration).
6. Torque 9 cross-tie bolts in not less than two increments to 950-1000 in. lbs., working from front to rear of engine, on opposite side of each cap (numerical sequence 28 through 36 in illustration).

**NOTE**

Whenever one or more but not all of the caps are removed and reinstalled, follow the same sequence, but by-pass the cross-tie bolts and cap nuts of the caps which were not removed. However, the cross-tie bolts of the two adjacent caps must be loosened before one or more caps are removed, and then retorqued in sequence along with the cross-tie bolts of the removed cap(s).

To torque main bearing caps which are located by a press fit along with piloted studs, proceed as follows:

1. Carefully install caps on studs until they start to engage press-fit portion of case. If it's available, use the spreader bar



**USING CRANKCASE SPREADER BAR TOOL**

tool (Waukesha Part No. 494021) to spread the case just enough (approximately 2 flats tightening of the spreader bar tool nut after it is hand-tight) so the caps will slip into place. A hydraulic jack may be used instead of the spreader bar tool, but extreme caution must be exercised so the case is not spread too far. If neither a spreader bar tool nor a hydraulic jack is available, the caps can be set into place using an appropriate bar or lever on the center of the bottom of the cap, or by using the cap nuts. If the cap nuts are used to seat the bearing caps, first bring them into contact with the bearing caps by hand, and then tighten them in stages approximately one flat at a time, alternating from one side of the cap to the other until the cap is seated. If the cap nuts are not used to seat the bearing caps, they should be installed hand-tight (not over 50 in. lbs.) after the caps are seated (numerical sequence 10 through 27 in illustration). If the cap nuts are used to seat the bearing caps they should be backed off and reinstalled hand tight.

2. If applicable, remove the spreader bar or jack.
3. Install all cross-tie bolts but do not tighten even hand-tight (numerical sequence 1 through 9 and 28 through 36 in illustration).

4. If main bearing caps were installed with the use of either the spreader bar tool or a hydraulic jack, the thrust bearing cap must now be properly set to obtain correct crankshaft end play. Use either the spreader bar tool or a hydraulic jack to spread the case at the thrust bearing cap. Move the crankshaft fore and aft at least twice to properly position the thrust bearing cap. Check for correct crankshaft end play. After the thrust cap is properly positioned, remove the spreader bar tool or hydraulic jack and hand-tighten (not over 25 in. lbs.) all cross-tie bolts (numerical sequence 1 through 9 and 28 through 36 in illustration). Torque all main bearing cap nuts to full torque of 7200-7250 in. lbs. in 25% increments, alternating the nuts on a cap as each increment is accomplished, working from front to rear of engine, first left side of each cap, and then opposite side of each cap (numerical sequence 10 through 27 in illustration).
5. If main bearing caps were seated with a bar or lever, or by using the capnuts, the thrust bearing cap must now be properly set to obtain correct crankshaft end play. Proceed as follows:
  - a. Torque all main bearing cap nuts, except thrust bearing cap nuts to full torque of 7200-7250 in. lbs. in 25% increments, alternating the nuts on a cap as each increment is accomplished, working from front to rear of engine, first left side of each cap, and then opposite side of each cap (numerical sequence 10 through 27 in illustration). Leave thrust bearing cap nuts hand-tight.
  - b. Use a bar to move the crankshaft fore and aft at least twice to move and set the thrust cap.
  - c. Check for proper crankshaft end play.
  - d. Hand-tighten (not over 25 in. lbs.) all cross-tie bolts (numerical sequence 1 through 9 and 28 through 36 in illustration).
  - e. Torque thrust bearing cap nuts to full torque of 7200-7250 in. lbs. in 25% increments, alternating from one side of the cap to the other as each increment is accomplished.
6. Torque 9 cross-tie bolts to 950-1000 in. lbs., in not less than two increments, on the left side of the engine, starting with the center cross-tie bolt and then alternating towards the front and rear of the engine (numerical sequence 5, 4, 6, 3, 7, 2, 8, 1, 9 in illustration).
7. Torque 9 cross-tie bolts to 950-1000 in. lbs., in not less than two increments, on the opposite side of the engine, starting with the center cross-tie bolt and then alternating towards the front and rear of the engine (numerical sequence 32, 31, 33, 30, 34, 29, 35, 28, 36 in illustration).

**CAUTION**

A single main bearing cap may be removed and replaced without disturbing other main bearing caps, except that the cross-tie bolts of at least the two adjacent caps must be loosened to prevent damage to the crankcase when either the spreader bar tool or a hydraulic jack is used. To retorque, first torque the cap nuts of the replaced cap, then the cross-tie bolts of the two adjacent caps, and finally the cross-tie bolts of the replaced cap. As described in the preceding torquing procedures for installing all the main bearing caps, the cap nuts and cross-tie bolts must first be hand-tightened and then torqued in increments to the required values. If only the thrust bearing cap is removed, follow either Step 4 or 5 as applicable for replacement.

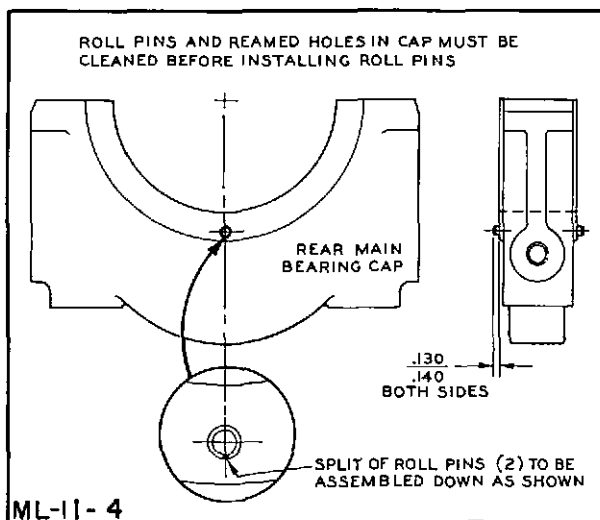
8. With all bearings properly installed, the crankshaft must turn freely and smoothly with bearing cap nuts and side bolts properly torqued. Measure crankshaft end play with a dial indicator. Use a small pinch bar to move crankshaft forward against the thrust washer of the rear main bearing. Set the indicator at zero and use the bar to thrust the shaft to the rear. End play must be within the limits specified in Chapter 8.

**CAUTION**

The importance of correct crankshaft end play cannot be overstressed. Operation of an engine having insufficient or excessive crankshaft end play 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.

**PROPER INSTALLATION OF THRUST WASHER ROLL PINS**

As illustrated, if thrust washer roll pins are to be installed, the split in the roll pins must be towards the bottom of the bearing cap and the roll pins must protrude .130" to .140" from the face of the cap. Also, both the roll pins and the reamed holes in the bearing cap must be cleaned before installing the roll pins. Improper installation of thrust washer roll pins can result in damage of the thrust washers and/or the crankshaft thrust surfaces.

**THRUST WASHER ROLL PIN INSTALLATION****PROPER INSTALLATION OF MAIN BEARING STUDS**

If main bearing studs are replaced, they must be oiled and installed by hand until they bottom. Do not use a torque wrench to install main bearing studs.

**FRONT ACCESSORY DRIVE**

When the front accessory drive includes either one or two driving hubs (as illustrated), these driving hub(s) must be shimmed to provide the proper end clearance. As noted in the illustration, this dimension is the same for all ignition drives (except P2154G low tension MSB8A magnetos), for diesel engine "air shut-off valve" type overspeed governor drive, and for diesel engine fuel supply pump drive, as applicable. The driving hubs used to drive P2154G low tension MSB8A magnetos must be shimmed to obtain a dimension of .770" to .775" from the face of the bearing retainer to the face of the driving hub.

**FLYWHEEL HOUSING ATTACHING PARTS**

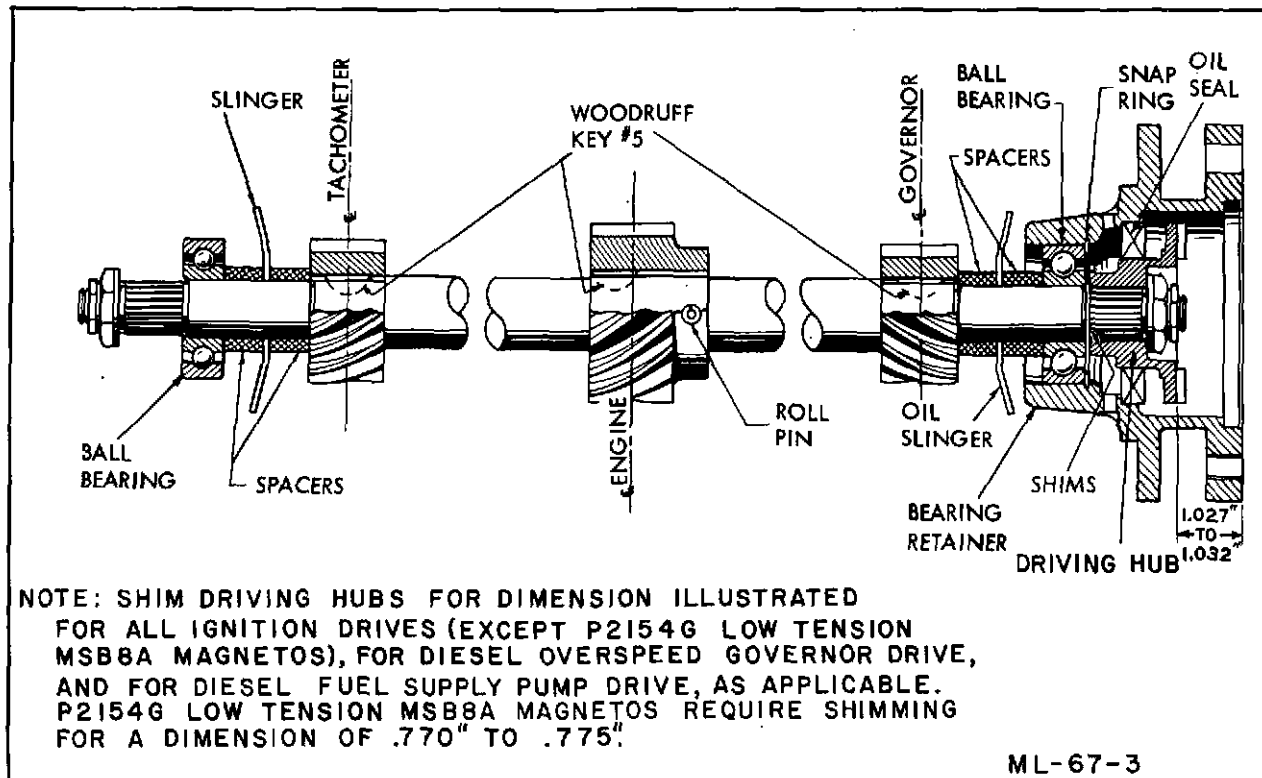
When installing four cap screws with flat washers and O-rings, make sure that flat washers are of the proper 3/32" thickness and have not dished out, which could cause oil leaks at the O-rings.

**WOODWARD GOVERNOR REPLACEMENT**

When the governor is installed on the engine, particular care should be exercised to see that it is mounted squarely and that the drive connection to the engine is properly aligned. A gasket must be used between the base of the governor and the engine mounting pad. Be certain the gasket does not block off any holes in the governor base. The splined drive shaft must fit the engine drive with a free, slip fit; no tightness is permitted. Install fuel control linkage, making sure that the governor in its closed position can cut fuel flow off completely and that it is capable of opening fuel control mechanism to its full load position. Be sure linkage is free from friction or lost motion.

**FUEL SUPPLY PUMP SEALS**

The fuel supply pump used on current production engines is equipped with a double seal on the drive shaft with a vent and drain between the two seals. This allows any fuel oil seepage past the supply pump side seal to be drained externally and prevents it from entering the engine lubricating oil. However, if fuel oil is draining from this passage, the seals should be replaced. Previous supply pumps had only a single seal and no drain passage. Any fuel leakage past this seal into the engine requires replacement of the pump assembly to ensure prevention of further leakage.



FRONT ACCESSORY DRIVE

**WATER PUMP SEAL**

When installing a new water pump seal, carefully wipe the carbon or teepelite sealing surface and the mating ceramic surface with a soft cloth or 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 of the sealing faces.

Lubrication of the seal after installation is provided by the engine coolant. When using only water as the engine coolant, about 1% soluble oil should be added as a seal lubricant and cooling system corrosion inhibitor.

**STUB SHAFT TO PLATE RUNOUT**

Assemble stub shaft to stub shaft plate so high spots (marked "H" on OD) are approximately 180° apart. Torque cap screws to specified value with threads oiled. Check runout of stub shaft plate surface as close as practical to OD. Mark high spot with plus sign (+) followed by amount of runout. This can be done with paint but not on mounting surface.

Maximum allowable runout is .0005" per inch of diameter of plate.

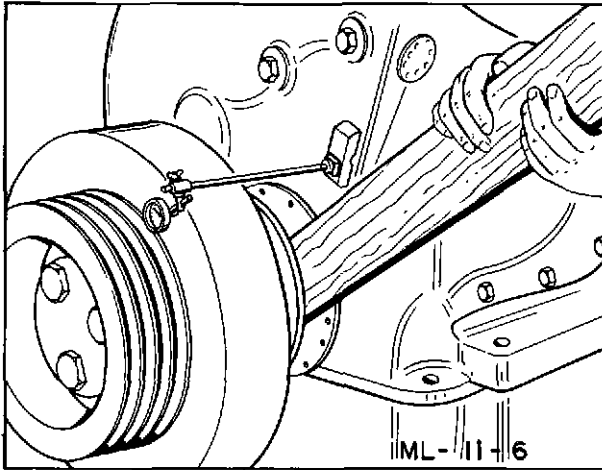
With location of high spot runout and amount of runout indicated on stub shaft assembly, and measurement of flywheel runout and location, determine stub shaft to flywheel placement that will result in smallest stub shaft runout.

**CHECKING VISCOUS VIBRATION DAMPER RUNOUT**

The accompanying graph provides data covering the permissible radial and face runout of various sizes of viscous vibration dampers. 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 chart gives the permissible runout as



CHECKING VIBRATION DAMPER  
FACE RUN-OUT

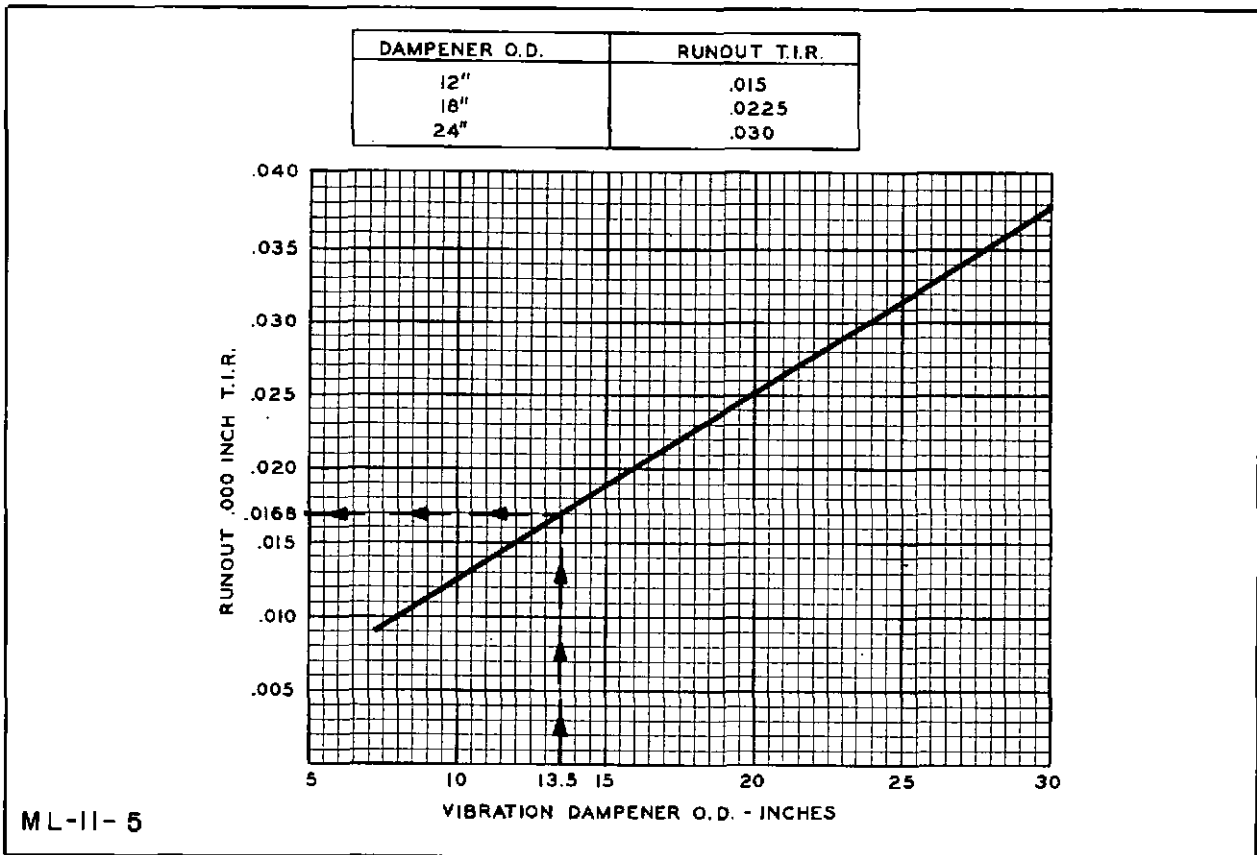
the TOTAL indicator reading. To avoid introducing crankshaft end play into this reading, the crankshaft must be forced either rearward or forward (but always in the same direction) against the thrust bearing at each point of reading.

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 mounting surface. It may be necessary to mount the damper in a lathe and check the damper itself.

The graph may be used when the diameter of the damper is known. Locate the diameter of the damper along the horizontal axis and then follow up the graph to the diagonal line. Now move across the graph to the vertical axis to read the permissible runout. For example, for a 13.5 inch diameter damper the runout should be less than .0168 inch.

**CAUTION**

A true running damper does not indicate the quality of the damper. The quality can only be determined by test. A damper manufactured by 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



GRAPH FOR OUTSIDE DIAMETER OTHER THAN SPECIFIED

REPAIR AND  
REPLACEMENT

possible service life. There is a service charge for the test. The Waukesha Engine Division recommends that a viscous damper be replaced at major overhaul periods.

### SLOW-DOWN TYPE OVERSPEED GOVERNOR DIAPHRAGM

Whenever replacing or reinstalling the diaphragm in the slow-down type overspeed governor, the fabric side of the diaphragm must be installed facing up, that is, towards the diaphragm piston.

To clean the diaphragm, wash it with soap and water.

### REPLACING A TURBOCHARGER

1. Inspect air intake system for cleanliness and foreign material.
2. Inspect exhaust manifold for foreign material.
3. Inspect oil drain line. Make certain inside diameter has not been reduced and that line is not clogged.
4. Inspect oil supply line for clogging or possibility of leaking under pressure.
5. Inspect the turbocharger mounting pad on the manifold to make certain that all of old gasket has been removed.
6. Install new gasket between turbocharger and manifold. Make certain gasket does not protrude into opening of manifold.
7. Install and tighten attaching parts.
8. Connect oil supply line, but leave oil drain line disconnected at this time.
9. Connect compressor inlet and outlet piping. Check all joints for possible leaks. Make certain that piping is not producing strain on compressor cover.
10. Crank engine without firing until a steady flow of oil is noted coming from oil drain line.
11. Stop cranking, connect oil drain to crankcase.

## CARE AND OVERHAUL OF UNIT INJECTORS

### General

The unit fuel injector is one of the most important and precisely built components of the engine. On this unit depends the injection of the correct amount of fuel at exactly the right time into the combustion chamber. Because the injector operates against high pressures in the combustion chamber, efficient operation demands that injectors be maintained in first-class condition at all times. Proper maintenance of the fuel system and the use of the recommended type fuel filters and clean water-free fuel of the proper specification are the keys to trouble-free operation of the injectors.

### NOTE

Although these unit fuel injectors are manufactured by General Motors, they are a proprietary item of the Waukesha Engine Division. Service parts for these injectors are not interchangeable with other General Motors injector service parts, and can therefore be procured only from the Waukesha Engine Division and its authorized Distributors.

Servicing an injector is not a difficult task and may be performed by the average serviceman. However, due to the close tolerances of various injector parts, extreme cleanliness and strict adherence to service instructions are required.

All injector repairs should be performed in a clean, well-lighted room with a dust-free atmosphere. An ideal injector repair room should be slightly pressurized by means of an electric fan which draws air into the room through a filter. This pressure will prevent particles of dirt and dust from entering the room through doors and windows. A suitable air outlet will remove solvent fumes along with the outgoing air.

The injector repair room should be provided with a supply of filtered, moisture-free compressed air for drying injector parts after they have been cleaned. Wash pans of rust-proof material should be deep enough to permit all injector parts to be completely covered by the cleaning agent, usually clean fuel oil, when submerged in wire baskets of 16 mesh wire screen.

The baskets should support the parts above the bottom of the pan to avoid contact with foreign material which settles at the bottom. Also, a source for 110 volt A.C. electric power should be provided.

Waste or rags should NEVER be used for cleaning injector parts since this would leave lint and other particles which could clog parts of the injector when it is assembled. A lint-free cleaning tissue is a good, inexpensive material for wiping injector parts.

When servicing injectors, the following instructions should be carefully followed:

1. After the injectors have been operated in an engine, the filter caps or filters should not be removed while the injectors are in the engine. Filter elements should be replaced only at the time of complete disassembly and re-assembly of an injector in order to prevent dirt from entering the injector.
2. Whenever an injector has been removed and reinstalled, or a new injector has been installed in an engine, the following adjustments must be made:
  - a. Time the injector. Refer to UNIT INJECTOR TIMING in Chapter 4.
  - b. Position the injector control rack. Refer to ADJUSTMENT OF DIESEL FUEL CONTROLS AND LINKAGE in Chapter 4.
  - c. Re-set valve clearance. Refer to VALVE CLEARANCE SETTINGS in Chapter 4.
3. Whenever an engine is to be out of service for an extended period, the fuel system should be preserved in accordance with storage instructions in Chapter 6.
4. When a reconditioned injector is to be placed in stock, it should be filled with a quality grade of rust preventative oil. Install shipping caps on both filter caps immediately after filling. Do not fill the injector with fuel oil if it is to be stored.

### CAUTION

Make sure that new filters have been installed in a reconditioned injector which is to be placed in stock. This precaution will pre-

vent dirt particles from entering the injector due to a possible reversal of fuel flow when installing the injector in an engine other than the original unit.

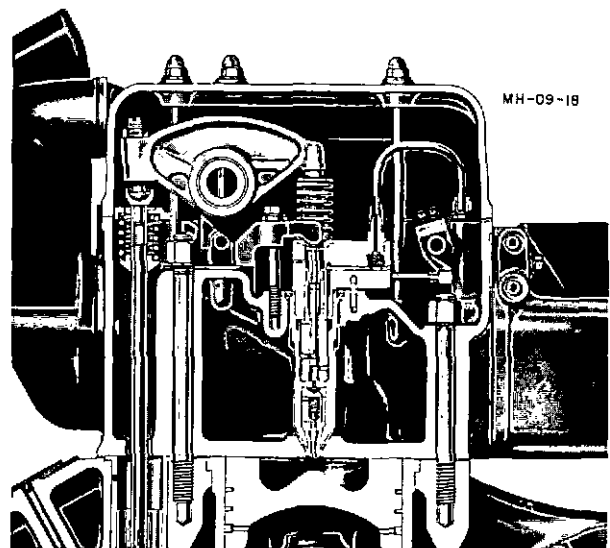
### Removal and Reinstallation of Injectors

Remove valve rocker cover and fuel pipes from injector and fuel connectors.

### CAUTION

Immediately after removal of fuel pipes from injector, cover filter caps with shipping caps to prevent dirt from entering injector. Also, protect fuel pipes and fuel connectors from entry of dirt or foreign material. Special attention should be paid to the condition of the fuel line coupling threads and fittings since leakage from these could introduce fuel oil into the engine lubrication system.

After removing injector from head, remove and discard injector washer, and cover injector tube to keep foreign particles out of combustion chamber. Clean exterior of injector with clean fuel oil and dry with compressed air.



UNIT INJECTOR AND COMBUSTION CHAMBER - SECTIONAL

**CAUTION**

Installation of the unit type injector requires the normal precautions of cleanliness and accuracy of workmanship associated with all diesel injection system work. The injector seating surface in the tube and the retaining clamp must be in good condition and free of burrs or damage.

Before installing an injector in an engine, remove the carbon deposits from the injector tube beveled seat in cylinder head using 494012 injector tube reamer. Exercise care to remove only the carbon so proper depth of the injector tip into cylinder head is maintained. Pack the flutes of reamer with grease to retain carbon removed from injector tube.

Always reinstall injectors in same position from which removed. If this is not possible, always replace filters and clean tip thoroughly before reinstalling. Always use a new injector washer.

**CAUTION**

Until recently, only certain applications of VC series diesel engines included individual injector rack stop clips, which limit maximum output of the injectors. All current VC series diesel engines now include injector rack stop clips. Because these rack stop clips are selectively specified according to the engine application and power requirement, they must be used as supplied with the engine unless approval is obtained from the Waukesha Engine Division. Unauthorized modification of any engine can affect the engine warranty. Therefore, whenever a replacement injector is installed on an engine which is equipped with rack stop clips, the rack stop clip must be removed from the replaced injector and installed on the replacement injector. Obviously, a new rack stop clip may also be used if necessary, but it must be the same dimension as the previously used clip. Also, if rack stop clips are to be installed on an engine which was not originally equipped with them, the Waukesha Engine Division must be consulted to determine the proper clip to be used for the application and power requirement of the engine. Engines equipped with rack stop clips do not require either the external rack lever stop bracket as-

sembly or the internal rack stop lever. For further information on the proper use of rack stop clips, refer to Service Bulletin No. 9-1932B.

When installing either new or reconditioned injectors, prime injectors with fuel oil if there is evidence of leakage of rust preventative oil from injectors. Priming is accomplished by pouring clean fuel oil into injector inlet until it emerges from outlet. After injectors are installed, prime entire fuel system before starting engine. These precautions are necessary to prevent injector plunger and bushing scoring.

**Test Injector**

Inspect injector for any external damage and perform following tests to check injector operation. Injectors found to be in serviceable condition as the result of these tests may be considered satisfactory for service. After testing, tag each injector to record valve opening pressure and fuel output and to provide identification. If injector fails one or more of these tests, it must be repaired or rebuilt and retested.

**CAUTION**

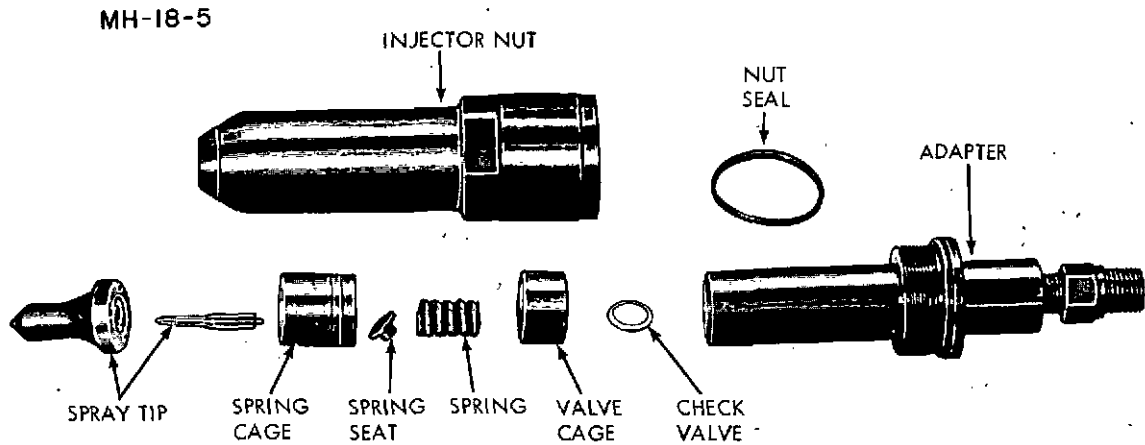
When testing injectors, never allow the follower stop pin to snap against the end of its slot in the body, as this can result in breaking or cracking the stop pin. During operation in the engine, the stop pin doesn't travel to the end of its slot.

**Injector Rack and Plunger Movement Test**

Place injector in test stand as illustrated, push rack in to no fuel position, and operate handle to depress follower to bottom of its stroke. Release plunger spring pressure slowly while pulling rack out by hand. Repeat this operation three times.

**WARNING**

When depressing the follower, keep hands away from the area of the injector spray tip. Any fuel oil remaining in the injector will be forced out under pressure. The force of the pressure could drive the fuel through the skin and into the blood stream where blood poisoning could result. This warning applies to all injector tests.



SPECIAL TEST ADAPTER AND SPRAY TIP ASSEMBLY COMPONENTS

Follower must depress freely and rack movement must be free.

Any binding or lack of free movement in plunger or rack indicates damaged or misaligned internal parts. Misalignment can be corrected by loosening injector nut and rotating spray tip 60°. Retorque nut and repeat test. Spray tip can be rotated five times at 60° each time. If rotation of spray tip does not correct problem, then injector must be disassembled and repaired.

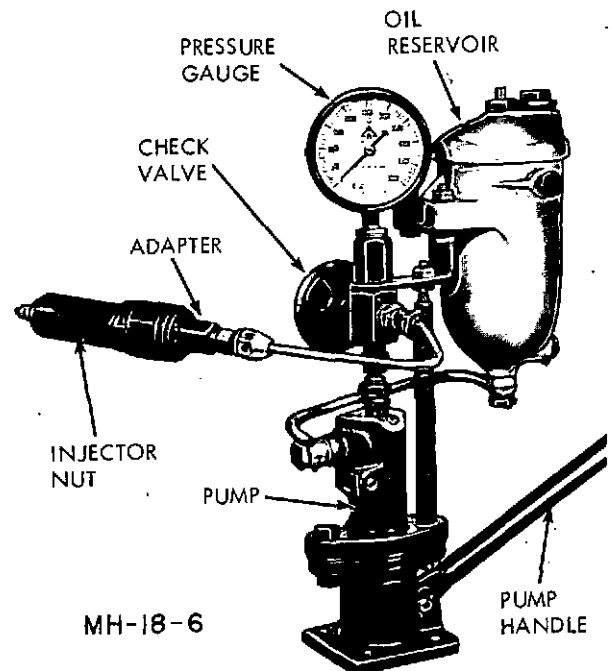
Valve Opening Pressure, Leakage, and Spray Pattern Tests

NOTE

A nozzle and injector tester, complete with test adaptor, for Waukesha Engine Division unit injectors, is available as Part No. 499978.

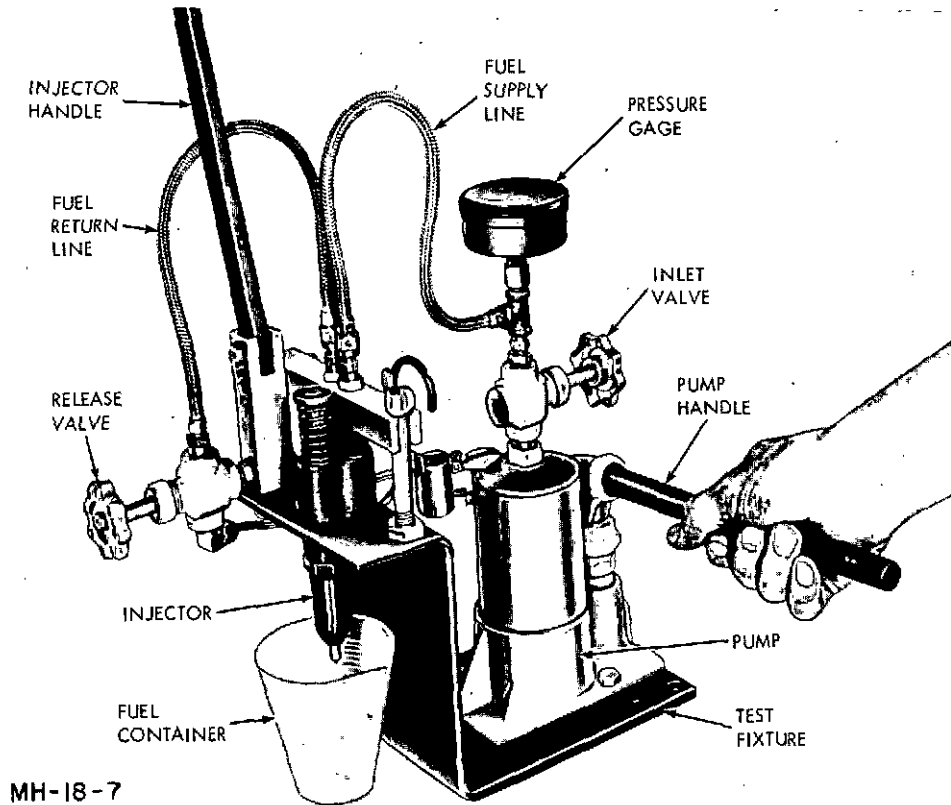
Assemble test adaptor, spray tip assembly and injector nut, as illustrated. Torque injector nut to 100-120 ft. lbs. Install this special test assembly in suitable test fixture similar to one illustrated, equipped with pressure gauge to indicate pressure when injector sprays fuel. Open and close tester pump valves as required.

Pump fixture handle to purge all air from injector and test fixture.



TESTING INJECTOR OPENING PRESSURE WITH SPECIAL TEST ASSEMBLY

REPAIR AND REPLACEMENT



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### INJECTOR HOLDING PRESSURE TEST

Pump handle at 40 smooth, even, sharp strokes per minute, simulating action of spray tip functioning in engine. Record pressure indicated on gauge when special test assembly sprays fuel. This is valve opening pressure.

Pressure indication should be 2700 to 3300 psi for used injector. A fine, atomized spray should be discharged from all spray tip orifices. If pressure is below 2700 psi, replace needle valve spring.

If atomization is not correct, loosen injector nut and rotate injector spray tip 60°. Re-torque injector nut. Repeat spray pattern test. If atomization is still not acceptable replace needle valve and spray tip assembly.

To check spray tip for leakage, wipe tip with a clean dry paper towel. Operate pump handle as slowly as possible (approximately 4-6 strokes per minute). If test oil dribbles out of spray tip before minimum opening pressure (2700 psi) is reached, spray tip and needle valve assembly is leaking and must be repaired or replaced.

A properly functioning injector will have an audible squeak or chatter as spray tip begins to

discharge test oil in the 2700-3300 psi range while operating pump handle at 4-6 strokes per minute.

#### NOTE

Injectors that do not pass the dribble test will result in hard starting and produce excessive exhaust smoke when installed in the engine.

#### Injector Spray Tip Pressure Holding Check

Operate pump handle to bring pressure up to 2000 psi and immediately close shut-off valve on tester. Pressure drop should not exceed 500 psi in 10 seconds. If pressure drop is out of range, replace spray tip and needle valve assembly.

#### High Pressure Leak and Pressure Holding Test

These tests are performed to check for internal and external leaks. Refer to trouble shooting guide.

## WAUKESHA VC SERIES

Place injector in tester and connect fittings.

Purge air from injector. Be certain injector is clean and dry externally.

With injector rack in full fuel position, pump up tester pressure to 2350 psi. If there is excessive clearance between plunger and bushing, pressure beyond 2300 psi cannot be obtained. Replace plunger and bushing to correct. Check for external leaks and make necessary corrections. It is normal for test oil to seep out around rack due to high pressure fuel applied to a normally low pressure area. Release pressure from injector.

Pump pressure to 1500 psi. Close shut-off valve to lock pressure in injector. Pressure should not drop more than 500 psi in 30 seconds for new injectors and 20 seconds for used or rebuilt injectors.

Refer to trouble shooting guide for causes and corrections. A drop or two of test oil at spray tip is only an indication of oil trapped in spray tip at beginning of test.

### CAUTION

Do not increase pressure in test fixture to equal or exceed capacity of pressure gauge.

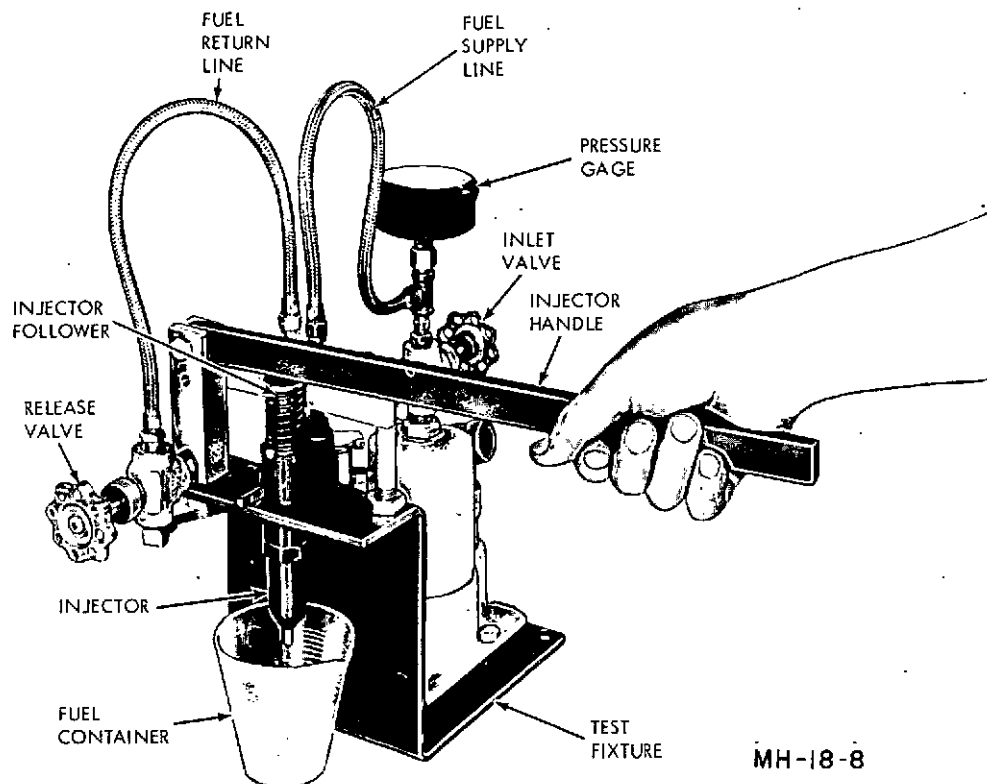
### Fuel Output Test

#### NOTE

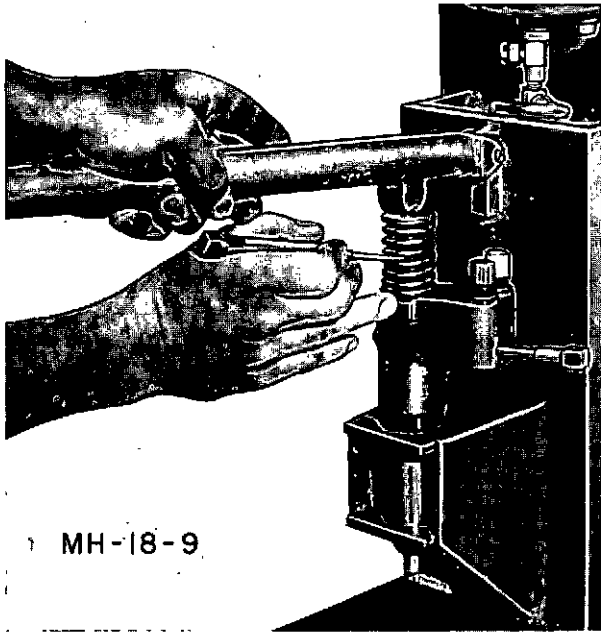
An injector flow comparator for Waukesha Engine Division unit injectors is available as Part No. 499980.

The injector fuel output test can be performed on a comparator such as Bacharach or Hartridge.

Before placing injector in comparator (if removed from engine) remove carbon residue from injector tip and nut, using a brass wire brush. Do not brush over spray orifices! Refer to manufacturer's instructions for comparator operation. Clamp injector into position on comparator. Install .300" spacer on control rack.



CHECKING INJECTOR SPRAY PATTERN

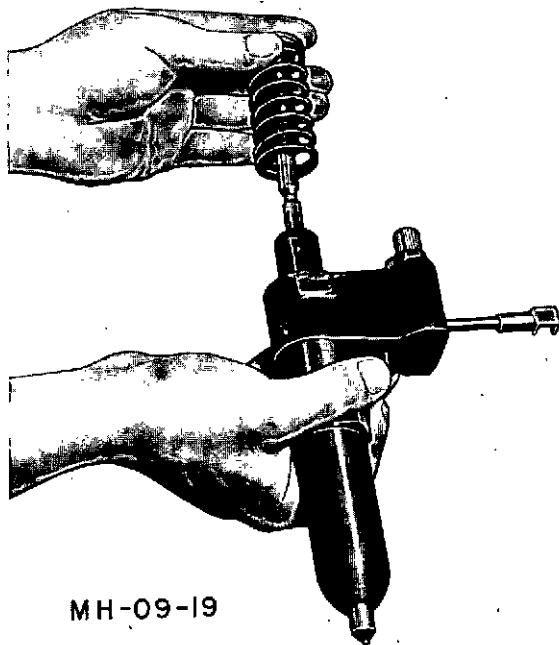


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**DISENGAGING FOLLOWER STOP PIN**

Pull control rack out to no fuel position. Start comparator.

Hold control rack in against the .300" spacer to full fuel position. Allow injector to operate for 30 seconds to purge air out of system.



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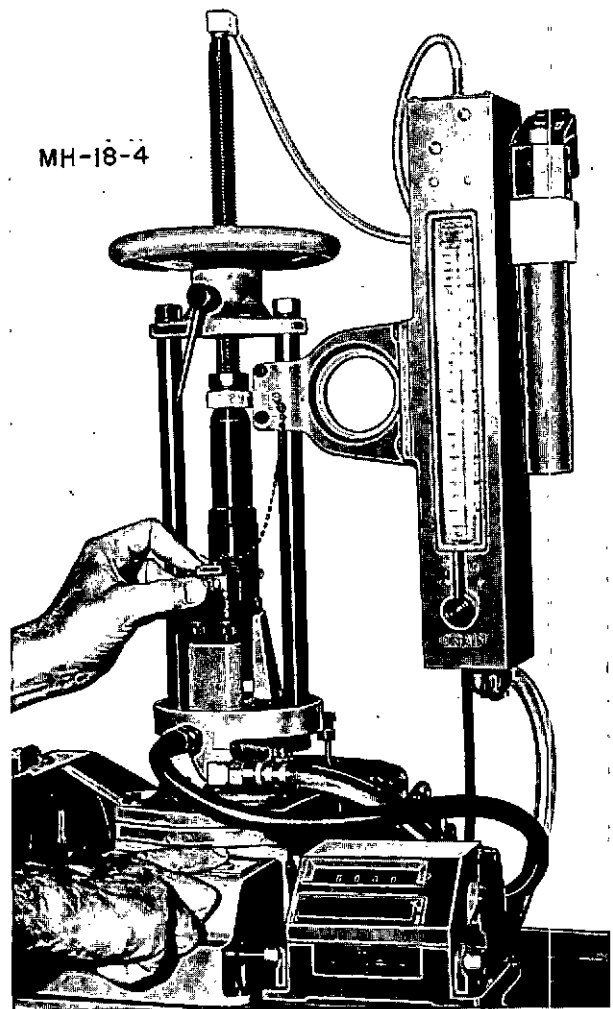
**REMOVING SPRING AND PLUNGER**

The fuel output can be checked by using a counted number of strokes and comparing fuel output against that of an injector known to be in good condition. Best calibration accuracy will be obtained by using the average of three consecutive output measurements. Refer to fuel output chart for specifications. Refer to trouble-shooting guide for different factors that may affect injector output.

It is good practice to group rebuilt injectors according to part numbers and flow rates by color codes. Injectors of one color code should be installed on an engine to give nearly equal performance per cylinder.

An example of color coded injectors per flow rate on Bacharach:

115cc-118cc	dot of yellow paint
119cc-121cc	dot of green paint
122cc-125cc	dot of red paint

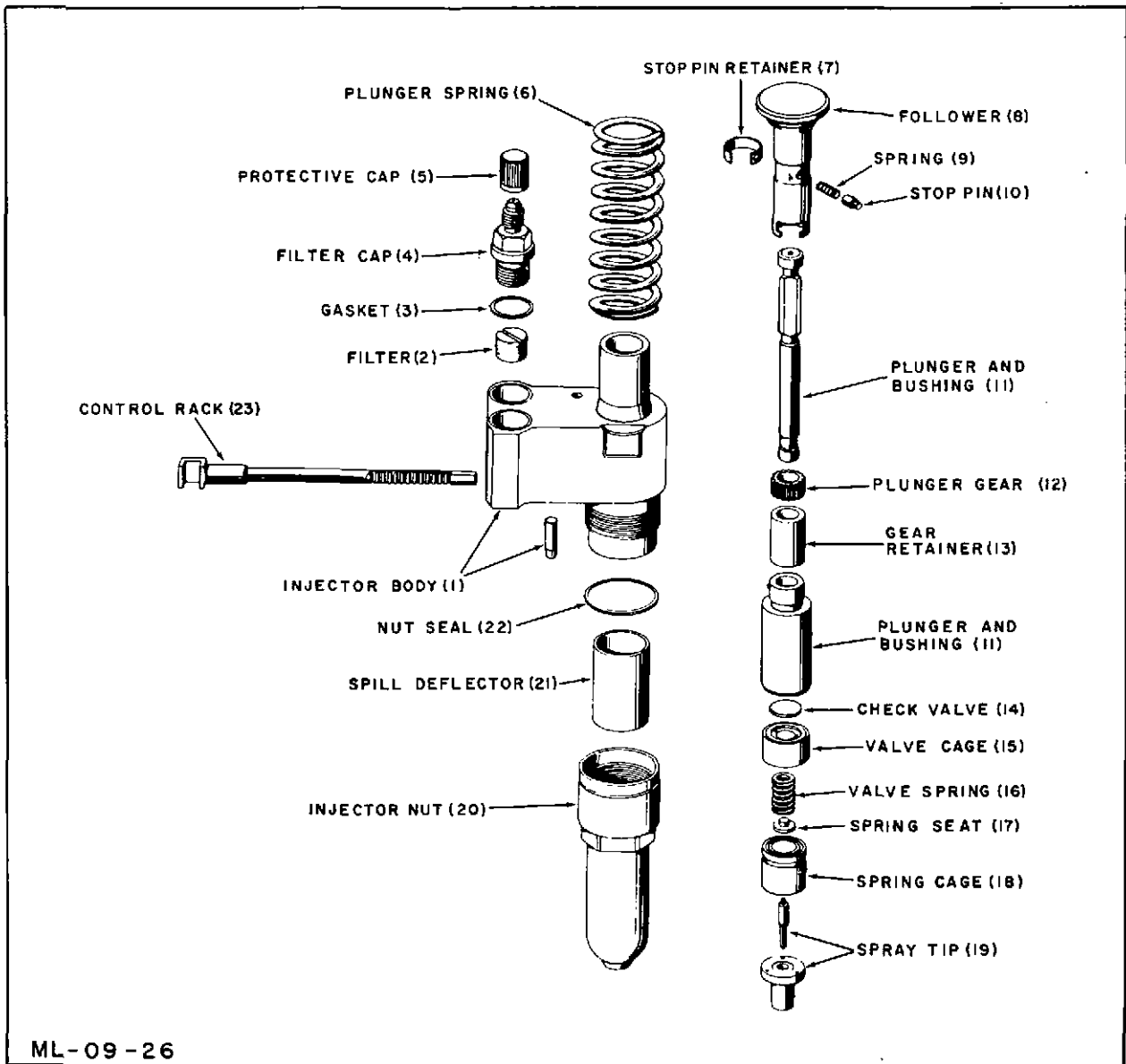


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**CHECKING INJECTOR FUEL OUTPUT WITH INJECTOR FLOW COMPARATOR**

FUEL OUTPUT CHART

COMPARATOR	INJECTOR	MIN.	MAX.
Bacharach	69452 A & E	115 cc Per 600 Strokes	125 cc Per 600 Strokes
	69452 C & F	141 cc Per 600 Strokes	151 cc Per 600 Strokes
Hartridge	69452 A & E	.183 cc Per Stroke	.193 cc Per Stroke
	69452 C & F	.236 cc Per Stroke	.248 cc Per Stroke



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FUEL INJECTOR - EXPLODED VIEW

REPAIR AND  
REPLACEMENT

NOTE

Calibrated injectors may be ordered from Waukesha Engine Division Technical Services Department.

Disassembly (See Exploded View)

NOTE

An injector service tool kit for Waukesha Engine Division unit injectors is available as Part No. 499982.

Support injector assembly in a suitable holding fixture.

Remove two filter caps (4), gaskets (3), and filters (2) from injector body.

Depress stop pin (10) as illustrated.

Remove follower (8), plunger spring (6) and plunger (11) from injector (see illustration).

Invert injector in holding fixture, using a special socket to loosen injector nut (20).

With finger tip, hold parts in the injector nut while lifting nut straight up from body. Remove parts from nut, place nut upright on smooth wood block, dislodge tip with soft face hammer. Do not nick or dent during removal. Place all small parts in a suitable receptacle until ready to clean.

Remove spill deflector (21) and bushing (11) from injector body. Remove body from holding fixture, remove gear retainer (13) and gear (12) from body.

Remove control rack (23) and nut seal (22). Discard seal.

Cleaning

NOTE

An injector cleaning kit for Waukesha Engine Division unit injectors is available as Part No. 499983.

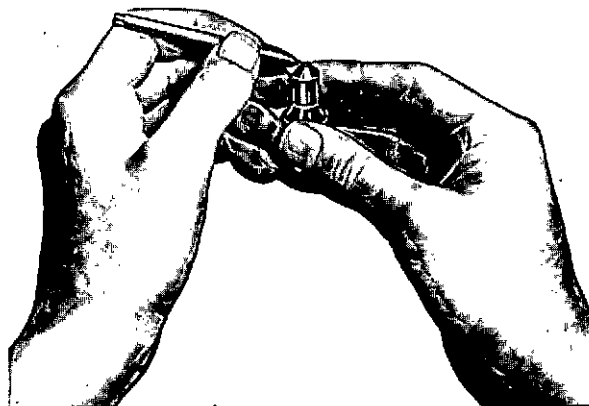
Since most injector problems are the result of dirt, it is essential to provide a clean area to place parts after cleaning and inspection.

Wash all parts with a suitable cleaning solvent, such as Methyl Ethyl Ketone. Then dry all parts with clean filtered compressed air. Keep spray tip-needle valve, and plunger-bushing together as they are matched parts.

Insert a .012" steel wire in pin vise and extend tip of wire 1/8". Hone tip of wire using a fine grit stone until smooth and free of burrs. Clean spray tip orifices with steel wire.

Clean spray tip bore with carbon removing tool. Clean exterior with brass wire brush. Do not brush spray tip orifices.

MH-18-11



CLEANING SPRAY TIP ORIFICES

Using the flat carbon removing tool, clean the flat seat of injector nut by turning tool clockwise.

Using the tapered carbon removing tool, clean the tapered bore of injector nut by turning tool clockwise.

Clean all passages in the injector.

Wash all injector parts a second time and dry with clean filtered compressed air. Submerge parts in clean test oil.

**CAUTION**

Carbon deposits on spray tip seating surfaces in injector nut will result in poor sealing and fuel leakage around spray tip. Avoid touching lapped surfaces of injector plunger with fingers.

If high pressure hole in side of bushing is plugged, fuel leakage will occur at upper end of bushing and drain out of injector body vent rack holes during engine operation, causing an oil dilution problem.

### Inspection and Repair

#### CAUTION

Use a magnifying glass when necessary.

Inspect teeth on gear and control rack for wear and damage. Check bore of gear for wear. Replace gear or rack if worn or damaged.

Inspect injector follower and stop pin for wear and damage. Replace parts if worn or damaged.

Inspect follower spring. Spring should have free length of 2.676 inches and 123 to 137 pounds should be required to compress new spring to length of 1.406 inches. Replace spring if broken, any evidence of pitting or corrosion, or if load less than 110 pounds compresses the spring to 1.406 inches.

Inspect seal ring area of injector body for burrs and scratches. Inspect bushing contact surfaces in body for scratches, scuff marks or other damage. Repair minor damage by lapping this surface. If dowel pin or body plugs are loose, install new plugs or dowel pin. Replace any body that is damaged beyond repair. Install proper number tag on replacement body.

Inspect the injector plunger for scoring, erosion, chipping, or wear. Inspect portion of plunger that contacts gear for sharp edges. Remove sharp edges with 500 grit honing stone. Clean plunger after stoning.

Inspect bushing for cracks and chipping. If locating pin in bushing is damaged or sheared, it must be replaced. Immerse plunger and bushing in clean diesel oil and insert plunger in bushing. Plunger should move freely in bushing. If either plunger or bushing are damaged and must be replaced, both parts must be replaced as a matched set since they are mated at manufacture. Never attempt to rework a plunger.

Inspect spray tip seating surface in tip nut for nicks, burrs, or brinelling. Refinish surface using reamer to remove nicks or burrs. If damaged beyond repair, replace tip nut.

Inspect valve spring for weak or broken condition, and for pitting and corrosion. Replace as required.

Inspect sealing surfaces on spray tip, valve, and valve cage. Examine surfaces with magnifying glass. Inspect for burrs, nicks, erosion, cracks, chipping and wear. Check spray tip holes for enlargement. Replace damaged or worn parts. Needle valve and spray tip must be replaced as an assembly if either part requires replacement.

Lap all serviceable valve parts to assure good sealing surface. Clean lapping blocks with compressed air. Spread 600 grit dry lapping compound on a lapping block. Move parts on compound and block in figure eight motion with only enough pressure to keep part flat on block at all times. After each 4 or 5 passes clean lapping compound from part by sliding across a clean tissue paper placed on flat surface; then inspect part. When part is flat, wash in cleaning solvent and dry with compressed air.

Spread 600 grit lapping compound on second block and repeat lapping with very light pressure in figure 8 motion.

Lap part on third block. Do not use lapping compound. This gives part a mirror finish required for perfect sealing. Wash all the injector parts in cleaning solvent and dry with compressed air.

Lapping blocks can be lapped together to keep them smooth and flat.

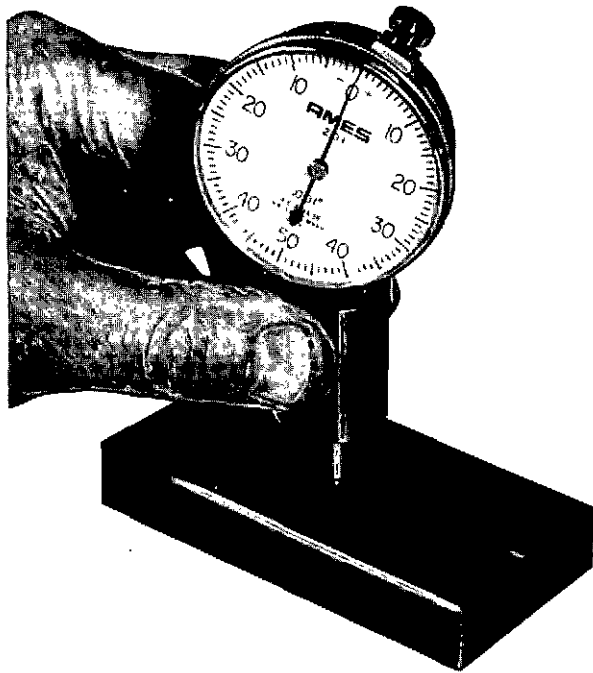
Inspect needle valve and spray tip for wear, burrs, and damage to needle valve quill where it contacts valve spring seat. Seating surfaces of needle and spray tip must be free of scoring and scratches. Replace any damaged parts. Needle valve and spray tip must be replaced as an assembly if either part requires replacement.

### Spray Tip and Needle Valve Lift Measurement

Use special dial indicator (see Service Bulletin No. 15-1913) for checking spray tip needle valve lift.

Zero dial indicator by placing bottom surface of plunger assembly on bottom of lapping block, then zero indicator dial as illustrated.

Place spray tip and needle valve assembly tight against bottom of dial indicator with quill



**ZEROING DIAL INDICATOR FOR  
NEEDLE VALVE LIFT MEASUREMENT**

of needle valve in hole of plunger as illustrated. Dial indicator should read .012"-.016".

If reading is more than .016", replace spray tip and needle valve assembly.

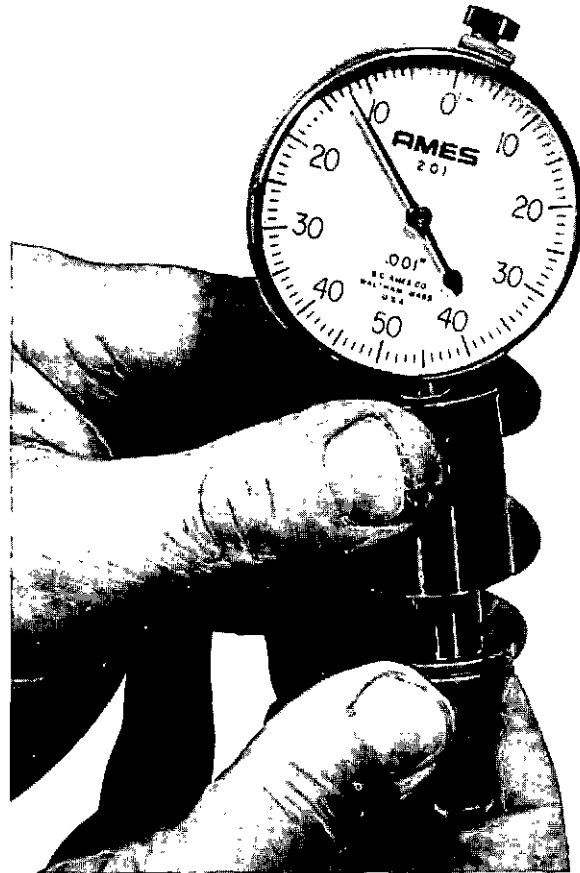
If reading is less than .012", inspect and remove any foreign material between needle valve and spray tip seat.

**Reassembly (See Exploded View)**

Be certain the work bench is extremely clean. New and used injector parts must be washed in solvent.

Install two new filters (2) and new gaskets (3) in body with filter slotted ends up. Lubricate threads of filter caps (4) with engine oil and install caps on body. Tighten filter caps to torque of 65 to 75 foot pounds. Place protective plastic caps on filter caps to prevent entrance of foreign matter.

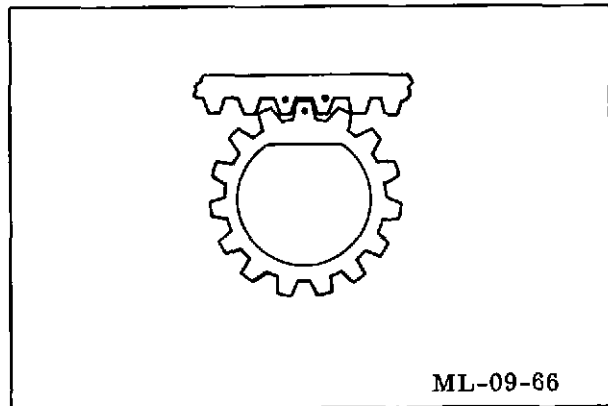
Note drill marks on rack and gear. Hold body (1) bottom up, and slide control rack (23) through hole in body. Move rack in body to be able to see drill marks.



**NEEDLE VALVE LIFT MEASUREMENT**

Install gear (12) in injector body with marked tooth on gear engaged between two marked teeth on control rack as illustrated.

Install gear retainer (13) on top of gear. Install bushing in injector body with locating pin in slot in body.



ML-09-66

**ALIGNMENT OF GEAR AND RACK  
DRILL MARKS**

## WAUKESHA VC SERIES

Install injector body, tip side up, in vise with soft jaws. Install new seal ring (22) wetted with test oil on shoulder of body. Install deflector on body around bushing.

Install check valve (14) on lapped face of bushing.

Install spring check valve cage (15) over check valve and against bushing.

Install spring seat (17) in valve spring (16) and insert into spring cage (18). Place valve spring assembly on top of check valve cage.

Install needle and spray tip (19) on valve spring cage with quill end of needle valve in hole of cage.

Align the stacked parts. Lubricate threads of tip nut with engine oil and screw nut on valve body by hand. Spray tip and parts must seat correctly in counterbore of nut. Do not force nut over parts. Rotate end of spray tip, if necessary, to aid in installing nut.

Tighten tip nut to torque of 100 to 120 foot pounds. Do not exceed this torque. Excessive torque could result in improper sealing of lapped surfaces.

Reverse position of injector in vise. Push control rack all the way in.

Install spring (9), stop pin (10) and retainer (7) in follower (8).

Engage head of plunger (11) with slot in follower (8) and slide spring (6) on follower. Install free end of plunger in injector body.

Align pin in follower with slot in body and flat side of plunger with flat in gear. Press down on follower and release stop pin to engage slot in follower.

Check concentricity of tip with dial indicator. Tip must be concentric to tip nut with 0.008 inch total indicator reading. If concentricity exceeds this, loosen tip nut, center spray tip, and retorque tip nut. Check concentricity. If tip cannot be adjusted to hold concentricity within limit, check assembly of injector.

### INJECTOR TROUBLE SHOOTING GUIDE

TROUBLE	PROBABLE CAUSE	SUGGESTED REMEDY
LOW VALVE OPENING PRESSURE	1. Worn or eroded needle valve or valve seat in spray tip.	1. Replace needle valve and spray tip assembly.
	2. Worn or damaged needle valve quill.	2. Replace needle valve and spray tip assembly.
	3. Worn or damaged needle valve spring seat.	3. Replace spring seat.
	4. Worn or broken valve spring.	4. Replace valve spring.
	5. Dirt or foreign material in injector.	5. Disassemble injector and clean all parts.
	NOTE: A partially plugged spray tip will not cause high valve opening pressure. It can, however, cause high injection pressure and low output because of the added restriction.	

REPAIR AND REPLACEMENT

INJECTOR TROUBLE SHOOTING GUIDE (Cont.)

TROUBLE	PROBABLE CAUSE	SUGGESTED REMEDY
<p>INSUFFICIENT INJECTOR HOLDING TIME</p>	<ol style="list-style-type: none"> <li>1. Poor bushing in body fit.</li> <li>2. Injector nut not tightened to specified torque.</li> <li>3. Excessive plunger to bushing clearance.</li> <li>4. Cracked spray tip.</li> <li>5. Worn or eroded needle valve.</li> <li>6. Worn or eroded needle valve seat in spray tip.</li> <li>7. Worn or broken needle valve quill.</li> <li>8. Worn or broken valve spring.</li> <li>9. Worn or damaged valve spring seat.</li> <li>10. Defective seal ring.</li> <li>11. Body plug leaks.</li> <li>12. Filter gaskets leak.</li> <li>13. Poor sealing surfaces on fuel fittings.</li> <li>14. Dirt or foreign material in injector.</li> </ol>	<ol style="list-style-type: none"> <li>1. Lap injector body.</li> <li>2. Tighten injector nut to 100 - 120 lb. ft. torque. Do not exceed specified torque.</li> <li>3. Replace plunger and bushing.</li> <li>4. Replace needle valve and spray tip assembly.</li> <li>5. Replace needle valve and spray tip assembly.</li> <li>6. Replace needle valve and spray tip assembly.</li> <li>7. Replace needle valve and spray tip assembly.</li> <li>8. Replace valve spring.</li> <li>9. Replace valve spring seat.</li> <li>10. Replace seal ring.</li> <li>11. Install new body plugs.</li> <li>12. Replace filter cap gaskets and tighten filter caps to 65 - 75 ft. lb. torque.</li> <li>13. Clean sealing surfaces or replace filter caps, if necessary. Replace filter if a cap is replaced.</li> <li>14. Disassemble injector and clean all parts.</li> </ol>

INJECTOR TROUBLE SHOOTING GUIDE (Cont.)

TROUBLE	PROBABLE CAUSE	SUGGESTED REMEDY
<p>INCORRECT INJECTOR OUTPUT</p>	<ol style="list-style-type: none"> <li>1. Spray tip or orifices partially plugged.</li> <li>2. Spray tip orifices enlarged.</li> <li>3. Carbon build-up in spray tip.</li> <li>4. Worn plunger and bushing.</li> <li>5. Worn or damaged needle valve quill.</li> <li>6. Worn or damaged needle valve spring seat.</li> <li>7. Worn or broken valve spring.</li> <li>8. Cracked check valve cage, spring cage, or spray tip.</li> <li>9. Cracked bushing.</li> <li>10. Improperly lapped surfaces.</li> <li>11. Foreign material between valve and seat.</li> <li>12. Rack and gear not in time.</li> <li>13. Spray tip-plunger and bushing combination provides incorrect output.</li> </ol>	<ol style="list-style-type: none"> <li>1. Clean spray tip as outlined under injector parts cleaning.</li> <li>2. Replace needle valve and spray tip assembly.</li> <li>3. Clean spray tip.</li> <li>4. After possibility of an incorrect or faulty spray tip has been eliminated and injector output still does not fall within its specific limits, replace plunger and bushing with a new assembly.</li> <li>5. Replace needle valve and spray tip assembly.</li> <li>6. Replace spring seat.</li> <li>7. Replace valve spring.</li> <li>8. Replace cracked parts.</li> <li>9. Replace plunger and bushing assembly.</li> <li>10. Lap sealing surfaces.</li> <li>11. Disassemble injector and clean all parts.</li> <li>12. Assemble gear with drill spot mark on tooth engaged between two marked teeth on rack.</li> <li>13. Replace spray tip and/or plunger and bushing assembly to provide correct output.</li> </ol>

NOTE: Fuel output of an injector varies with use of different spray tips of same size due to manufacturing tolerances in drilling tips. If fuel output does not fall within specified limits, try changing spray tip. However, use only tip specified for injector being tested.

REPAIR AND REPLACEMENT

**INJECTOR TUBE REMOVAL AND INSTALLATION**

The removal and replacement of injector tubes in VC series diesel engine cylinder heads is a precision operation requiring a special tool set. This special tool set, Part No. 499926, is available from the Waukesha Engine Division.

To remove injector tubes, proceed as follows:

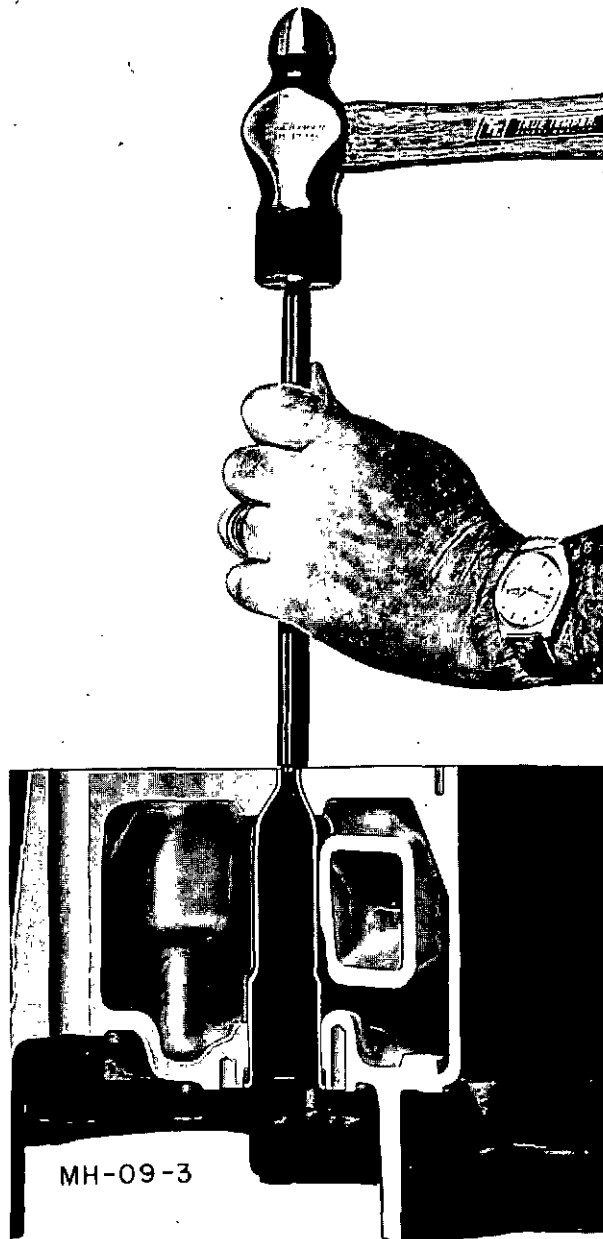
1. Insert pilot of removal tool into end of injector tube.
2. Loosen injector tube by striking removal tool with hammer as illustrated.
3. Withdraw injector tube from cylinder head.

To install new injector tubes, proceed as follows:

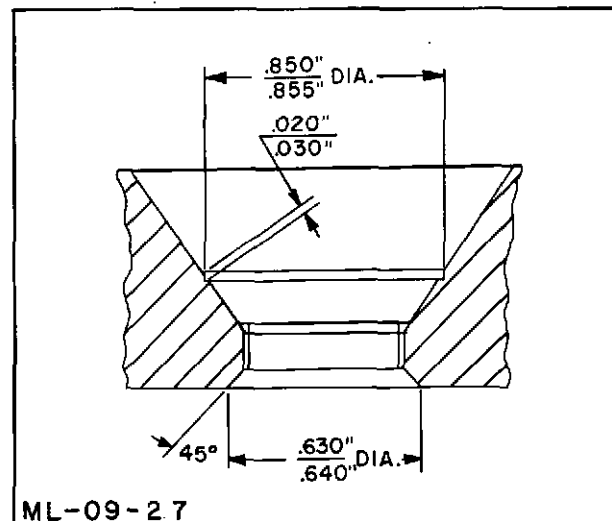
**NOTE**

Injector tubes used in cylinder heads without tube hole lower end grooves used Gasoila sealant on the lower end of the tubes. To remove this sealant, first squirt some Chlorothene in the tube hole, and then use a small carbon brush with a welded extension, driven by a drill. Dip the brush in Chlorothene before inserting in the hole. Use compressed air to blow tube hole clean.

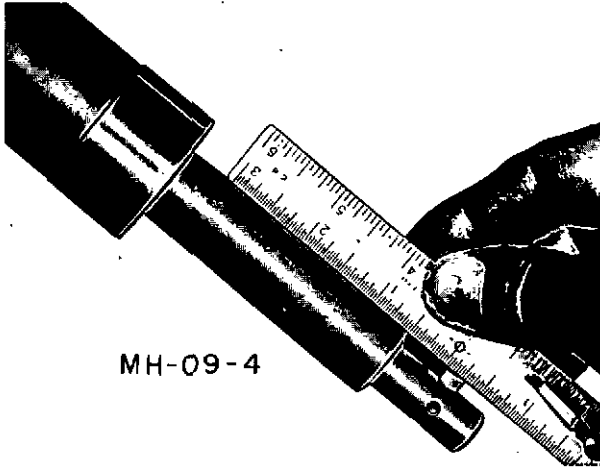
1. Thoroughly clean injector tube hole in cylinder head of dirt, burrs, or foreign material to provide a good seating surface for new tube. If injector tube hole in cylinder head does not have groove cut near lower end as illustrated, use special piloted cutter to cut groove. With cylinder head face down on flat plate, special cutter will bottom against plate when groove is properly cut. Also, as illustrated, lower end chamfer of tube hole should be reworked to 45° instead of 30°.



**LOOSENING INJECTOR TUBE**

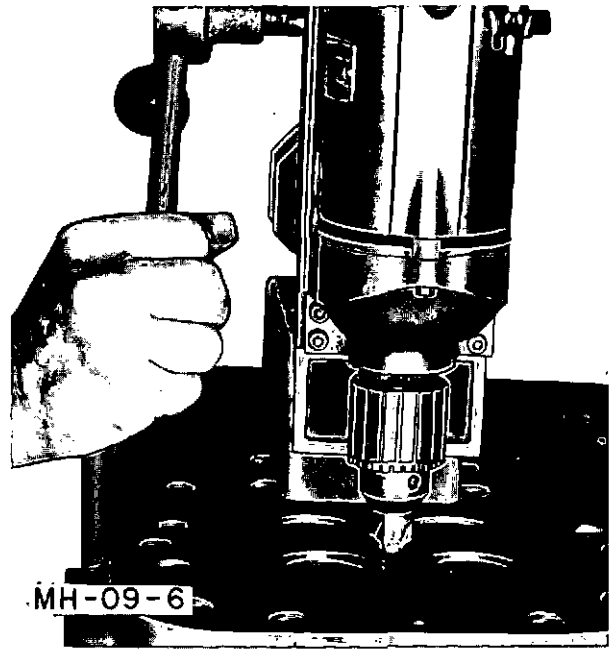


**INJECTOR TUBE HOLE REWORK**



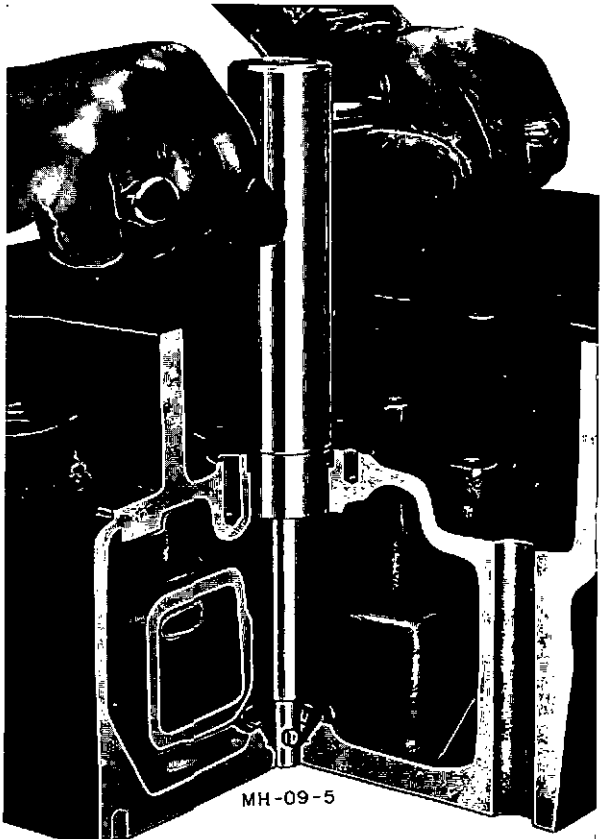
MH-09-4

CHECKING CUTTER BIT POSITION IN GROOVE CUTTING TOOL



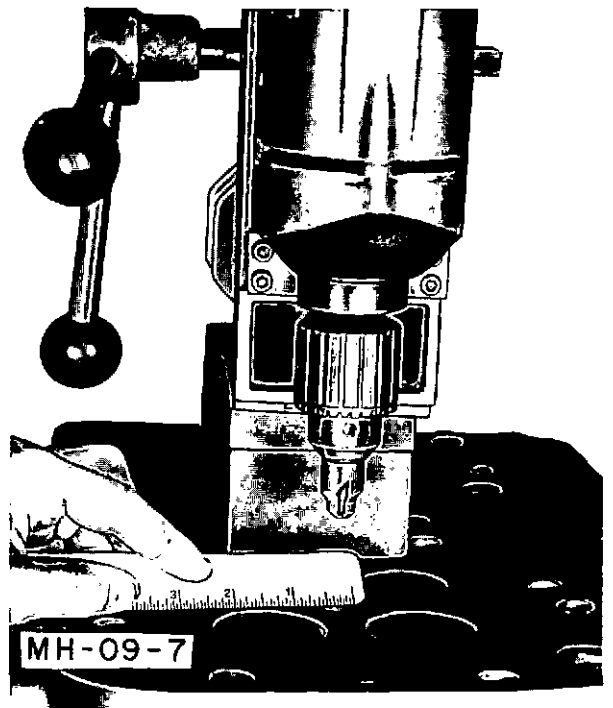
MH-09-6

REWORKING LOWER END CHAMFER OF TUBE HOLE TO 45°



MH-09-5

CUTTING GROOVE IN CYLINDER HEAD TUBE SEAT



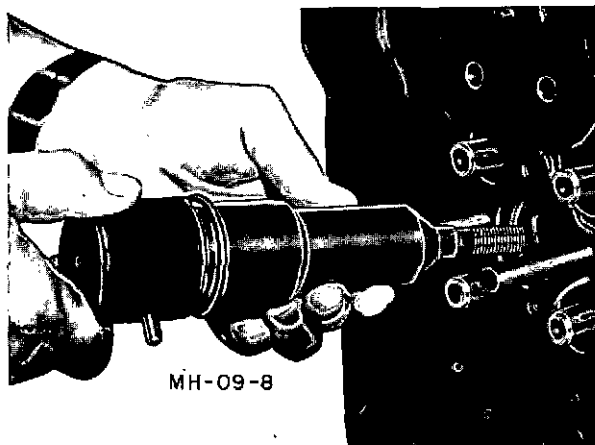
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MEASURING 45° CHAMFER

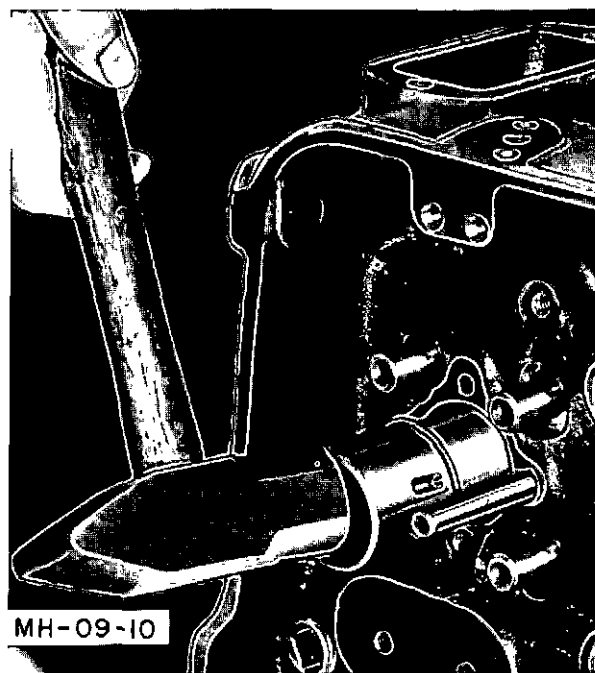
REPAIR AND REPLACEMENT

NOTE

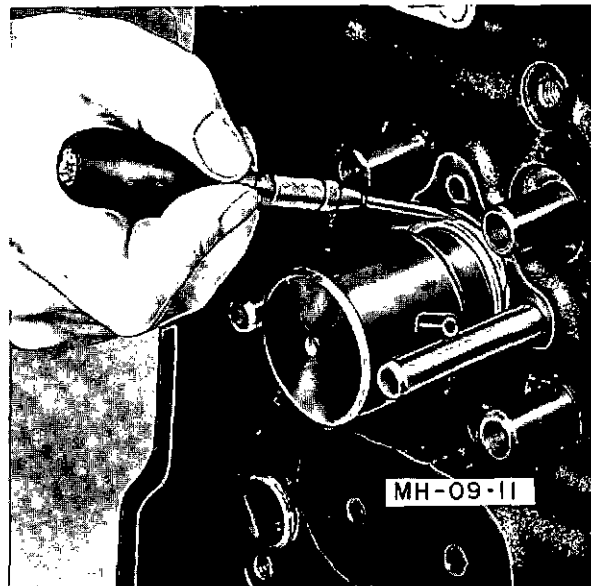
These modifications improve tube retention and help to prevent leaks and should be accomplished when engine is overhauled even if injector tubes do not require replacement. When special pilot-ed cutter needs to be resharpened, it will also be necessary to adjust cutter bit. This can be accomplished by using a straight edge. The reference point is the lower body diameter of .8535" - .8530". After adjustment, make sure set screw is tightened.



INSERTING INJECTOR TUBE

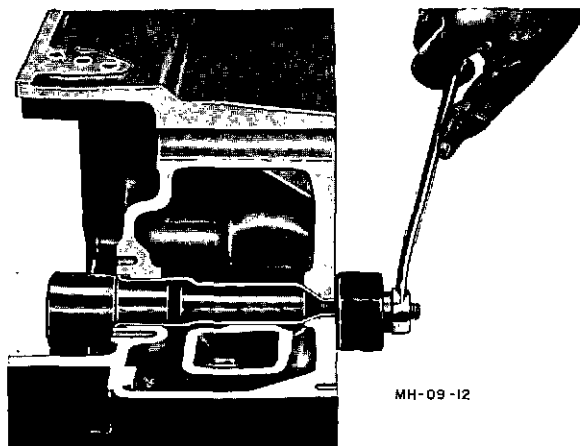


DRIVING TUBE INTO CYLINDER HEAD

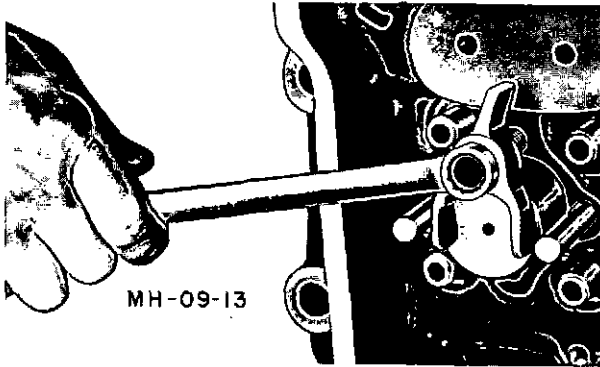


CHECKING INJECTOR TUBE SEAL RING

2. Place new seal ring coated with vaseline on upper end of injector tube.
3. Place installer body in injector tube. Then insert pilot stud of seating tool through small opening of injector tube and thread pilot stud into tapped end of installer body. Apply a bead of silicone rubber adhesive sealant (such as General Electric R.T.V. 106) around outside of injector tube.
4. Drive injector tube and installer body into cylinder head. Before upper flange of tube seats on seal ring, inspect ring closely to see that it is correctly located in counterbore (as illustrated). Clamp tube down firmly and use seating tool by installing spacer, washer, and nut on stud to seat it. Torque to 620-630 inch pounds.

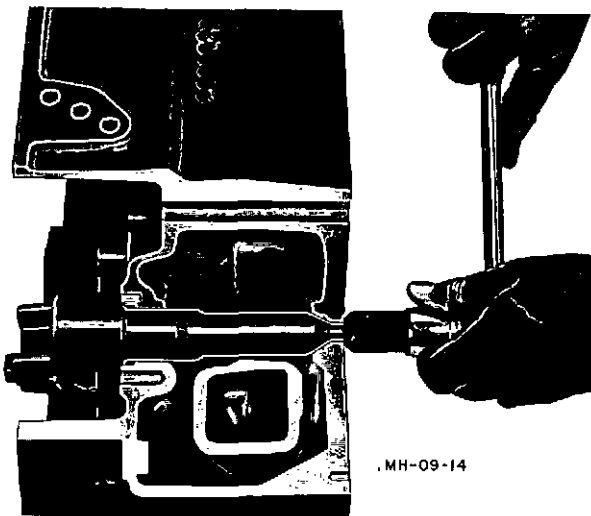


SEATING INJECTOR TUBE



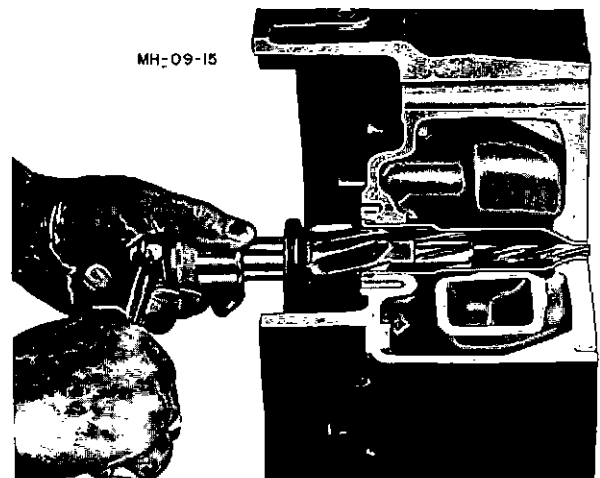
CLAMPING INJECTOR TUBE TOOL  
IN PLACE

5. Install injector clamp and clamp screw on top of installer body. Torque to 620-630 inch pounds. Then remove nut, washer, spacer, and stud from opposite end of installer body.
6. With injector tube properly seated, thread flaring tool into tapped end of installer body. Using socket and torque wrench, apply approximately 620-630 inch pounds torque to flaring tool. Remove tube installing tools. Make sure injector tube is clean.



FLARING LOWER END OF TUBE

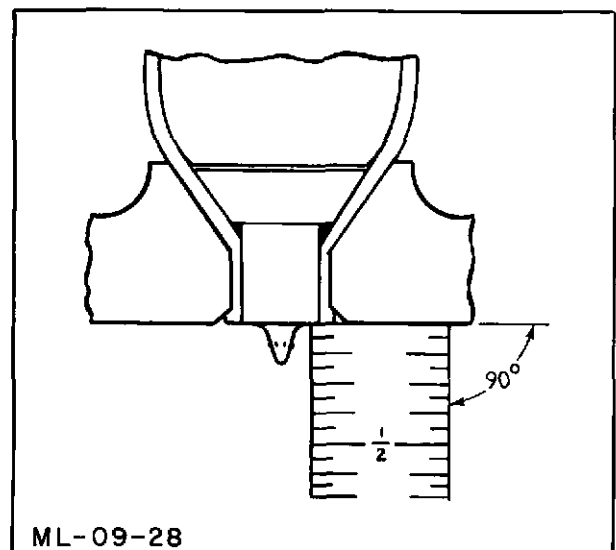
7. Using tube reaming tool, ream tube to receive injector body nut and spray tip. Place a few drops of light cutting oil on reamer flutes. Ream carefully and without undue force or speed to avoid cutting through thin wall of injector tube.



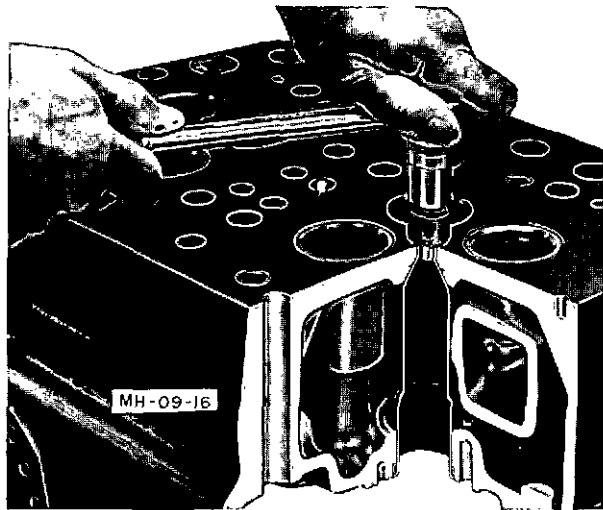
REAMING INJECTOR TUBE

Turn reamer in clockwise direction only, both when inserting and when withdrawing. Movement in opposite direction will dull cutting edges of reamer flutes. Clean out all chips.

8. Remove excess stock from tube lower end using tube tip trimming tool. Insert pilot of trimming tool into small hole of injector tube. Using socket and speed handle, remove excess stock so that lower end of tube is flush to .005" recessed below surface of cylinder head.

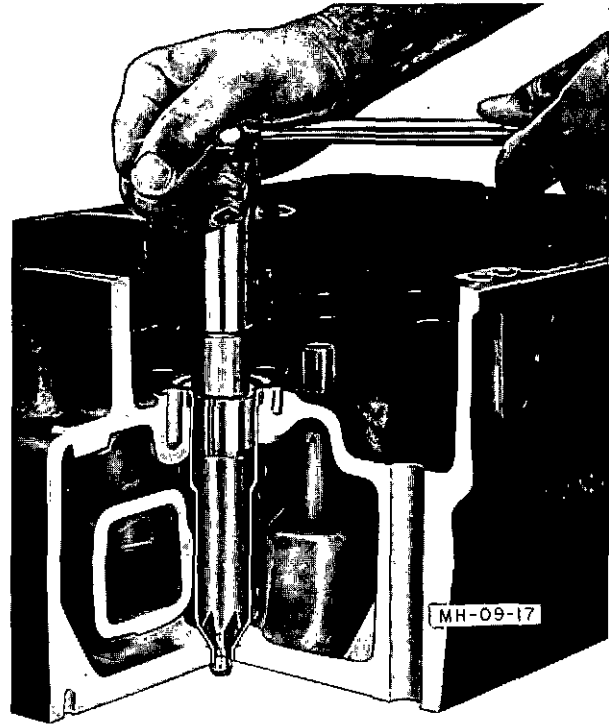


CHECKING LOCATION OF INJECTOR  
SPRAY TIP



TRIMMING INJECTOR TUBE

9. Ream bevel seat in injector tube to provide smooth and true seat for lower end of injector. First wash interior of injector tube with diesel oil or other petroleum solvent and dry with compressed air. Place a few drops of cutting oil on bevel seat of injector tube. Carefully lower tube seat reamer into tube until it contacts bevel seat. Without applying any downward force, make trial cut by turning reamer steadily. Remove reamer, blow out chips, and note what portion of bevel seat has been cut. Proceed carefully with reaming operation. Withdraw reamer occasionally to check progress. Remove chips from tube by washing with diesel oil or other petroleum solvent.

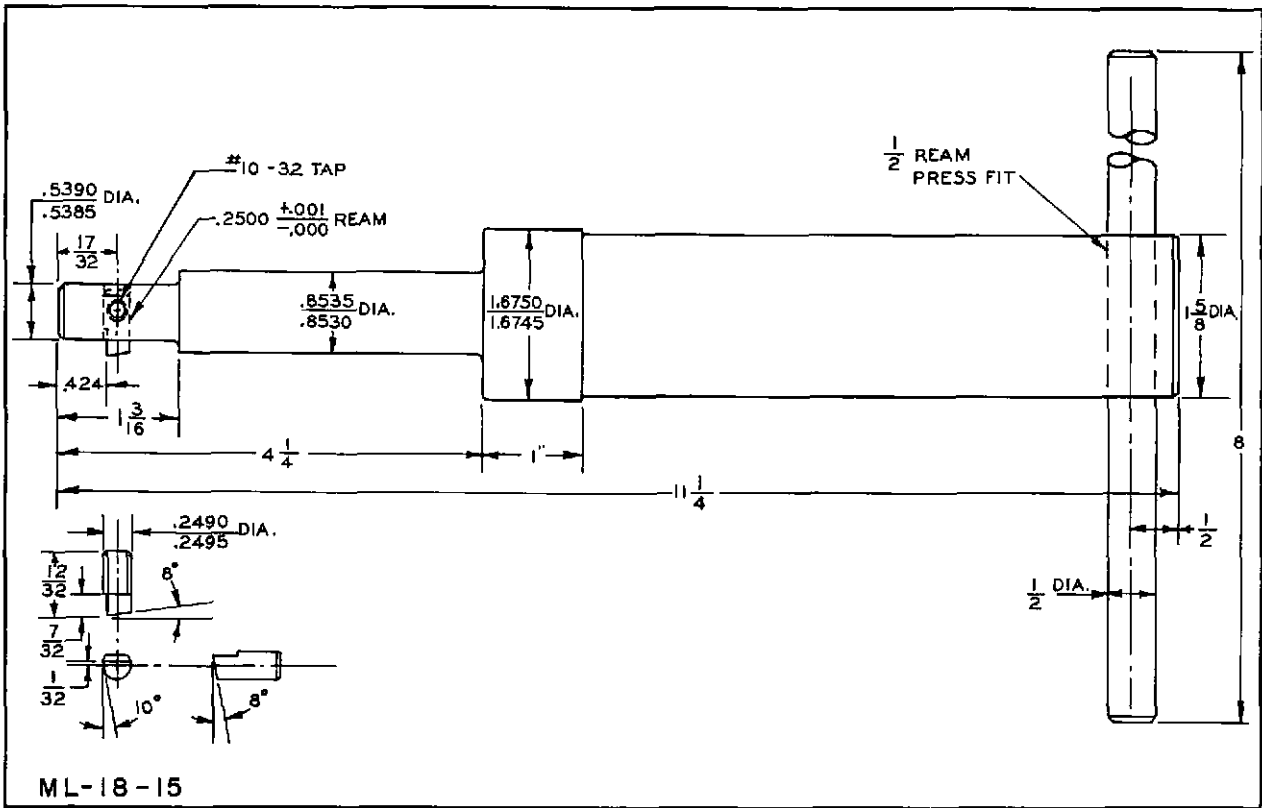


REAMING INJECTOR-TUBE BEVEL SEAT

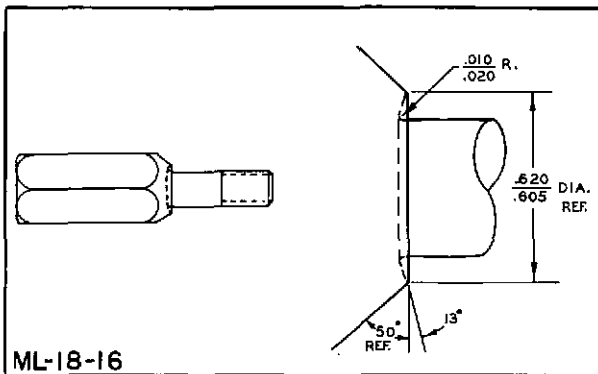
To improve the earlier special tool sets for removal and installation of injector tubes, as well as to include additional tools to rework injector tube holes (groove added and bevel angle changed) and to seat the tubes more securely, the current special tool sets consist of the following unchanged, reworked, and new components. The tool set part number remains the same.

WAUKESHA PART NUMBER	WAUKESHA TOOL NUMBER	TOOL DESCRIPTION	COMMENT
499987	66206	Tube Seat Groove Cutting Tool	New - See Illustration
499985	66207	Tube End Flaring Tool	Reworked - See Illustration
499986	66208	Tube Seating Tool	New - See Illustration
499984	66209	Tube Removal Tool	New - See Illustration
499988	66210	Tube Installer Body	Reworked - See Illustration
494011	66596	Tube Tip Trimming Tool	Unchanged
494012	66597	Tube Seat Reamer	Unchanged
494013	66598	Tube Reamer	Unchanged
494014	66715	45° Chamfer Tool	New
None	None	Threaded Tube Removal Tool	No Longer Used

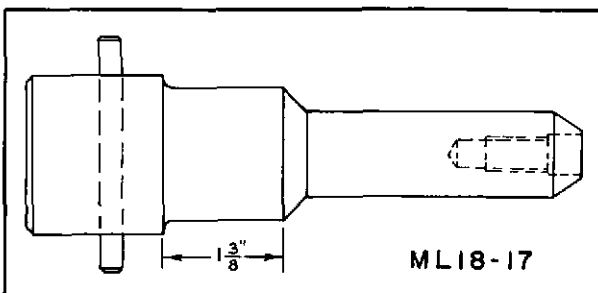
WAUKESHA VC SERIES



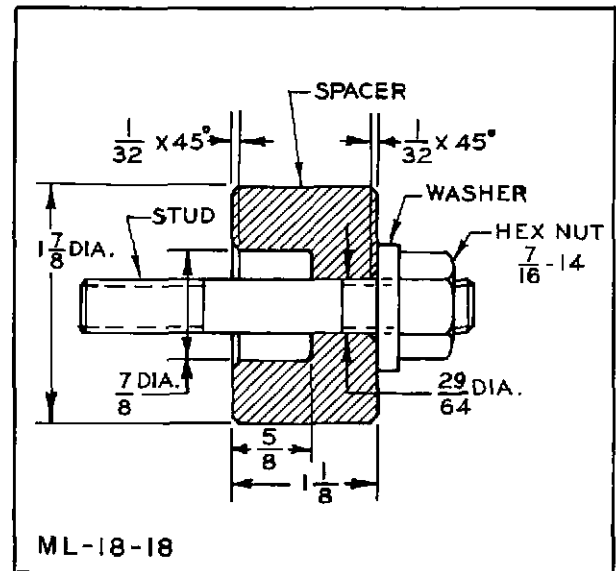
TUBE SEAT GROOVE CUTTING TOOL (NEW)



TUBE END FLARING TOOL (REWORKED)



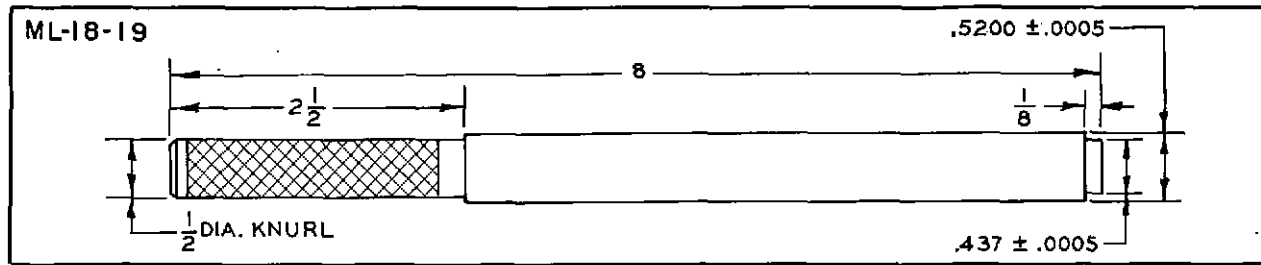
TUBE INSTALLER BODY (REWORKED)



TUBE SEATING TOOL (NEW)

An earlier tool set may be updated either by buying the new and reworked components or by reworking to revise tools and fabricating new tools.

REPAIR AND REPLACEMENT



TUBE REMOVAL TOOL (NEW)

**INSTALLATION OF DIESEL FUEL CONTROLS AND LINKAGE**

To install flexible couplings, proceed as follows (see illustration):

ends in intermediate cylinder head and remove control shaft sections from inside of intermediate head. Leave injector control lever on each control shaft section. Slide flexible couplings from shaft ends.

**WARNING**

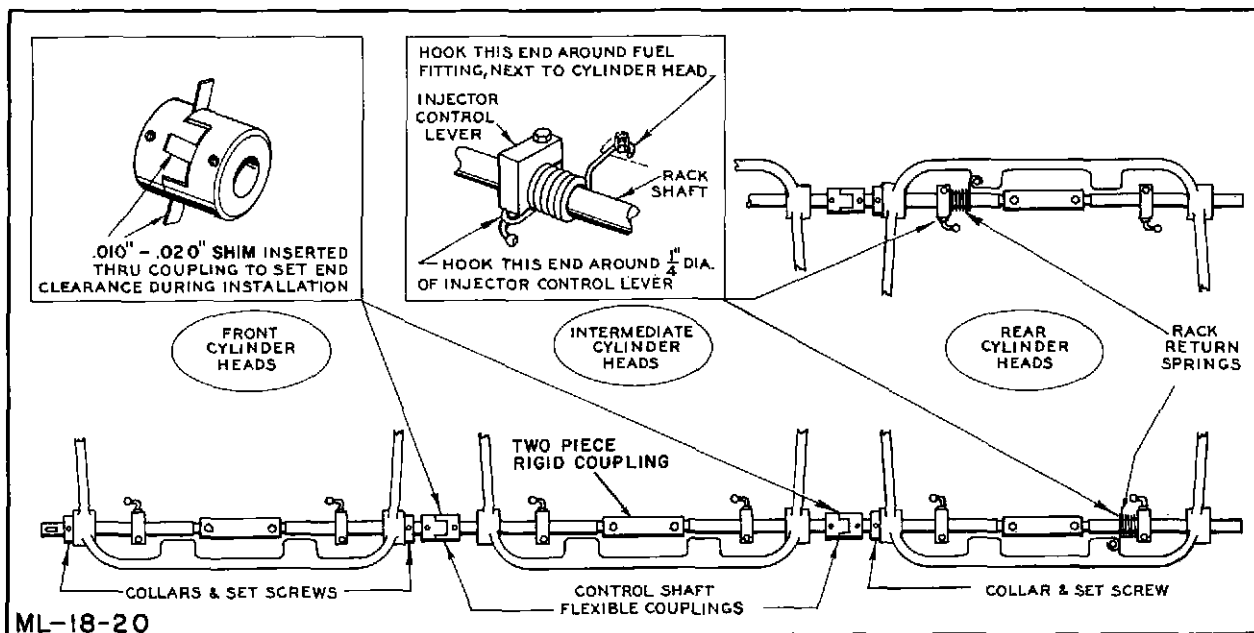
The control shaft flexible couplings must be handled carefully as the center portion is spring loaded. The rubber boot should always be on the coupling except during the installation procedure when inserting shims to set coupling end clearance and when tightening coupling set-screws. Reinstall the boot after the setscrews are tightened.

**NOTE**

This procedure applies to the L1616D series engines. For H1077D and P2154D series engines, this procedure must be modified accordingly, since the H1077D does not have an intermediate cylinder head while the P2154D has two intermediate cylinder heads.

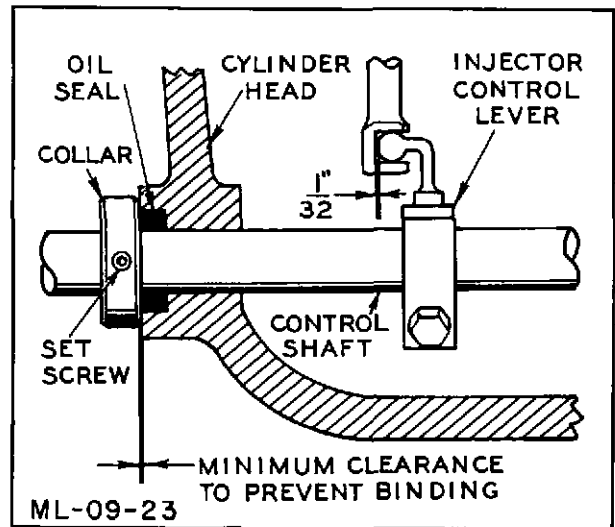
1. Loosen flexible coupling setscrews, remove two-piece rigid coupling from shaft

2. Install new rack coupling on control shaft at rear of front cylinder head, aligning setscrew in coupling with flat on shaft.



INSTALLATION OF CONTROL SHAFT FLEXIBLE COUPLINGS

3. Position collar on control shaft at front of rear cylinder head so that 1-3/16" of control shaft extends beyond rear of head (this should allow bevel on shaft to extend just beyond face of shaft seal in head).
4. Install new rack coupling on control shaft at front of rear cylinder head, aligning setscrew in coupling with flat on shaft.
5. Reinstall control shaft sections (with injector control levers attached) in intermediate cylinder head, inserting extending shaft ends into new couplings, and aligning flats on shafts with setscrews in couplings. Connect shaft ends in cylinder head with two-piece rigid coupling removed in Step 1.
6. Roll back rubber boots on new couplings and insert .010" - .020" shim stock thru couplings as illustrated.
7. Position the shaft assemblies (reinstalled in 5 above), so that they are approximately centered longitudinally in the head (so that the beveled edges of both ends are outside the seals). Center the flexible coupling between the heads and tighten the coupling setscrews to both adjacent shafts. Do this on both ends of the intermediate head and when tightening the last setscrew, push the shaft assemblies together so as to remove all free play between the coupling parts.
8. Recheck position of rear collar adjusted in Step 3 and reposition, if necessary, with minimum clearance between it and rear cylinder head, to prevent binding, with control shaft as far forward as it will go. Remove shim stock from couplings



POSITIONING CONTROL SHAFT COLLARS

plings and roll rubber boots back onto couplings.

9. To adjust controls and linkage, refer to ADJUSTMENT OF DIESEL FUEL CONTROLS AND LINKAGE in Chapter 4.

To install new rack return springs, the rigid couplings in the rear cylinder heads must be removed to slide the springs off of and onto the shafts. Install springs as illustrated, winding them up 240° from free position. Current injector control levers include a hole for the spring end.

If installing the entire control shaft linkage, the front cylinder head control shaft collars should be positioned to allow minimum clearance without binding, with the control shaft extending 1-3/16" from the rear of the head.

## CHAPTER 8 DATA, FITS AND CLEARANCES

NOTE: All of the information in this chapter is applicable to all VC series engines unless otherwise noted.

### GENERAL DATA

Bore and stroke . . . . .	5-3/4 by 5-3/16	Connecting rod bolts . . . . .	3800-3850
Displacement (cubic in.)		Vibration damper bolts:	
H1077 (V8) . . . . .	1077	H1077 and L1616 . . . . .	1500-1550
L1616 (V12) . . . . .	1616	P2154 . . . . .	3800-3850
P2154 (V16) . . . . .	2154	Flywheel bolts:	
Compression ratio:		H1077 and L1616 . . . . .	2050-2100
Gas engines . . . . .	10.0:1	P2154 . . . . .	3800-3850
Diesel engines -		Crankshaft pulley bolts . . . . .	650-700
naturally aspirated . . . . .	16:1	Rocker arm support:	
turbo supercharged . . . . .	14:1	3/8" nuts . . . . .	350-400
Firing order (standard rotation engines):		7/16" nuts . . . . .	650-700
H1077 . . . . .	1R-1L-3R-3L-4R-4L-2R-2L	Intake manifold bolts . . . . .	250-300
L1616 . . . . .	1R-6L-5R-2L-3R-4L-6R-1L-2R-5L-4R-3L	Exhaust manifold:	
P2154 . . . . .	1R-8L-3R-6L-7R-2L-5R-4L-8R-1L-6R-3L-2R-7L-4R-5L	Standard bolts . . . . .	650-700
Firing order (opposite rotation engines):		Lok-thred bolts . . . . .	950-1000
H1077 . . . . .	1L-1R-2L-2R-4L-4R-3L-3R	Stub shaft plate to stub shaft bolts . . . . .	2050-2100
L1616 . . . . .	1L-6R-4L-3R-2L-5R-6L-1R-3L-4R-5L-2R	Stub shaft plate to flywheel bolts . . . . .	650-700
P2154 . . . . .	1L-8R-4L-5R-2L-7R-6L-3R-8L-1R-5L-4R-7L-2R-3L-6R	Balancing system spindle flange bolt and bearing carrier (H1077) . . . . .	350-400
Flywheel housing size . . . . .	SAE No. 0	Separable fan pulley bolts . . . . .	650-700

### SPECIAL TORQUE VALUES

Note: All torque values are stated in pounds inch. Divide by 12 for values in pounds foot. All torque values are for oiled threads, unless specified for dry threads.

*Cylinder head:	
5/8" nuts . . . . .	2230-2280
3/4" nuts . . . . .	3550-3600
3/4" capscrews . . . . .	3840-3900
**Main bearing cap nuts . . . . .	7200-7250
**Main bearing cap cross-tie bolts . . . . .	950-1000

***Camshaft gear nut . . . . .	1100-1200
Air compressor drive pulley nut . . . . .	750-800
***Water pump gear nut . . . . .	250-300
***Water pump impeller nut . . . . .	350-400
Raw water pump impeller nut . . . . .	350-400
Spark plug tube (gas engines - 18 mm plug) . . . . .	2900-3000
Spark plug tube nuts (gas engines - 14 mm plug) . . . . .	120-130
Spark plugs (gas engines - 18 mm): oiled threads . . . . .	288-342
Spark plugs (gas engines - 14 mm): oiled threads . . . . .	234-270
Injector bolt (diesels) . . . . .	620-630
Injector connection nuts (diesels) . . . . .	144-180
***Oil pump gear nut . . . . .	750-800

\*Refer to CYLINDER HEAD TORQUING PROCEDURES in Chapter 7 for proper torquing sequence and procedure.  
 \*\*Refer to MAIN BEARING TORQUING PROCEDURES in Chapter 7 for proper torquing sequence and procedure.  
 \*\*\*Add values listed to "run-down" torque as these are prevailing torque type lock nuts.

**FITS AND CLEARANCES**

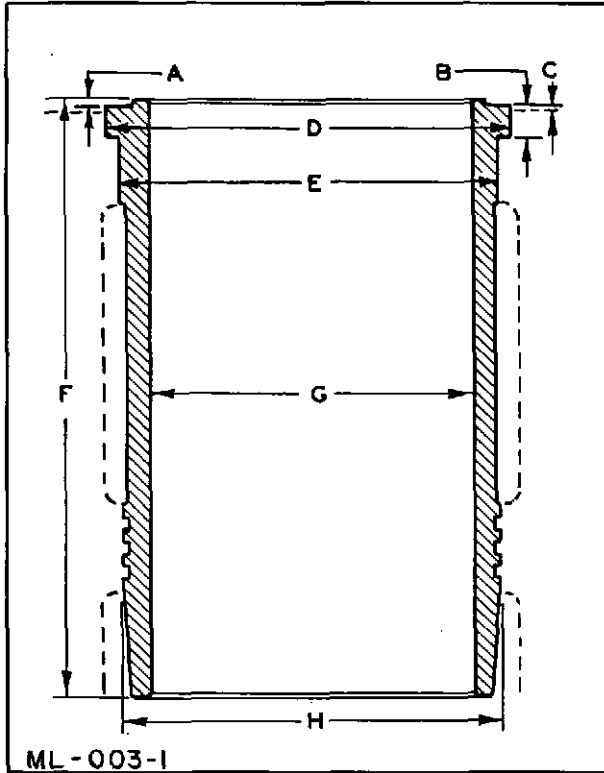
**WAUKESHA VC SERIES**

**GENERAL TORQUE VALUE 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  $\pm 3\%$  is permissible on these values.

HEAT TREATED MATERIAL SAE GRADE 5 & GRADE 8				
THREAD SIZE	SAFE TORQUE (LB-FT.) (Multiply by 12 for pounds inch)			
	GRADE 5 (3 radial dashes on bolt or cap screw head)		GRADE 8 (6 radial dashes on bolt or cap screw head)	
	DRY THREADS	OILED THREADS	DRY THREADS	OILED THREADS
1/4-20	8	6	12	9
1/4-28	10	7	14	11
5/16-18	17	13	24	18
5/16-24	19	15	27	21
3/8-16	31	24	44	34
3/8-24	35	27	49	38
7/16-14	49	38	70	54
7/16-20	55	42	78	60
1/2-13	75	58	105	82
1/2-20	85	65	120	90
9/16-12	110	84	155	120
9/16-18	120	93	170	132
5/8-11	150	115	210	165
5/8-18	170	130	240	185
3/4-10	270	205	375	290
3/4-16	295	230	420	320
7/8-9	395	305	605	455
7/8-14	435	335	670	515
1-8	590	455	905	695
1-14	660	510	1030	785
1-1/8-7	795	610	1285	990
1-1/8-12	890	685	1440	1110
1-1/4-7	1120	860	1820	1400
1-1/4-12	1240	955	2010	1550
1-3/8-6	1470	1130	2380	1830
1-3/8-12	1670	1290	2710	2085
1-1/2-6	1950	1500	3160	2430
1-1/2-12	2190	1690	3555	2730
1-3/4-5	3075	2370	4980	3810
2-4-1/2	4620	3550	7480	5760

**WAUKESHA VC SERIES**



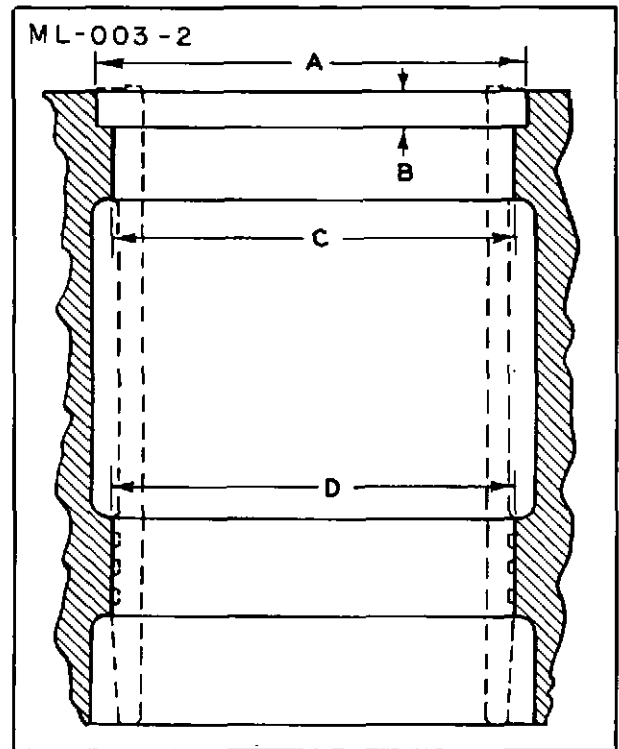
TYPICAL CYLINDER SLEEVE

**CYLINDER SLEEVES**

- (A) Heat dam projection:
  - Sleeves with smooth and grooved flanges . . . . . .042"-.047"
  - Sleeves with tongue at flange OD . . . . . .0365"-.0405"
- (B) Flange height:
  - Sleeves with smooth and grooved flanges . . . . . .376"-.377"
  - Sleeves with tongue at flange OD . . . . . .385"-.387"
- (C) Sleeve projection above crankcase:
  - Sleeves with smooth and grooved flanges . . . . . .001"-.004"
  - Sleeves with tongue at flange OD . . . . . .010"-.014"
- (D) Flange diameter . . . . . 6.9945"-6.9960"
- (E) Sleeve diameter below flange . . . 6-9/16"
- (F) Sleeve length . . . . . . . . . . . 11"
- (G) Sleeve bore . . . . . 5.750"-5.751"
- Maximum taper for sleeve bore . . . . .0025"
- Maximum out-of-round limit . . . . .0025"
- (H) Sleeve diameter lower seal area . . . . . 6.4985"-6.5000"
- Sleeve seal area to crankcase clearance . . . . . .0010"-.0035"

**CRANKCASE**

- (A) Sleeve counterbore diameter . . . . . 7.0000"-7.0015"
- (B) Sleeve counterbore depth . . . . .373"-.375"
- (C) Crankcase upper bore . . . . . 6.620"-6.630"
- (D) Crankcase lower bore . . . . . 6.501"-6.502"
- Crankcase main bearing bore . . . . . 5.313"-5.314"
- Crankcase camshaft bushing bore . . . . . 3.1870"-3.1885"



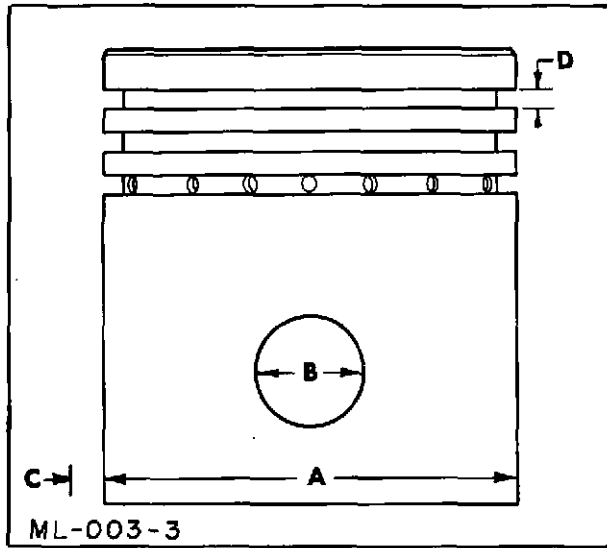
TYPICAL SECTION THROUGH CRANKCASE

**PISTONS**

- (A) Piston skirt diameter (bottom - 90° from pin hole):
  - Gas engines . . . . . 5.7414"-5.7424"
  - Diesel engines . . . . . 5.737"-5.739"
- (B) Piston pin hole bore . . . . . 2.0610"-2.0613"
- (C) Piston skirt to sleeve clearance (thrust area - 90° from pin hole):
  - Gas engines . . . . . .0076"-.0096"
  - Diesel engines . . . . . .011"-.014"

**FITS AND CLEARANCES**

**WAUKESHA VC SERIES**



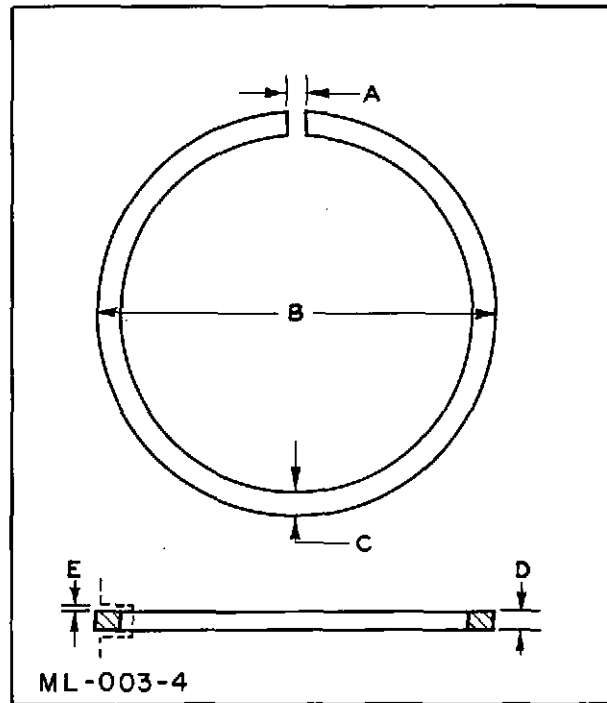
**TYPICAL PISTON**

**(D) Groove width:**

Top-gas engines . . . . .	.129"-.130"
Top-diesel engines . . . . .	Keystone
2nd-gas engines . . . . .	.0965"-.0975"
2nd and 3rd-diesel engines . . . . .	.096"-.097"
Oil-gas engines . . . . .	.2505"-.2515"
Oil-diesel engines . . . . .	.251"-.252"
Permissible weight variation . . . . .	±1/4 oz.

**PISTON PINS**

Piston pin diameter . . . . .	2.0601"-2.0604"
Clearance in piston . . . . .	.0006"-.0012"
Clearance in pin bushing . . . . .	.0016"-.0024"



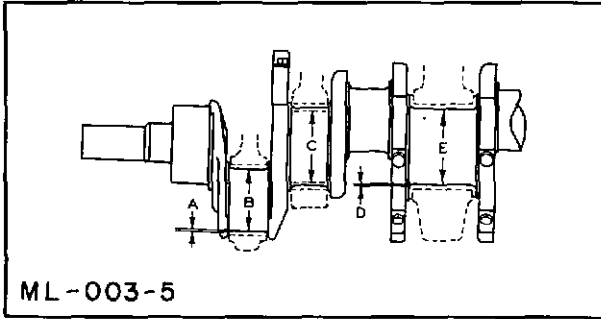
**TYPICAL PISTON RING**

**PISTON RINGS**

	(A) Ring Gap	(B) Ring Diameter 5.750"	(C) Ring Wall	(D) Ring Width	(E) Side Clearance
<b>Top:</b>					
Gas engines	.020"-.035"	@ 21# Min.	.225"-.240"	.123"-.124"	.005"-.007"
Diesel engines	.017"-.027"	@ 12# Min.	.210"-.220"	Keystone	Keystone
*2nd - gas engines	.017"-.027"	@ 7.0# Min.	.210"-.220"	.093"-.0935"	.003"-.0045"
*2nd and 3rd diesel engines	.017"-.027"	@ 7.0# Min.	.210"-.220"	.093"-.0935"	.0025"-.004"
<b>Oil:</b>					
Gas engines	.017"-.032"	@ 11 - 17#	.160"-.170"	.2485"-.249"	.0015"-.003"
Diesel engines	.017"-.032"	@ 11 - 17#	.160"-.170"	.2485"-.249"	.002"-.0035"

*\*Upper side of ring is marked TOP.*

**WAUKESHA VC SERIES**



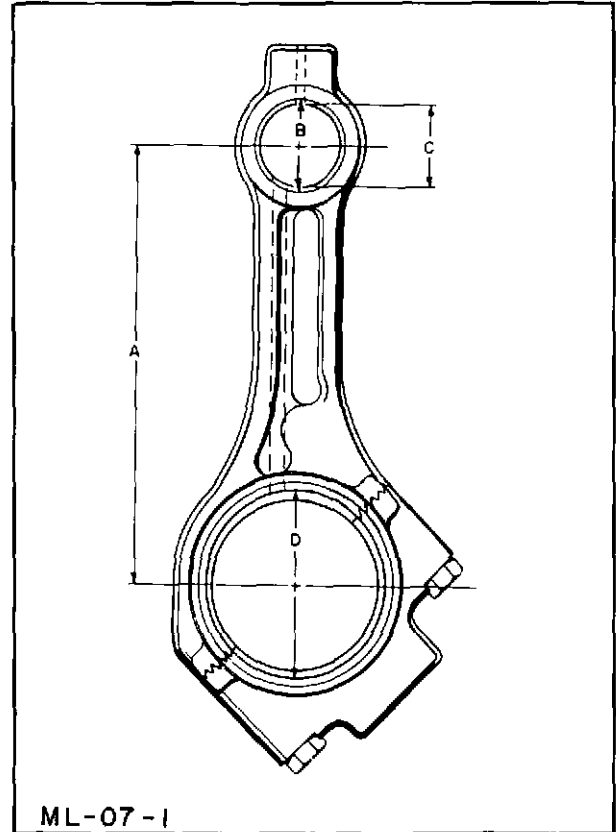
**TYPICAL CRANKSHAFT**

**CRANKSHAFT**

(A) Connecting rod bearing running clearance . . . . .	.0020"-.0054"
(B) Connecting rod bearing journal diameter . . . . .	4.249"-4.250"
(C) Main and rod bearing journal maximum undersize . . . . .	.040"
(D) Main bearing running clearance . . . . .	.0020"-.0054"
(E) Main bearing journal diameter . . . . .	4.999"-5.000"
Crankshaft end play . . . . .	.005"-.015"
Crankshaft thrust length (face to face) . . . . .	2.061"-2.063"
Thrust washer thickness (std.) . . . . .	.151"-.153"
Thrust washer thickness (.010 o/s) . . . . .	.161"-.163"
Main and rod bearing shell thickness . . . . .	.1548"-.1555"
Main and rod journal fillet radius . . . . .	.172"-.187"
Main bearing journal out-of-round maximum . . . . .	.002"
Rod bearing journal out-of-round maximum . . . . .	.0017"
Main bearing journal taper maximum . . . . .	.0006"
Rod bearing journal taper maximum . . . . .	.001"
Run out maximum . . . . .	.002"

**CONNECTING RODS**

(A) Rod length, center to center . . . . .	10.501"-10.502"
(B) Rod small end finish size . . . . .	2.2495"-2.2500"
(C) Bushing bore diameter . . . . .	2.0620"-2.0625"
(D) Rod large end finish size . . . . .	4.563"-4.564"
Rod width (rod used with narrow intermediate main bearings)	1.957"-1.959"



**TYPICAL CONNECTING ROD, BUSHING AND BEARING**

Rod width (rod used with wide intermediate main bearings)	1.8945" -1.8965"
Connecting rod side clearance . . . . .	.019"-.028"
Minimum installed side clearance . . . . .	.005"
Permissible weight variation . . . . .	±1/2 oz.

**CAMSHAFT**

Camshaft bushing installed I.D. . . . .	3.000"-3.0015"
Camshaft journal diameter . . . . .	2.997"-2.998"
Camshaft bushing running clearance . . . . .	.002"-.0045"
Camshaft end play . . . . .	.006"-.010"
Camshaft thrust plate thickness . . . . .	.246"-.244"
Cam lift - intake and exhaust . . . . .	.410"
Cam lift - injector . . . . .	.345"
Cam base circle . . . . .	1.990"-2.010"

**FITS AND CLEARANCES**

**WAUKESHA VC SERIES**

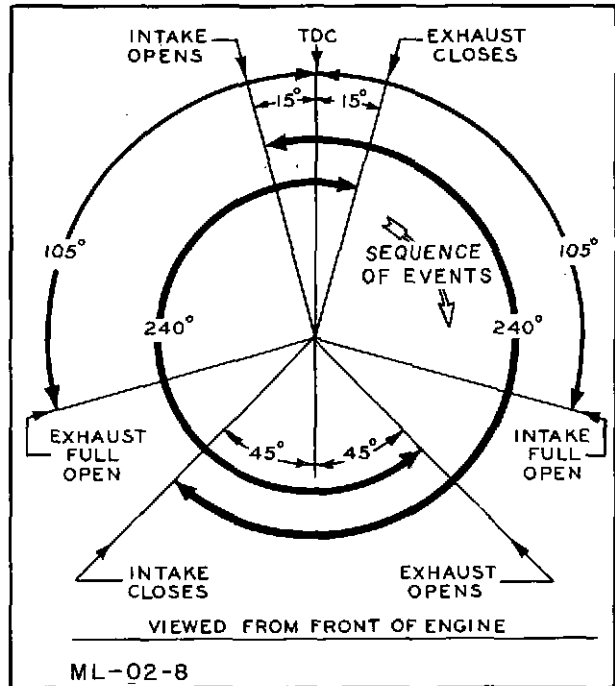
**VALVE SETTING CLEARANCE**

Note: Valve clearances to be adjusted with engine stopped and cooled to normal ambient temperature.

- Intake clearance:  
 Gas and diesel engines . . . . .011"-.013"
- Exhaust clearance:  
 Gas engines . . . . .024"-.026"  
 Diesel engines . . . . .019"-.021"

**VALVE AND INJECTOR LIFTERS**

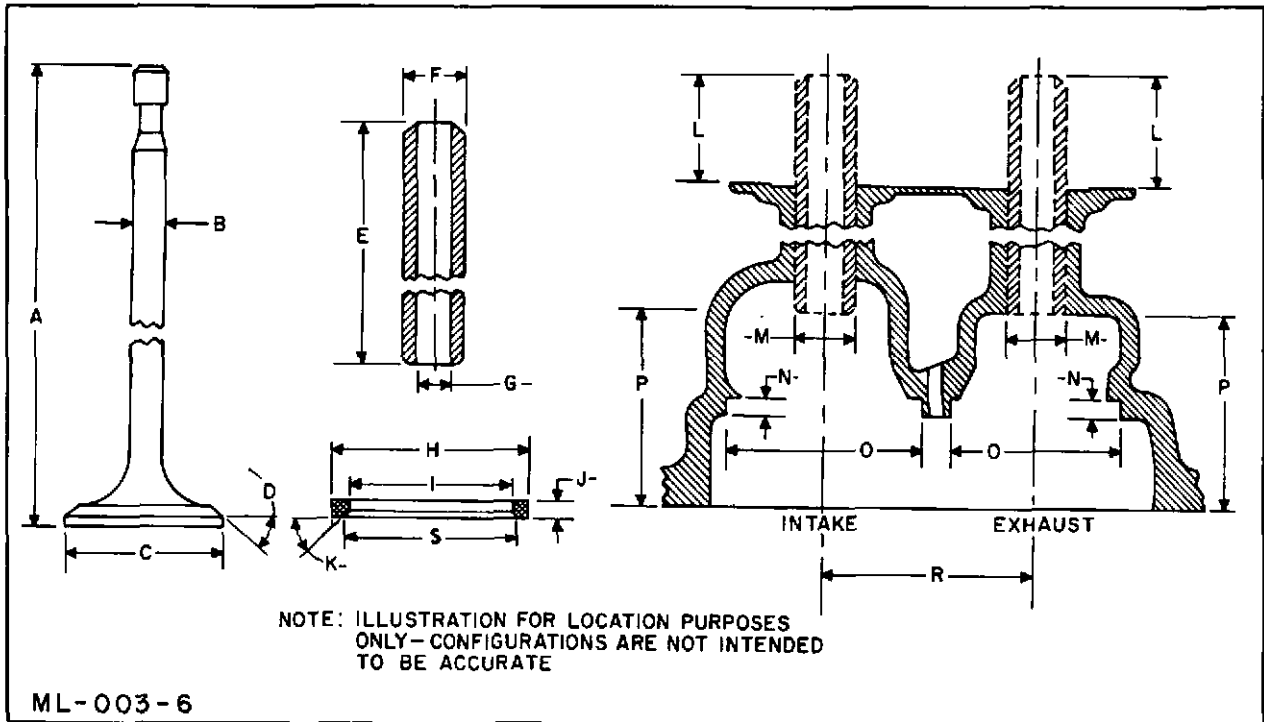
- Valve and injector lifter body to guide clearance:  
 (sleeve type) . . . . .002"-.004"  
 (sleeveless type) . . . . .0015"-.003"
- Valve and injector lifter body O.D. (sleeve type) . . . . .1.246"-1.247"
- Valve lifter body O.D. (sleeveless type) . . . . .1.2475"-1.248"
- Injector lifter body O.D. (sleeveless type) . . . . .1.5605"-1.561"
- Valve and injector lifter guide I.D. (sleeve type) . . . . .1.249"-1.250"
- Valve lifter crankcase bore I.D. (sleeveless type) . . . . .1.2495"-1.2505"
- Injector lifter crankcase bore I.D. (sleeveless type) . . . . .1.5625"-1.5635"



**VALVE SEQUENCE**

**VALVE TRAIN, VALVE PORT CLEARANCES**

	Intake & Exhaust
(A) Valve Length . . . . .	7.439" ± .005"
(B) Valve Stem Diameter . . . . .	.371"-.372"
(C) Valve Head Diameter (Nominal) . . . . .	1.930"-1.940"
Valve Stellite Face Thickness (Discard valves if stellite is less than .015" thick after grinding) . . . . .	.030"
(D) Valve Seat Angle (Diesel intake and exhaust - Gas exhaust only) . . . . .	45° - 45° 30'
(Gas intake only) . . . . .	30° - 30° 30'
(E) Guide Length . . . . .	3-1/2"
(F) Guide Outside Diameter . . . . .	.6255"-.6265"
(G) Guide Inside Diameter (ream in place) . . . . .	.374"-.375"
Guide I.D. to Stem O.D. Clearance . . . . .	.002"-.004"
(H) Insert Outside Diameter (standard size) . . . . .	2.128"-2.129"
Insert Outside Diameter (1/32" oversize) . . . . .	2.159"-2.160"
Insert Outside Diameter (1/16" oversize) . . . . .	2.190"-2.191"
(I) Insert Inside Diameter . . . . .	1.750"-1.760"
(J) Insert Thickness (diesel) . . . . .	.373"-.375"
Insert Thickness (gas) . . . . .	.311"-.313"
(K) Insert Seat Angle (Diesel intake and exhaust - Gas exhaust only) . . . . .	45°
(Gas intake only) . . . . .	30°



VALVE TRAIN, VALVE PORT CLEARANCES

	Intake & Exhaust
(L) Guide Extends Above Head . . . . . (Exhaust guides must not protrude into exhaust ports— should be 1/16" to 3/32" recessed)	1-1/16"
(M) Guide Bore in Head . . . . . Guide to Head Bore Press Fit . . . . .	.624" - .625" .0005" - .0025"
(N) Insert Counterbore Depth (diesel) . . . . . Insert Counterbore Depth (gas) . . . . .	.385" - .390" .322" - .327"
(O) Insert Counterbore Diameter (standard size) . . . . . Insert Counterbore Diameter (1/32" oversize) . . . . . Insert Counterbore Diameter (1/16" oversize) . . . . .	2.124" - 2.125" 2.155" - 2.156" 2.186" - 2.187"
(P) Valve Port Depth (Nominal) . . . . .	2-1/4"
(R) Valve-Centerline to Centerline . . . . .	2.562" - 2.582"
(S) Insert Seat O.D. . . . . Valve Insert Seat Width . . . . . Valve Insert Seat Run-out (max.) . . . . .	1-29/32" .095" - .115" .002" TIR
Valve Spring Free Length . . . . .	2.413" - 2.423"
Valve Closed Spring Length . . . . .	2.249" @ 62# ± 4#
Valve Open Spring Length . . . . .	1.792" @ 235# ± 15#
Rocker Arm Bushing I.D. (Chamfer both ends of bushing 1/64" by 45° after reaming)	1.469" - 1.470"
Rocker Arm Shaft O.D. . . . .	1.4665" - 1.4675"
Bushing to Shaft Clearance . . . . .	.0015" - .0035"

FITS AND CLEARANCES

**WAUKESHA VC SERIES**

**IGNITION DATA**

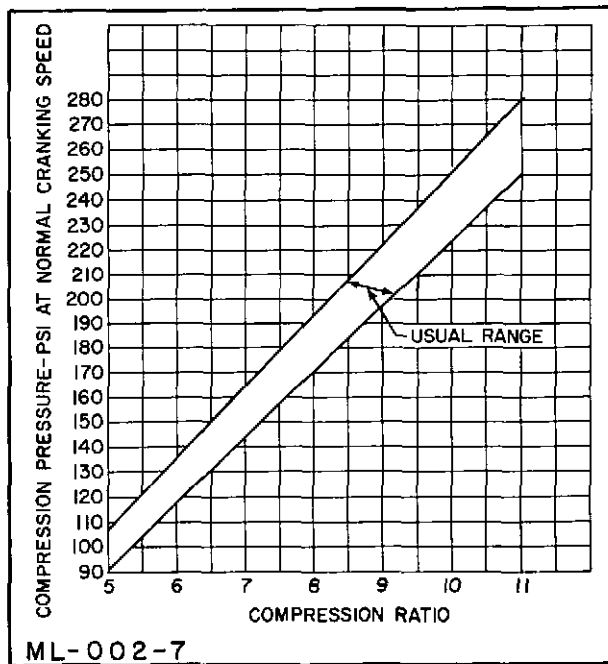
Spark plug size	
(previous)	. . . . . 18 mm with 1/2" reach
(current)	. . . . . 14 mm with 3/4" reach
Spark plug type	
(previous)	. . . . . 69489 (18 mm)
(current)	. . . . . 69683 (14 mm)
Spark plug gap (previous)	
	. . . . . .025" (18 mm)
(current)	
	. . . . . .014" (14 mm)
Low tension magneto point clearance:	
Fairbanks Morse FM-LTR	. . . . . .016"-.018"
American Bosch MSB8A	. . . . . .020"
Ignition timing (at governed rpm):	
H1077G (Natural gas	. . . . . 34° BTC
& (LPG (nat. asp.)	. . . . . 30° BTC
L1616G (LPG (turbo)	. . . . . 20° BTC
P2154G (Natural gas (nat. asp.)	. . . . . 32° BTC
(Natural gas (turbo)	. . . . . 28° BTC

NOTE: If shielded spark plugs are used, tighten all connector nuts and extensions finger tight, plus an additional 1/4 turn. Do not touch terminal connectors with fingers and make sure all parts are clean before assembling.

**INJECTION TIMING**

14 to 1 compression ratio	
(1200 rpm or below)	. . . . . 24° BTC
(above 1200 rpm)	. . . . . 28° BTC
16 to 1 compression ratio	. . . . . 32° BTC

**GAS ENGINE COMPRESSION PRESSURE**



COMPRESSION PRESSURE VS RATIO (GAS)

**DIESEL ENGINE COMPRESSION PRESSURE**

14 to 1 compression ratio	. . . . . 315 to 325 psi
	at 100 rpm cranking speed
16 to 1 compression ratio	. . . . . 340 to 350 psi
	at 100 rpm cranking speed

**IDLER GEAR BUSHING AND SPINDLE**

Idler spindle shaft O.D.	. . . . . 1.996"-1.997"
Idler gear bushing I.D.	. . . . . 1.999"-2.000"
Running clearance	. . . . . .002"-.004"
End clearance	. . . . . .003"-.007"

**FRONT BALANCE WEIGHT SHAFT BUSHINGS (PREVIOUS) (H1077 ONLY)**

Shaft diameter	. . . . . 1.4965"-1.4975"
Bushing bore	. . . . . 1.499"-1.500"
Running clearance	. . . . . .0015"-.0035"
Shaft end play	. . . . . .007"-.012"

**FRONT BALANCE WEIGHT AND SHAFT BUSHINGS (CURRENT) (H1077 ONLY)**

Shaft diameter (rear)	. . . . . 1.1965"-1.1975"
Bushing bore (rear)	. . . . . 1.199"-1.200"
Shaft running clearance	. . . . . .0015"-.0035"
Spindle diameter (front)	. . . . . 2.2500"-2.2505"
Balance weight bushing bore	. . . . . 2.2565"-2.2575"
Balance weight running clearance	. . . . . .006"-.0075"
Shaft end play	. . . . . .007"-.013"

**REAR BALANCE WEIGHT BUSHING (H1077 ONLY)**

Shaft diameter	. . . . . 1.749"-1.750"
Balance weight bushing bore	. . . . . 1.752"-1.753"
Running clearance	. . . . . .002"-.004"
Weight end play	. . . . . .005"-.009"



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 mm

---

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 Lbs. = 22,550 x .4536 = 10,228 Kg

---

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

---

# WAUKESHA VC SERIES

## UNITED STATES

### ALABAMA

**BIRMINGHAM, 35233**  
Carloesa Well Supply Company  
Branch Office  
2901 - 3rd Avenue, South  
Phone: (205) 324-0689  
Main Office - See Tennessee

### ALASKA

**ANCHORAGE, 99502**  
Waukesha-Alaska Corporation  
239 E. International Airport Road  
Phone: (907) 278-9651

### ARIZONA

**PHOENIX, 85005**  
Arizona Engine & Pump Co.  
P. O. Box 6159, Capital Station  
Phone: (602) 252-1731

**CASA GRANDE, 85222 - Branch Office**  
896 West Gila Bend Highway  
Phone: (602) 838-8731

### ARKANSAS

**FT. SMITH, 72901 - Branch Office**  
Waukesha-Pearce Industries, Inc.  
S. 32nd at Waco St.  
P. O. Box 6312  
Phone: (501) 646-4396

### CALIFORNIA

**EMERYVILLE, 94608**  
King-Knight Company  
6202 Christie Avenue  
Phone: (415) 658-9400

**COMPTON, 90221**  
Waukesha Engine Servicerter, Inc.  
17803 S. Santa Fe Avenue  
Phone: (213) 774-5700

**BAKERSFIELD, 93301 - Branch Office**  
1221 - 33rd Street  
Phone: (805) 327-7571

**VENTURA, 93001 - Branch Office**  
1636 N. Ventura Avenue  
Phone: (805) 648-1865

**EMERYVILLE, 94608**  
Waukesha Engine Division  
(Western Regional Office)  
1900 Powell St., Suite 455  
Phone: (415) 653-1824

### COLORADO

**DENVER, 80239**  
PAMCO  
P. O. Box 39068  
10777 East 45th Avenue  
Phone: (303) 371-0330

### FLORIDA

**FORT LAUDERDALE, 33305**  
Melley Energy Systems, Inc.  
2501 N. E. 13th Avenue  
Phone: (305) 565-5567

**JACKSONVILLE, 32205**  
Gator Service & Supply, Inc.  
5213 Edgewood Ct.  
P. O. Box 37446  
Phone: (904) 783-1280

### GEORGIA

**ATLANTA, 30315**  
Southeastern Engine & Generator, Inc.  
1170 Sylvan Rd., S.W.  
Phone: (404) 752-5188, 752-9273

**DECATUR, 30035**  
Waukesha Engine Division  
(Southeastern Regional Office)  
4336 Covington Highway  
Suite 204C  
Phone: (404) 289-0960

### ILLINOIS

**VILLA PARK, 60181**  
Charles Equipment Company  
P. O. Box 368  
187 East North Avenue  
Phone: (312) 634-6000

**GRAYVILLE, 62844**  
Oil Field Motor Service, Inc.  
P. O. Box 98  
Phone: (618) 375-2151

### INDIANA

**INDIANAPOLIS, 46202**  
Eagle Machine Company, Inc.  
P. O. Box 88  
635 East Market Street  
Phone: (317) 637-2521

### IOWA

**WATERLOO, 50704**  
Lewis Motor Supply Inc.  
1801 Washington Street  
P. O. Box 328  
Phone: (319) 235-1481

### KANSAS

**KANSAS CITY, 66103**  
AAA Engine & Electric, Inc.  
700 Southwest Blvd.  
Phone: (913) 236-8971

**GREAT BEND, 67530**  
PAMCO - Branch Office  
714 Patton Road  
Phone: (316) 793-3553  
Main Office - See Colorado

**LIBERAL, 67901**  
PAMCO - Branch Office  
210 Country Estates Road  
Phone: (316) 624-5674  
Main Office - See Colorado

### KENTUCKY

**LOUISVILLE, 40203**  
Atlas Machine & Supply Inc.  
1328 West Jefferson  
Phone: (502) 584-7262

### LOUISIANA

**HARVEY, 70059**  
Reagan Equipment Company  
P. O. Drawer 628  
2230 Peters Road  
Phone: (504) 367-1870

**MORGAN CITY, 70380 - Branch Office**  
P. O. Drawer 2487  
Highway 90 East  
Phone: (504) 631-0321

**VADALIA, 71373 - Branch Office**  
P. O. Box 914  
Highway 84 West  
Phone: (318) 336-7161

**NEW IBERIA, 70560**  
Waukesha-Pearce Industries, Inc.  
Branch Office  
P. O. Box 938  
939 Jane Street  
Phone: (318) 369-3741  
Main Office - See Texas

**SHREVEPORT, 71107**  
Waukesha-Pearce Industries, Inc.  
Branch Office  
P. O. Box 7066  
1815 Barton Drive  
Phone: (318) 221-4075  
Main Office - See Texas

### MASSACHUSETTS

**ALLSTON, BOSTON, 02134**  
W. A. Kraft Corporation  
308 North Harvard Street  
Phone: (617) 782-0076

### MICHIGAN

**NOVI, 48050**  
Engine Supply  
P. O. Box 437  
44455 Grand River  
Phone: (313) 349-9330

**SOUTHFIELD, 48076**  
Waukesha Engine Division  
Dresser Industries, Inc.  
(Central Regional Office)  
29433 Southfield Rd., Suite 102  
Phone: (313) 557-2470

### MINNESOTA

**SOUTH ST. LOUIS PARK, 55426**  
Jefico Power Systems  
2238 Florida Avenue S.  
Phone: (612) 546-5566

### MISSISSIPPI

**HEIDELBERG, 39439**  
Reagan Equipment Co. - Branch Office  
P. O. Box 285  
Highway 28 West  
Phone: (601) 787-2221  
Main Office - See Louisiana

**JACKSON, 39208**  
Reagan Equipment Co. - Branch Office  
P. O. Drawer 5700  
Highway 80 East  
Phone: (601) 939-4512  
Main Office - See Louisiana

### MISSOURI

**ST. LOUIS, 63118**  
Charles Equipment Company  
3100 Gravois Avenue  
Phone: (314) 771-4700

### NEW JERSEY

**CARLSTADT, 07072**  
W. A. Kraft Corporation - Branch Office  
485 Washington Avenue  
Phone: (201) 933-5151  
(212) 868-0135  
Main Office - See Massachusetts

### RIDGEWOOD, 07451

Waukesha Engine Division  
(Northeastern Regional Office)  
1156 East Ridgewood Avenue  
Phone: (201) 652-4808

### NEW MEXICO

**FARMINGTON, 87401**  
PAMCO - Branch Office  
P. O. Box 1558  
218 Airport Drive  
Phone: (505) 325-7529  
Main Office - See Colorado

### HOBBBS, 88240

Waukesha-Pearce Industries, Inc.  
Branch Office  
P. O. Box 488  
2601 West Marland  
Phone: (505) 393-9135  
Main Office - See Texas

## WAUKESHA VC SERIES

### NEW YORK

SYRACUSE, 13202  
Power Plant Equipment Corp.  
823 S. Salina Street  
Phone: (315) 475-7251

LATHAM, 12110  
Power Plant Equipment Corp.  
6 Northway Lane  
Phone: (518) 783-1991

TONAWANDA, 14150  
Ronco Power Systems  
695 Sheridan Drive  
Phone: (716) 873-0760

### NORTH DAKOTA

WILLISTON, 58801  
PAMCO - Branch Office  
P. O. Box 1147  
Highway 2 North  
Phone: (701) 572-6343  
Main Office - See Colorado

### OHIO

YOUNGSTOWN, 44508  
Power Equipment, Inc.  
168 South Meridian Road  
Phone: (216) 792-1475

COLUMBUS, 43219 - Branch Office  
P. O. Box 19085  
889 N. 22nd Street  
Phone: (614) 253-2711

### OKLAHOMA

WOODWARD, 73801  
Waukesha-Pearce Industries, Inc.  
Branch Office  
P. O. Box 1038  
Martin Road  
Phone: (405) 256-7421  
Main Office - See Texas

OKLAHOMA CITY, 73111  
Waukesha-Pearce Industries, Inc.  
Branch Office  
5800 N. Eastern Avenue  
P. O. Box 11196  
Phone: (405) 424-1466  
Main Office - See Texas

### OREGON

PORTLAND, 97210  
I-D, Inc.  
P. O. Box 10124  
2355 N. W. Quimby Avenue  
Phone: (503) 226-7966

### PENNSYLVANIA

PHILADELPHIA, 19134  
North American Engines Co., Inc.  
3219 "B" Street  
Phone: (215) 423-3700

PITTSBURGH, 15234  
P. C. McKenzie Company  
3561 Valley Drive  
Phone: (412) 833-2100

### SOUTH CAROLINA

CHARLESTON, 29405  
Diesel Engineers, Inc.  
2025 Austin Avenue  
P. O. Box 4398  
Phone: (803) 554-5151

### TENNESSEE

MEMPHIS, 38105  
Carlross Well Supply Company  
111 North Parkway Avenue  
Phone: (901) 526-1141

NASHVILLE, 37213 - Branch Office  
101 South First Street  
Phone: (615) 254-1669

### TEXAS

HOUSTON, 77035  
Waukesha-Pearce Industries, Inc.  
P. O. Box 35068  
12320 South Main Street  
Phone: (713) 723-1050

AHLENE, 79604 - Branch Office  
P. O. Box 1962  
3542 S. Treadaway  
Phone: (915) 892-4045

CORPUS CHRISTI, 78408 - Branch Office  
P. O. Box 9267  
5226 Frontage Road I-37  
Phone: (512) 884-8275

IRVING, 75060 - Branch Office  
P. O. Box 365  
525 North Loop 12  
Phone: (214) 259-1581

KILGORE, 75662 - Branch Office  
P. O. Box 1185  
Industrial Blvd.  
Phone: (214) 984-2011

ODESSA, 79760 - Branch Office  
P. O. Box 3549  
1000 West 2nd Street  
Phone: (915) 332-9106

PAMPA, 79066 - Branch Office  
P. O. Box 1976  
201 N. Price Road  
Phone: (806) 689-3251

SAN ANTONIO, 78217 - Branch Office  
8602 N. New Braunfels  
Phone: (512) 824-7256

SAN JUAN, 78589 - Branch Office  
P. O. Box 246  
Phone: (512) 787-4231

WICHITA FALLS, 76307 - Branch Office  
P. O. Box 2185  
4725 Jacksboro Highway  
Phone: (817) 767-9234

HOUSTON, 77027  
Waukesha Engine Division  
(Mid-Continent Regional Office)  
1535 West Loop South  
410 Honeywell Building  
Phone: (713) 626-0255

### UTAH

SALT LAKE CITY, 84115  
Diesel Electric Service & Supply  
P. O. Box 15858  
652 W. 17th Street, South  
Phone: (801) 972-1838

VERNAL, 84078  
PAMCO - Branch Office  
P. O. Box 400  
Highway 40 East  
Phone: (801) 769-3383  
Main Office - See Colorado

### VIRGINIA

HERNDON, 22070  
North American Engines Co., Inc. Branch Office  
13835 Redskin Drive  
Phone: (703) 471-5481  
Main Office - See Pennsylvania

### WASHINGTON

SEATTLE, 98107  
Kem Equipment, Inc.  
4301 Leary Way, N. W.  
Phone: (206) 784-2372

### WISCONSIN

APPLETON, 54911  
Arthur G. Dietrich Co., Inc.  
641 Hickory Farm Lane  
Phone: (414) 731-6666

MILWAUKEE, 53217  
Arthur G. Dietrich Co., Inc.  
8035 N. Port Washington Road  
Phone: (414) 352-7452

WAUKESHA, 53156  
Waukesha Engine Division  
Main Office  
P. O. Box 379  
1000 West St. Paul Avenue  
Phone: (414) 547-3311

### WYOMING

CASPER, 82601  
PAMCO - Branch Office  
P. O. Drawer 2795  
3400 West Yellowstone Road  
Phone: (307) 234-1548  
Main Office - See Colorado

## CANADA

### ALBERTA

EDMONTON 82 - T6E 4N6  
PAMCO, Ltd.  
P. O. Box 5798 Postal Station L  
8235 Wagner Road  
Phone: (403) 465-5371

CALGARY - T2C 1H9 - Branch Office  
8241 - 31st St., S. E.  
Phone: (403) 279-5561

REDCLIFFE - T1A 7N4 - Branch Office  
P. O. Box 1447  
No. 2 1001 Highway Avenue, N.  
Phone: (403) 548-3925

CALGARY X-T2P 0M2  
Waukesha Engine Division  
(Western Canada Regional Office)  
Aquitaine Tower, Suite 540  
540 - 5th Avenue, S. W.  
Phone: (403) 266-8666

### BRITISH COLUMBIA

NORTH VANCOUVER - V7P 1R4  
Farwest Diesel & Equipment, Ltd.  
1189 West 18th Street  
Phone: (604) 980-8394

### MANITOBA

WINNIPEG R34 0X8  
KeeWatn Electric & Diesels, Ltd.  
1040 Coulter Avenue  
Phone: (204) 772-0443

### NEW BRUNSWICK

MONCTON - E1C 8N6  
Consolidated Engines & Machinery  
Co., Ltd. - Branch Office  
146 Albert Street  
P. O. Box 848  
Phone: (506) 854-0982  
Main Office - See Quebec

### NOVA SCOTIA

HALIFAX  
Consolidated Engines & Machinery  
Co., Ltd. - Branch Office  
P. O. Box 1015, Suite 309  
The Trade Mart Building  
Scotia Square  
Phone: (902) 422-8421  
Main Office - See Quebec

### ONTARIO

TORONTO 16 - M4A 2N3  
Atlas Polar Company, Ltd.  
60 Northline Road, P. O. Box 180  
Phone: (416) 751-7740

### QUEBEC

MONTREAL H4T 1L7  
Consolidated Engines & Machinery  
Co., Ltd.  
8550 Delmeade Road  
Phone: (514) 342-9233

### SASKATCHEWAN

PAMCO Ltd. (See Alberta)

**INTERNATIONAL**

**ARGENTINA**

TIPSA—Tecnica Industrial y Comercial Petrolera, S. C. A.  
Territory: Argentina  
Cordoba 1367, 3rd Floor  
Buenos Aires, Argentina  
Phone: 42 1367 Cable: TIPSA  
  
Branch: San Martin 1002,  
Comodoro Rivadavia

**AUSTRALIA**

A. N. I. Perkins Division  
A. N. I. Australia Pty. Limited  
Territory: Australia  
16 Parramatta Road, P. O. Box 117  
Lidcombe, N. S. W., 2141, Australia  
Phone: 848-4088 Cable: PERKAUST  
SYDNEY

**AUSTRIA**

FILTOR  
Gross- und Kleinhandels-Ges. M. b. H.  
Territory: Austria  
Kaiser-Ebersdorferstrasse 254  
1110-Vienna, Austria  
Phone: (0222) 77 73 69

**BANGLADESH**

Dana Engineers, International  
Territory: Bangladesh  
67, Bangabandhu Avenue  
P. O. Box No. 914, Dacca-2  
Bangladesh  
Phone: 244028 Cable: DANARS-DACCA

**BELGIUM**

Waukesha Engine Division  
Dresser Europe S. A.  
(Brussels Regional Office)  
Boulevard Du Souverain 191-197 (B.3)  
B-1160 Brussels, Belgium  
Phone: 666.20.60 Cable: DRESSER CLARK  
  
Werkhuizen Frans Stevens N. V.  
Territory: Belgium  
Slachthuislaan-21  
2000 Antwerp  
B-Belgium  
Phone: 031-36.92.02 TELEX: 33342  
(STEVEN B)

**BOLIVIA**

Oil Industry Supply & Service Company  
Territory: Bolivia  
Calle Bueno No. 144 - Casilla 1268  
La Paz, Bolivia  
Phone: 23917 Cable: OISSCO

**COLOMBIA**

General Sales Corporation Ltda.  
Territory: Colombia - Marine Engines Only  
Air Mail Box 395  
Barranquilla, Colombia, S. A.  
Phone: 12-501 Cable: MAECO

Milchem Western Hemisphere, Inc.  
Territory: Colombia - Excluding Marine Engines  
Apartado Aereo 9313  
Bogota, D. E., Colombia  
Phone: 813704 Cable: MILCHEM

**ECUADOR**

Milchem Western Hemisphere, Inc.  
Territory: Ecuador  
Avenida de la Republica #20-50  
y 10 de Agosto, Casilla 41-43  
Quito, Ecuador  
Phone: 246-820, Cable: MILCHEM  
245-524

**EGYPT**

HCH Supply Co., Ltd.  
Territory: Arab Republic of Egypt  
110,26 July Street  
Zamalek, Cairo, Egypt  
Phone: 818721 TELEX: 2431HCH

**GREECE**

Gemco  
Stavropoulos-Leptourgos S. A.  
Territory: Greece  
24 Capodistriou St.  
Athens 208, Greece  
Phone: 21 364772 Cable: STAVROMOTORS

**GUYANA (British Guiana)**

Psaila Bros.  
Territory: Guyana  
P. O. Box 140  
Water & Holmes Streets  
Georgetown, Guyana  
Phone: 4170 Cable: PSAILA

**HONG KONG**

Gilman & Co. Ltd. Marine Department  
Territory: Hong Kong  
P. O. Box 56  
173 Gloucester Road  
Wanchai, Hong Kong  
Phone: 5-726388, 5-726387 TELEX: 83867 GILMN

**ICELAND**

Velasan, H. F.  
Territory: Iceland  
P. O. Box 1006  
Reykjavik, Iceland  
Cable: VELASAN

**INDIA**

AEICORP Private Limited  
Territory: India  
Mercantile Bldgs., 10,  
Lall Bazar Street  
Calcutta 700001, India  
Phone: 23-5120 and 23-0879  
Cable: EAGERNESS

Branch: Arun Chamber, Rm. 428 (4th Floor)  
Tardeo Rd., Bombay - 34  
Globe Agencies Chambers, HS-6,  
Kailash Colony Market, New Delhi 110048  
Central St., Haidpuri, Ranchi, Behar

**IRAN**

Shaya Co., Ltd.  
Territory: Iran  
Shaya Building, Argentine Square  
38, Alvand Street  
P. O. Box 155  
Tehran, Iran  
Phone: 685-261 to 685-265  
Cable: TEKMO SHAVER TEHRAN

**ITALY**

Eurodiesel-Milano S. R. L.  
Territory: Italy  
Via E. Cosenz 44  
Milano, Italy  
Phone: 3763450 Cable: EURODIESEL

**KUWAIT**

The Trading & Industrial Equipment Co.  
Territory: Kuwait, Iraq, & United Gulf Emirates  
P. O. Box Safat 2159  
Kuwait Town, State of Kuwait  
Phone: 819179/819188 Cable: SUCCESS - KUWAIT

Waukesha Engine Division  
Dresser Europe S. A.  
(Middle East Regional Office)  
P. O. Box Safat 2159  
Kuwait Town, State of Kuwait  
Phone: 819179/819188 Cable: SUCCESS - KUWAIT

**LEBANON**

S. Sadaka & Sons  
Territory: Lebanon, Syria, Jordan  
P. O. Box 4  
Zahle, Lebanon  
Phone: 82-00-31 TELEX: 21211

**LIBYA**

Sahara Oilfield Services Co. of Libya, Ltd.  
Territory: Libya  
Sc. Sidi Issa; P. O. Box 800  
Tripoli, Libya  
Phone: 34874/37773 Cable: SOS

**MALAYSIA**

Malayan Development Machinery SDN. BHD.  
Territory: Malaysia  
12/18 Jalan Kemajuan, Petaling Jaya  
P. O. Box 1033  
Kuala Lumpur, Selangor, Malaysia  
Phone: 51111/6 Cable: EARTHMOVE

**MAURITIUS & REUNION ISLANDS**

Robert Le Maire, Ltd.  
Territory: Mauritius & Reunion Islands  
28 Sir William Newton Street  
Port Louis, Mauritius  
Cable: ROBMER

**MEXICO**

Moto Equipos, S. A.  
Territory: Republic of Mexico (Excluding state of Sonora, state of Sinaloa up to and including Cabo Corrientes in the State of Jalisco for Marine Products Only)

Alemania 14  
Mexico 21, D. F., Mexico  
Phone: 549-32-65/66/67 Cable: MEOSA

Propulsion Industrial y Marine, S. A.  
Territory: State of Sonora, state of Sinaloa up to and including Cabo Corrientes in the State of Jalisco (Marine Engines Only)

A. Serdan y Calle 27-AP 74  
Guaymas, Sonora, Mexico  
Phone: 2-05-20

Waukesha Engine Division  
Dresser International, S. A.  
(Mexico/Central America/Caribbean Regional Offices)

Reforma 95-1101  
Mexico 1, D. F., Mexico  
Phone: 535-75-58,  
535-36-08 TELEX: 00177-2588

## WAUKESHA VC SERIES

### MOROCCO

Stanislas Jullien  
Territory: Morocco  
256 Boulevard Ba Hamad  
Casablanca, Morocco  
Cable: ORBI

### MOZAMBIQUE (Portuguese East Africa)

Santos, Marques & Silva Ltda.  
Territory: Mozambique  
Rua da Electricidade 9 a 11  
Lourenco Marques, Mozambique  
Cable: ELECTRO

### NETHERLANDS

Landre & Glinderman, N.V.  
Division Landre Ruhaak Motoren  
Territory: Netherlands (Industrial Gas and  
Diesel Products Only)  
P. O. Box 63  
Industrieweg, 30  
Vianen (Z.H.) 2620, The Netherlands  
Phone: 3473-3044 Cable: LANDREMAN  
Branch: Rotterdam; Hengelo

Laan & Kooy Technische Handelmaatschappij BV  
Territory: The Netherlands (Marine Products Only)  
Zwinstraat 46  
Den Oever, Holland  
Phone: 02271-841

### NEW ZEALAND

Motor Specialties Limited  
Territory: New Zealand  
80-86 Anzac Avenue, P.O. Box 3201  
Auckland 1, New Zealand  
Phone: 71-679 Cable: MOTOSPECS

### NICARAGUA

Casa Comercial McGregor, S.A.  
Territory: Nicaragua  
3a. Calle S.E. No. 104; Aptdo. 448  
Managua, Nicaragua  
Phone: 2-1311 Cable: MCGREGOR

### NIGERIA

Allied Oilfield Services, Ltd.  
Territory: Nigeria  
39, Norman Williams Street  
S.W. Ikoyi  
P.O. Box 7403  
Lagos, Nigeria  
Phone: 22863/27469/  
56068 Cable: OILTOOLS

### NORWAY

Sverre Nilsen, Jr. A/S  
Territory: Norway  
Prinsengt, 3B  
P.O. Box 655/8 - Sentrum  
Oslo 1, Norway  
Phone: (02) 41 85 80 Cable: MOTORNILSEN

### PAKISTAN

Brentford, Yusuf & Company Limited  
Territory: Pakistan  
'Canaan', 4-B, Lalazar  
P.O. Box No. 4327  
Karachi, Pakistan  
Phone: 230029 Cable: BRENTICO  
Branch: P.O. Box 85, The Mall, Lahore

### PORTUGAL

Motodiesel Limitada  
Territory: Portugal  
Rua de Sao Paulo 246, 1°  
Apartado 2053  
Lisbon, Portugal  
Phone: 32 39 38 Cable: MOTODIESEL

### PUERTO RICO & VIRGIN ISLANDS

West India Machinery & Supply Company  
Territory: Puerto Rico and Virgin Islands  
Roosevelt Avenue at 26th Street  
G. P. O. Box 4308  
San Juan, Puerto Rico 00936  
Phone: 782 2850 Cable: WIMSCO

### SAUDI ARABIA

Abdullah Ibrahim Alkhorayef  
Territory: Saudi Arabia  
P.O. Box 305  
Riyadh, Saudi Arabia  
Phone: 51479, Cable: AL-KHORAYEF  
51480

### SINGAPORE

Avery-Laurence Equipment PTE, Ltd.  
Territory: Singapore, Indonesia, Brunei &  
Burma, Petroleum Products Only  
8th Floor, Cathay Building  
P.O. Box 190  
Singapore 9  
Phone: 324121 Cable: AVLAU  
Branch: 22nd Floor, Prince's Building  
G.P.O. Box 690, Hong Kong

Waukesha Engine Division  
Dresser Industries, Inc.  
(Singapore Regional Office)  
358 Orchard Rd.  
1st Floor, Lido Theatre Building  
Singapore 9  
Phone: 370-888  
Cable: WAUKASIA SINGAPORE

### SPAIN

Iberdiesel/Navalux S.A.  
Territory: Spain, including Majorca,  
Ibiza, & Canary Islands  
Honduras, 4 1°  
Madrid (16), Spain  
Phone: 457 56 62 TELEX: 42237 NAIB

### SUDAN

The New Plant Equipment Company  
Territory: Sudan  
P.O. Box 2221, 865  
Khartoum, Sudan  
Phone: 71275 - 72565 Cable: PLECOY

### TAIWAN (Republic of China)

William Hunt & Co. (Int'l.) Inc.  
Territory: Taiwan, Republic of China  
8th Floor, Lung-Men Building  
128 Chung Hsiao East Road, Sec. 4  
Taipei, Taiwan, Republic of China  
Phone: 721-9711/9713/9716 Cable: WILHUNT

### TRINIDAD & TOBAGO, B.W.I.

Engineering Services & Supply Co., Ltd.  
Territory: Trinidad and Tobago  
Lady Hailes Avenue  
P.O. Box 104  
San Fernando, Trinidad  
Phone: 77355 Cable: ESSCOL

### TURKEY

OBA Automotive & Mining Co. Ltd.  
Territory: Turkey  
Vali Dr. Resit Cad. 40/2  
Cankaya, Ankara, Turkey  
Phone: 27-10-28,  
27-79-52 TELEX: 42835

### UNITED ARAB EMIRATES

The Trading & Industrial Equipment Co.  
P.O. Box 5291 Deira  
Dubai, United Arab Emirates  
Phone: 26255 Cable: TIECO-DUBAI

### UNITED KINGDOM

Daegam Ltd.  
Applied Energy Systems  
Territory: United Kingdom, Northern and  
Republic of Ireland  
1 Whippendell Road  
Watford Herts WD1 7LZ, England  
Phone: Watford 42222 TELEX: 935926

### WEST GERMANY

Industrie & Schiffstechnik  
Territory: West Germany  
2000 Hamburg-Schnefeld  
Osterbrookweg, 21  
P.O. Box 1365  
West Germany  
Phone: 40 830 5041 Telex: 0212635

### VENEZUELA

Bompert de Venezuela C.A.  
Territory: Venezuela  
Apartado 749  
Maracaibo, Venezuela  
Phone: 71163 Cable: USIVEN

Dresser International S.A.  
Waukesha Engine Division  
(South American Regional Office)  
Bompert de Venezuela, C.A.  
Edificio Acacias, Planta Baja Of. No. 7  
Avenida Rio Paragua, Complejo Prado Humboldt  
Prados Del Este, Caracas 108, Venezuela  
Phone: 978-03-68,  
978-21-46 TELEX: 395-232-67

### YUGOSLAVIA

Stojan International  
Territory: Yugoslavia  
Trattnerhof 2, Postfach 12  
1014 Vienna, Austria  
Phone: 52 75 53 TELEX: 01-1675

**Waukesha** **DRESSER**