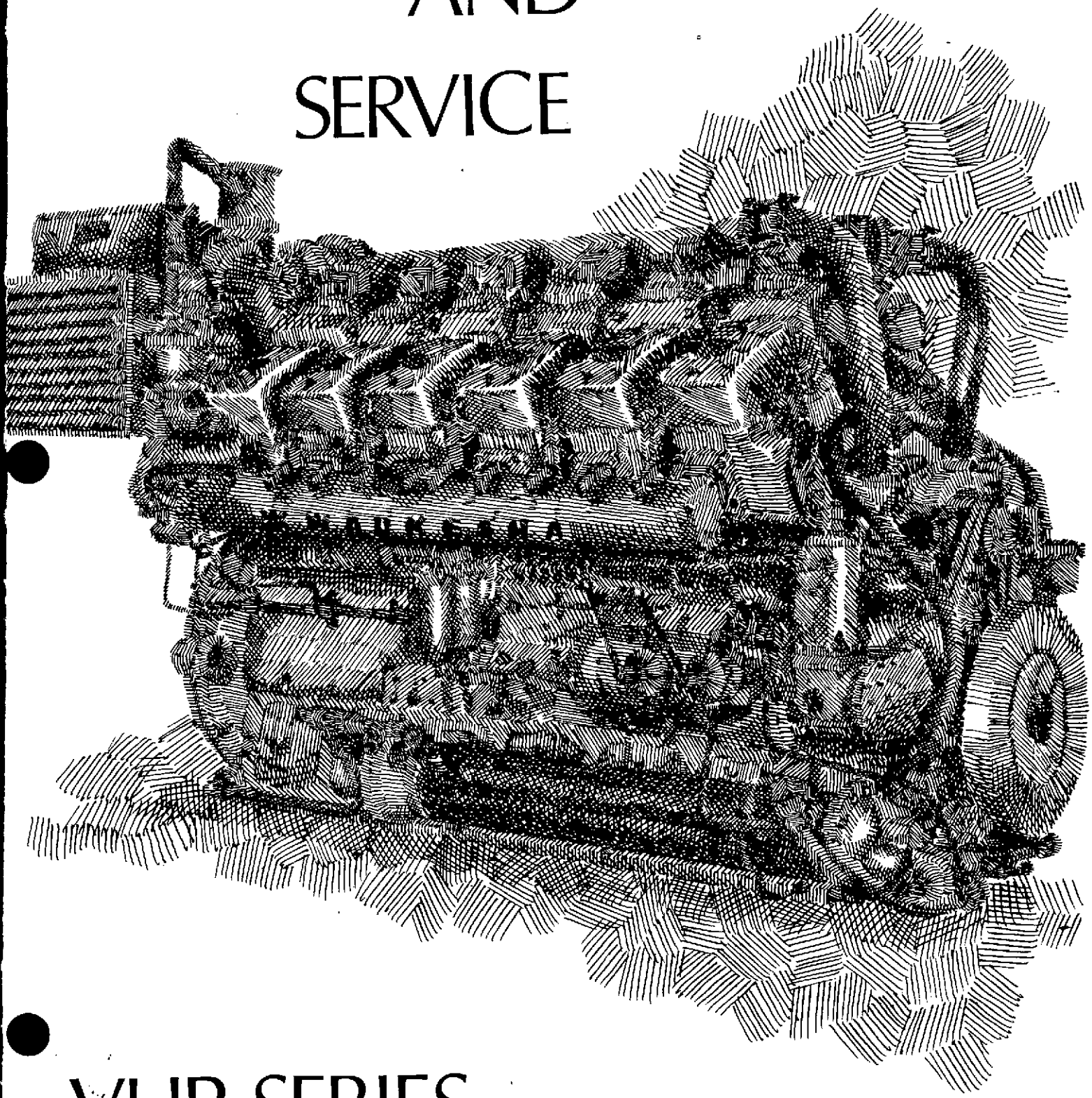
OPERATION AND SERVICE



VHP SERIES

WANTED!

ENGINE POPULATION INFORMATION

To help provide proper backup parts stock and availability at Distributor and Factory levels, it is important that we have information of your engine's location and application. We would appreciate it if you would supply us with the necessary information requested below. A complimentary gift will be forwarded upon receipt of card.

Name & Title _____ Company Name _____

Engine Purchased From _____

Model _____ Serial No. _____ (G) Specification No. _____

Type Service (Use, Equipment, etc)

☐ Standby ☐ Continuous ☐ Intermittent

Please List Any Other Waukesha Engines You Own Or Service

Model	Serial No.	Type Service

Name & Title _____ Company Name _____

Engine Purchased From _____

Model _____ Serial No. _____ (G) Specification No. _____

Type Service (Use, Equipment, etc)

☐ Standby ☐ Continuous ☐ Intermittent

Please List Any Other Waukesha Engines You Own Or Service

Model	Serial No.	Type Service

First Class
Permit No. 903
Waukesha, Wi.

BUSINESS REPLY MAIL
No postage stamp necessary if mailed in this United States

POSTAGE WILL BE PAID BY

Waukesha Engine Division
Dresser Industries, Inc.
Parts Marketing Department
P.O. Box 379
Waukesha, Wisconsin 53186

First Class
Permit No. 903
Waukesha, Wi.

BUSINESS REPLY MAIL
No postage stamp necessary if mailed in this United States

POSTAGE WILL BE PAID BY

Waukesha Engine Division
Dresser Industries, Inc.
Parts Marketing Department
P.O. Box 379
Waukesha, Wisconsin 53186

OPERATION AND SERVICE MANUAL

WAUKESHA VHP SERIES GAS AND DIESEL ENGINES

F2895G
F2895D
F2896D
F3521G
L5108G
L5790G
L5790D
L5792D
L7042G

Waukesha | DRESSER

PRINTED IN U. S. A. 10/77 3M-HL

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 Distilate. 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 accidently 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.

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.

DISTRIBUTORS AND SERVICE

The Waukesha Engine Division 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 Division, 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 Engine Division 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 the Waukesha Engine Division 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.

Distributor Directory

UNITED STATES

ALABAMA

BIRMINGHAM, 35233
Carloss 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 Servicenter, 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

JACKSONVILLE, 32205
Gator Service & Supply, Inc.
5213 Edgewood Ct.
P.O. Box 37446
Phone: (904) 783-1280

POMPANO BEACH, 33061
Melley Energy Systems, Inc.
P.O. Box 999
941 S.W. 12th Avenue
Phone: (305) 941-0200

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) 834-6000

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, 70058
Reagan Equipment Company
P.O. Drawer 628
2230 St. Joseph Lane
Phone: (504) 367-1870

MORGAN CITY, 70380 - Branch Office
P.O. Drawer 2487
Highway 90 East
Phone: (504) 631-0321

VIDALIA, 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 7068
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, 48075
Waukesha Engine Division
Dresser Industries, Inc.
(Central Regional Office)
29433 Southfield Rd., Suite 102
Phone: (313) 557-2470

MINNESOTA

SOUTH ST. LOUIS PARK, 55426
Jeffco 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

HOBBS, 88240
Waukesha-Pearce Industries, Inc.
Branch Office
P.O. Box 488
2601 West Marland
Phone: (505) 393-9135

Main Office - See Texas

5/15/77

NEW YORK

SYRACUSE, 13202
Power Plant Equipment Corp.
929 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
595 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, 44509
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

NORTH ROYALTON, 44133 - Branch Office
10156 Royalton Road
Phone: (216) 237-1818

OKLAHOMA

WOODWARD, 73801
Waukesha-Pearce Industries, Inc.
Branch Office
P.O. Box 1086
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) 424-1468

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
Carloss 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

ABILENE, 79604 - Branch Office
P.O. Box 1982
3542 S. Treadaway
Phone: (915) 692-4045

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) 669-3251

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) 972-1836

VERNAL, 84078
PAMCO - Branch Office
P.O. Box 400
Highway 40 East
Phone: (801) 789-3383

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, 53186
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) 548-3935

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 16th Street
Phone: (604) 980-8394

MANITOBA

WINNIPEG R34 0X8
Keewatin 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
Station "O", P.O. Box 160
Phone: (416) 751-7740

QUEBEC

MONTREAL H4T 1L7
Consolidated Engines & Machinery
Co., Ltd.
8550 Delmeade Road
Phone: (514) 342-9233

LORETTEVILLE G2A AT2
Consolidated Engines & Machinery
Co., Ltd.
38, Louis Hebert
Phone: (418) 842-8531

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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: 648-4088 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: 660.20.60 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, 245-524 Cable: MILCHEM

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
178 Gloucester Road
Wanchai, Hong Kong
Phone: 5-726386, 5-726387 TELEX: 83667 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., Hindpiri, Ranchi, Behar

IRAN

Shaya Co., Ltd.
Territory: Iran
Shaya Building, Argentine Square
38, Alvand Street
P. O. Box 155
Tehran, Iran
Phone: 685-281 to 685-285
Cable: TEKMOSHAVER 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, Pakistan
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 4544
Kuwait Town, State of Kuwait
Phone: 412120/412124 Cable: DRESSERIND–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
26 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)
Dinamarca 85-4 Piso
Mexico 6, D. F., Mexico
Phone: (905) 533-0809 TELEX: 00177-2588

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MOROCCO

Stanislas Jullien
Territory: Morocco
256 Boulevard Ba Hamad
Casablanca, Morocco
Cable: ORBI

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 45
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 655/6 - 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: 77275 - 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

THAILAND

East Asia International Co., Ltd.
Territory: Thailand
142 N. Sathon Road
Bangkok, Thailand
Phone: 34595/36202 Cable: EASIAINCO

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: 42535

UNITED ARAB EMIRATES

The Trading & Industrial Equipment Co.
P. O. Box 5291 Deira
Dubai, United Arab Emirates
Phone: 26255 Cable: TIECO-DUBAI

UNITED KINGDOM

Dnegam 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-Schenefeld
Osterbrooksweg, 21
P. O. Box 1365
West Germany
Phone: 40 830 5041 Telex: 0212635

VENEZUELA

Bompet 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)
Bompet 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 58 TELEX: 01-1675

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Waukesha DRESSER

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 NEG*LIGENCE AND STRICT LIABILITY) OF OTHER THEORIES, MUST BE COMMENCED WITHIN ONE (1)* YEAR AFTER THE CAUSE OF ACTION ACCRUES OR IT SHALL BE BARRED.

INTRODUCTION

Waukesha VHP engines are intended for use in very high power applications. They are four stroke cycle, medium speed, overhead valve engines, available as six cylinder in-line or as twelve cylinder 60° Vee versions, gas or diesel fueled, naturally aspirated or turbocharged.

The information in this manual has been written in an easy to read style and arranged in a time saving manner to provide factual technical information for Waukesha VHP engines. The common construction features of these engines makes it convenient to operate and service any engine in the series through the use of this manual. Differences in procedures due to fuel use, aspiration, and in-line or Vee type construction will be pointed out as needed. Overhaul instructions are not included, except where certain special procedures are required. SPECIFICATIONS information, located in the REPAIR AND REPLACEMENT UNIT, will allow a competent mechanic to determine when parts are no longer usable.

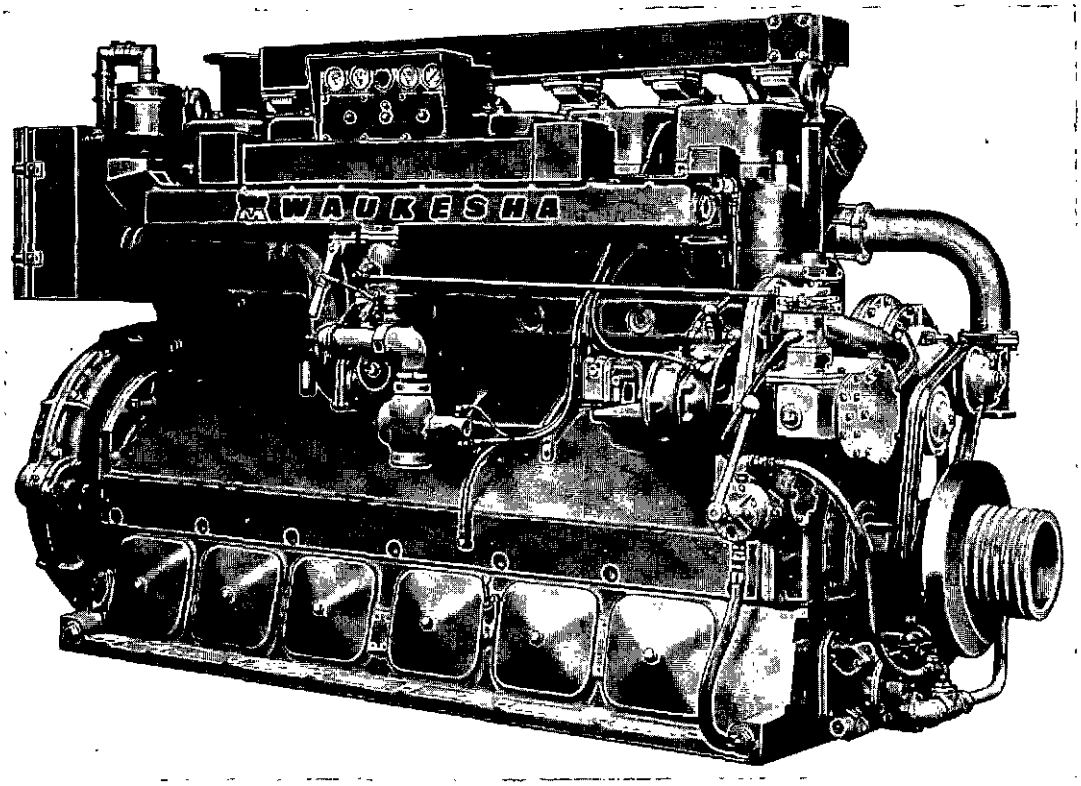
All tabular data and recommendations contained in this manual represent the latest information available at the time of printing, and are of course subject to change.

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

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

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

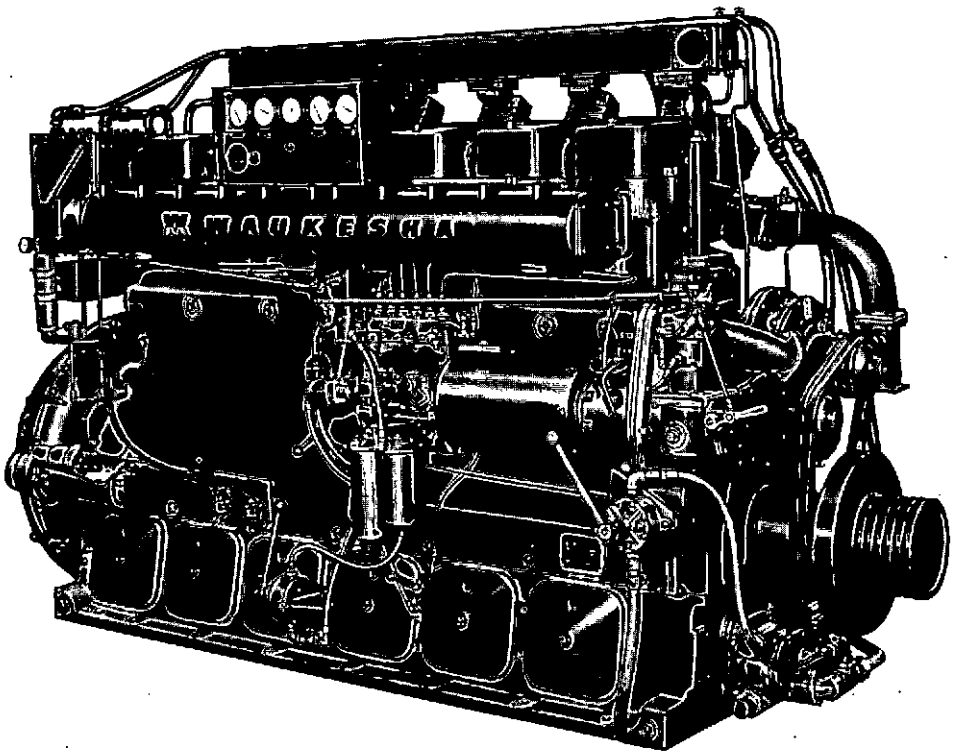
NOTE . . . . . This symbol preceeds information which is vital to the operation or maintenance of the engine.



F2895G illustrated MH-001-161

F2895G - F3521G SERIES NATURAL OR LIQUIFIED PETROLEUM (LPG) GAS FUEL ENGINES

ENGINE MODEL SERIES		F2895G	F3521G
Displacement	cu. in. liters	2894 47,4	3520 57,7
Bore	inches mm	8-1/2 216	9-3/8 238
Stroke	inches mm	8-1/2 216	8-1/2 216
Speed Range	rpm	450-1200	450-1200
Maximum Continuous Horsepower - Turbocharged 85° Intercooler Water In		570 @ 1200 rpm	694 @ 1200 rpm
Normal Oil Pressure	psi	45 ± 5	45 ± 5
Oil Temperature	°F °C	185° 85°	185° 85°
Normal Coolant Temperature Out of Engine	°F °C	180° 82°	180° 82°
Standard Spark Plug		Waukesha 69512 - Gap .015	

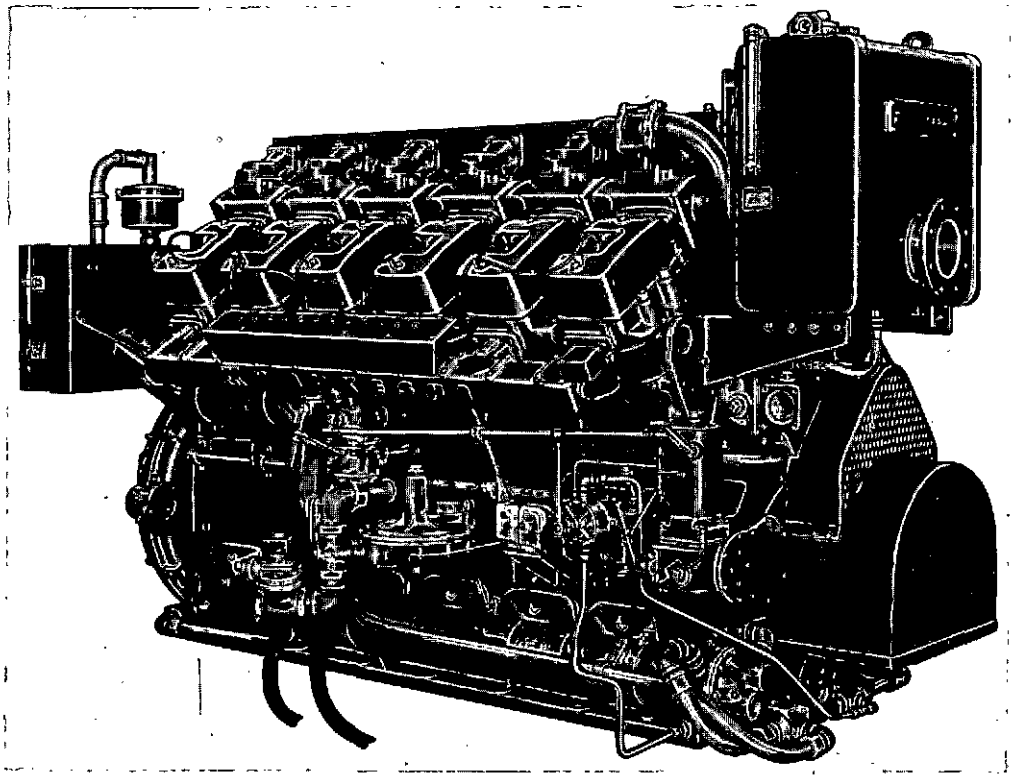


F2896DSI illustrated

MH-001-35

F2895D - F2896D SERIES DIESEL FUEL ENGINES

ENGINE MODEL SERIES		F2895D - F2896D
Displacement	cu. in. liters	2894 47,4
Bore	inches mm	8-1/2 216
Stroke	inches mm	8-1/2 216
Speed Range	rpm	450-1200
Maximum Continuous Horsepower - Turbocharged 85° Intercooler Water In		702 @ 1200 rpm
Normal Oil Pressure	psi	45 ± 5
Oil Temperature	°F °C	185° 85°
Normal Coolant Temperature Out of Engine	°F °C	180° 82°

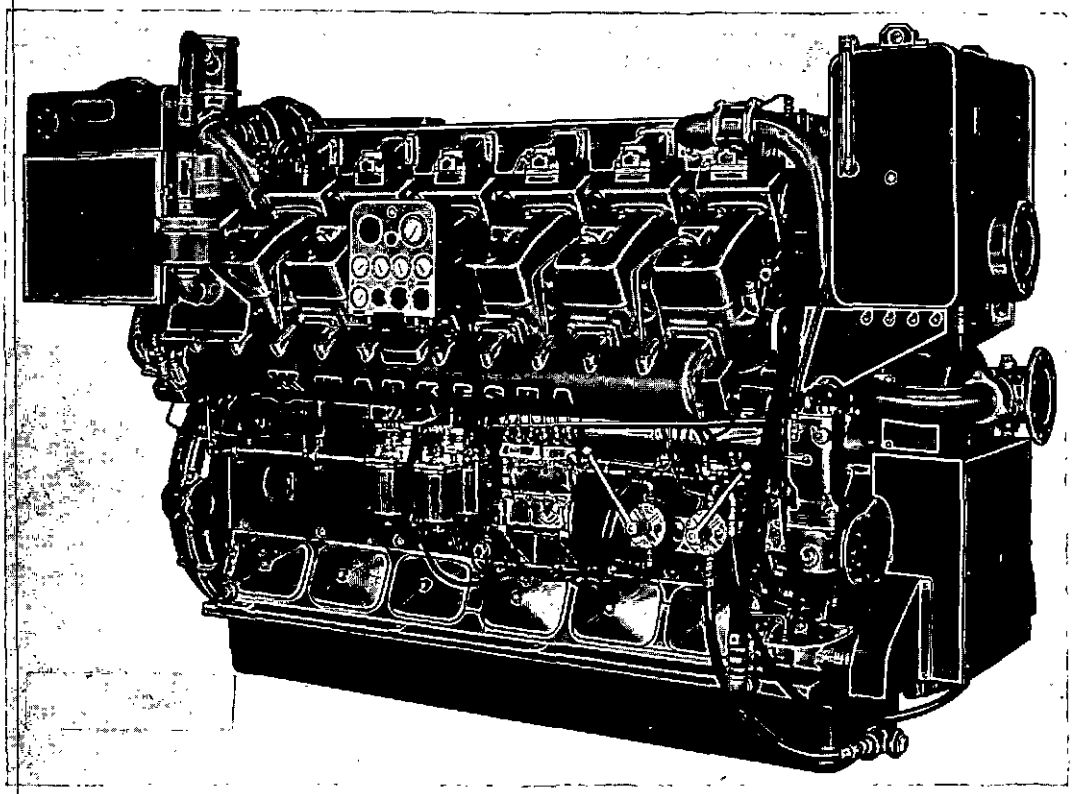


L5790G illustrated

MH-001-32

L5108G - L5790G - L7042G SERIES NATURAL OR LIQUIFIED PETROLEUM (LPG) GAS FUEL ENGINES

ENGINE MODEL SERIES		L5108G	L5790G	L7042G
Displacement	cu. in. liters	5100 83,6	5788 94,9	7040 115,4
Bore	inches mm	8-1/2 216	8-1/2 216	9-3/8 238
Stroke	inches mm	7-1/2 190,5	8-1/2 216	8-1/2 216
Speed Range	rpm	450-1200	450-1200	450-1200
Maximum Continuous Horsepower - Turbocharged 85° Intercooler Water In		1006 @ 1200 rpm	1140 @ 1200 rpm	1387 @ 1200 rpm
Normal Oil Pressure	psi	45 ± 5	45 ± 5	45 ± 5
Oil Temperature	°F °C	185 88	185° 88°	185° 88°
Normal Coolant Temperature	°F °C	180 85	180° 85°	180° 85°
Standard Spark Plug			Waukesha 69512 - Gap .015	



L5792DSI MARINE illustrated

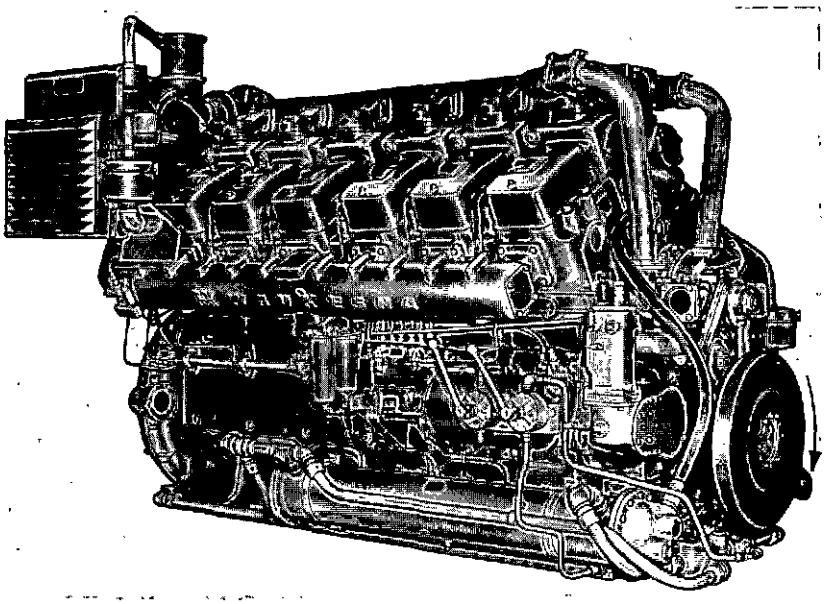
MH-001-29

L5790D - L5792D SERIES DIESEL FUEL ENGINES

ENGINE MODEL SERIES		L5790D - L5792D
Displacement	cu. in. liters	5788 94,9
Bore	inches mm	8-1/2 216
Stroke	inches mm	8-1/2 216
Speed Range	rpm	450-1200
Maximum Continuous Horsepower - Turbocharged 85° Intercooler Water In		1403 @ 1200 rpm
Normal Oil Pressure	psi	45 ± 5
Oil Temperature	°F °C	185° 85°
Normal Coolant Temperature	°F °C	180° 82°

ENGINE REFERENCE POINTS

REAR
flywheel end

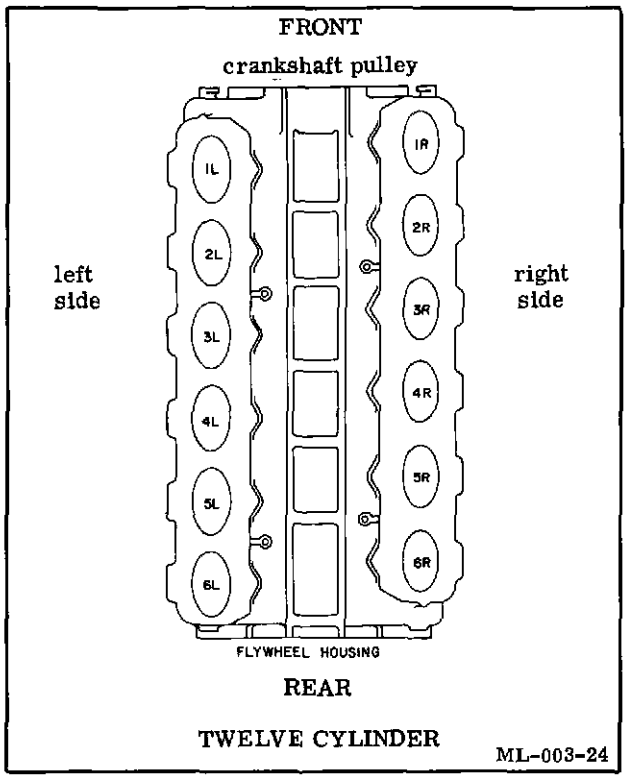


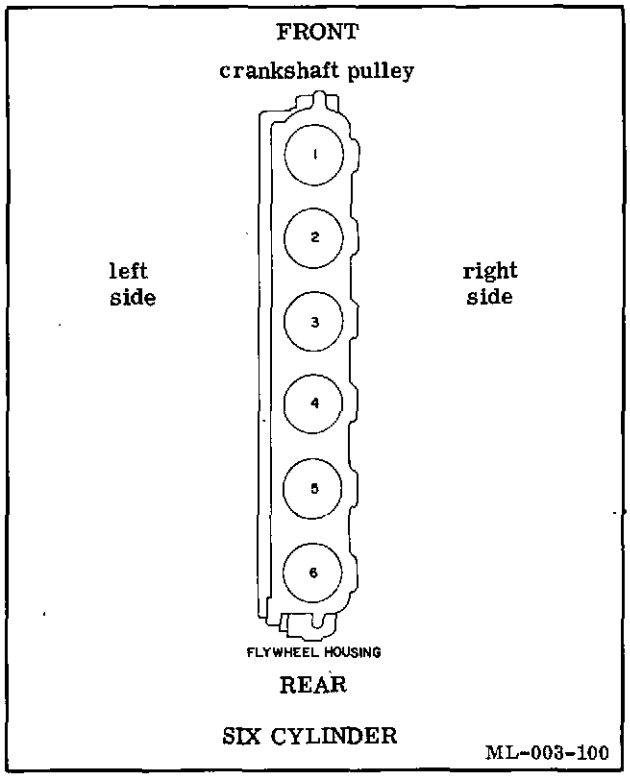
FRONT
crankshaft pulley end

STANDARD
ROTATION

MH-001-28

CYLINDER NUMBERING - Cylinders are numbered consecutively from one to six (on both right and left banks, Vee engines) starting from the front of the engine.





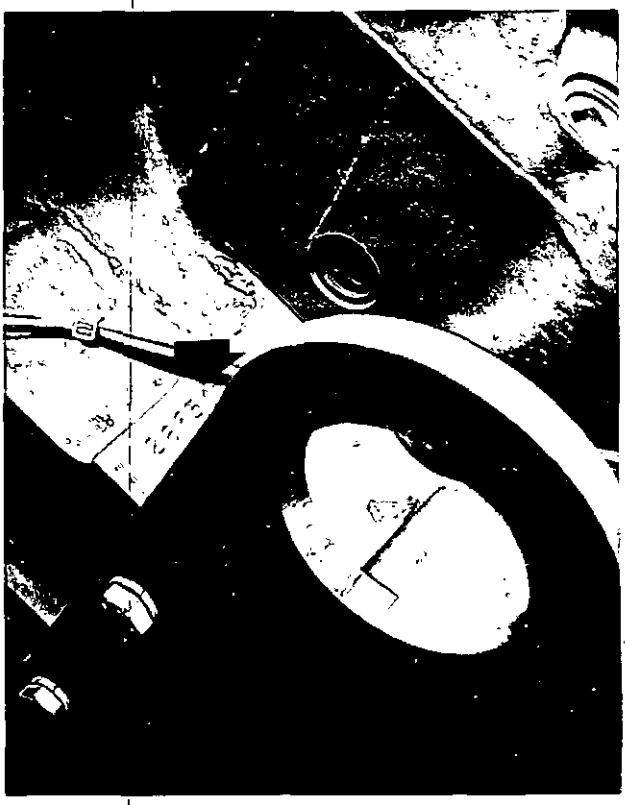
FIRING ORDER:

SIX CYLINDER - 1 5 3 6 2 4 (Standard Rotation)
- 6 3 5 1 4 2 (Opposite Rotation)

TWELVE CYLINDER - 1R 6L 5R 2L 3R 4L 6R 1L 2R 5L 4R 3L (Standard Rotation)
- 1L 6R 4L 3R 2L 5R 6L 1R 3L 4R 5L 2R (Opposite Rotation)

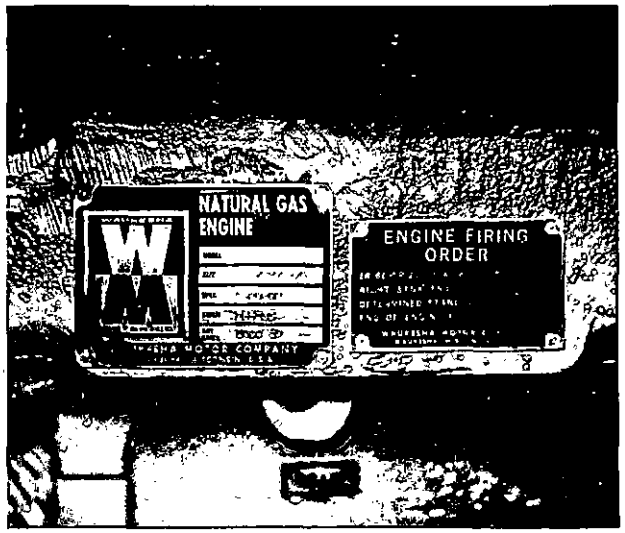
MODEL, SERIAL, AND SPECIFICATION NUMBERS

The model, serial, and specification numbers are stamped on the name plate. The name plate is located on the cylinder block, toward the left front side on twelve cylinder engines, and the center right side on six cylinder engines. The serial number is also stamped on the cylinder block, above the name plate pad on six cylinder models, and on the top of the cylinder block in front of the number one left cylinder head on the twelve cylinder models.



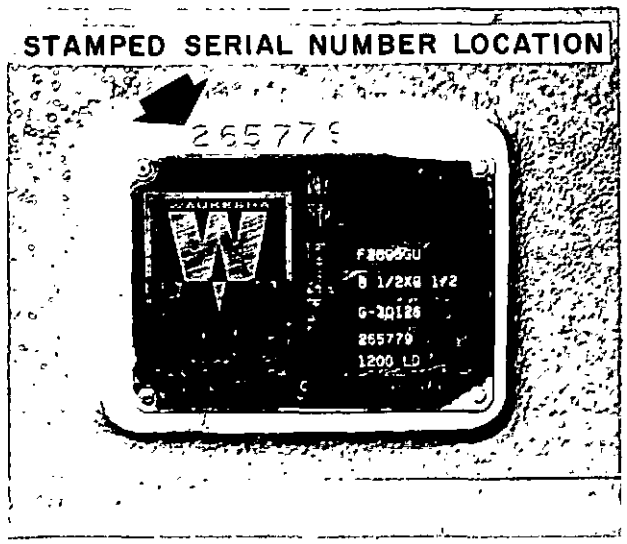
MH-16-7

STAMPED SERIAL NUMBER LOCATION — TWELVE CYLINDER



MH-16-5

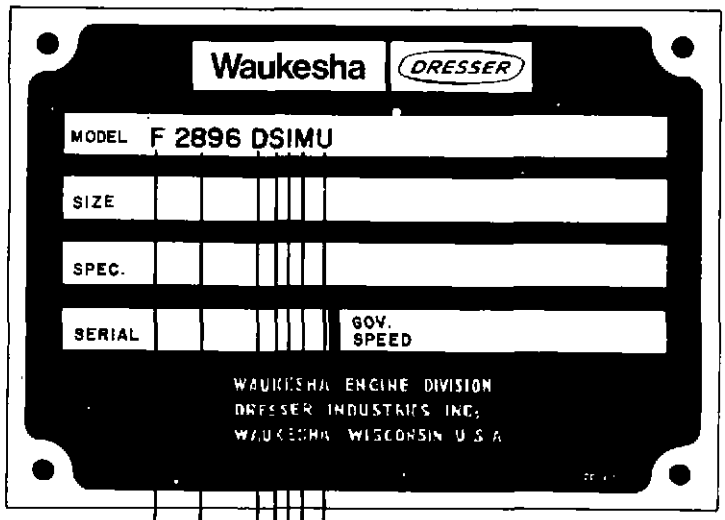
NAME PLATE TWELVE CYLINDER LOCATION



MH-16-4

NAME PLATE LOCATION — SIX CYLINDER

UNDERSTANDING WAUKESHA MODEL DESIGNATIONS



ML-16-9

Number of cylinders, F = 6, L = 12

Displacement in cubic inches (nominal)

Type of fuel, G = Gas, D = Diesel

Turbo-supercharged

Intercooler equipped

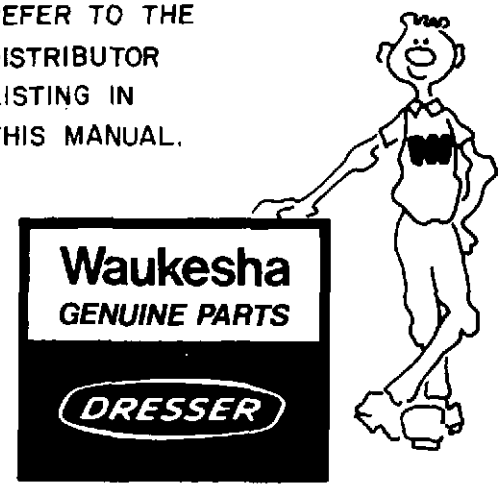
Marine equipped

Power unit

OPERATION

PARTS ORDERING

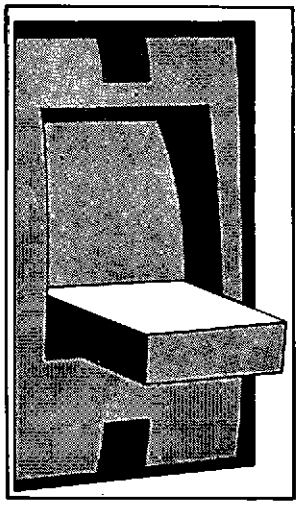
GENUINE WAUKESHA PARTS ARE AVAILABLE WORLDWIDE AND MUST BE ORDERED THROUGH YOUR LOCAL WAUKESHA DISTRIBUTOR. FOR THE DISTRIBUTOR CLOSEST TO YOU, *REFER TO THE* DISTRIBUTOR LISTING IN THIS MANUAL.



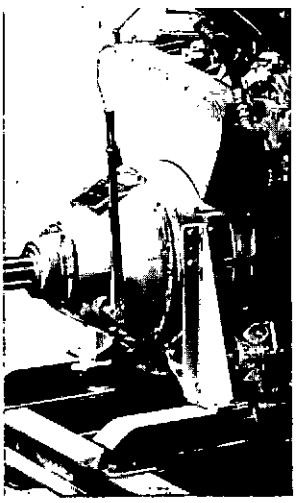
ML-1000-30

BEFORE STARTING

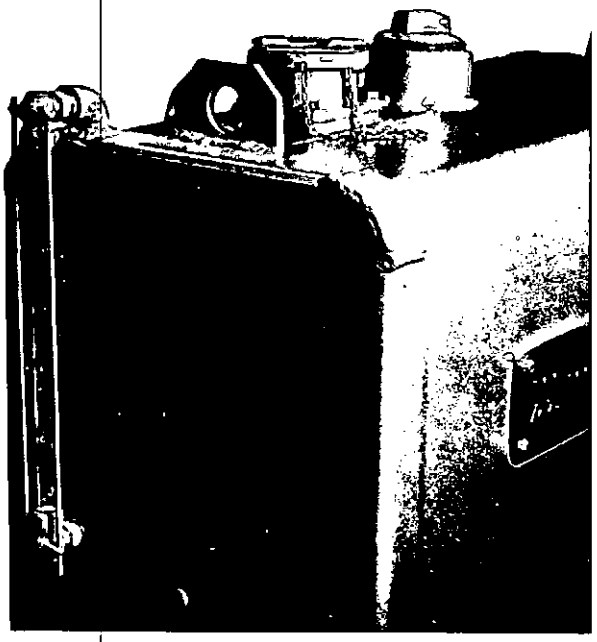
Be sure that the clutch, circuit breaker, or other main power transmission device is disconnected.



ML-500-49



MH-001-151

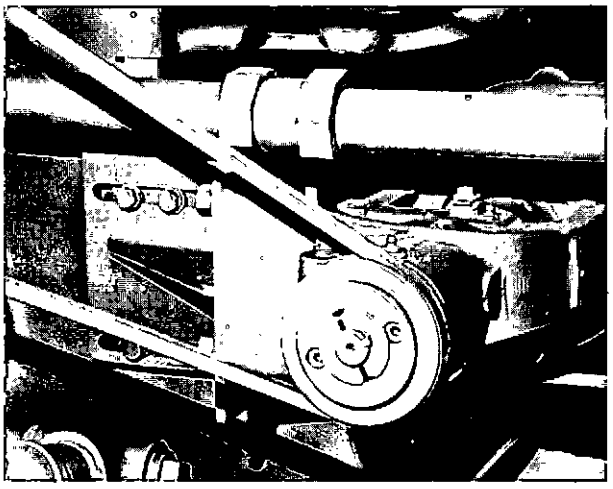


MH-200-50

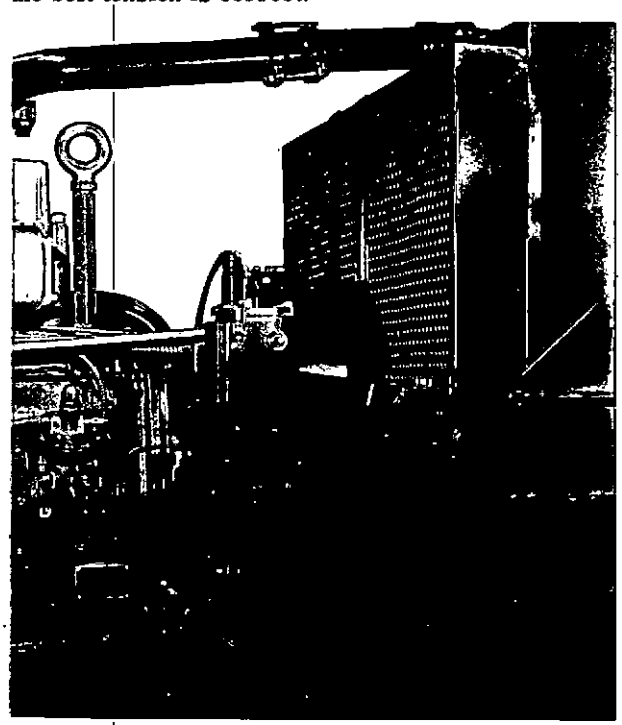
Check the coolant level. If it is necessary to add a large quantity of coolant, be sure to open the cooling system air vents to allow any air trapped in the system to escape.

Trace the entire cooling system to be sure all control valves are properly opened and all drain cocks are closed.

Inspect drive belts (oil cooler water pump, alternator, or other driven equipment). Examine for good condition and correct tension. If a cooling fan is used, be sure it is free to turn, properly lubricated, and the belt tension is correct.



MH-60-104

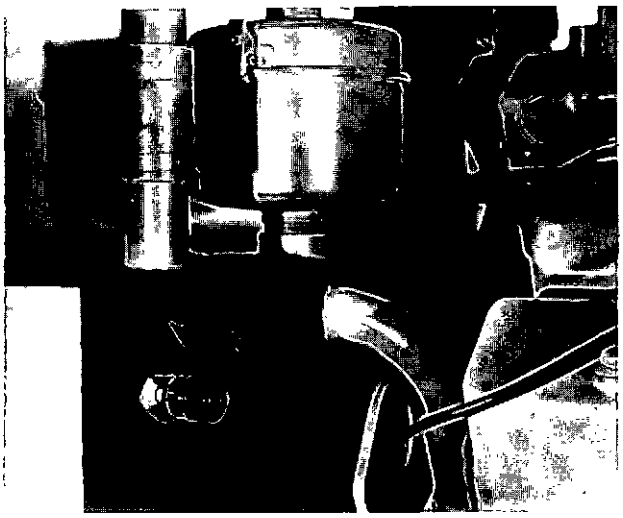


MH-201-1

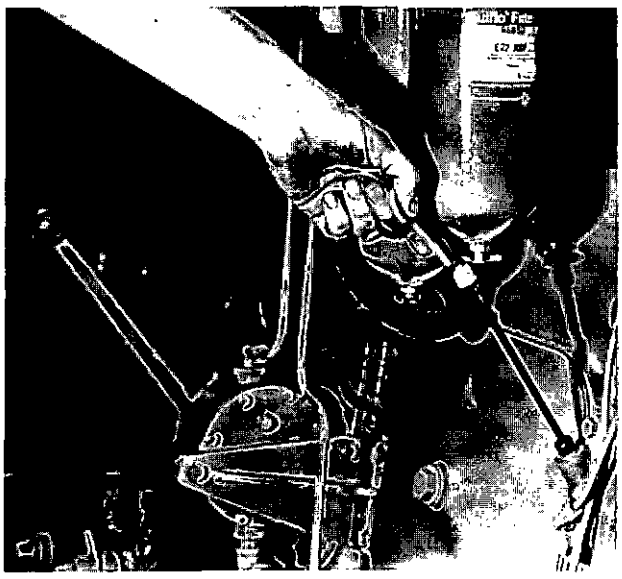
Make certain all guards are secure on engine and equipment.

BEFORE STARTING (Continued)

Check air cleaner restriction indicator. Clean air filter if indicator shows red.



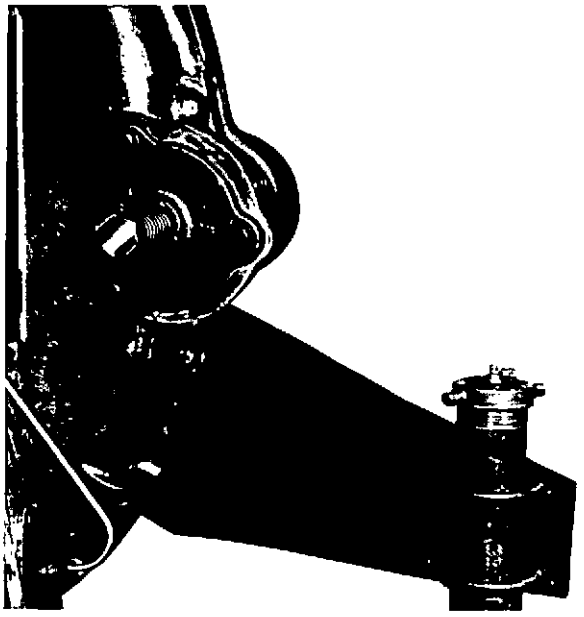
MH-208-20



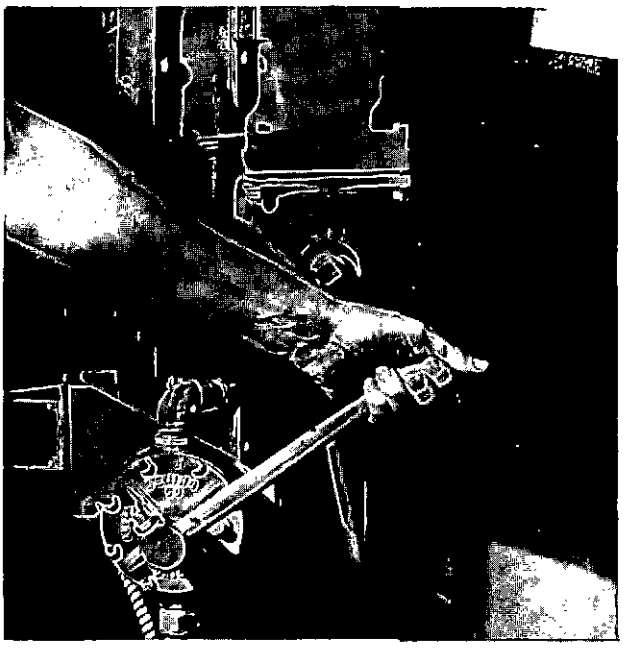
MH-03-1

Check the oil level as indicated on the dipstick. Add recommended oil as needed. Make sure the injection pump(s) are filled with lube oil, especially on new engine start-up or if pump was removed and reinstalled or replaced.

Use the barring device (if installed) or starter to turn the engine over several revolutions to be sure that nothing will interfere with operation.



MH-57-7

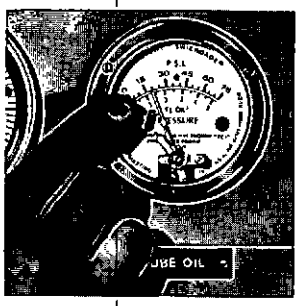


MH-80-63

Operate the manual lubrication pump until a positive indication is seen on the oil pressure gauge.

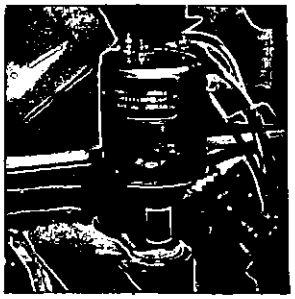
BEFORE STARTING (Continued)

GAS



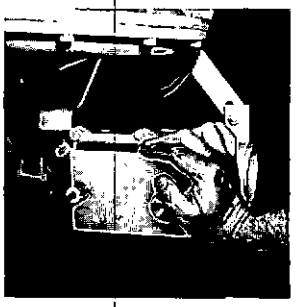
MH-213-2

Push in gauge button until lockout engages.



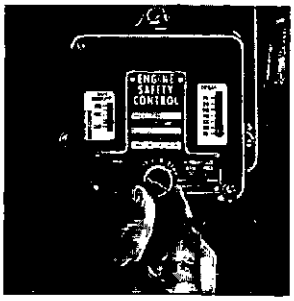
MH-233-1

Re-set overspeed switch if engine shut down on overspeed.



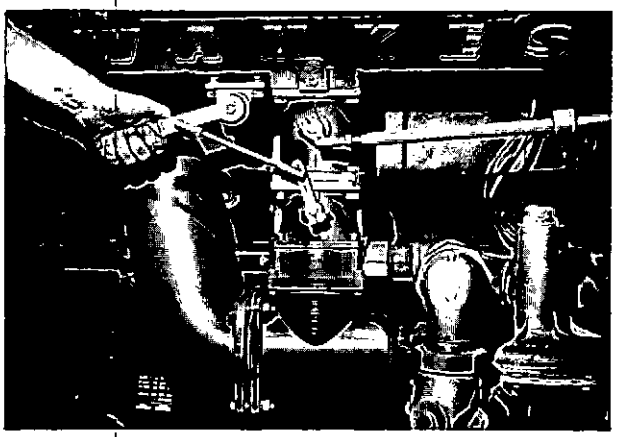
MH-213-37

Open fuel shut-off valve (both sides on twelve cylinder).



MH-213-3

Turn ENGINE SAFETY CONTROL knob to START position.



MH-214-65

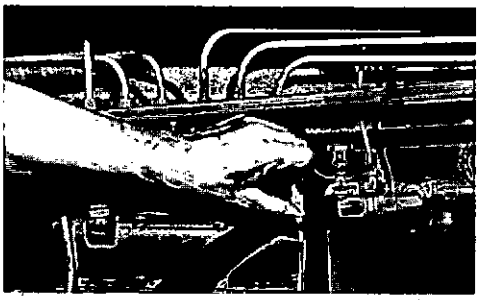
Make sure that auxiliary throttle is in open position.

NOTE

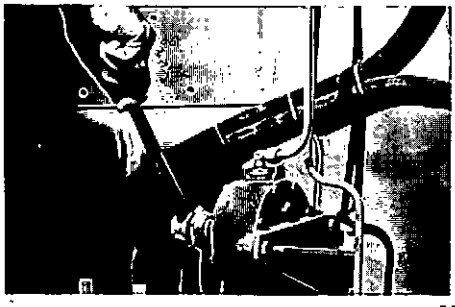
Engines equipped for using either natural gas or LPG: be sure the proper valve for starting has been turned on and the other valve turned off.

DIESEL

Check fuel level in diesel oil tank and open fuel line shut-off valve.

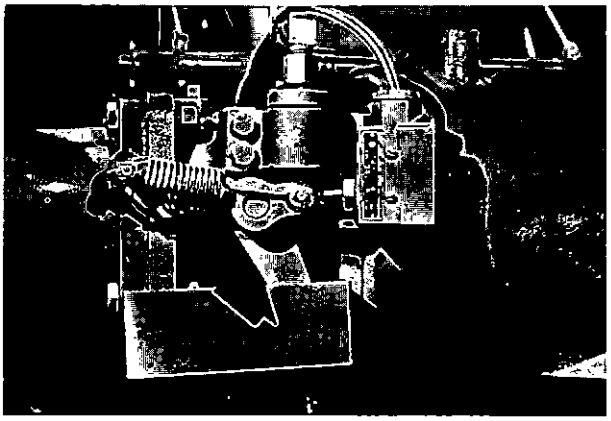


MH-08-118



MH-19-6

Open fuel injection pump bleed valve. Hold Amot control lever up (start position) and operate manual fuel oil pressure pump to clear filters and injection pump of air. Release Amot lever and close injection pump bleed valve.



MH-41-3

Check to be certain that the air shut-off valves are open.

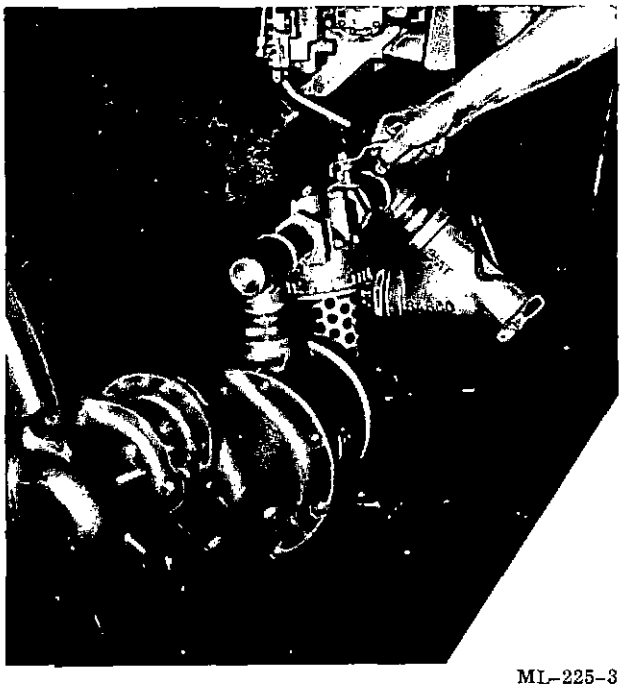
WARNING

NEVER RESTART AN ENGINE WHICH HAS BEEN STOPPED BY CLOSING THE AIR SHUT-OFF VALVES WITHOUT FIRST CHECKING THE ENGINE. BAR THE ENGINE OVER BY HAND TO BE SURE THAT THE CYLINDERS ARE CLEAR.

STARTING

GAS

1. Place governor throttle control lever one-third open. Be sure main ignition switch is on.
2. Operate starter control.



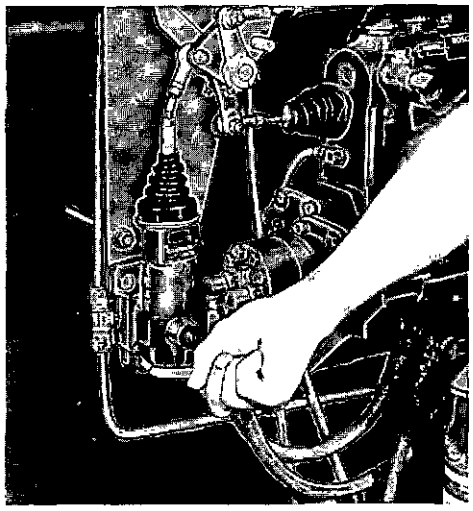
ML-225-3

DIESEL

1. Place governor throttle control lever in low speed position.
2. Operate starter control while holding Amot lever in "up" position.

NOTE

All marine and some other VHP diesel engines utilize an Amot control lever which latches and does not require holding during start-up. *See Service Bulletin 1-1824 for additional information.*



MH-08-107

NOTE

For starting with gasoline starting engine, see page 1-10.

3. *Check for oil pressure indication when engine starts.*

WARNING

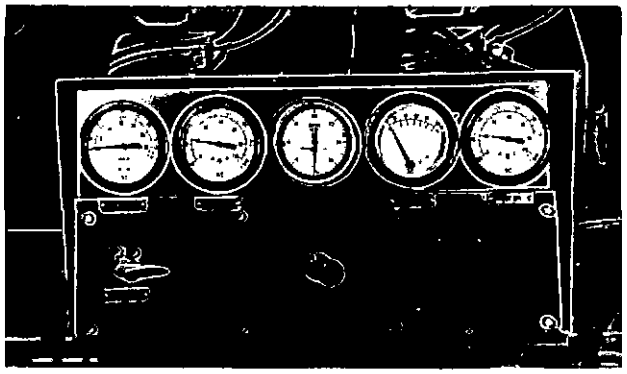
IF OIL PRESSURE IS NOT INDICATED WITHIN 30 SECONDS, SHUT ENGINE DOWN AT ONCE.

4. Warm engine by running with little or no load until oil pressure is normal and coolant temperature reaches 100°F (38°C). NOTE: Do not run turbocharged engines at low power or idle speed for extended periods of time. Running under these conditions can foul the turbocharger.
5. If possible, apply load to engine gradually to avoid overloading engine. NOTE: Turbocharged engines are somewhat more sensitive to the rate at which a load is applied. Apply the load at a rate which allows the turbocharger time to respond to the increasing exhaust gas energy.

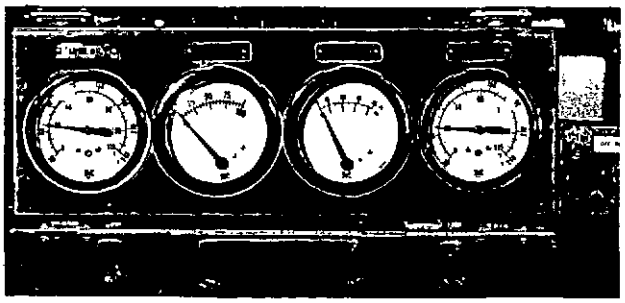
OPERATING

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

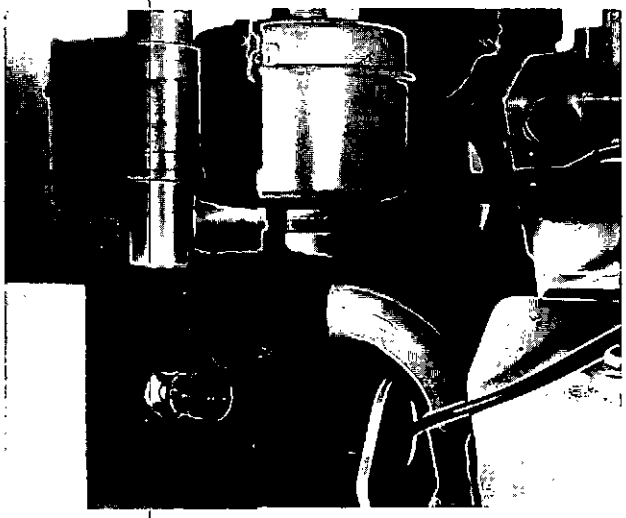
Observe and record the normal operating readings. Oil pressure 40-50 psi, water and oil temperature 160°F to 180°F. Changes from normal may be signs of developing trouble.



GAS MH-202-7



DIESEL MH-202-8



MH-208-20

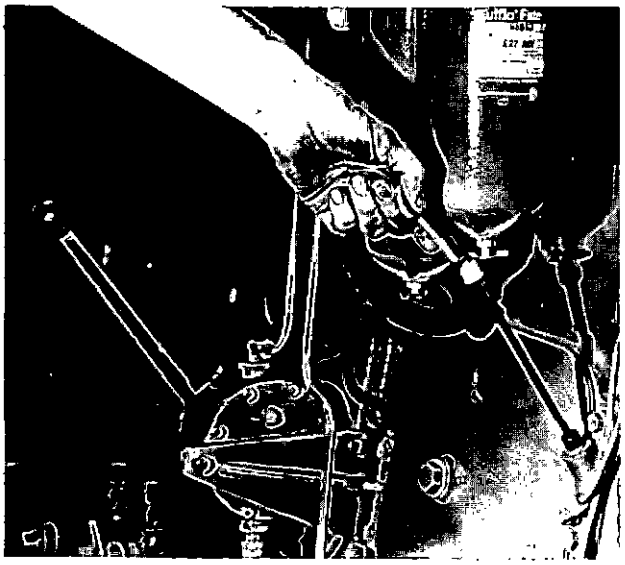
Check the air intake restriction indicator while engine is running.

Listen to the engine. Certain problems, such as occasional misfiring, turbocharger bearing failure, or accessory water pump problems may first be noticeable in the engine sound.

Check for oil or coolant leaks.

Check oil level daily, adding oil as necessary to maintain level above low mark. Dipstick bayonet gauge may be read while engine is running.

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

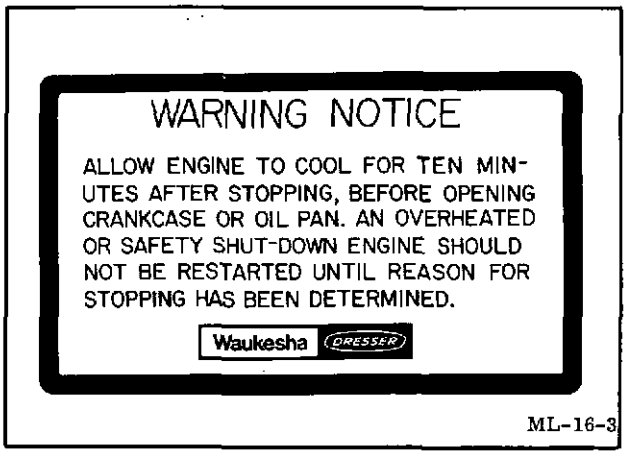


MH-03-1

STOPPING

1. Remove load by disengaging main clutch or other power transmission device (generator circuit breaker, etc.)

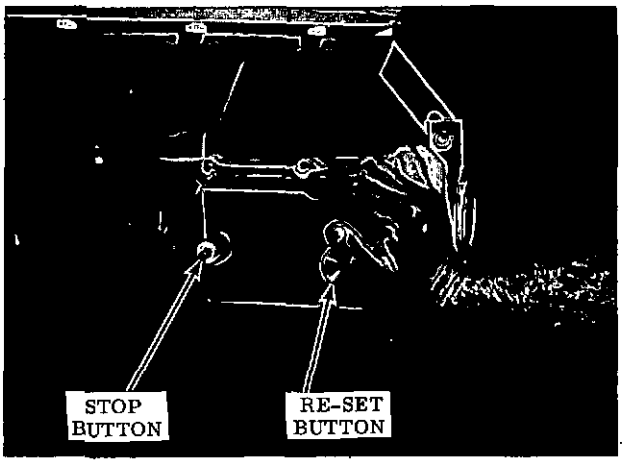
2. Place throttle control lever in medium idle speed position and allow engine to idle for a few minutes *to equalize engine temperatures.*



ML-16-3

GAS

3. 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. Gas engines equipped with Murphy safety controls can be stopped by depressing the stop button) (see illustration).



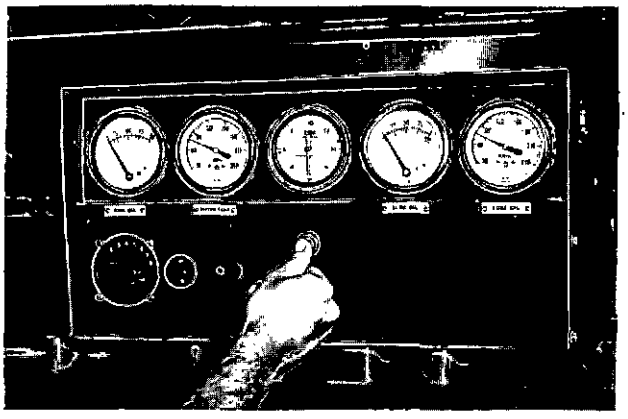
MH-213-37

DIESEL

3. Engines equipped with Amot safety controls can be stopped by depressing the manual dump button on the instrument panel. On marine engines the PULL/STOP knob located near the instrument panel should be pulled.

NOTE

For emergency shutdowns, engines equipped with air shutoff valves can be stopped by closing the air shutoff valves. On marine engines, the knob on the Amot control can be pulled to shut the engine down. See Service Bulletin No. 1-1824 for additional information.



MH-202-3

NOTE

Unless otherwise protected, the exhaust pipe should be capped after 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.

doesn't start | slow start | low power | runs hot | new noises

QUICK TROUBLE CHECK CHART FOR OPERATORS

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

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

STARTING WITH GASOLINE STARTING ENGINE

1. Empty any water or dirt present in glass sediment bowl. Open fuel valve below the small tank.
2. Turn out float lock on carburetor.
3. Open throttle one-quarter.
4. Close choke valve and turn engine over several times with crank.

NOTE

Choking is not always needed in warm weather or with warm engine. Never choke a hot engine.

5. Turn ignition switch on.
6. Pull up starting crank quickly. Reduce choking as required to keep engine running.

CAUTION

BE SURE TO RELEASE THE STARTING CRANK WHEN ENGINE STARTS.

7. Oil pressure should be about fifteen psi. after engine warms up.
8. After engine is warm, engage the clutch and turn the main engine over several times (with fuel off) to be sure it is free.
9. In cold weather, place gasoline engine spark control in full retard position and open throttle to full speed. This will supply extra heat to the main engine. Experience will indicate the proper heating period for easy starting at various temperatures.
10. Return spark control to advance position and maintain full throttle.
11. Follow starting procedures provided for gas or diesel engine.

CAUTION

The starting engine for turbocharged engines should not be run without starting the main engine, as lube oil from the main engine oil header is required to recharge the turbocharger pre-lube accumulator after the starting engine has been shut down.

12. Engage clutch momentarily until Bendix engages flywheel, then apply enough pressure to crank engine. Release clutch when engine starts.

To Stop Gasoline Engine

1. Close throttle to idle position.
2. Close fuel valve on small fuel tank and allow engine to run carburetor dry.
3. Turn ignition switch off.
4. Turn in carburetor float lock.

COLD WEATHER STARTING

ENGINES EQUIPPED WITH PRE-HEATERS

Engines normally required to start at temperatures below 32°F (0°C) should be equipped with oil and/or coolant heaters. These heaters permit starting the engine while using oil of the correct viscosity for operating conditions. If the heaters are manually controlled, turn them on in time to allow the engine to become warm enough for normal starting.

ENGINE WITHOUT PRE-HEATERS

Priming the lubrication system is especially important in cold weather. The engine should not be started if the priming system cannot produce a pressure indication on the oil pressure gauge.

At certain low temperatures, the engine may attempt to start, yet not develop enough torque to overcome internal friction sufficiently to run. If this occurs, pre-heaters must be installed, or a method of removing the oil after shut-down and warming it before refilling the crankcase must be developed.

BREAK-IN PROCEDURE

Break-in procedures allow the working parts of a new or repaired engine to develop the tolerances needed for full power operation. The engine should be run for brief periods under medium to heavy load, followed by cooling periods (about five minutes). Follow the proper schedule listed below. Minor variations of this schedule may be required due to individual characteristics of the installation, however, an equal schedule should be worked out for every new or overhauled engine.

BREAK-IN SCHEDULE FOR FIXED SPEED LOADS
generators, certain compressors, etc.

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)

*Repeat 50% load and idle cycle three times, then continue cycling at 75% load for thirty minutes with five minute cooling periods, for a total of six operating hours.

CAUTION

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

BREAK-IN SCHEDULE FOR VARIABLE SPEEDS AND LOADS
oil field use, marine engines, etc.

OPERATING SPEED	OPERATING INSTRUCTIONS PERFORM NORMAL START-UP INSTALLATION & ENGINE CHECKS
600 RPM	Starting and warm-up (30 min.)
1000 RPM	Operate 10 minutes 25% load
700 RPM	Idle engine five minutes (No Load)
1200 RPM	Operate 15 minutes 50% load
700 RPM	Idle engine five minutes (No Load)

*Repeat 50% load and idle cycle three times, then continue cycling at rated load for thirty minutes at governed RPM, for a total of six operating hours.

NOTE

Do not idle engine in excess of ten minute periods until it has operated for 100 hours. An oil and filter change after the first 100 hours is recommended. The normal operating oil should be used during the break-in period.

EXERCISE OF STANDBY UNITS

A generator set or other standby unit should be exercised once each week. A record should be maintained of performance and servicing of both the engine and driven equipment.

Always run 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 two hours will be needed.

CAUTION

"TURBOCHARGED ENGINES SHOULD NOT BE IDLED FOR EXTENDED PERIODS. ACCUMULATED CARBON MAY DAMAGE TURBOCHARGER. SHUT DOWN AND RESTART WHEN NEEDED".

Some types of driven equipment cannot be operated without fairly extensive procedures to "put them on the line".

Weekly exercise may have to consist of periods long enough to prove the engine's ability to crank and start, or check starting circuitry and safety equipment with the starter disabled. Special attention must be taken to prevent internal corrosion, sticking and gumming of fuel controls, and deteriorated starting batteries. Arrangements should be made to run the engine and driven equipment under load at least every 90 days.

ENGINE PERFORMANCE RECORD

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

HOUR METER READING _____

TACHOMETER (RPM) _____

FUEL METER READING _____

ENGINE OIL PRESSURE _____

ENGINE OIL TEMP _____

COOLANT TEMPERATURE _____

INTERCOOLER WATER TEMP _____

OIL COOLER WATER TEMP _____

GAS PRESSURE @ CARBURETOR INTAKE _____

MANIFOLD PRESSURE pos/neg _____

CRANKCASE PRESSURE pos/neg _____

UNUSUAL NOISE(S) VIBRATION _____

OIL LEAKS _____

COOLANT LEAKS _____

ALTERNATOR OUTPUT _____

OPERATIONAL INSPECTION

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

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

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

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

PREVENTIVE MAINTENANCE

PARTS ORDERING

ANTICIPATE YOUR PARTS REQUIREMENTS:

a) ORDER PARTS EARLY IN THE DAY.

b) KEEP A SUPPLY OF NORMAL MAINTENANCE PARTS IN STOCK.

c) OBTAIN A PARTS STOCKING RECOMMENDATION FROM YOUR DISTRIBUTOR.

ML-1000-28

FUELS

GAS - Waukesha VHP gas engines are designed to burn several different types of fuel. Fuels most commonly used are natural gas and liquified petroleum gas (LPG). It is important that gas engine users are aware of the possible variations in the LPG fuel they purchase and the results of these variations.

Natural gas is normally considered as having an anti-knock (octane) rating equivalent to 120. This is an excellent anti-knock value and many engines are designed to take advantage of it. Substitution of liquified petroleum gas (LPG), which has a lower octane rating, for natural gas reduces the margin of anti-knock safety and requires RETARDED IGNITION TIMING if the correct natural gas timing was used (see adjustments). LPG also has a high vapor pressure, so unless a vaporizer or converter of adequate size is installed to warm LPG enough to force fuel to the regulator in adequate volume, the engine will be operating on a lean mixture, a condition which often causes detonation.

DIESEL - The VHP 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 due to 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 is considered, the Engineering Department of the Waukesha Engine Division should be consulted.

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

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

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

LUBRICATING OILS

The Waukesha Engine Division does not recommend lubricating oils by brand name. A table of lubricating oils, and the performance grades for which their suppliers indicate these products are qualified, is available from the Engine Manufacturers Association, 111 East Wacker Drive, Chicago, Illinois - 60601. This publication is titled, "EMA Lubricating Oils Data Book for Heavy-Duty Automotive and Industrial Engines". All Waukesha VHP engines are considered Class B, that is over 1000 cu. in. (163, 9 1) displacement.

CLASS B GAS ENGINES - We recommend lubricating oil compounded for natural gas engine operation. The additive level of the lubricating oil shall have 5,000 PPM of barium, calcium, or combination of both with a maximum of .03 percent zinc. The sulfate ash level should be 2 to 3.4% by weight. High ash oils reduce valve face and seat erosion. The EMA Lubrication Oils Data Book specification columns headed "Nat. Gas/LPG-High Ash" and "Ash Content % by WT." will assist in selection of oils to this specification. However, several oil companies have now successfully formulated low ash oils that also protect valve seats and faces. Check with your oil supplier.

Waukesha Engine Division's warranty does not include responsibility for satisfactory performance of the lubricating oil. This is the responsibility of the oil supplier.

CLASS B DIESEL ENGINES - We recommend lubricating oils designated by the API (American Petroleum Institute) as "CD", by the military as "MIL-L-45199B" or "MIL-L-2104C", or by the manufacturer as S-3.

SELECTING OIL VISCOSITY

The correct lubricating oil viscosity (often referred to as "weight") must be determined with the engine operating under its normal loaded speed and temperature, using either SAE 30 or SAE 40 oil.

1. Start and load engine as described under "STARTING".
2. After oil and coolant temperatures no longer increasing, note the temperature of the oil in the oil header or oil pan. Use a temperature gauge of known accuracy. Compare this temperature with the chart at the top of next column. The correct oil viscosity will be found in the right hand column.

Multi-viscosity oils (10W-30, for example) should be used only when cold starting conditions make it absolutely necessary. Oil change periods should not exceed 25 hours, because multi-viscosity oils may rapidly lose their highest viscosity rating in industrial service.

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

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

OIL CONSUMPTION

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

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

LUBRICANTS

Lubrication points and recommended lubricants are in the lubrication chart. The intervals are recommendations for normal service only. These intervals should be changed if dirt, excessive heat, or unusual wear of parts is apparent.

1. Store all lubricants in closed containers in a clean dry place away from heat.
2. Keep lubrication equipment clean and ready for use.
3. Clean areas around lubrication points with a lint free cloth, moistened with solvent to remove hardened lubricants.
4. Do not over lubricate. Wherever possible, recommended quantities of lubricant are stated in the lubrication chart.

The following service schedule has been determined for normal operating conditions. It may be necessary to change some of the intervals of service to meet abnormal operating conditions such as extreme cold or very dirty conditions.

OIL CHANGES

The crankcase level should be checked prior to each day's engine operation and at the same time the con-

dition 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. 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 Class B engines, an oil change period of 500 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 "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.

OIL FILTER (7 and 14 Element)

Change elements when filter outlet pressure gauge reads 15 psi under inlet pressure. If not equipped with gauges, change filters during oil change.

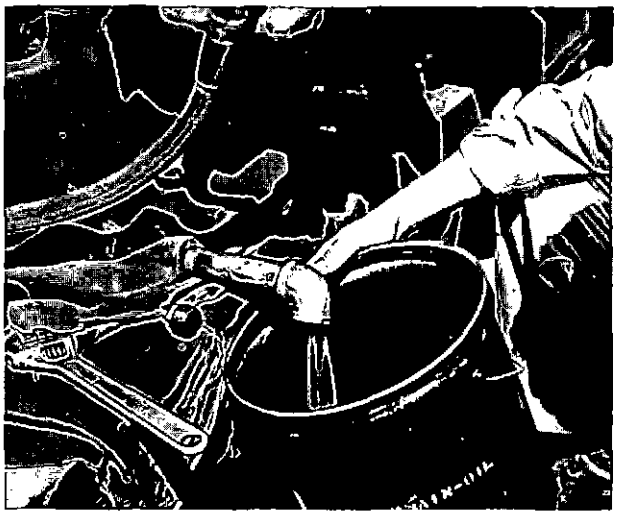
Place index mark on cover and filter body. Remove drain plug; drain filter. Release the swing-bolts securing cover; remove cover taking care not to damage the "O" ring.

NOTE

The large cover "O" ring should be replaced at least every fourth filter change and more often if inspection shows signs of deterioration. The small ring on the standpipe should be carefully inspected at each filter change, and changed when necessary.

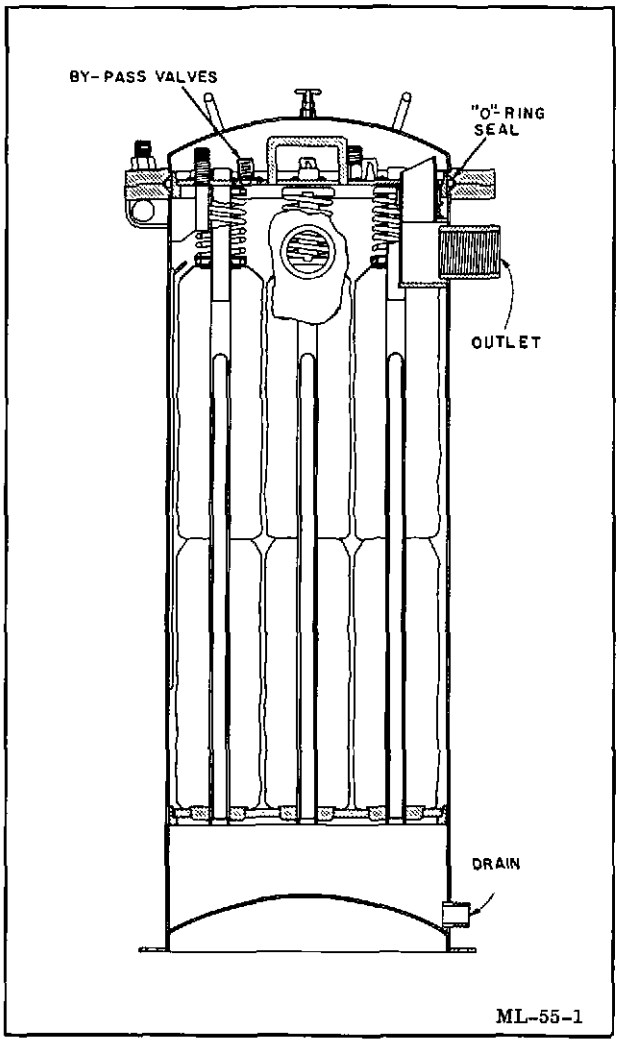
Remove nuts and washers securing spider; remove spider and follower springs. Remove old elements and clean shell thoroughly.

Select dual density standard element No. 167602 (double length No. 168660) or dual density treated element No. 167602-A (double length No. 168660-A) which is used when high sulphur fuels are involved. Install new elements over center tubes placing arrow on element toward bottom. Fill filter with lubricating oil, let stand to soak elements and add oil until oil level stabilizes.



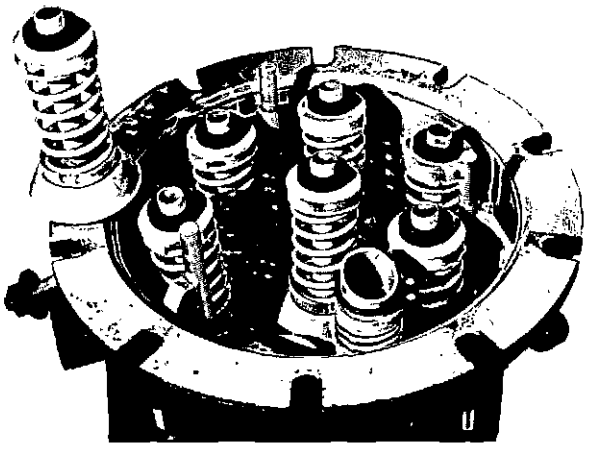
MH-14-5

DRAINING OIL FROM OIL PAN



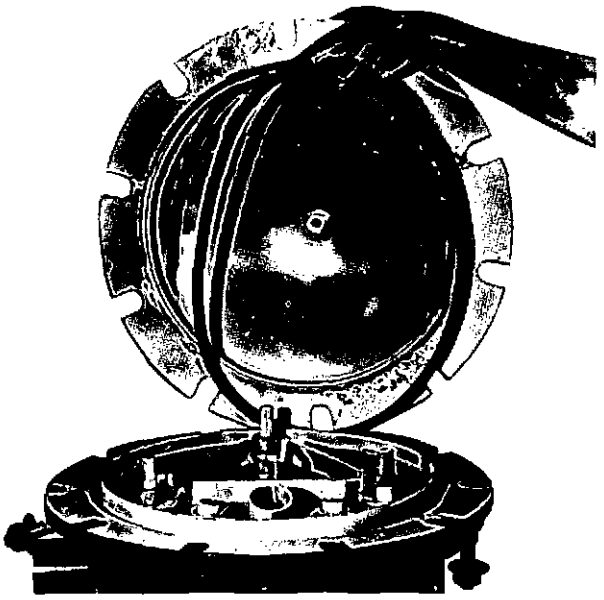
ML-55-1

14 ELEMENT FULL FLOW OIL FILTER



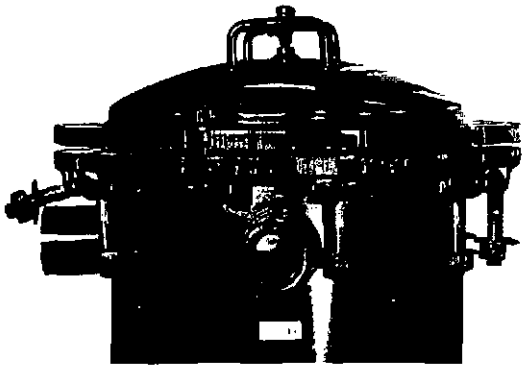
MH-55-20

Install sealing washers (7) No. 199270, follower spring assemblies, and upper seal plate spider. Replace sealing washers if they harden, crack, or become otherwise unserviceable. Check filter by-pass valves to ensure they close fully and seat properly.



MH-55-22

Install washers and nuts over seal plate. Tighten each nut several turns, and repeat until solid bottoming is felt. Install cover with cover "O" ring, using index marks on cover and body to maintain alignment.



MH-55-21

Secure cover with swing-bolts.

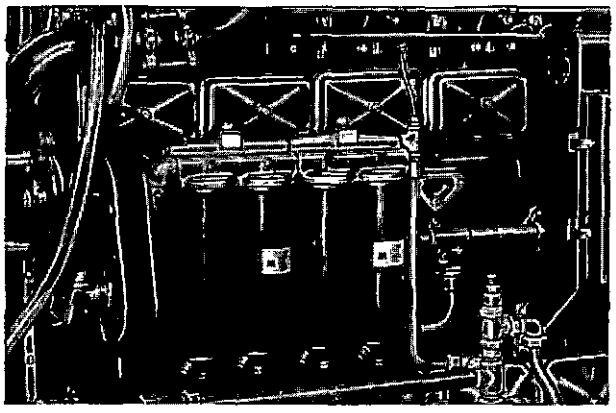
NOTE

Tighten each nut several turns, then repeat until snug. Torque each nut to 35 to 37 lbs. ft.

OIL FILTER (4 Element)

To replace 4 element filter elements, proceed as follows:

Drain filters. Loosen the bolts securing the filter shells. Remove shells and clean thoroughly. Replace elements and install drain plugs. Install the shell assemblies and tighten bolts to 60 lbs. ft.

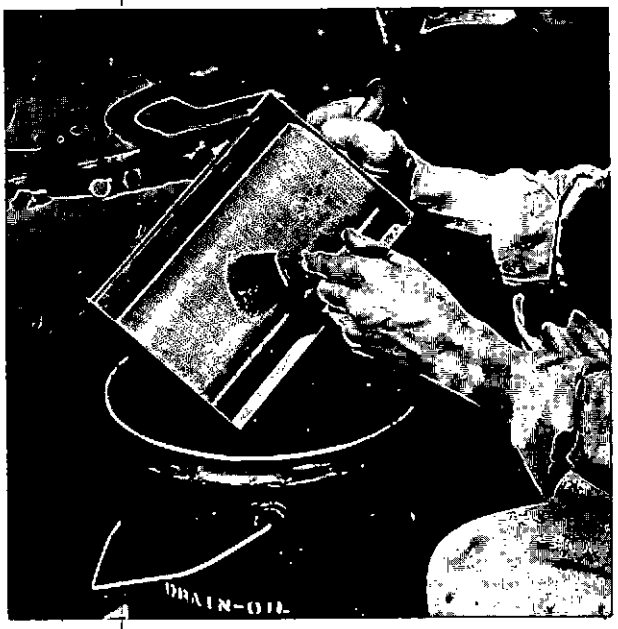


MH-001-34

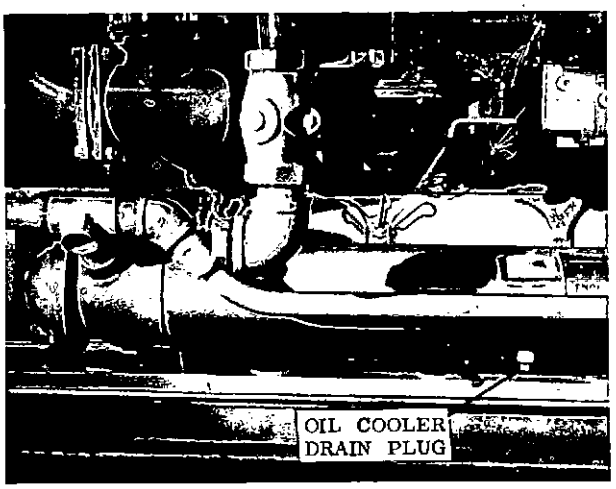
SERVICE SCHEDULE AND PROCEDURES

OIL COOLER

Drain and clean at each engine oil change.



MH-14-2



MH-17-21

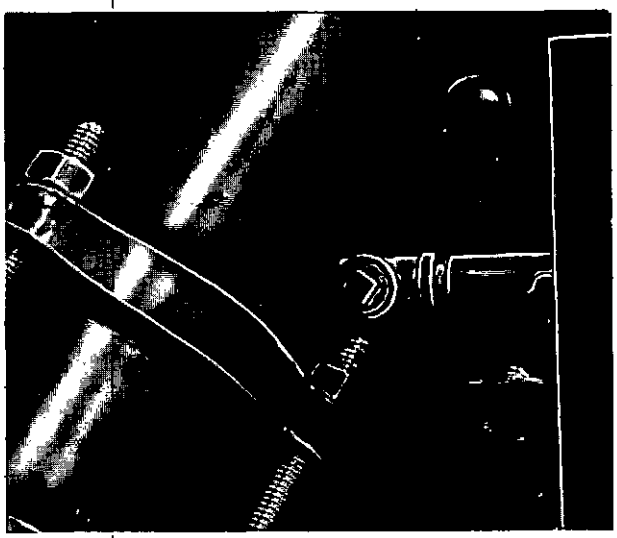
CRANKCASE

OIL SCREENS

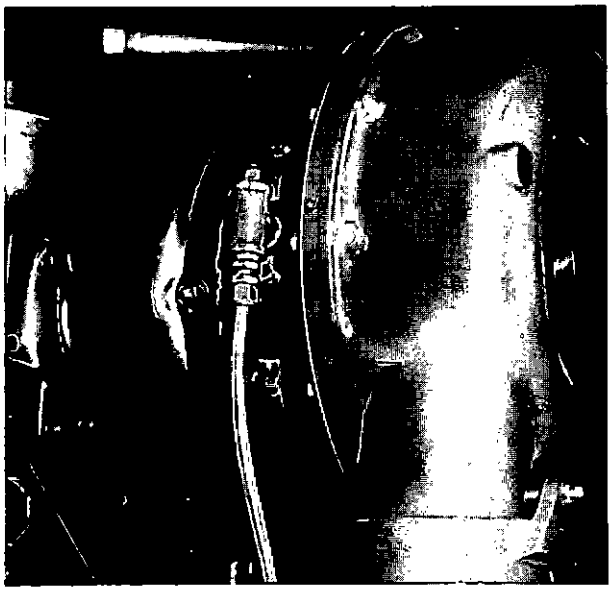
Clean at 2500 hours, less frequently depending on condition.

MAGNETIC PLUGS

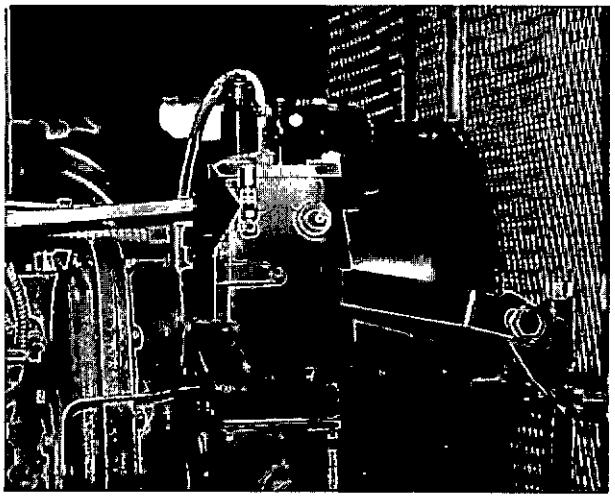
Inspect and clean at each oil change.



MH-66-15



MH-66-14



MH-201-1

FUEL INJECTION PUMP(S)

Change oil whenever engine oil is changed. Use same oil as used in engine.

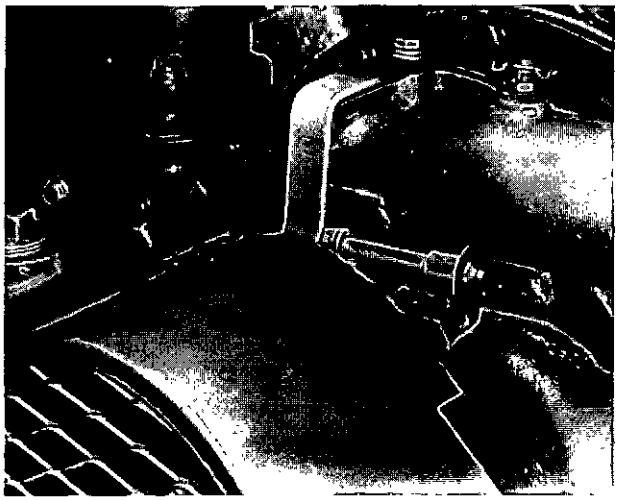
FAN

Pack bearings with lithium soap
Grease every 2000 hours

WATER PUMPS (ENGINE AND SEA WATER)

Apply lithium soap grease to auxiliary pump, V12 only, 2 grease fitting.
Use hand-gun, 1 stroke, every 720 hours.

Apply water pump grease to auxiliary water pump stuffing box. 1 stroke, every 100 hours (some models).



MH-60-105

GOVERNOR (UG8 ONLY)

Check oil level in sight gauge daily.

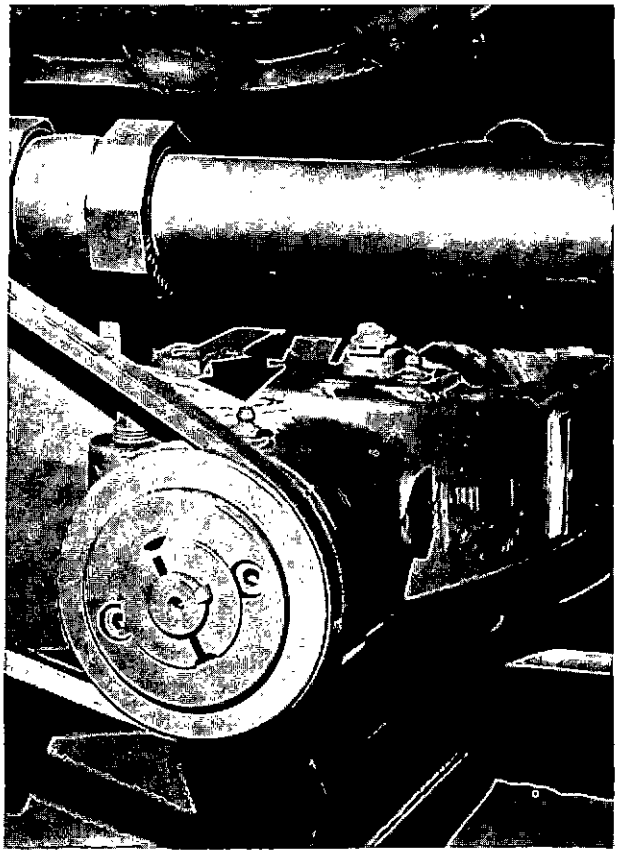
Change oil every 1000 hours or every six months. Use the same lubricating oil used in the engine.

SYNCHRONIZING MOTOR (Governor)

Below 32°F (0°C), use Bodine LG2 or Beacon No. 325.

Above 32°F (0°C), use D.A. Stuart HMP Hodson No. 2-1000.

Above 212°F (100°C), or with motor mounted with gear housing up, use Dow Corning No. 44; put grease directly on gears.



MH-60-104

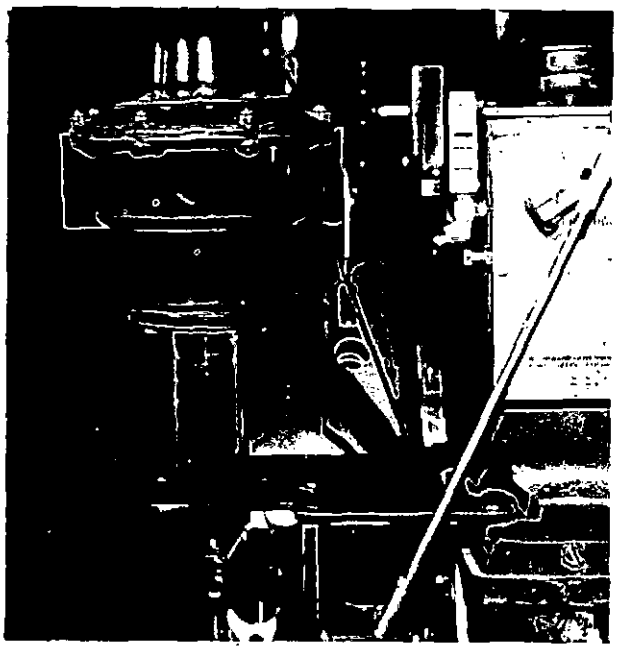
Apply lithium soap grease to engine pump and sea water pump (1 grease fitting).
Use hand-gun, 1 stroke, every 720 hours.

WATER PUMP IDLER PULLEY

Apply lithium soap grease to grease fitting.
Use hand-gun, 1 stroke, every 720 hours.

AIR ACTUATOR

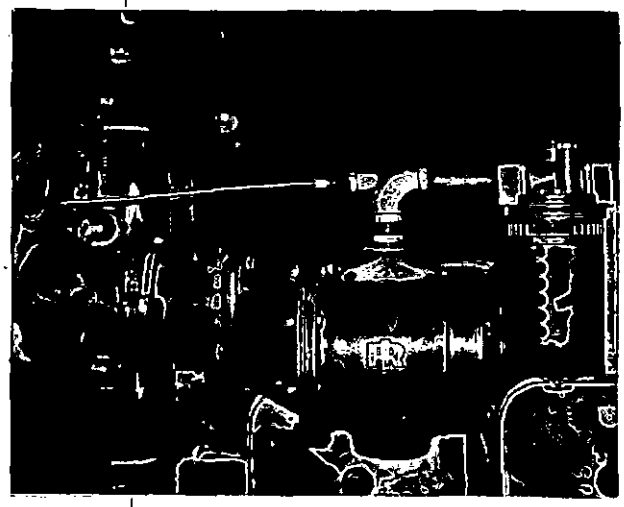
Lithium soap grease
Hand-gun, 2 grease fittings every 720 hours.



MH-34-1

STARTING ENGINE

Check oil level daily, change oil every 100 hours. Oil pan capacity four quarts. Transmission oil independent of engine lubrication. Use 1/2 pint SAE 10 engine oil for transmission. Fill and turn down Bendix grease cups weekly.



MH-225-5

AIR STARTER

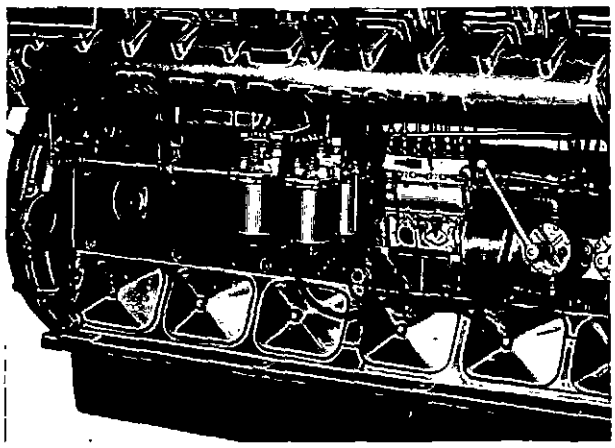
Keep lubricator filled to level with SAE 10W oil above 32°F, 0°C, or No. 2 Diesel Oil below 32°F, 0°C. Lubricate every three months with No. 2 cup grease through grease fittings. Adjust lubricator to provide a light oil vapor at the starter exhaust.

FUEL FILTERS

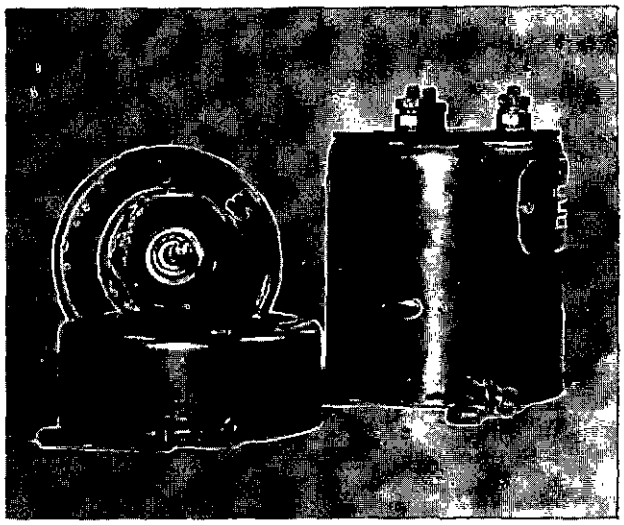
Replace elements at about 720 hours operation, or if fuel system pressure either drops or is erratic. Use manual priming pump to fill filters after element replacement.

FUEL STRAINER (If used)

Wash the strainer element discs in lacquer thinner at approximately 720 hours of operation. Do not blow off with direct air! If strainer is knife type, clean weekly, more often if fuel pressure either drops or is erratic.



MH-001-29



MH-218-42

SPARK PLUGS (Replace as needed)

Spark plug size . . . . . 18 mm with 1/2" reach
Torque to 40 to 45 lbs. ft. dry
Torque to 30 to 34 lbs. ft. oiled

Spark plug type:
(standard - for all applications) 69512
(platinum tip - for all applications except generator sets) . . 60999B
(shielded - for all applications except generator sets) . . 60999E
(shielded - for generator set applications only) 167037

Spark plug gap:
(standard) . . . . . .020"
(platinum tip) . . . . . .011"
(shielded - except gen. sets) . . . . . .015"
(shielded - gen. sets only) . . . . . .025"

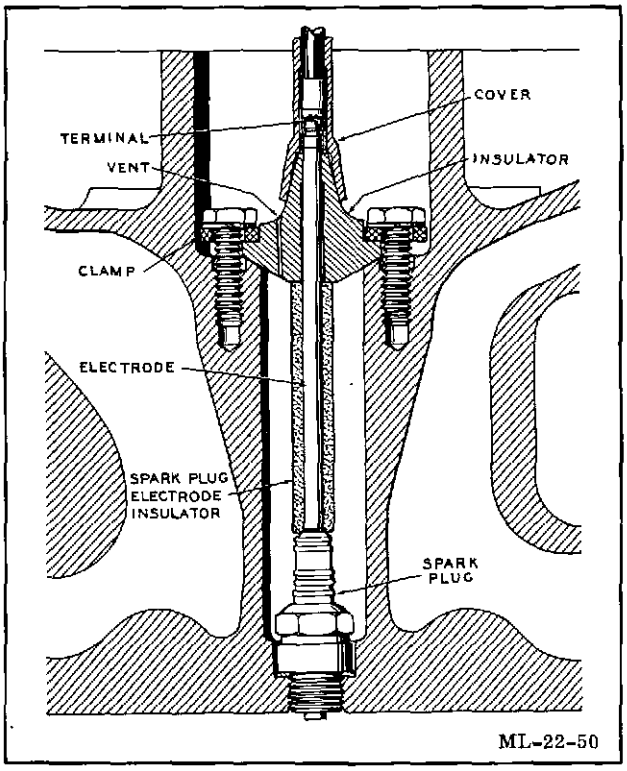
Magneto point clearance . . . . . .016"-.018"

MH-70-14

SYNCHRO-START OVERSPEED SWITCH

Aero Shell 7A MIL-G-23827 or equivalent
Lubricate every six months. (New models since 1972 require no lubrication.)

Remove cap and switch, and weights and shaft assemblies. Fill 3/4 full between bearings. Reassemble. Adjust to ten percent above high idle speed by loosening and rotating cap clockwise to lower or counter-clockwise to raise shut off speed. Hold cap and tighten lock screw.



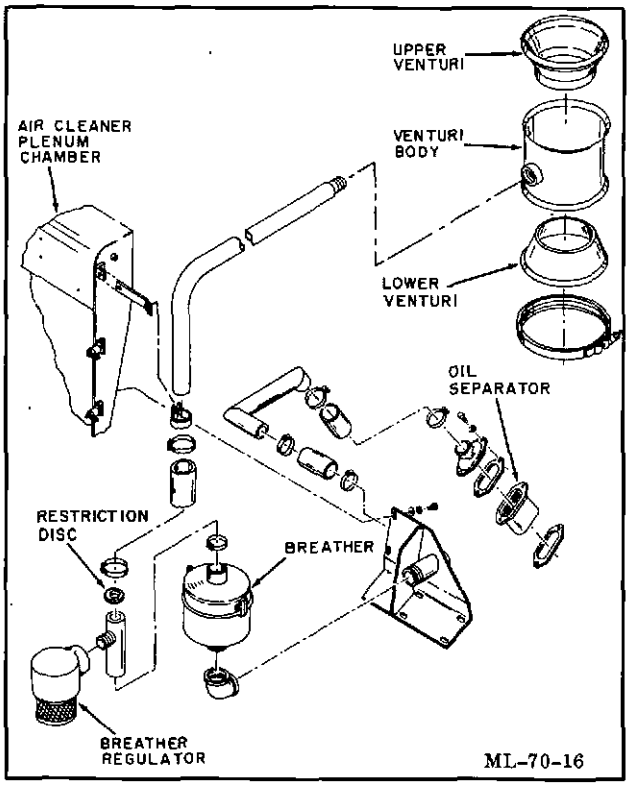
ML-22-50

CRANKCASE BREATHER

Disassemble and clean monthly. 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. Remove and clean oil separator at crankcase. 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.

BREATHER REGULATOR (Turbocharged Engines)

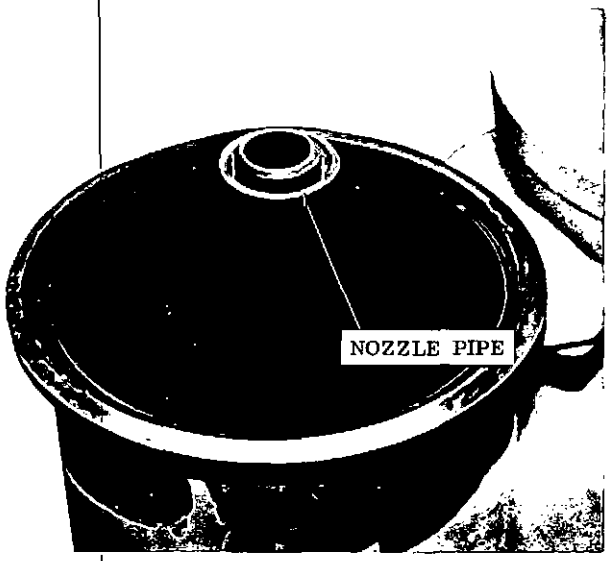
The breather regulator characteristics have been carefully worked out and no adjustment of this regulator is required in maintaining correct crankcase pressures.



ML-70-16

CRANKCASE BREATHER VENTURI (12 Cylinder Turbocharged Engines)

If the venturi assembly is not functioning properly due to carbon deposits, it must be disassembled and cleaned. A restriction disc is installed in the hose just above the breather regulator. This disc is required for proper operation of the crankcase ventilation system.



MH-70-15

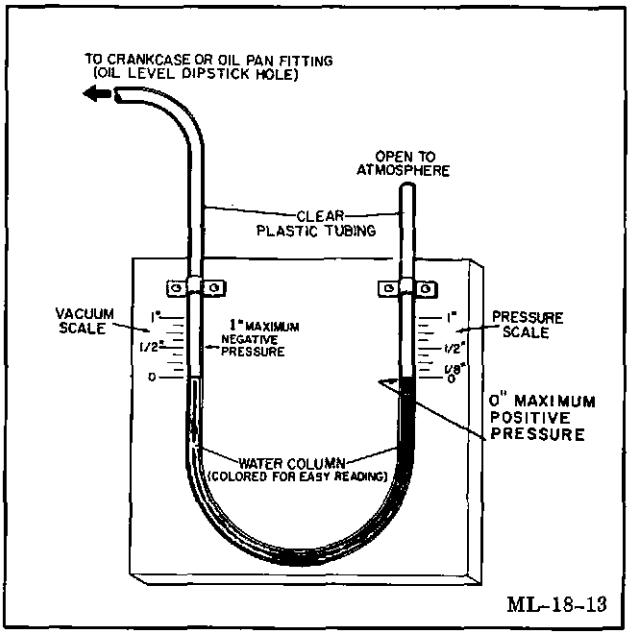
CRANKCASE BREATHER VENTURI (6 Cylinder Turbocharged Engines)

If the venturi fails to function properly due to carbon deposits, it must be cleaned. The nozzle must be rodded out or soaked in a carbon solvent.

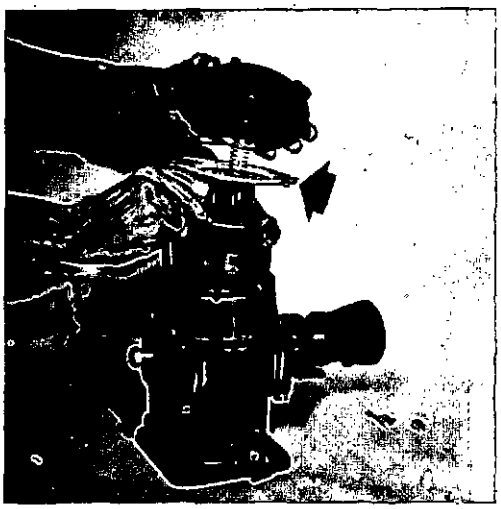
Crankcase Air Pressure Measurement

To measure crankcase pressure, remove the pipe plug from the oil depth gauge support and replace it with a 1/8 inch nipple. Then connect a length of clear plastic tubing to the nipple.

Bend the plastic tubing into a "U" shape and clip it to a section of wood to make a manometer with negative and positive 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. Dye or ink added to the water aids in reading the manometer when the engine is in operation.



ML-18-13



MH-214-69

CLEANING PANEL TYPE DRY AIR FILTER ELEMENTS

Air filters should be cleaned when the air cleaner restriction indicator shows red. If differential pressure indicator is used, the element should be cleaned at fifteen inches of water restriction. Filters should not be cleaned and reused more than three times.

1. Water wash (Preferred Method)

   a. Soak element in a lukewarm water and non-foaming detergent solution for approximately 10 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 a dust free area with outlet side down.

   e. When element is completely dry, examine it carefully from the outlet side for breaks or ruptures. If any breaks or ruptures are apparent, the element must be discarded.

2. Air wash

   a. Use a soft, open jet of compressed air from the outlet side. Never use air pressure over 20 PSI to avoid rupturing the element.

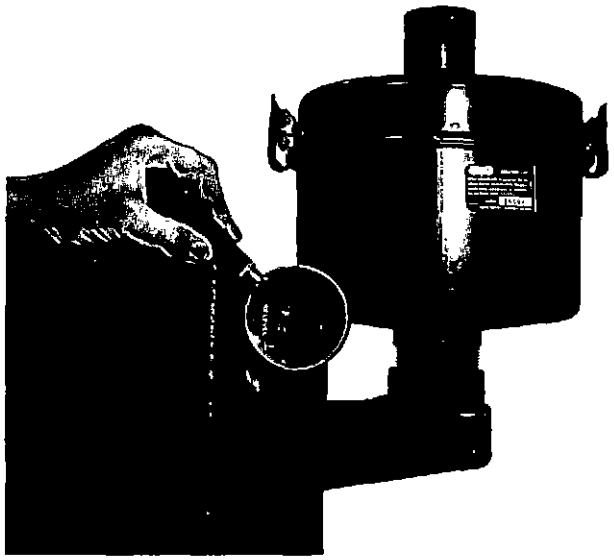
   b. Shake loosened contaminants from the element holding the inlet side down.

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.

Be sure to install filter element so that particle escape holes are on bottom side of housing.

GAS CARBURETOR DIAPHRAGM

Inspect annually and replace if cracked.



MH-208-24

CLEANING OF MARINE ENGINE AIR CLEANER ELEMENTS

Wetted Metal Mesh Type

NOTE

Metal mesh marine air cleaner elements can be cleaned and reused indefinitely unless they become damaged so that unfiltered air can enter the engine air intake.

1. Where hot water, compressed air and draining facilities are available

   Method A. Immerse filter in a boiling solution of water and a suitable grease solvent (Oakite No. 20; 3 pounds to 5 gallons of water, Tri-Sodium Phosphate, 2 pounds to 5 gallons of water). Boil 20 to 30 minutes. Rinse in plain hot water and allow to dry.

   Method B. Stand or hang filter and flush with hot solution (150 to 180°F) of water and suitable grease solvent. Spray from outlet side first and then from inlet side. Rinse in clear hot water and allow to dry.

CAUTION

DO NOT USE CAUSTIC SODA OR LYE.

2. Where hot water is available at normal tap pressure of 65 to 90 psi.

   Method A. Immerse filter in a 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.

   Method B. Stand or hang filter and flush with hot water (150 to 180°F). Hold nozzle 3 inches from surface to be cleaned. Flush outlet side of filter first, then inlet side. An ordinary garden hose can be used, but it requires many transverses of the filter to assure complete cleaning.

CAUTION

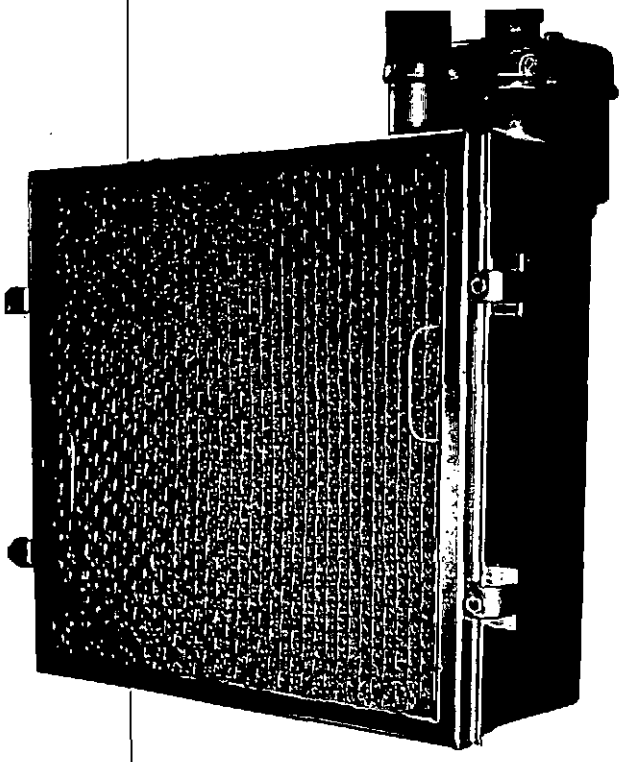
DO NOT USE CAUSTIC SODA OR LYE.

3. Where hot water and compressed air are not available

   Method A. Immerse filter in Oakite Sturol or Oakite No. 9 and agitate. It may be necessary to use a scrub brush. Rinse thoroughly in plain water and allow to dry.

CAUTION

Use rubber gloves for protection of hands.



MH-208-22

   Method B. Immerse filter in a commercial petroleum solvent and let it soak. Agitate until filter is clean. Remove and allow to dry. IMPORTANT: Do not put back into air stream until completely dry.

CAUTION

This is emergency method only and should be used outdoors to eliminate danger of explosion.

4. Servicing Inspection

Look through the filter toward the light. When thoroughly clean, no cloudy areas will be seen. While the entire media can be cleaned bright, it is not necessary to wash off blackened oil coating on wire element. Inspect for damage and replace if required.

5. Wetting

Immerse filter in Air-Maze Filterkote or other suitable adhesive (SAE 30-50 engine oil). Permit surplus oil to drain off. Place filter in heated chamber where temperature of 20 to 30°F above working ambient temperature is maintained. Allow filter to drain for a minimum of 8 hours. Wipe surplus oil from frame.

Where only compressed air is available, immerse filter in Air-Maze Filterkote. Permit surplus oil to drain off. Use compressed air of 85-100 PSI, starting at top of element with nozzle and working down. Blow heavy oil deposit off from both sides. Wipe surplus oil from frame.

Place filter over a drain pan. Pour Air-Maze Filterkote or oil over the element, making sure the entire area is covered. Allow surplus oil to drain off and use compressed air to blow off heavy oil deposits. Wipe surplus oil from frame before mounting in air box.

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

Dry Paper Type

INSPECTION

These air cleaner elements should be inspected daily and serviced whenever a substantial dirt build up can

be observed on the surface. If an air restriction indicator is installed, clean element when indicator shows red.

CLEANING

It is recommended that the dry paper type element be cleaned a maximum of three times before being replaced. Use one of the following methods:

Method A: Cleaning with compressed air.
Direct compressed air (100 psi max.) through the element opposite the direction of the air flow arrows on the element. Do this until the element is clean at which time it can be reinstalled.

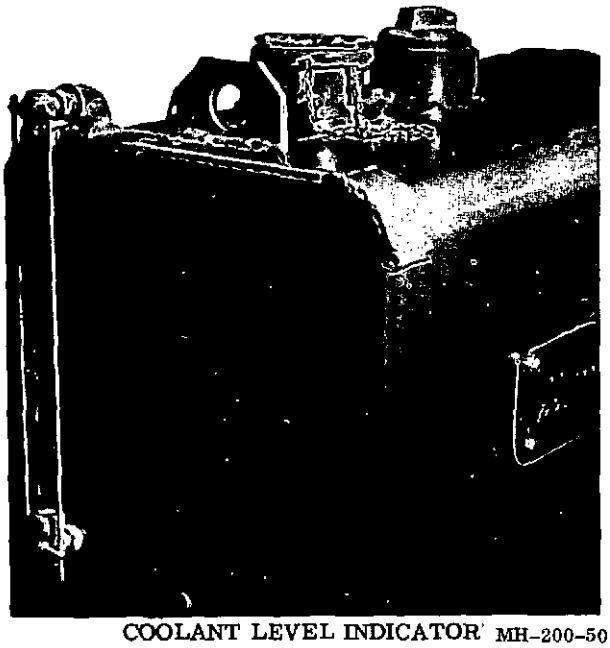
Method B: Water washing
Soak element in water and mild detergent. Rinse with water (40 psi max.) until clean. Air dry element and reinstall. Do not use compressed air to air dry element.

COOLING SYSTEM

Clean and flush the entire cooling system about once each year, unless evidence of corrosion or sediment build-up shows the need for more frequent coolant changes. Use clean, soft water, free from silt and not contaminated by organic acids or sulphur.

1. Run engine until normal temperature is reached. Stop engine and slowly and carefully remove pressure cap. Open all vent and drain cocks.

2. After system has completely drained, close all drain cocks and fill cooling system with solvent solution that will not harm engine parts. Close vent cocks after cooling system is filled.



COOLANT LEVEL INDICATOR MH-200-50

3. Run engine with solvent solution in it for about an hour. Drain system as above.

4. 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.

5. 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.

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.

VALVE ADJUSTMENT

CAUTION

DO NOT ROTATE THE CRANKSHAFT UNTIL THE ADJUSTING SCREWS ARE COMPLETELY BACKED OFF AFTER ANY PROCEDURE WHERE ROCKER ARMS HAVE BEEN DISTURBED, OR A CYLINDER HEAD REPLACED, OR FAULTY VALVE ADJUSTMENT IS SUSPECTED. COLLISION BETWEEN VALVES AND PISTONS IS ALWAYS SERIOUS.

These procedures must be carried out in sequence on each cylinder head with each piston brought into approximate top center position, compression stroke.

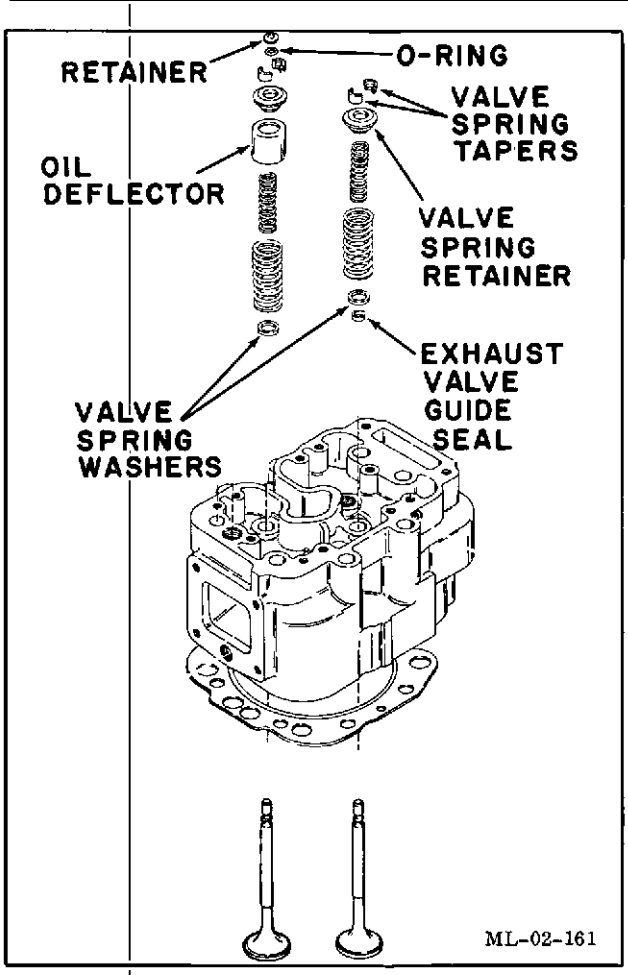
Valve adjustment must be repeated occasionally to compensate for slight differences in wear between valves and seats. Whenever a rocker cover is removed, check for evidence of inadequate lubrication. Excessive sludge in the rocker area may show low oil operating temperatures, inadequate filtering, or improper lubricating oil.

GAS ENGINES HYDRAULIC PUSH RODS -- CURRENT MODELS

These engines may be identified by removing the rocker arm cover and checking for a cap screw (non-adjustable) over the push rods. See illustration on page 2-16.

CAUTION

Be sure that the O-rings and retainer rings are NOT installed on turbocharged engines which operate between 0" to 1" positive pressure. If the engine is operating over 1" positive pressure, the oil deflector, O-rings and retainers should all be removed. These oil control parts are intended for use only when engine operates with negative intake manifold pressure.



CYLINDER HEAD - EXPLODED VIEW

Gas engines are equipped with hydraulic push rods to reduce the frequency of valve lash adjustment intervals often found necessary in operation with this fuel. The hydraulic unit is located at the top of the push rod.

1. Loosen the lock nuts and adjusting screws at all four valve stem tips.

NOTE

Observe the contact between the flats and the valve stem tips. The contact should be fairly well centered on the valve stem tip. If not, minor adjustment can be made by loosening the rocker arm supports and shifting them slightly.

2. Carefully back out both non-adjustable screws 1/2 turn.

NOTE

The 1/2 turn is important for setting preload on hydraulic pushrods. Incorrect procedure may result in hydraulic lifter bottoming.

3. Insert a piece of .005" (0,13 mm) shim stock, five inches (127,0 mm) long between the flats of both the intake valve adjusting screws.

NOTE

It is important that .005" (0,13 mm) be present over each pair of valve stems at the same time to avoid incorrect setting of the last screw tightened.

4. Turn the valve adjusting screws down with finger pressure until the fixed screw just contacts the push rod socket without depressing it. See illustration. Use a screw driver and wrench to lock the adjusting screw nuts.

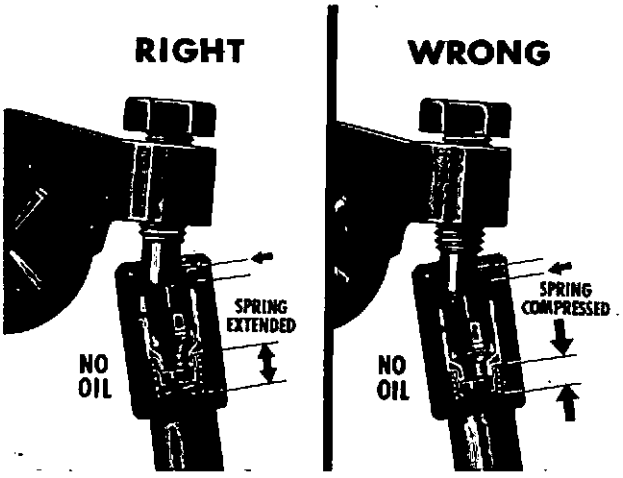
5. Remove the shim stock. Recheck both adjustments to be sure screws did not turn by sliding the shim under the screw while holding the non-adjustable screw in contact with the push rod.

6. Repeat steps 3, 4, and 5 for the exhaust valves.

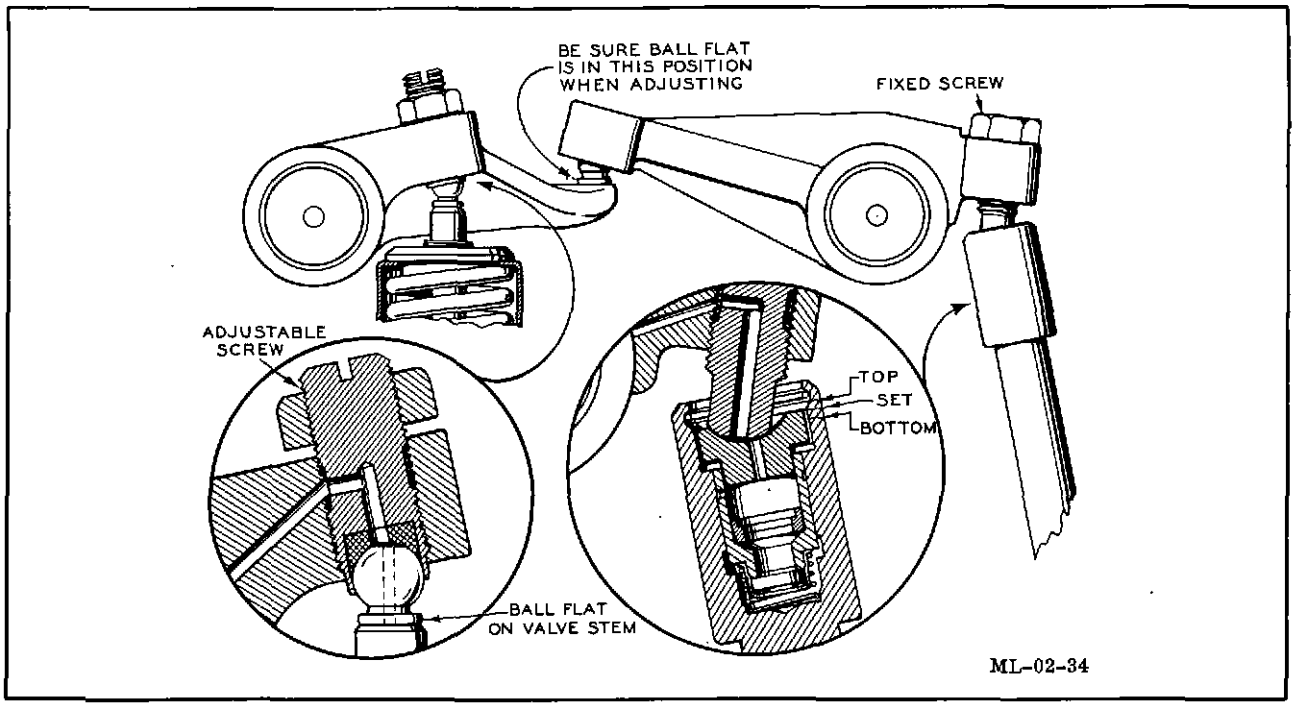
NOTE

Be sure the internal socket of the hydraulic lifter on each push rod is fully extended against the ring at the TOP of its travel and that the lifter is filled with engine oil.

7. Tighten both non-adjustable screws one-half turn, (until seated) then torque each screw to 60 ft. lbs. (8,30 mkp). This will pre-load the push rod lifter correctly into the upper range of lifter travel.



RIGHT AND WRONG ADJUSTING SCREW CONTACT



VALVE ADJUSTING COMPONENTS

Before starting the engine, rotate the crankshaft manually to be certain that no oversights have occurred which might cause valve and piston interference. After starting, and before tightening down the rocker covers, observe the action and oiling of each set of rocker arms.

DIESEL ENGINE SOLID PUSH RODS -- CURRENT ENGINES

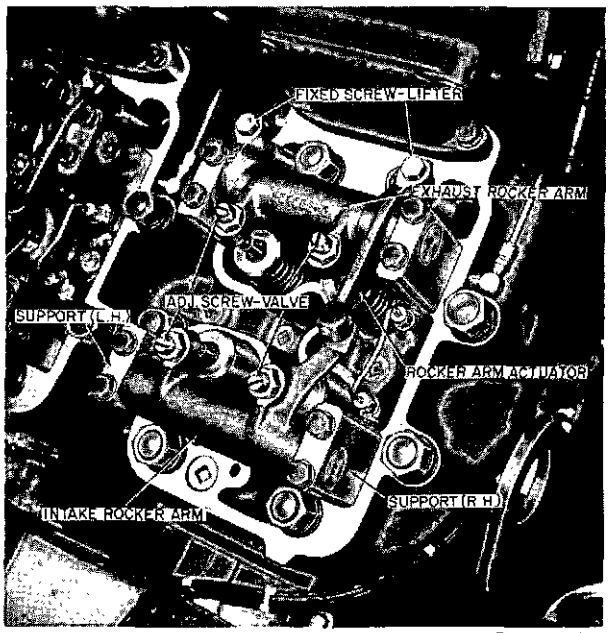
This valve adjustment procedure must be repeated every thirty days as a service measure to compensate for slight differences in valve and seat wear between the two valves of each pair.

1. Inspect the contact between the adjusting screw flats and the valve stem tips. The contact should be fairly well centered on the valve stem tip. If not, minor adjustment can be made by loosening the rocker arm supports and shifting them slightly; then loosen the lock nuts and adjusting screws at all four valve stem tips.

2. Make sure the two non-adjustable screws are fully seated. The non-adjustable screws should be torqued to 60 ft. lbs. They are a fixed position screw and are not used in this valve adjustment sequence.

3. Insert a piece of .005" (0,13 mm) shim stock, five inches (127,0 mm) long between the flats of the intake valve adjusting screws and the valve stem tips. Turn valve adjusting screws down with finger pressure until a slight drag is felt when trying to remove the feeler. Use a screw driver to hold the adjusting screws in this position while using a wrench to lock the adjusting screw nuts. Recheck the .005" clearance to ensure that the adjusting screws did not rotate while locking the adjusting screw nuts.

4. Repeat step 3 for the exhaust valves using .021" feelers.



VALVE ADJUSTING ARRANGEMENT

5. Before starting the engine, rotate the crankshaft manually to be certain that no oversights have occurred which might cause valve and piston interference. After starting and before tightening down the rocker arm covers, observe the action and oiling of each set of rocker arms.

GAS AND DIESEL ENGINES HYDRAULIC PUSH RODS -- EARLY MODELS

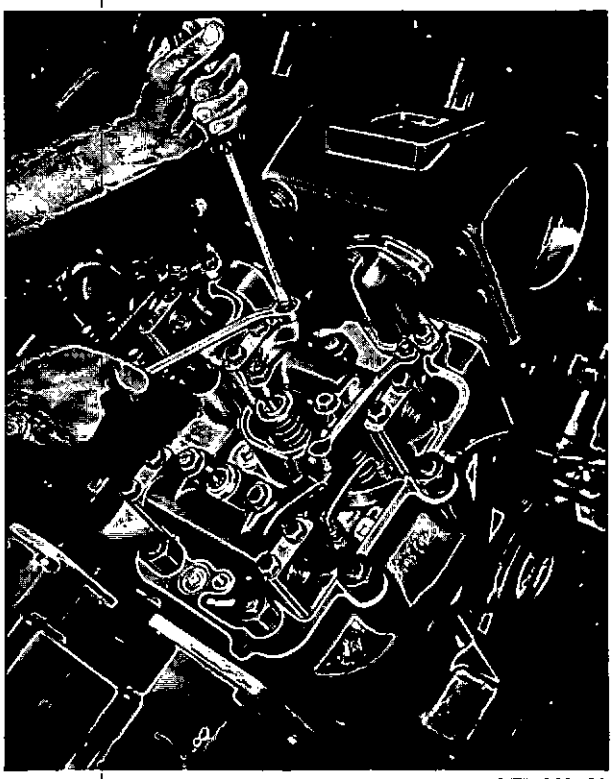
These engines may be identified by removing the rocker arm cover and checking for adjusting screws located over both push rods, and fixed screws located over one intake and one exhaust valve. See illustration.

1. Loosen the lock nuts and adjusting screws at the push rods.

2. Taking each pair of valve contacts in turn hold the fixed screw contact firmly against the valve stem tip with finger pressure.

3. Turn down the matching adjusting screw on the same side of the head with finger pressure until the flat just contacts the valve stem tip.

4. Use a screw driver and wrench to lock the adjusting screw nut. Both flats should just be contacting the valve stem. Check to be sure the screw did not turn while locking by trying to slide a .0015" piece of feeler stock under either side while holding the rocker assembly down manually.



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VALVE ADJUSTMENT (Early Hydraulic)

5. Repeat the above procedures, 2 through 4, for the opposite pair of contacts.

6. Be sure the internal socket of the hydraulic lifter on each push rod is fully extended against the ring at the TOP of the travel.

7. Using fingers only, and with the contacts held against the valves, turn down the adjusting screw at the push rod end of either rocker arm until it just touches the lifter socket without actually depressing it.

8. Turn the screw 1/2 turn more in a clockwise direction. Lock the adjusting screw. This will bring the adjustment into the mid-range of the lifter travel or SET position.

9. Repeat steps 7 and 8 above on the other rocker arm.

Before starting the engine, rotate the crankshaft manually to be certain no oversights have occurred which might cause valve and piston interference. After starting and before tightening the rocker arm covers, observe the action and oiling of each set of rocker arms. Oil flow down the back of the long rocker arm to the contact shoe which actuates the intake rocker arms should be adjusted by bottoming the metering screw in the long rocker arm and then backing it out just enough to establish a light flow of oil. Later rocker arms may not have this adjustment and require none because the oil is conducted internally.

COMPRESSION TESTING

Normal compression pressures at cranking are listed in GENERAL ENGINE DATA. Uneven compression or pressures lower than normal call for further investigation. It may indicate the need for valve regrinding, piston ring replacement, or other overhaul procedures.

GAS ENGINE COMPRESSION TESTING

Before checking compression, be sure the engine has been warmed up to operating temperature, the throttle is held in open position, and the ignition and gas supply is shut off so that the engine cannot start during the test. A standard automotive type compression tester with threaded adaptor should be used. Note the number of compression strokes required to obtain the highest indication. Repeat compression testing for each cylinder using the same number of strokes.

DIESEL ENGINE COMPRESSION TESTING

A special compression test adaptor, Part No. 499941, and a standard compression gauge and hose assembly is required to perform a compression check. The rocker cover and injector must be removed and the adaptor with the injector sealing washer installed. Use the injector hold down clamp to hold the adaptor. Engines equipped with air shut-off valves connected to the Amot control must have the Amot control reset lever held in the raised position during the test.

WARNING

Be sure the throttle control lever is in OFF position so the engine can't start while cranking for test.

CARBURETOR AND REGULATOR ADJUSTMENT

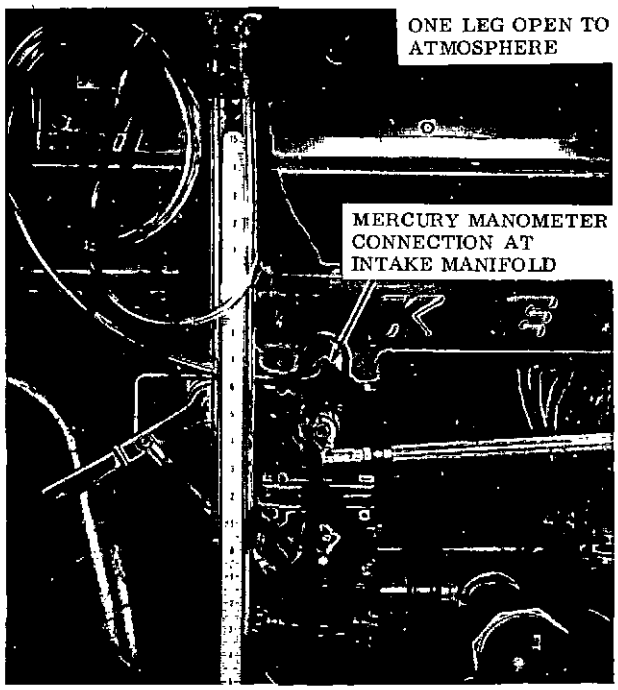
The settings used in this manual apply to engines using sales or field gas with a BTU value of 875 - 1000 LHV.

NOTE

Prior to making any adjustments to the fuel system, it is very important that the linkages between the butterfly valve housings and between the carburetors be adjusted, if necessary, so that butterflies are synchronized--that is, both butterflies are fully open and fully closed simultaneously. If adjustment is required, it is accomplished by a slight rotational movement of the universal joint coupling spiders, which is possible with the coupling bolts loosened.

NATURALLY ASPIRATED ENGINES (Models 600, 600D and 200T)

1. Set the primary, or "line" regulator to have 10 to 25 PSI at the inlet to the engine mounted regulator.
2. Adjust the engine mounted regulator so that the pressure at the carburetor inlet is 5" water column, plus or minus 1/2", with the engine idling.



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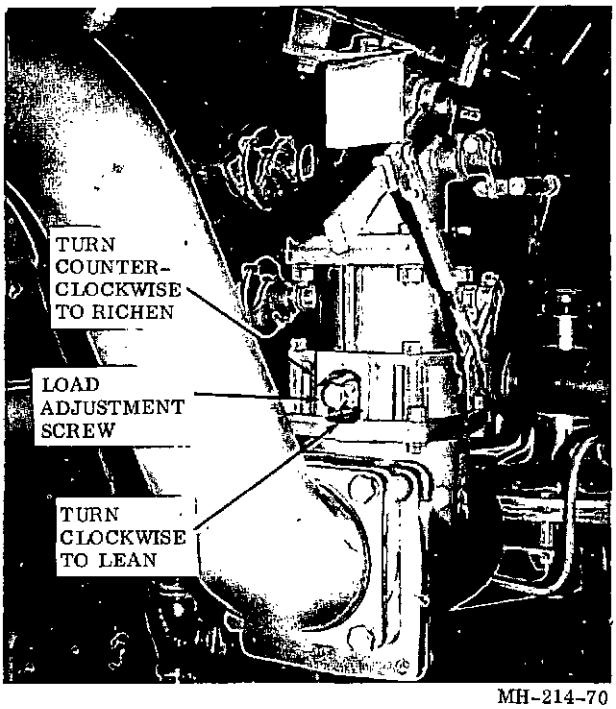
INTAKE MANIFOLD PRESSURE CONNECTIONS, MERCURY (hg) MANOMETER



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CARBURETOR LOAD ADJUSTMENT

Carburetor Load Adjustment (6-Cylinder Engines)

1. Apply load until 7" mercury or less intake manifold vacuum is observed.
2. Turn the load adjusting screw toward the rich direction until the intake manifold vacuum drops 1" of mercury in vacuum.
3. Turn the load adjusting screw from rich toward lean until the highest intake manifold vacuum reading is obtained. Note this reading.
4. Continue to turn the load adjustment in the lean direction, slowly, far enough to lower the intake manifold vacuum reading to 1/2" mercury vacuum below the reading noted in step three.

Carburetor Load Adjustment (Each bank of 12 and 16 cylinder engines)

1. Apply load until 7" mercury or less intake manifold vacuum is observed.
2. Turn load adjusting screw toward the rich direction until the intake manifold vacuum drops 1" of mercury.
3. Turn load adjusting screw from rich toward lean until the highest intake manifold reading is obtained. Note this reading.
4. Continue to turn the load adjustment in the lean direction far enough to lower the intake manifold vacuum reading of each bank by 1/4" mercury. This adjustment should give a total change in manifold vacuum of 1/2" mercury below the reading noted in Step 3 for each bank. If the reading is

not 1/2" lower, adjust both banks in equal increments until 1/2" is obtained.

NOTE

It is important that the gas supply be sufficient to allow the carburetor to be set "over-rich" with engine at full load. This can be determined by moving the load adjustment from rich toward lean and back again. Somewhere between these two points should be a position where highest manifold vacuum is obtained. With the engine at full load, the gas pressure to the carburetor should not be any less than 2 to 3 inches of water pressure lower than the initial setting (5" water pressure). If the full load pressure is less than this, it indicates one of the following: undersize piping and/or gas regulators, incorrect orifice or spring in the regulator, insufficient pressure in the line to the regulator.

Balance the Banks (on Vee engines only)

1. Check the intake manifold vacuum on both banks. Neither bank should show more than 1/2" mercury greater or less than the other.
2. If the difference is greater than 1/2" check and if necessary readjust the engine mounted Fisher regulators so that the gas pressure is the same, within 1/2" of water column.
3. If step 2 does not balance banks, adjust linkage between butterfly valves to balance banks.

TURBOCHARGED ENGINES (Models 600, 600D and 200T)

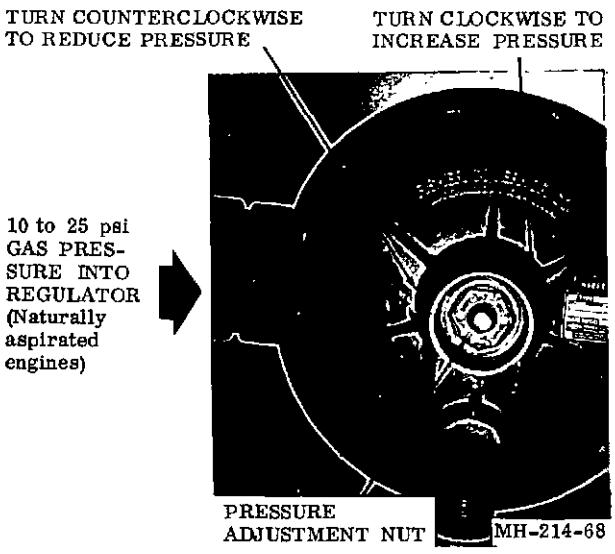
1. Set the primary, or "line" regulator to have 20 to 25 PSI at the inlet to the engine mounted regulator.
2. Adjust the engine mounted regulator so that the pressure at the carburetor inlet is 5" water column, plus or minus 1/2", with the engine idling.

Carburetor Load Adjustment (600, 600D and 200T under 130 BMEP)

1. Apply full load to engine.
2. Start with the load adjusting screw turned toward the rich direction to obtain an over-rich mixture.
3. Turn the load adjusting screw from rich toward lean until the lowest manifold pressure reading is obtained.

(200T over 130 BMEP)

1. Apply full load to the engine.
2. Turn the load adjusting screw toward the rich direction until the intake manifold pressure increases 1" mercury.



REGULATOR ADJUSTMENT

3. Then turn the load adjusting screw from rich toward lean until the lowest intake manifold pressure reading is obtained.
4. Now turn the load adjusting screw toward the rich direction far enough to increase the manifold pressure by 1/2" mercury.
5. Recheck the engine mounted Fisher regulators so that the gas/air pressure is positive.

Balance the Banks (on Vee engines only)

1. Check the intake manifold pressure on both banks. Neither bank should show more than 1/2" mercury greater or less than the other.
2. If more than 1/2" mercury pressure differential exists, check and if necessary readjust the engine mounted Fisher regulators so that the gas over air pressure of both regulators is positive and the same within 1/2" of water column.

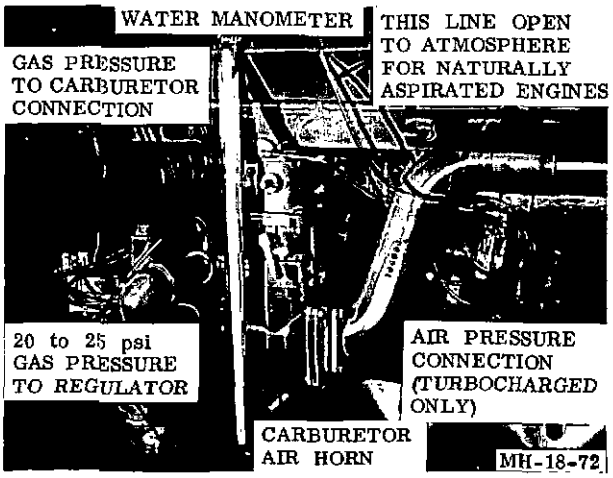
NOTE

Gas over air is defined as the difference in air pressure between the carburetor air horn and the carburetor natural gas inlet. It is measured with a water manometer connected to these two points.

3. If step 2 does not balance banks, adjust linkage between butterly valves to balance banks.

NOTE

It is important that the gas supply be sufficient to allow the carburetor to be set "over-rich" with engine at full load. This can be determined by moving the load adjustment from rich toward lean and back again. Somewhere between these two points should be a position where lowest manifold pressure is obtained. With the engine at full load, the gas pressure



GAS AND GAS OVER AIR CONNECTIONS, WATER MANOMETER

to the carburetor should not be any less than 2 to 3 inches of water pressure lower than the initial setting (5" water pressure). If the full load pressure is less than this, it indicates one of the following: undersize piping and/or gas regulators, incorrect orifice or spring in the regulator, insufficient pressure in the line to the regulator.

LPG (Liquified Petroleum Gas)

The adjustment sequence for Impco 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 Impco "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 Impco 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. Dual fuel installations require load adjustment for both fuels, since they utilize separate load adjustment controls.

DIGESTER GAS ADJUSTMENT

The adjustment sequence for Impco 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, Impco 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. Dual fuel installations require load adjustment for both fuels, since they utilize separate load adjustment controls.

POWER LIMITER ADJUSTMENT

The power limiter should be adjusted only if absolutely necessary and only after determining the engine is operating properly with correct ignition timing and fuel settings, and both banks are equalized (12 cylinder engines only). Before setting the power limiter, determine the intake manifold pressure required to produce the designed brake horsepower at maximum full load governed speed. This information can be obtained from the Waukesha Engineering Department by supplying the engine's serial number or by referring to Standard Sheet Series S-5911 and selecting the correct model and curve. If a gage value is obtained for sea level, it may be corrected by adding 1.0" Hg per 1,000 feet altitude above sea level. Absolute intake manifold pressure values do not need correction.

To Set Power Limiters, Proceed as Follows:

1. With the engine stopped, disconnect the power limiter control rod from the carburetor throttle control shaft lever. Secure the carburetor throttle butterfly valve in full open position.
2. Remove the linkage guard from the power limiter and inspect to assure the linkage is free. Check the travel of the control rod—it should travel 3/4" to 7/8" from the fully retracted position to the fully extended position. Also, check the free action of the spring loaded control rod. This rod is made with a slip joint so the butterfly can be closed to low idle manually, if necessary. If rust, gum, or paint prevent it from extending to its normal length after compressing the spring, the length of the push rod assembly may vary in operation and the butterfly valve position will not be consistent.
3. With the carburetor throttle butterfly secured in full open position, start the engine, allow it to warm up, and then apply the designed load at governed speed.
4. Use a mercury manometer to measure intake manifold pressure. Manifold pressure should agree with the pressure listed for the designed load. Loosen the spring locking clamp. Use a screw driver to turn in or back out the spring adjusting plug so that the control rod of the power limiter just begins to move at this intake manifold pressure. Tighten the spring locking clamp.
5. Unlock and move the throttle butterfly toward the closed position until it starts to take control of the engine. Note that when the throttle butterfly takes control of the engine, the governor butterfly will start to move towards full open position.
6. Adjust the heim joint on the power limiter control rod so the capscrew through the heim joint easily aligns with the hole in the lever on the throttle control shaft, without moving either the throttle butterfly or the power limiter control rod. In some cases, the lever on the throttle control shaft will require relocating.
7. Turn the carburetor load adjustment towards "R"

(left bank only of 12 cylinder engines) to gradually increase intake manifold pressure. You will notice the power limiter closing the throttle butterfly to take control of the engine. When manifold pressure has increased about 1.0" Hg, the power limiter will take control of the engine.

8. Re-set the carburetor load adjustment to its original setting. Note that the throttle butterfly moves toward open position and the governor butterfly moves toward closed position, thus regaining control of the engine. Repeat the carburetor load adjustment several times to assure that the power limiter takes control of the engine approximately 1.0" Hg above the normal designed BHP intake manifold pressure. The spring adjusting plug of the power limiter can be trimmed slightly if necessary for minor corrections. A final check can be made if a small overload can be applied to the engine temporarily to increase intake manifold pressure. The power limiter should take control of the engine after approximately a 1.0" Hg increase in manifold pressure.
9. After the power limiter is set correctly, disconnect its control rod from the throttle control shaft lever, replace the linkage guard and re-seal it. When the engine is either stopped or operating with intake manifold vacuum, the carburetor throttle butterfly should be approximately 10 degrees from full open position, and the control rod of the power limiter should be completely retracted.

In installations where full load is not available, the power limiter must be set by applying air pressure equal to designed load pressure. Disconnect the manifold pressure line and connect an air supply line. Connect a mercury manometer in the air supply line and set the power limiter as previously described. Adjusting the power limiter under these conditions is not as accurate, but it will provide protection for the engine and driven equipment until such time when a full load is available. When full load is available, it will be necessary to readjust the power limiter.

TIMING AND ADJUSTING THE FUEL SYSTEM

Timing Tapes and Charts

The timing tapes attached to the flywheel, are silver color with black markings and indicate flywheel positions from 40° before top center to 20° after top center. The engine direction of rotation and the top dead center (TDC) point are also shown.

The positioning of the correct flywheel degree mark under the housing pointer differs from the early stamped marks in that the serviceman must now refer to a timing data plate on the engine crankcase. This displays the necessary timing information.

Timing Injection Pump to Engine

Injection pump timing is properly set and sealed at the factory and should not be disturbed unless it is necessary to replace the injection pump or timing gears. When timing an injection pump follow this procedure.

1. Examine the new injection pump for any evidence of dirt or packing material (excelsior, and so on) that might adhere around the delivery valves or in similar locations.

2. If the engine is in an installation and is dirty, take time to wash away all loose dirt from the injection pump and surrounding area.

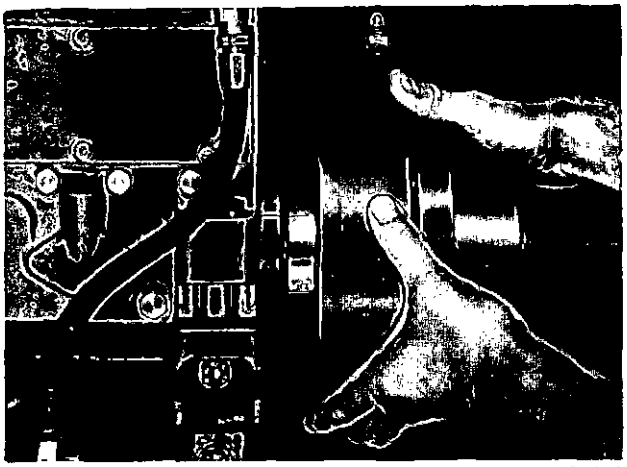
3. Refer to INJECTION PUMP TIMING in FITS AND CLEARANCES at the rear of section 4 to determine proper injection timing. To time 12 cylinder engines, bar the engine over in the direction of normal rotation until number one piston (right bank) is at the injection point before top center on the compression stroke. For left bank injection pump timing, time the pump to number 6 left bank piston. Six cylinder engines are timed to number one piston. The flywheel is marked for top center for both banks and has a timing tape with each top center marking. To be sure that the cylinder being timed is actually on compression, be sure intake and exhaust valves for that cylinder are closed.

NOTE

Opposite rotation 12 cylinder engines are timed to number six piston (right bank) and number one piston (left bank). Opposite rotation 6 cylinder engines are timed to number six piston.

The injection point must be accurately established by means of the correct degree mark on the timing tape and the pointer centered in the opening on the flywheel housing. When bringing the flywheel into this position, turn it very carefully as the mark and the pointer start to line up. If the flywheel is accidentally turned too far, it will be necessary to turn it back against rotation for about one-quarter turn and then come up on the pointer again in the direction of normal rotation. This avoids inaccuracies due to the normal running clearances of the gears. The engine should not be disturbed now until the pump is installed and bolted to the coupling.

4. Rotate the coupling on the injection pump until the chisel mark on the rotating member (use the RH mark for the right bank pump and the LH mark for the left bank pump) and the angular chisel mark (approx. 45° from vertical) on the injection pump are in alignment. Six cylinder engines are timed using the RH mark only.



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ALIGNING PUMP TIMING MARKS

5. Place the pump on the support bracket, and install the hold-down bolts. The saddle mount prevents angular misalignment, and the mount should be positioned so that the spaces between the ends and the center part of the coupling are approximately equal. The disc pack of the coupling should be flat. For fuel injection pump drive flex disc replacement and alignment, refer to Service Bulletin No. 9-2017.
6. Re-align, if necessary, the two chisel marks mentioned above, this time with great accuracy, and hold this alignment while installing two capscrews in the multiple-hole coupling. Two opposite holes will be found to align.
7. Inspect chisel marks and flywheel marks once more for evidence of accidental moving, then safety-wire the coupling capscrews.

DIESEL FUEL CONTROL RACK ADJUSTMENT

The control rack on the six cylinder engines (right bank on twelve cylinder engines) is set at the factory by an adjustable stop (see illustration) for full load delivery. The left bank injection pump on the V-12 is not equipped with an adjustable stop for full load fuel delivery since both pump racks operate together from full "off" to full load. The measurement for rack projection from the back face of the injection pump for full load operation is listed under "Calibration" in the General Engine Data section at the back of this manual. Due to operating variables, especially altitude, this stop usually has to be adjusted for smoke control on a naturally aspirated engine or exhaust temperature on a turbocharged engine when a fuel injection pump is installed.

On V-12 engines, the right and left control racks must move equally and simultaneously from the complete fuel shut-off position. This is provided for by the cross-engine governor linkage. All control rods are adjustable in length to provide accurate control.

NOTE

For adjustment procedures, the right bank on the V-12 engines is identical to the 6 cylinder engines and the left bank is for V-12 engines only.

First disconnect the governor rod end from the control shaft lever, and with the stop control lever or Amot control in "Stop" position, adjust the right bank pump rod so the right bank pump rack is in full "off" position when the pump rod end aligns with the hole in the control shaft lever. Reconnect the pump rod end to the control shaft lever.

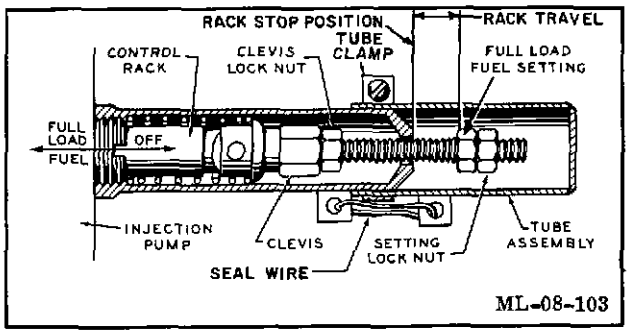
Now with the right bank pump in full "off" position, adjust the left bank pump rod so that it is in full "off" position too. This provides a starting point so both pumps can open up from full "off" position.

Next check the right bank full load rack travel and reset it if necessary to the measured length given in the General Engine Data section. This setting may require trimming later.

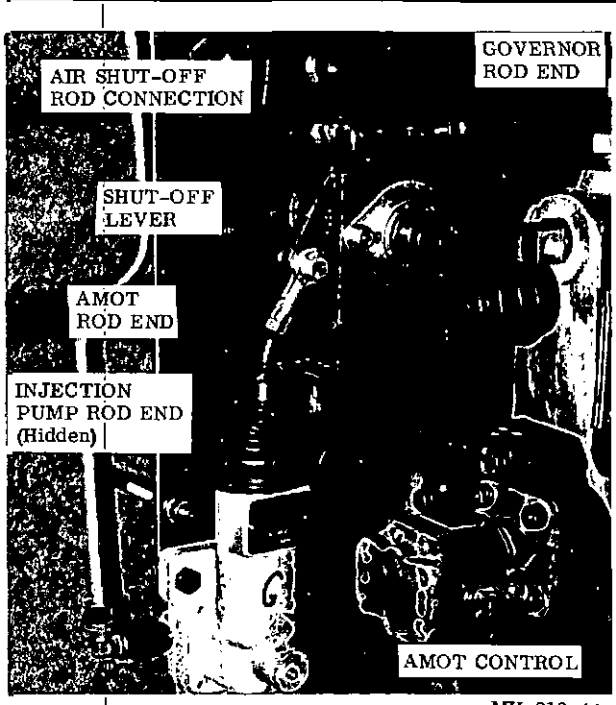
With the fuel injection pump rack in the full OFF position and with the governor lever on the terminal shaft in the OFF position, adjust the governor rod end so it just aligns with the hole in the control shaft lever without compressing the spring and without any mechanical strain on these parts. Reconnect the governor rod end to the control shaft lever. If the governor is a UG8, and the governor lever will not rotate to OFF position, trapped oil below the power piston in the governor must be relieved. If the governor is a UG8 dial control type, turn the load limit knob towards 0 while rotating the lever to OFF position. If the governor is a UG8 lever control type, lift the oil filler cap and with a long nosed pliers lift up on the shutdown rod while rotating the lever to the OFF position.

The governor lever on the terminal shaft should be positioned so that when the lever is in mid-range it is perpendicular to the governor rod. Note that the governor rod connects to the end hole in the governor lever.

With the fuel injection pump in the full OFF position, disconnect and adjust the overspeed air shut-off control rod end so that the air shut-off valve is in its fully closed position when the rod end aligns with



SETTING RACK STOP



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AMOT CONTROL LINKAGE

the hole in the shut-off lever. Reconnect the rod end to the shut-off lever. The valve is fully open when the rod end is closest to the fuel injection pump. The overspeed air shut-off device on this engine provides a quicker shut-off by blocking the air intake manifold when the injection pump rack is moved to the OFF position.

The engine may now be run, and if further trimming of the full load stop is required to reduce smoke at full load, or to reduce exhaust temperatures on a supercharged engine, adjust the control rack adjustable "smoke" stop as required.

Make a final check of the governor and rack linkage system to be sure that the stop control linkage is correctly adjusted. When the stop control lever or Amot control moves the injection pump control rod toward the shut-off position, the governor will naturally open up in response to the engine speed drop. The compression spring on the fuel control rack absorbs this governor action and allows the rack to be closed in spite of the governor. Check for free action, full rack closing, snug and secure rod end assemblies, and freedom from bottoming of the coil springs. Set rack position indicator at "0" at high idle, no load.

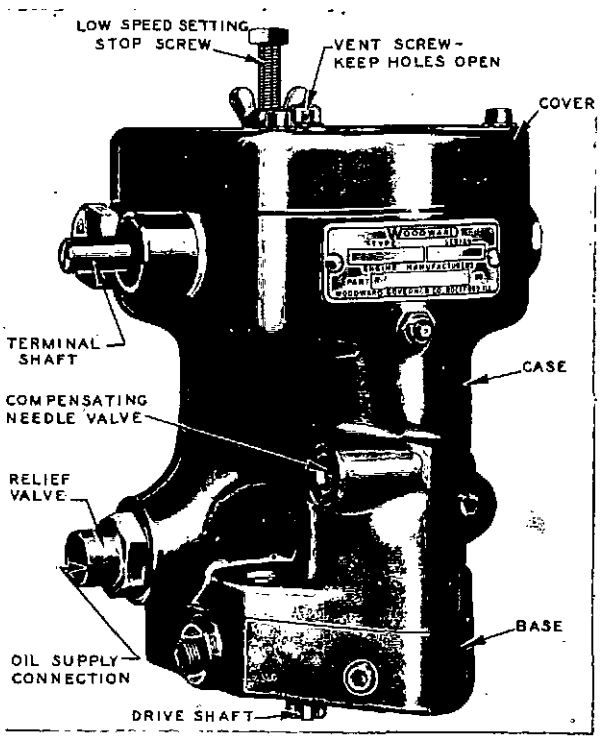
If the control rack cover on the front of the injection pump is removed, be certain that the clevis lock nut which locks the threaded control rack extension on the control rack with a clevis is securely in place and that the extension is fully threaded into the clevis. If this nut is not snug, it will prevent the control rack from being moved to the complete fuel shut-off position. This is also possible if the stop nuts are not loosened and turned separately as the threaded extension could then be turned out of the clevis.

If the control rack cover is removed, note the shims between it and the pump face. These shims are no longer necessary.

WOODWARD SG AND PSG GOVERNORS

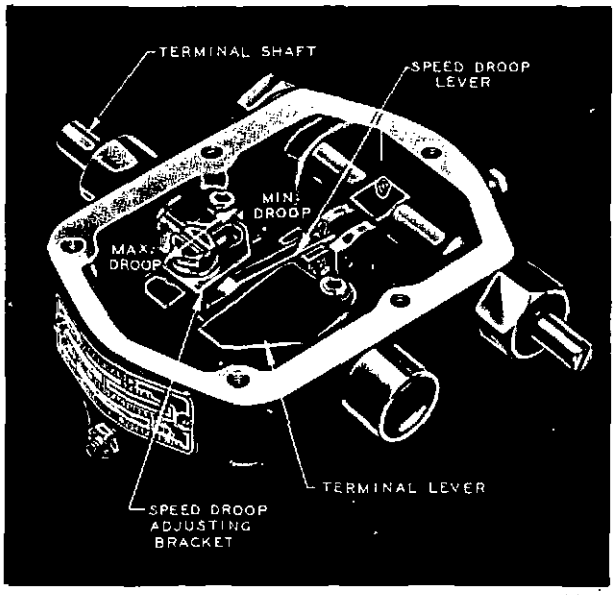
VHP Diesel engines are equipped with either Woodward SG or PSG hydraulic governors. The governor is vertically mounted and is driven through the accessory drive. The Woodward SG governor is a speed droop type governor used when isochronous (constant speed) control is not required. The design of the speed 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.



MH-31-1

PSG WOODWARD GOVERNOR



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PSG GOVERNOR - COVER REMOVED

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.

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.

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.

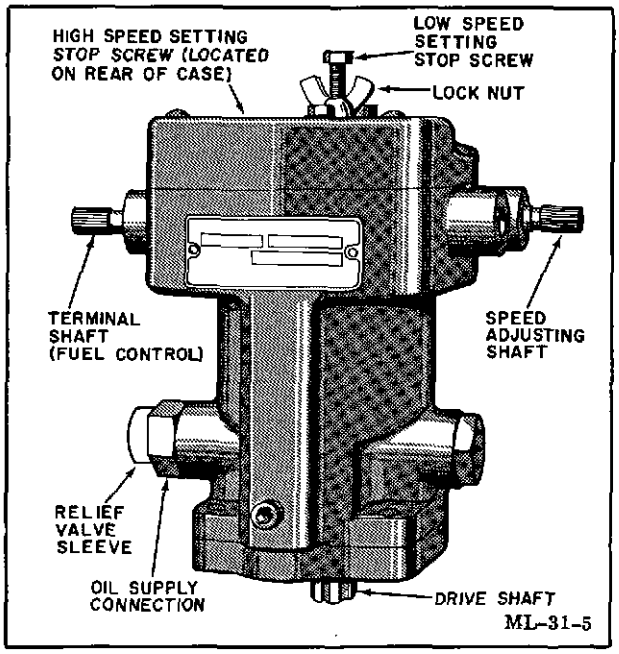
Shut-down of the engine can be accomplished by turning the speed adjusting shaft below the idle speed setting position.

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 adjustment 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 pin is at the shaft center, rotation produces no vertical movement of the pin and, therefore, no movement of the speed



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SG WOODWARD GOVERNOR

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.

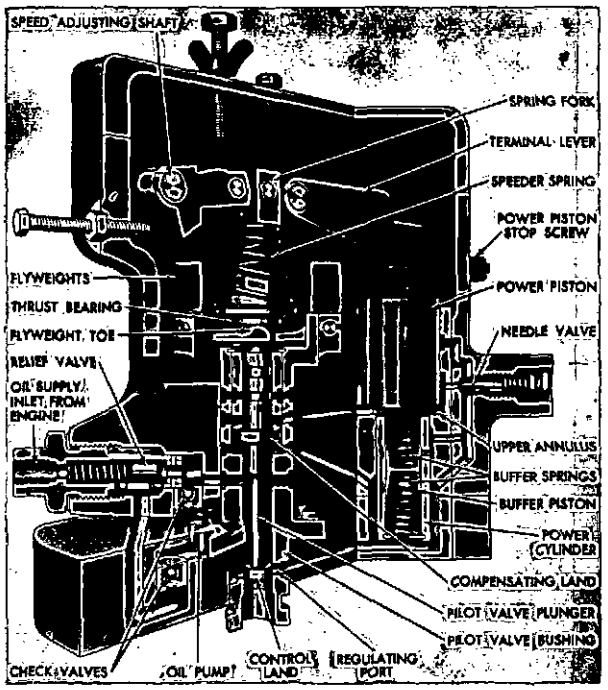
The system frequency is adjusted by changing the speed setting of the governor having zero droop. The distribution of load between units is accomplished by changing the speed setting of the governors having speed droop.

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.



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WOODWARD GOVERNOR - SECTIONAL VIEW

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

WOODWARD SG AND PSG GOVERNOR

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.

WOODWARD GOVERNOR, UG8 TYPE

The engine may be equipped with either a UG8 dial type governor or a UG8 lever type governor, depending upon engine application requirements.

The UG8 dial type governor is of the hydraulic type and isochronous (will maintain the same engine speed regardless of engine load). Speed adjustment, speed droop and load limit controls are standard features. The UG8 lever type governor does not have an external speed droop control.

UG8 Dial Type Governor

The synchronizer, or speed adjusting control, is used to change the engine speed when running alone or to change the engine load when the engine has been paralleled with other units. The synchronizer indicator located directly below the synchronizer merely indicates the number of revolutions of the synchronizer knob.

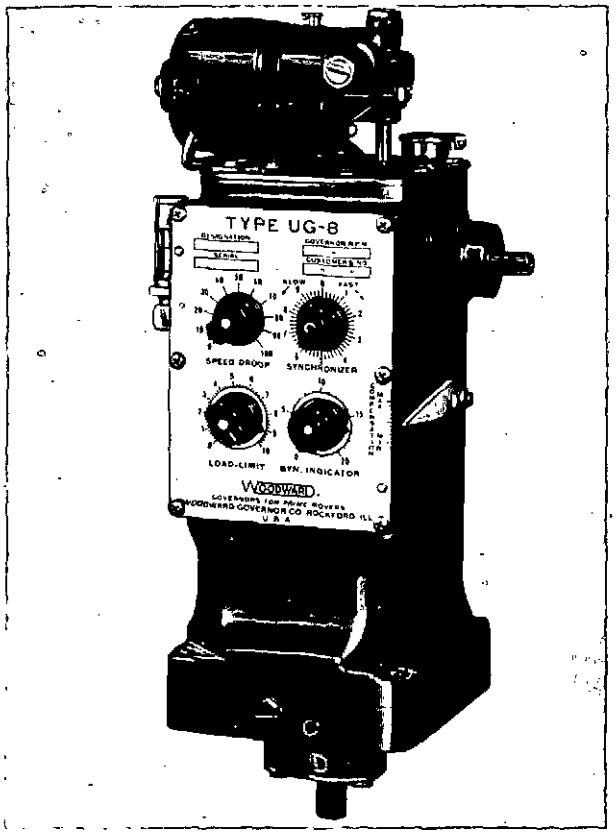
An optional synchronizing motor may be mounted on a special cover for the governor to provide remote speed control. Its use enables the operator to match the output of an engine driven machine with that of other units. The motor is of the split field, series wound, reversible type. It can be used on either direct current or alternating current at its specified voltage. A slip coupling is provided between the motor shaft and the synchronizer adjusting gear to allow the engine operator to adjust speed by turning the synchronizer control knob on the governor. This coupling is of the friction type.

The speed droop control can be set to automatically divide and balance the load between engines driving the same shaft, or paralleled in an electrical system.

Droop is incorporated in the governor through a linkage which varies the compression of the speeder (speed adjusting) spring as the terminal shaft rotates. Increased fuel reduces spring compression, reduces the governor setting accordingly, and the unit will gradually reduce its speed as load is applied. This relationship between load and speed acts as a resistance to load changes when the unit is interconnected with other units either mechanically or electrically.

As droop is reduced toward zero the unit becomes able to change load without changing speed. As a general rule, units running alone should be set on zero droop, interconnected units should be run at the lowest droop setting that will give satisfactory load division.

Alternating current generating units tied in with other units should have droop set sufficiently high (30 to 50 on the dial) to prevent interchange of load between the 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 the load changes within the limits of its capacity and will control frequency if its capacity is not exceeded.



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UG-8 DIAL CONTROL GOVERNOR

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

For more detailed instructions on speed droop settings, see the Woodward Governor bulletin on Plant Operating Problems.

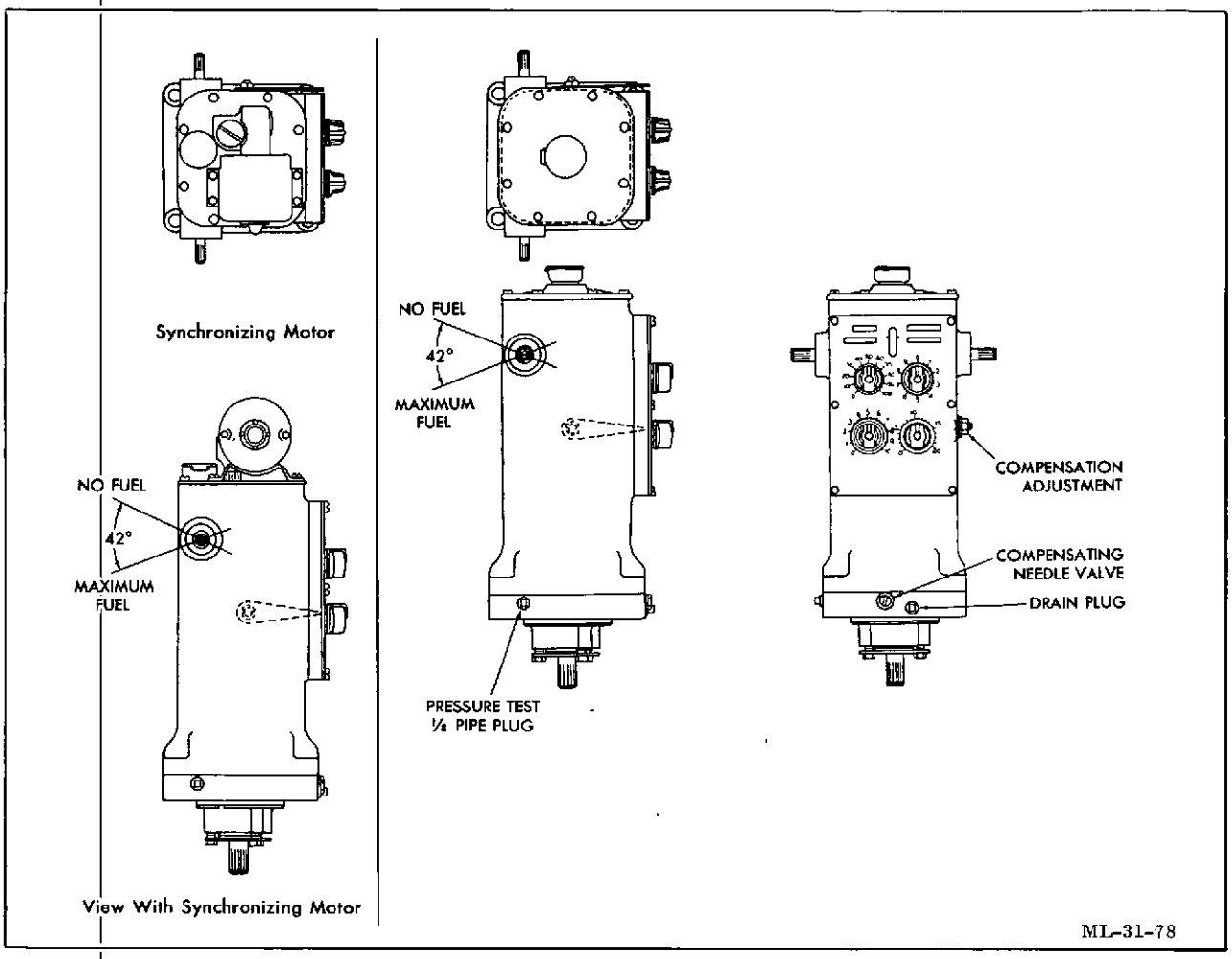
The load limit control hydraulically limits the load that can be put on the engine by restricting the angular terminal shaft rotation of the governor, and consequently, the quantity of fuel supplied to the engine. The control may also be used for shutting down the engine by turning it to zero.

CAUTION

Do not manually force engine linkage to increase fuel without first turning load limit knob to 10.

UG8 Governor Installation

The engine is normally shipped with the governor installed on the engine. If it should become necessary to install the governor on the engine, be sure it is



SERVICE ADJUSTMENTS - UG8 DIAL CONTROL GOVERNOR

mounted squarely and that the drive connection to the engine is aligned properly. A gasket should be placed between the base of the governor and the mounting pad on the engine.

CAUTION

Do not drop or rest the governor on its drive shaft.

The gear placed on the governor drive shaft should be checked to insure that it is meshing properly. There should be neither excessive backlash nor binding. Irregularities caused by uneven gear teeth, shaft runout, etc., will be picked up by the governor, transmitted to the fuel control system, and will result in erratic governing.

Since the load limit device operates hydraulically rather than mechanically, the load indicating pointer position cannot be changed by turning the load limit control unless the governor is running (or has oil pressure in its accumulators). When installing governor the terminal shaft must be rotated by a lever in order to obtain no fuel (zero load) position.

The linkage from the governor terminal shaft to the fuel control system should be free from lost motion or excessive friction.

UG8 Governor Lubrication

A neutral (non-acid, non-alkali) petroleum oil is the most satisfactory for use in governors. Normally the same oil that is used in the engine may be used in the governor. Use SAE 20 or 30 oil for ordinary temperature conditions. If governor operating conditions are extremely hot, use SAE 40 or 50, if extremely cold, use SAE 10. The oil must not contain additives which are used to free up rings, remove carbon, etc., unless a non-foaming additive is also present. The oil should not foam or sludge excessively when agitated, nor form gummy deposits when heated. Oil contaminated with water will cause foaming.

DIRTY OIL CAUSES MOST GOVERNOR TROUBLES

All containers must be clean and should be rinsed with light grade fuel oil or kerosene before using. Use clean new oil or filtered oil.

The correct level is when the oil is between the upper and lower lines on the sight glass with the engine warm and running. Keep governor oil at the correct level. Change the oil every 4,500 running hours if operating conditions are normal. If the governor is extremely active it may be necessary to change the oil oftener as required to maintain good governor operation.

UG8 Governor Servicing

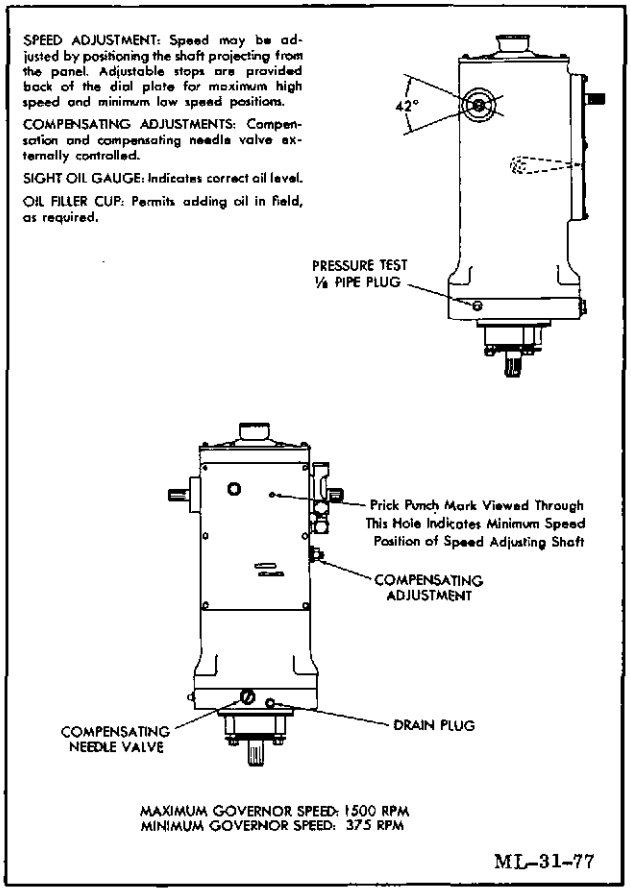
It is impossible to anticipate every kind of trouble that will be encountered in the field. Poor regulation may be due to faulty governor performance, or due to the governor attempting to correct for faulty operation of auxiliary equipment. If auxiliary equipment is used the effect of this equipment on the overall control required of the governor must be considered.

Approximately 95% of all trouble may be corrected by following these instructions, the other 5% will be of a nature requiring the service of a governor engineering specialist.

UG8 Governor Compensating Adjustment

The compensating needle valve must be adjusted with the governor controlling the engine, although the compensation may have been previously adjusted at the factory or on governor test equipment.

Although the governor may appear to be operating satisfactorily because the engine runs at constant speed (without load) the governor still may not be correctly adjusted. High overspeeds and low underspeeds after load changes and slow return to normal speed are some of results of incorrect compensation adjustments.



SERVICE ADJUSTMENTS - UG8 LEVER CONTROL GOVERNOR

IGNITION SYSTEM MAINTENANCE

For top engine performance, each unit of the ignition system must be in good condition and properly adjusted. This table will be 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.
Spark plug size:	18 mm with 1/2" reach. Torque to 40 to 45 lbs. ft. (dry); 30 to 34 lbs. ft. (oiled).
Spark plug type: (Standard) (Platinum tip) (Shielded) (Shielded)	 For all applications . . . . . Waukesha Part No. 69512 For all applications except generator sets . . . . Waukesha Part No. 60999B For all applications except generator sets . . . . Waukesha Part No. 60999E For generator set applications only . . . . . Waukesha Part No. 167037
Spark plug gap	.020" (standard) .015" (shielded — except generator sets) .011" (platinum tip) .025" (shielded — generator sets only)
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 point contacts meeting squarely and not excessively pitted; point gap .016"-.018" for FM-LTR.
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.

LOW TENSION MAGNETO TIMING

General

1. Bar engine flywheel so correct degree mark on timing tape for bank being timed is centered in timing hole and first piston of that bank in firing order (1R or 6L for 12 cylinder engines and 1R for 6 cylinder engines) is approaching top center, compression stroke. The first pistons in firing order for opposite rotation engines are 1L or 6R for 12 cylinder engines and 1L for 6 cylinder engines. This is the point at which firing occurs when engine is running and impulse coupling has disengaged.

2. Remove the timing bolt from the top of the magneto end cap. Turn the magneto rotor shaft backwards until the yellow timing mark on the edge of the distributor disc is centered in the timing window. This mark denotes that the end cap cover terminal stamped No. 1 is approximately ready to fire No. 1 cylinder.

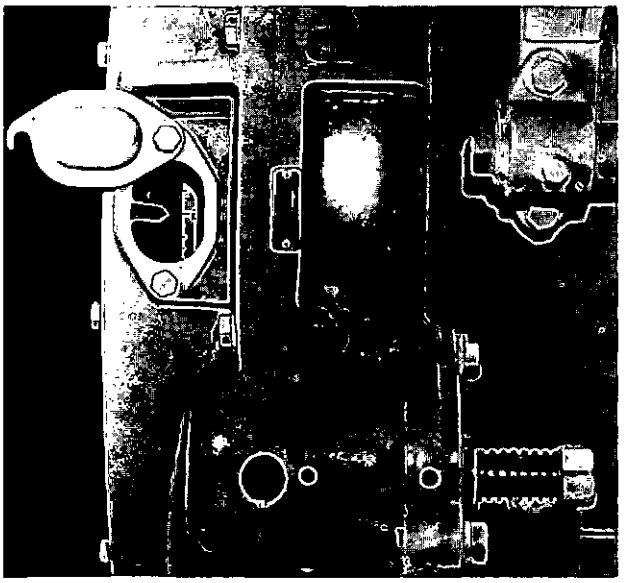
Base Mounted Magnetos

Since all base mounted magnetos are connected to the engine drive shaft by a drive member, the alignment of the timed magneto to the engine drive unit must be made by adjusting the drive coupling.

Timing must be checked using timing light with engine operating at governed RPM. Use temporary high tension lead between plug and coil to connect timing light. Be sure to lockwire drive coupling screws when timing is correct.

Flange Mounted Magneto

Timing must be checked using timing light with engine operating at governed RPM. Use temporary high tension lead between plug and coil to connect timing light. 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.



MH-08-105

TIMING MARK

MAGNETO CONNECTIONS

After low tension 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 cap cover, No. 1 terminal is at upper left. Connect wires in counterclockwise rotation as viewed from terminal end of magneto. 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. Magneto rotation for opposite rotation engines is clockwise. 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.

TIMING BREAKERLESS IGNITION SYSTEMS

When leading edge of longest (red) finger of distributor rotor is approximately in center of timing window in cover of Magtronic, it's ready to fire the first cylinder in the firing order.

When red mark on distributor shaft aligns with CCW mark on Altronic III housing, it's ready to fire the first cylinder in the firing order. Opposite rotation engines must have the CW marks aligned.

When slot on intermediate drive disc is aligned in center of timing window in cover of Bendix housing, it's ready to fire the first cylinder in the firing order.

When yellow timing mark is centered in timing opening, the Fairbanks Morse SCSA unit is ready to fire the first cylinder in the firing order.

Timing must be checked with stroboscopic type timing light at governed rpm. If timing is not correct, shutdown engine and readjust.

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.

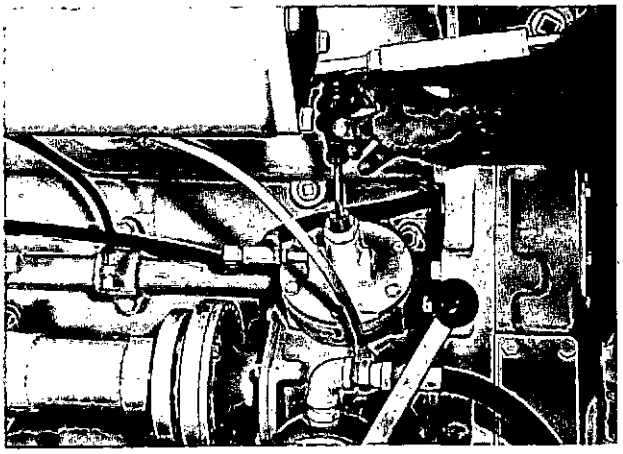
If the engine should develop trouble which appears to be definitely associated with its ignition system, inspect wiring, spark plugs, and transformer coils for the difficulty. If the trouble appears definitely related to the ignition generator, remove it from the engine and replace it with a unit known 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 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.

ADJUSTING THE OVERSPEED GOVERNOR

Use a tachometer of the hand or cable type. Remove the acorn nut from the overspeed governor and loosen the thin hexagon nut to permit adjustment. Turn the adjusting screw inward to raise the shutdown speed or outward to lower it. Overspeed governors are generally adjusted to 10% above desired high idle speed. Using a screwdriver to maintain this setting, tighten the thin hexagon nut. Then install the acorn nut to protect the adjusting screw.



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ADJUSTING THE OVERSPEED GOVERNOR

OIL PRESSURE ADJUSTMENT

Adjustment of the oil-pressure relief valve is seldom necessary. It is important that the proper grade of clean oil, bearing clearances, no leakage, and so on, be satisfactory before attempting to adjust the oil pressure.

CAUTION

The following procedures are based on fairly cool oil. If the initial setting of 75 to 80 psi. were made with hot oil, the relief valve would probably be bottomed solidly and cause oil pump damage on cold start.

Engines With Non-Adjustable Oil Pump Valve

1. Start engine and adjust relief valve at oil cooler

outlet to 45 psi header pressure as indicated by oil gauge in instrument panel.

2. Operate engine until oil is up to normal engine operating temperature (minimum 160°F, 71°C), then readjust relief valve at oil cooler outlet to 45 psi header pressure, if required.

Engines With Adjustable Oil Pump Valve and Auxiliary Oil Relief Valve

1. Start up engine and operate until oil temperature is approximately 50 to 60°F. If possible, operate engine at high idle, no load, while making adjustment.

2. Close auxiliary relief valve by turning adjusting screws all the way in.

3. Adjust engine oil pump relief valve until oil gauge in instrument panel indicates 75 to 80 psi (header pressure).

4. Start engine and adjust relief valve at oil cooler outlet to 45 psi header pressure as indicated by oil gauge in instrument panel.

5. Operate engine until oil is up to normal engine operating temperature (minimum 160°F, 71°C), then readjust relief valve at oil cooler outlet to 45 psi header pressure, if required.

Engines With Adjustable Oil Pump Valve and Without Auxiliary Oil Relief Valve

1. Start engine adn adjust relief valve at oil pump to 45 psi header pressure as indicated by the oil gauge in instrument panel.

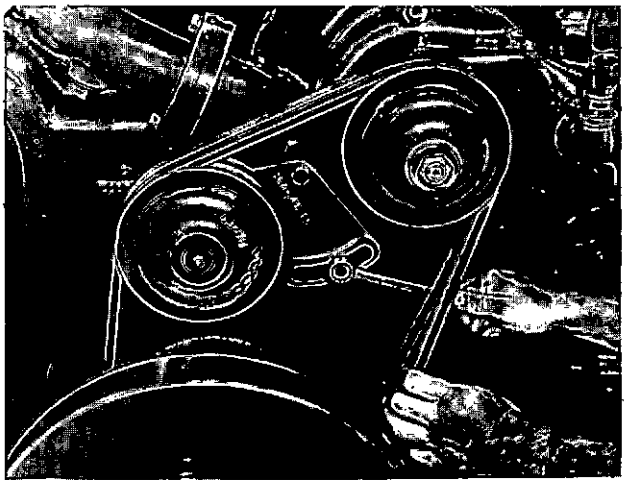
2. Operate engine until oil is up to normal engine operating temperature (minimum 160°F, 71°C), then readjust oil pump relief valve to 45 psi if needed.

NOTE

Field reports have indicated that some operators have been attempting to adjust oil pressure by loosening the large lock nut which retains and locks the relief valve sleeve screw. This results in violent movement of the plunger and causes rapid and severe wear. All users should be advised that the sleeve should be bottomed and its threaded retainer drawn down snugly and locked to prevent this condition. If reassembling the relief valve sleeve screw, thread it approximately 1/2" into the oil pump body, apply a drop of Loctite Sealer to the exposed threads, and then thread it in until it bottoms.

WATER PUMP DRIVE BELTS

1. Loosen the bolts which secure the idler pulley mounting bracket to the engine.



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WATER PUMP BELT TENSION

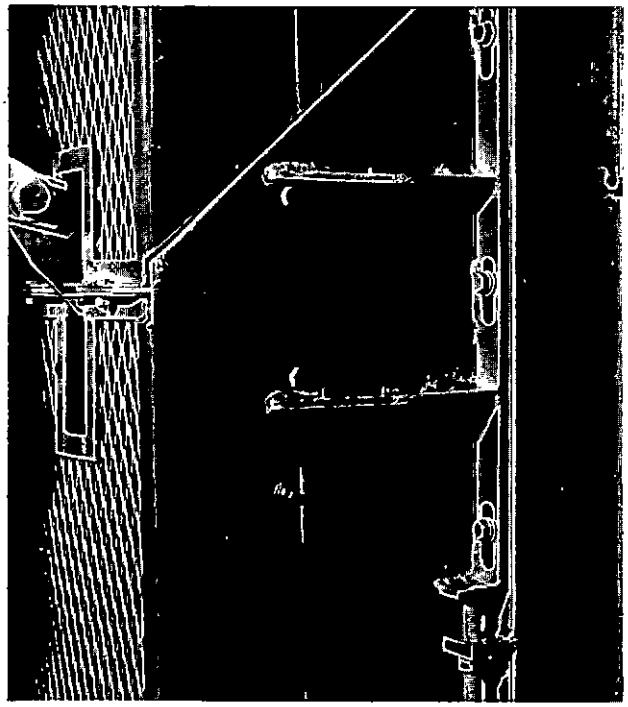
2. Pivot the idler pulley bracket toward the center until the old belts can be slipped free.

WARNING

ALWAYS REPLACE DRIVE BELTS IN PAIRS.

3. Slip the new belts over the pulleys and move the idler pulley bracket outward until the belts permit movement by hand of 1/4" to 1/2" as illustrated.

4. Retighten the idler pulley bracket bolts.



MH-200-49

FAN BELT ADJUSTMENT

ENGINE STORAGE

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

1. Protection of machined metal surfaces, cylinders, valves, bearings, and so on, from the effects of both dampness and salt or other corrosive substances in the atmosphere.

2. Protection of openings into the engine against entrance of dirt, abrasive material, and foreign matter of all types.

3. Protection of accessory equipment, including carburetors, gas regulators, magnetos, starters, generators, and fan belts against corrosion, dirt, moisture saturation and progressive deterioration.

4. Protection of cooling system, intercoolers, and LPG vaporizers against freezing, rusting, or seizure of water pump seals.

5. Protection of a general nature against the elements, rain, snow, and extremes of temperature.

6. Protection of batteries by disconnecting and removing them to a slow charging station where they can be kept fully charged. If this is neglected, the plates may be damaged and ruined by becoming sulphated.

7. Protection of the generator or alternator by covering all openings to prevent the entry of dust, moisture, dirt, and rodents. A heavy 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 judgement of the person in charge of the equipement. 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

Nucle-Oil, a product of the Daubert Chemical Company, is offered in one gallon cans through Waukesha Motor Company under Part No. 166709-A and offers a practical and economical solution to storage problem. This product is similar in appearance to a conventional lubricating oil of about SAE No. 10 viscosity. 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.

WARNING

Nucle-Oil contains Petroleum Distilate. 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.

NUCLE-OIL APPLICATION CHART

	Upper Cylinder		Crankcase		Oil Bath Air Filter	Injection Pump(s)	Total Ounces Engine	Fuel Tank
Number of Cylinders	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	Nucle-Oil Required	Ozs. Nucle-Oil
Six	3-1/2 (100 cc)	21 (620 cc)	43 (40.7 liters)	110 (3250 cc)	2 (60 cc)	3 (90 cc)	136 (4020 cc)	1 oz. per 20 gal. of air space (30 cc per 75 liters) (additional for lines)
Twelve	3-1/2 (100 cc)	42 (1240 cc)	43 (40.7 liters)	110 (3250 cc)	4 (120 cc)	6 (180 cc)	162 (4790 cc)	

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

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. 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 has left highly corrosive oil in the bearings and close contact surfaces, 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 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. Refer to those steps under CONVENTIONAL STORAGE for external protection recommendations.

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.

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 and multi-plunger injection pumps.
3. Crank engine for 20 seconds, if possible, to help disperse Nucle-Oil, with fuel supply line picking up Nucle-Oil to protect injectors, and single plunger injection pumps (when applicable).
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 represerve 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. All VHP 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. Circumstances may compel omitting some steps and, on the other hand, special conditions may point to greater emphasis on other steps. 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 reinstall.

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

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

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

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

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

Engines treated in accordance with these instructions will normally be protected for 6 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 formrcorrosive 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 almostuall 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 antifreeze, ample lubricating oil of the correct type and viscosity, and proper adjustments.

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

CAUTION

All generators and switchgear which have been stored must be checked for 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, supressors and any other solid state devices which may be connected to the stator or rotor windings. The megger value should be: operating voltage ÷ 1000 + 1 (i.e., machine voltage of 480 V.A.C. ÷ 1000 = .480 + 1 = 1.480 megohms). If any circuit to ground measures less than calculated value, consult the Waukesha Motor Company Service Department for uny cmrrective 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) Nucle Oil #120 Mil Spec. MIL-L-46002 Grade 2	U. S. Army Spec. 2-121 (Waxy Coating) 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.

PREVENTIVE MAINTENANCE SERVICE REPORT

OWNER _____ DATE ORDERED _____

ADDRESS _____ DATE LAST PM _____

SITE _____ SPEC NO. _____

MACHINE DESC. _____ SERIAL NO. _____

HOURMETER READING _____ DATE PUT IN SERVICE _____

OIL USED: BRAND _____ TYPE _____ SAE _____

OK	NEEDS ATT.	WORK COMPL.

A. Engine Running:

1. Record crankcase oil pressures _____ PSI
2. Record water temperature _____ °F.
3. Record battery charge rate _____ Amps. DC
4. Record AC volts _____ Volts
5. Record AC current _____ Amps.
6. Record AC watts _____ KW
7. Record engine speed _____ RPM
8. Record Frequency _____ HZ
9. Check governor stability - linkage tight?
   Governor line secure?
10. Check exhaust, water, fuel, oil piping for leaks
11. Check for loose wires on sensors or batteries
12. Any unusual noise or vibration?
    Generator bearing?
13. Running smoothly?
14. Any shutdown lights on?

B. Shut Engine Down — Open Breakers or Switches:

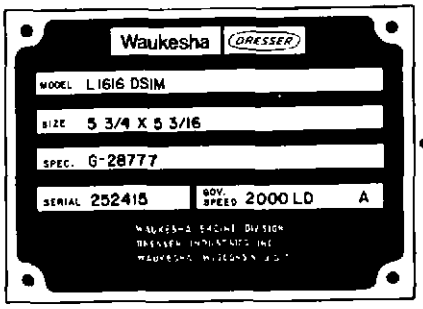
1. Drain oil. Any unusual foreign material?
2. Oil electric starter sparingly
3. Change air cleaner oil
4. Clean and/or replace oil and fuel filters
5. Replace plug and fill crankcase with oil
6. Check oil level gauge
7. Check water level
8. Take compression check
   Left 1___ 2___ 3___ 4___ 5___ 6___
   Right 1___ 2___ 3___ 4___ 5___ 6___
9. If low compression, check rings and valves.
10. Check safety shutdowns
11. Check battery fluid level. Specify gravity
12. Vacuum clean control box, alternator, radiator

C. Start engine manually:

1. Record crankcase oil pressure _____ PSI
2. Check injection timing
   Right _____ °BTDC
   Left _____ °BTDC
3. Record engine speed _____ RPM
4. Record Frequency _____ HZ
5. Record AC volts _____ Volts
6. Check governor stability
7. Check for air, exhaust and oil leaks—especially around filters
8. Check controls and breakers to be sure unit is in standby/ready position.

TROUBLE SHOOTING

PARTS ORDERING



ALWAYS SPECIFY THE ENGINE MODEL DESIGNATION, SPECIFICATION NUMBER, AND SERIAL NUMBER, AS FOUND ON THE ENGINE NAMEPLATE.

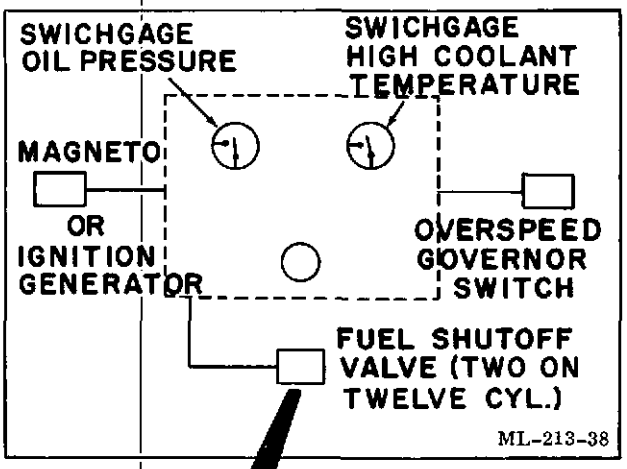
ML-1000-29

TROUBLE SHOOTING

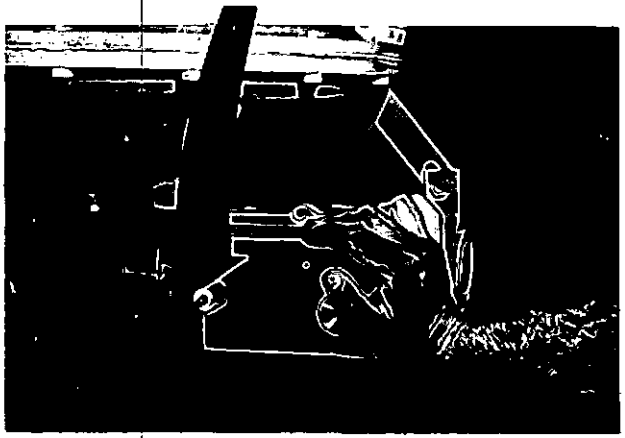
Good trouble shooting methods determine the cause or causes of unsatisfactory operation and point out the action needed to correct the problem. Knowledge of how engine systems work, together with the trouble shooting chart in this unit and current information from the engine instrument panel provide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

AUTOMATIC ENGINE CONTROLS

Gas engine automatic controls operate through the ignition system to provide engine shutdown whenever a harmful operating condition develops. When any of these control devices detects a system fault, the magneto or ignition generator stops driving the high voltage coils and trips the gas fuel supply shut-off valves(s).



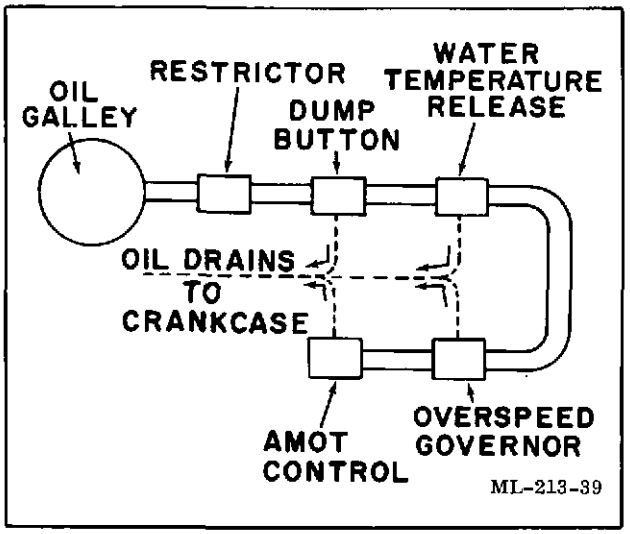
GAS ENGINE CONTROLS - BLOCK DIAGRAM



MH-213-37

Diesel engine automatic controls (except marine) use engine oil pressure to control a spring loaded shutdown device (Amot control). After the engine is started, engine oil pressure holds the Amot safety control in the RUN position. Low oil pressure, high water temperature, engine overspeed, or operation of the manual dump valve relieves the oil pressure to the safety control, which closes the injection pump fuel rack(s) and the intake manifold air shut-off valves, to stop the engine.

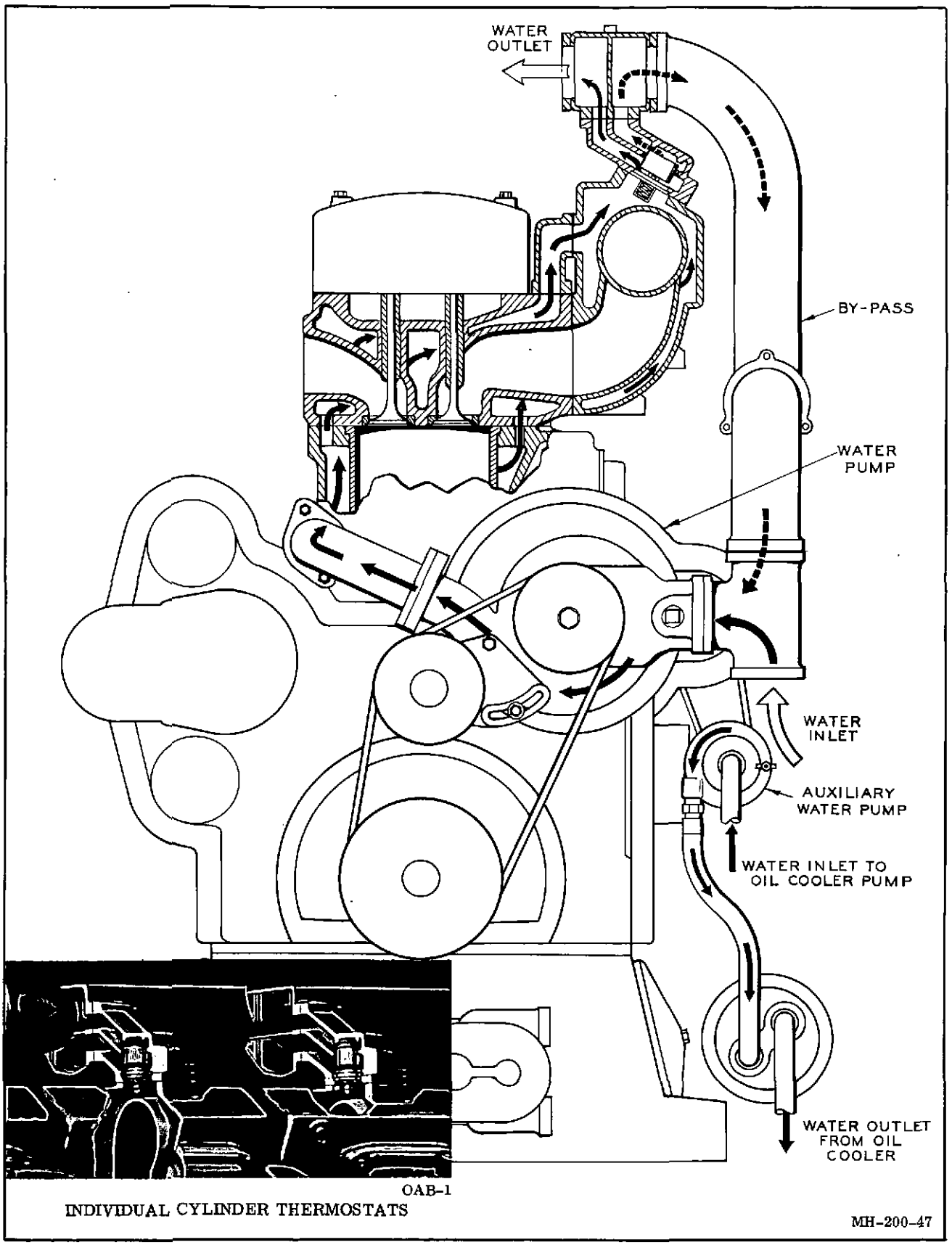
Since there is no oil pressure when starting the engine, the operator must lift and hold the safety control lever in the RESET position until the engine starts and the oil pressure builds up to a safe operating minimum. This prevents false starts and starting with low oil pressure. Marine engine Amot safety controls actuate for shutdown on oil pressure, only if the engine overspeeds, or when engine is shut down. When lifted to RESET position, the marine Amot control latches and the handle can be released. The latching Amot control is optional equipment on other VHP diesel engines.



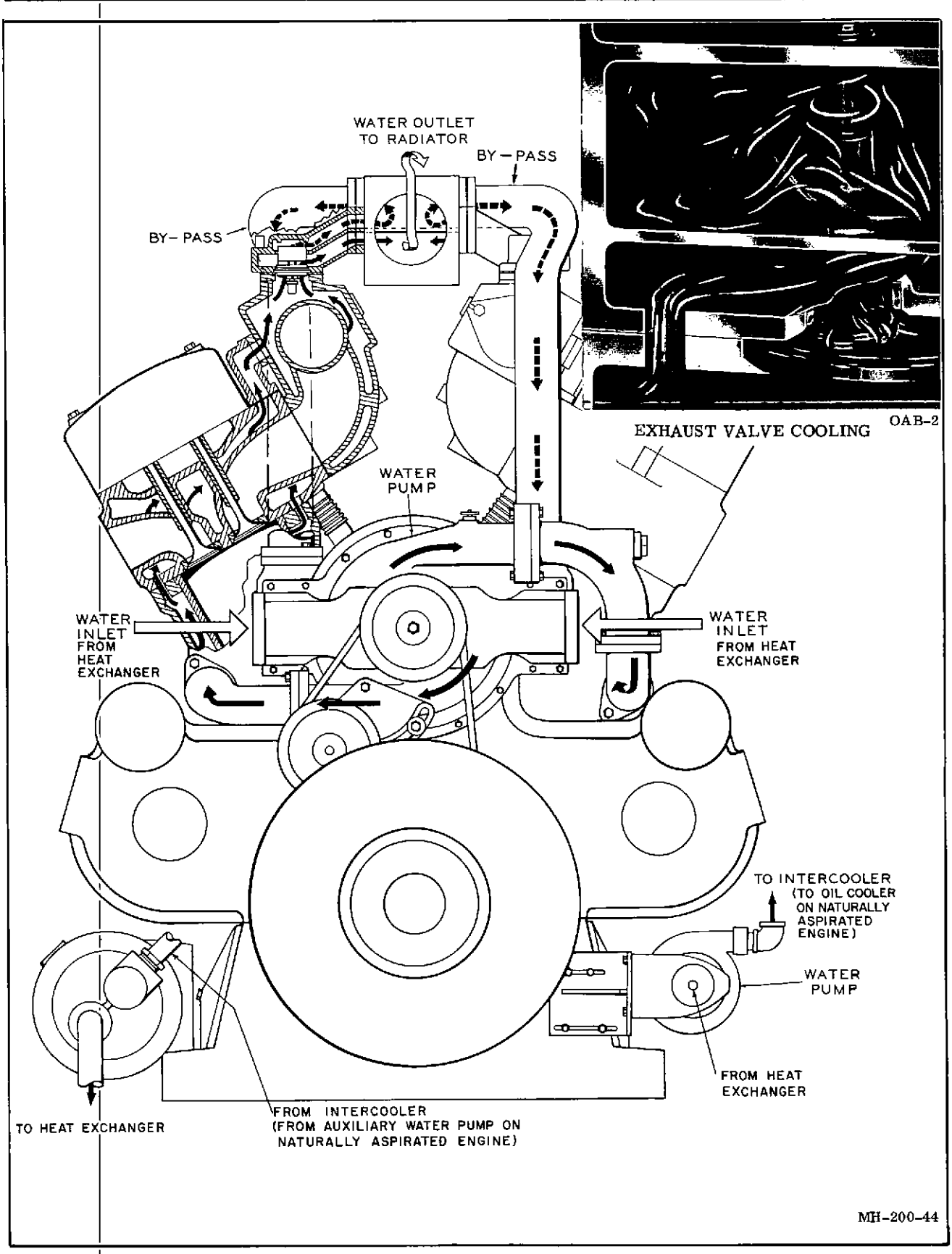
DIESEL ENGINE CONTROLS - EXCEPT MARINE BLOCK DIAGRAM

COOLING SYSTEM

The single centrifugal type water pump is mounted on the center of the gear cover and is driven by two belts from the crankshaft pulley. The pump causes the coolant to pass into the cylinder block water jacket, where it circulates around the cylinder sleeves. The coolant enters each cylinder head where it is directed especially at the valve area, then passes to the exhaust manifold. Current engines, equipped with a thermostat for each cylinder head, use the thermostat housing to pass the coolant to the "water" cooled exhaust manifold. Earlier engines use a simple elbow from head to cooled exhaust manifold, while temperature control is maintained by a single valve type thermostat atop the exhaust manifold. The coolant discharge from the engine may be cooled by one of a variety of devices, such as a radiator, heat exchanger, and so on.



SIX CYLINDER COOLING SYSTEM SCHEMATIC



TWELVE CYLINDER COOLING SYSTEM SCHEMATIC - WITH SINGLE OIL COOLER

AIR INTAKE SYSTEM

Huge quantities of combustion air are required for all internal combustion engines. Common sources of trouble in air intake systems are most often related to inadequate installation, and include the following:

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, reducing power rating. Generous access to outside air must be provided.

EXHAUST SYSTEM

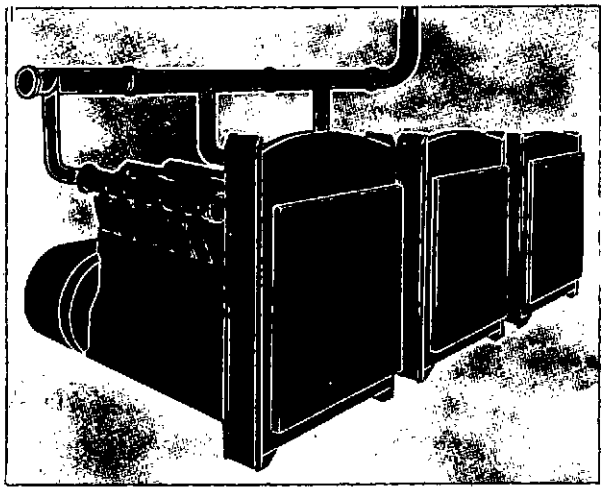
The huge quantities of combustion air consumed by internal combustion engines must be properly exhausted after combustion occurs. Therefore, every possible provision must be made to minimize restriction with resultant back pressure of an exhaust system.

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

Vent passages or a chimney in an existing structure not specifically designed for service as an engine exhaust passage 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 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. Welded tube turns with a radius of four or five diameters should be used.

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.



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MULTIPLE EXHAUST CONNECTIONS TO A COMMON HEADER ARE VERY POOR PRACTICES

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.

CRANKCASE BREATHERS

Naturally Aspirated

A slight negative crankcase pressure (0 to 1" water column) is maintained by using the pressure drop in the air intake system of the engine. A filter located in the line prevents oil vapor from entering the intake system.

MH-70-14

CRANKCASE BREATHER - NATURALLY ASPIRATED

Turbocharged Engine

Turbocharged engines are equipped with a closed positive type venturi breather system. On this type of breather system, the crankcase fumes pass through an oil separator, then on through a breather where the oil mist is filtered out, condensed and allowed to drain back to the oil pan. The required negative pressure is obtained through a venturi located in the exhaust outlet.

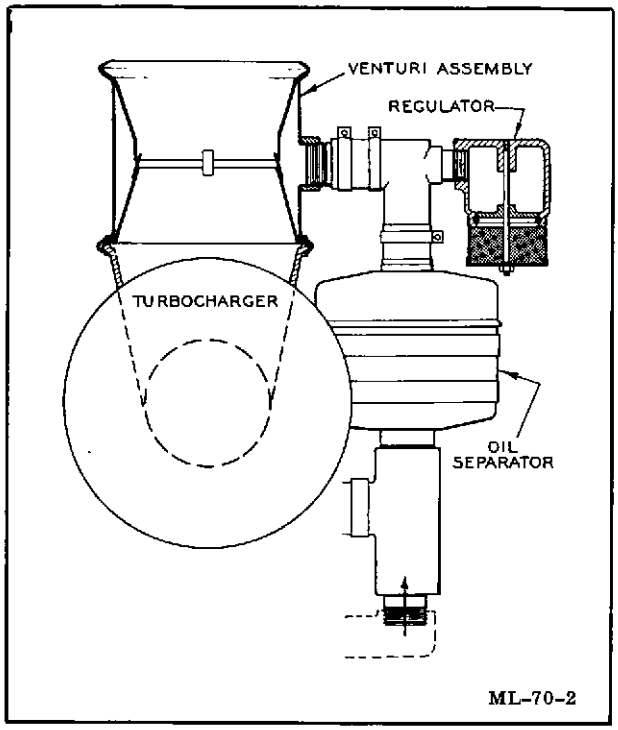
Carburetion

To understand the operation of the IMPCO air valve type of carburetor, it is necessary only to realize that the flow of air through the carburetor is controlled by the butterfly valve in the carburetor throat (the same as any other carburetor). This flow is measured by the air-flow measuring valve in the bowl of the carburetor. The greater the air flow, the higher the air-flow measuring valve rises. The gas metering valve is connected directly to the air valve so that it rises exactly the same amount. The gas valve is shaped to admit the correct amount of gas at any height to which the air-flow measuring valve rises. The air-flow measuring valve sets up a pressure drop of 5" of water column which gives a very high metering force up to the fuel entering the carburetor at low engine speeds and allows easy starting without priming, with excellent low speed torque. At full engine speed, with the air-flow measuring valve at the top of its travel, it becomes an inverted venturi and will allow passage of a great amount of air beyond that point.

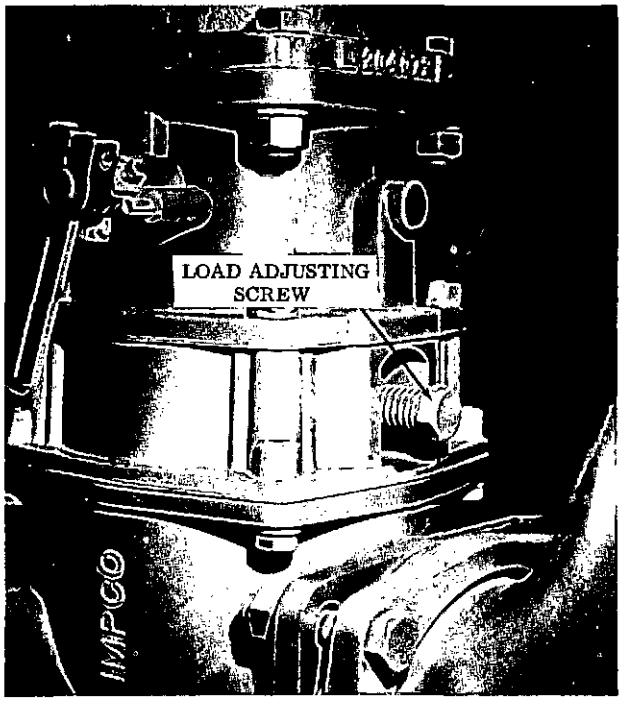
A strong metering force on the fuel entering the bowl of the carburetor is of great benefit in minimizing the effect of air-cleaner drag. A balance line from the carburetor to the regulator is seldom necessary. Tests show that the effect of air-cleaner drag on natural gas mixtures is negligible.

Operation

IMPCO carburetors are designed to use natural gas under pressure. These carburetors have a built-in shutoff valve to stop the flow of gas when the engine is stopped. No atmospheric regulator is needed with natural gas. Natural gas carburetors normally operate with approximately three ounces of pressure at idle with 1000 BTU gas. Full-load gas pressure may drop 1 to 1-1/2 ounces at the carburetor inlet. As long as power mixture adjustment is effective, exact pressure at full load is immaterial. Natural gas with higher or lower BTU values can be accommodated by raising or lowering the output pressure of the regulator.

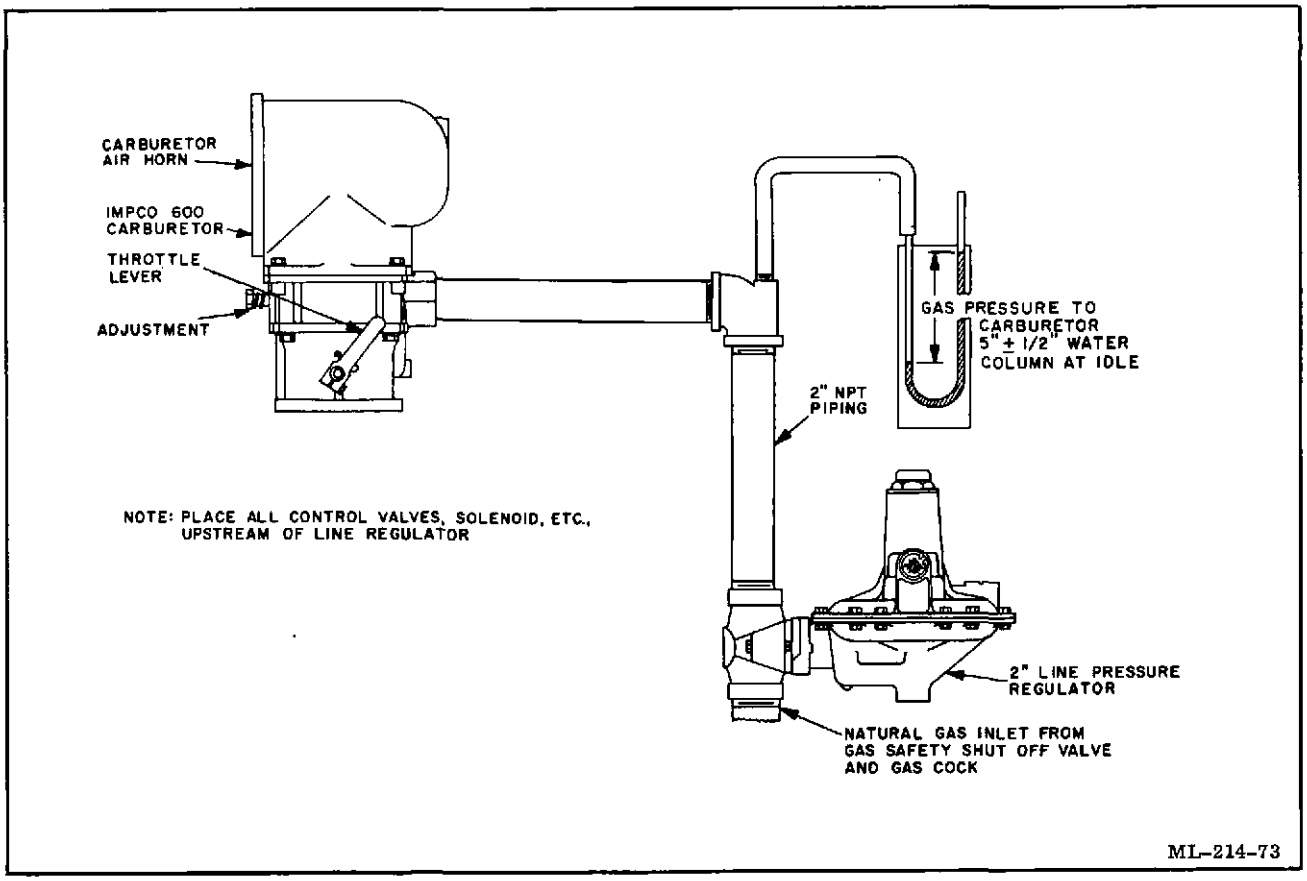


VENTURI TYPE BREATHER SYSTEM

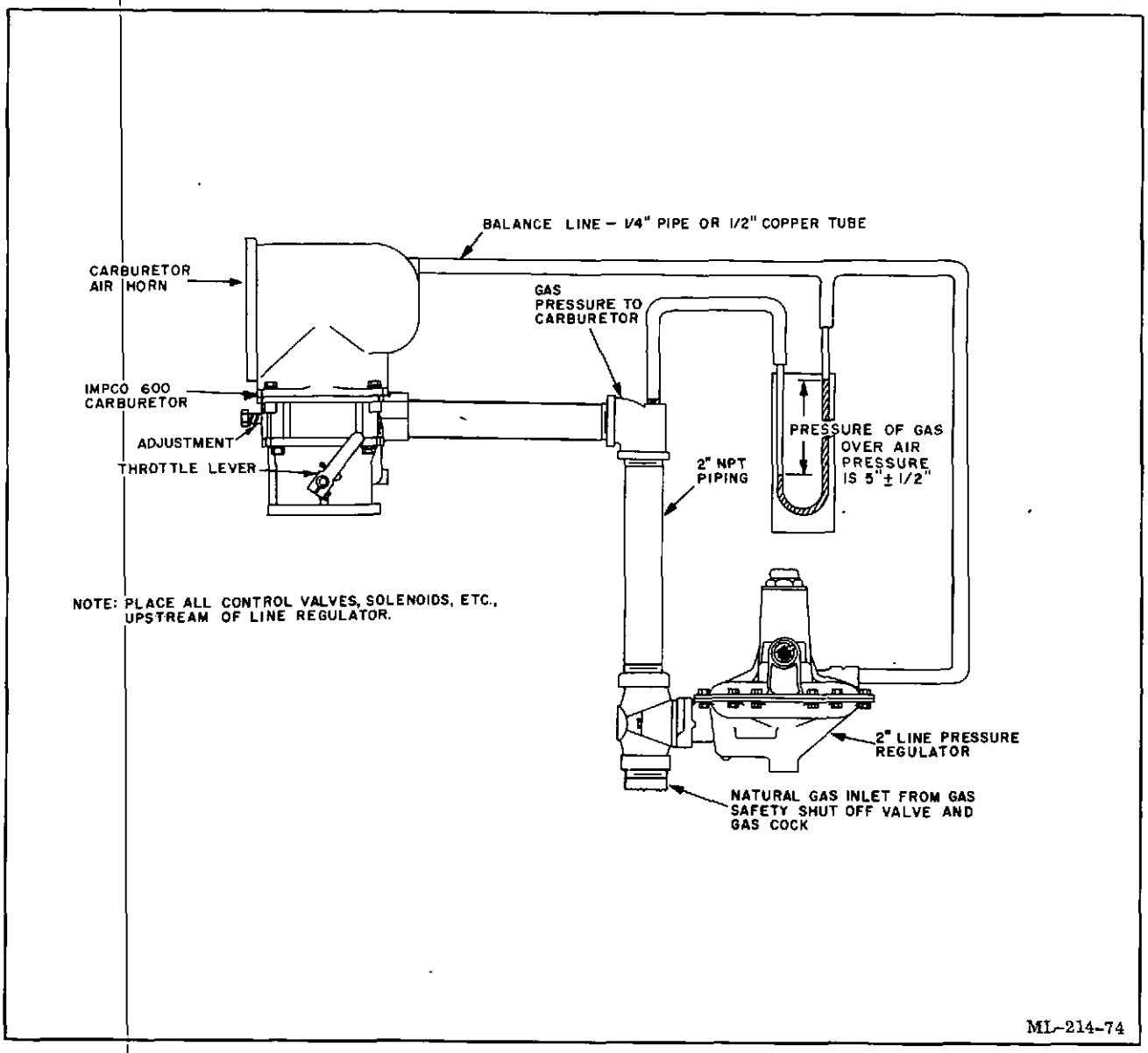


POWER MIXTURE ADJUSTMENT MH-214-66

IMPCO carburetors may be used with liquid petroleum gas by using a final stage of regulation to atmospheric pressure. All mixtures are controlled by pressure in these air-valve carburetors. LP-gas contains more BTU value than natural gas, consequently the inlet pressure to the carburetor must be lower on a fuel with more BTU value and higher pressures must be used with natural gas or manufactured gas. Natural gas may be used with LP-gas as a standby fuel. Both fuels are fed to the carburetor through a tee. A gate or globe valve is installed ahead of the natural gas line regulator. With this valve open the pressure of the natural gas will keep the LP-gas regulator closed. If the natural gas supply is cut off, the lack of natural gas pressure automatically opens the LP-gas regulator. The changeover from natural gas to LP-gas is made without a change of orifices or power settings—the engine does not stop during changeover.



SCHEMATIC DIAGRAM FOR TYPICAL NATURALLY ASPIRATED NATURAL GAS ENGINE WITH IMPCO 600 CARBURETORS



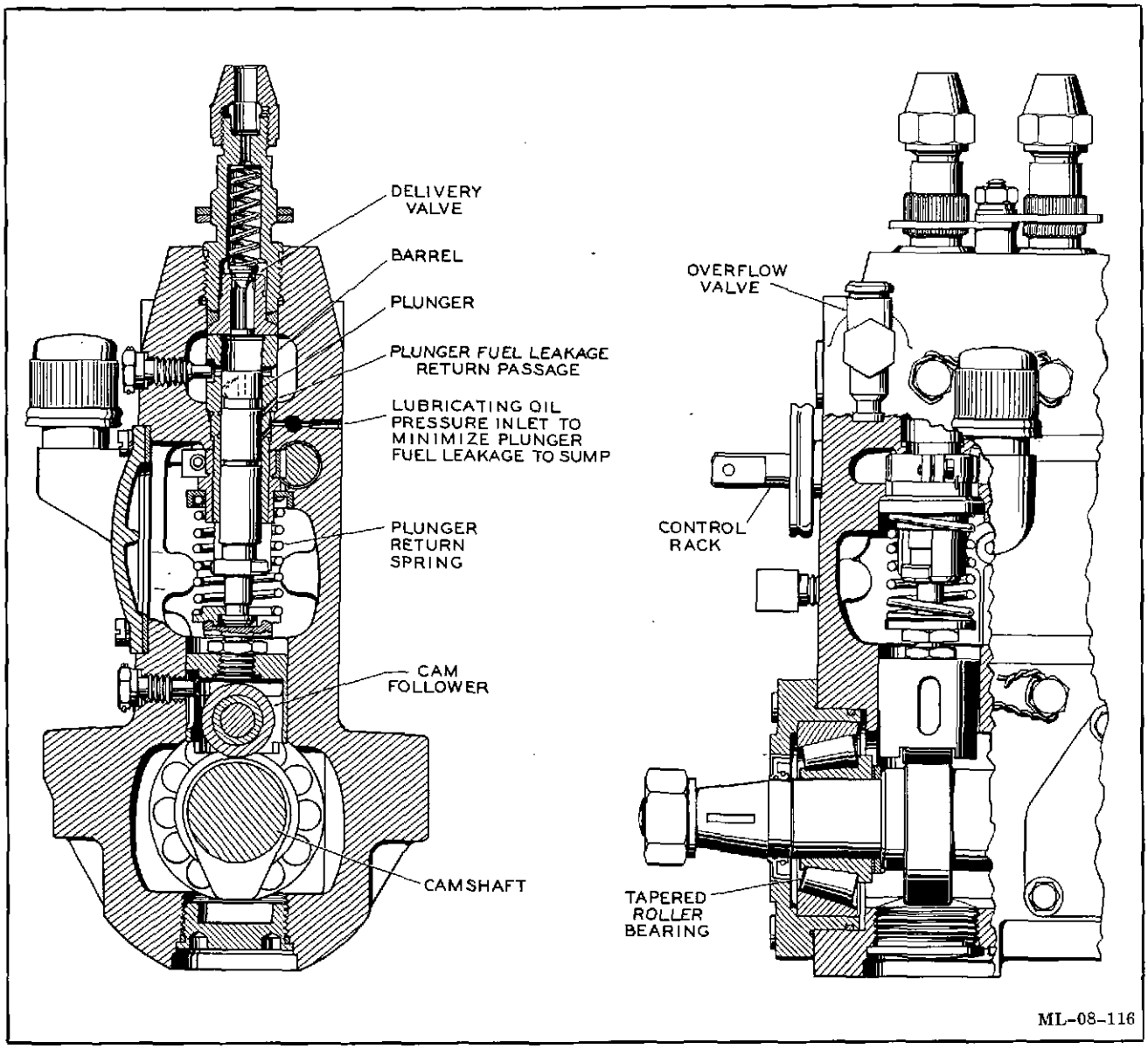
SCHEMATIC DIAGRAM FOR TYPICAL TURBOCHARGED NATURAL GAS ENGINE WITH IMPCO 600 CARBURETORS

DIESEL FUEL SYSTEM

The fuel system consists of a fuel tank, a primary (coarse) fuel filter or strainer, a fuel priming pump, a fuel supply pump, and secondary (fine) fuel filter, a fuel injection pump and fuel injectors.

Fuel injection pumps have a control rack which regulates the amount of fuel discharged by each plunger stroke. The governor moves the control rack according to the engine load and so matches the fuel delivery and power output to load requirements. The point at which injection begins is fixed and does not vary with engine speed or load.

The injection pump plungers have no pumping action on the inlet side and must be supplied with fuel under pressure. It is usually necessary to transfer fuel from a tank located a short distance from the engine. These two purposes are both provided for by a positive displacement gear pump. This pump is driven from the rear of the right bank injection pump and is of very simple and long-lived design since the only moving parts are the two pumping gears and the drive shaft. Unless dirt is permitted to pass through this

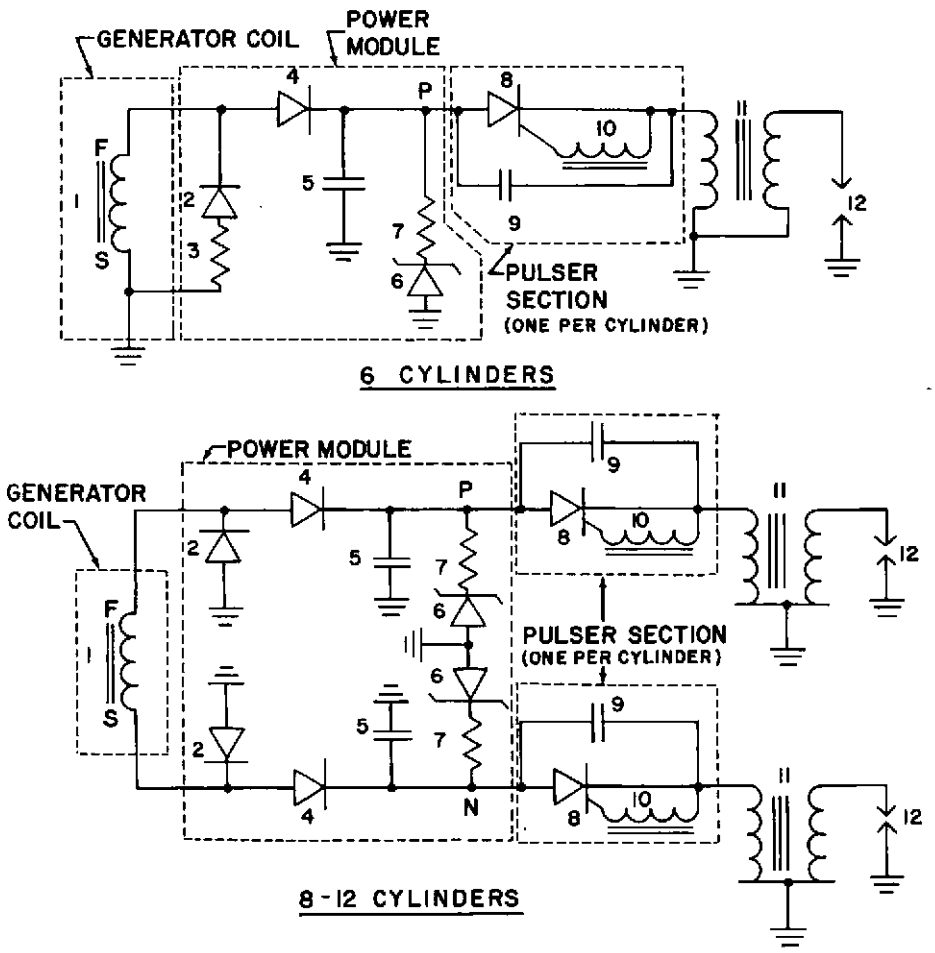


SECTIONAL VIEW OF FUEL INJECTION PUMP

pump, very little service attention is required. Large particles of foreign material will jam the gears and result in shearing of the drive pin. The pump is capable of delivering approximately 2 gallons of fuel per minute at 1200 rpm and will develop pressure far greater than needed by the injection pump. This provides for an adequate flow through the injection pump at all times, thus returning air or fuel vapor to the tank. This type of pump is not recommended that vertical fuel lifts of over 12 feet be attempted without an auxiliary pump.

Injection pump(s) must be filled with lube oil prior to new engine start-up or if the pump was removed and reinstalled or replaced. They are then supplied with a constant metered flow of filtered lubricating oil from the engine with the overflow returning to the engine sump. Lube oil is used to lubricate the pump camshaft, bearings, and other components in the lower portion of the pump.

If repair of the fuel injection pump becomes necessary, contact an authorized Waukesha Distributor who will usually have exchange equipment available, or contact an authorized Robert Bosch service station.



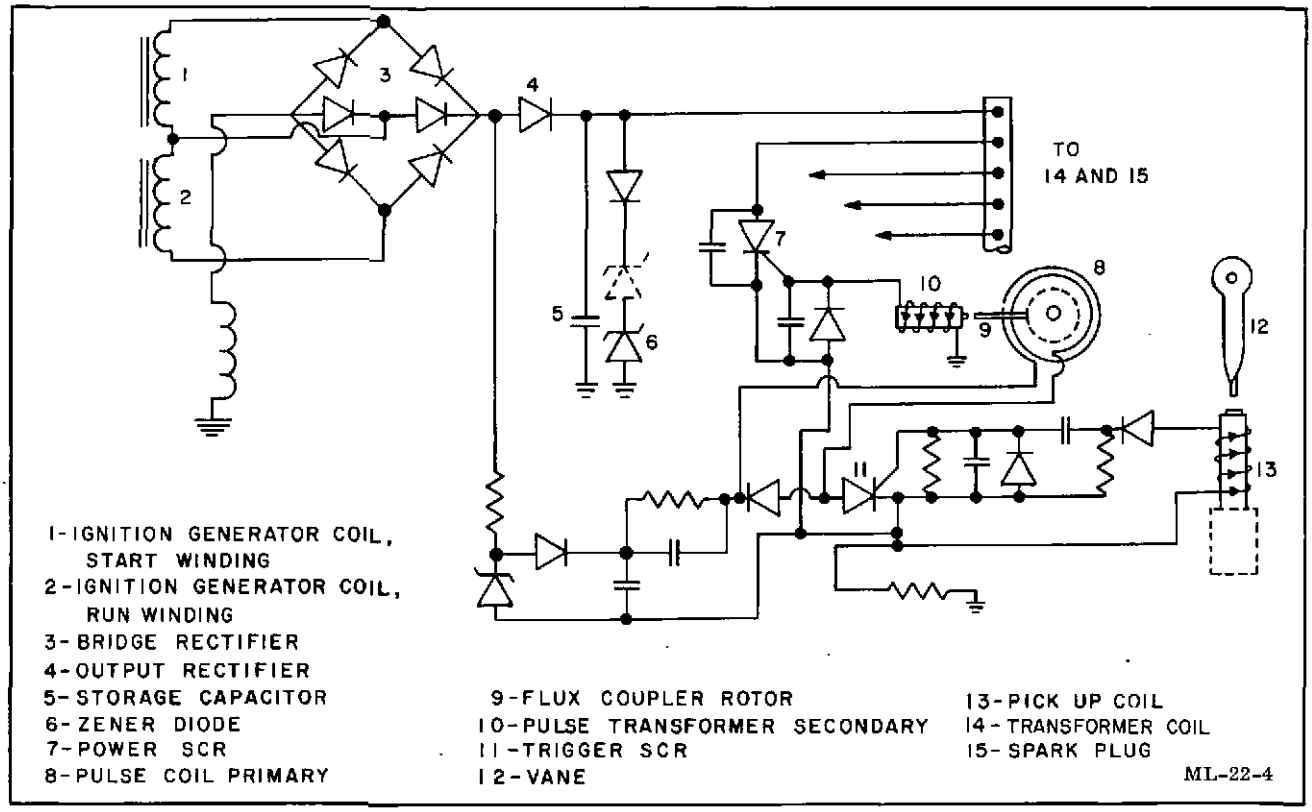
MAGTRONIC IGNITION SCHEMATIC

BREAKERLESS IGNITION SYSTEMS

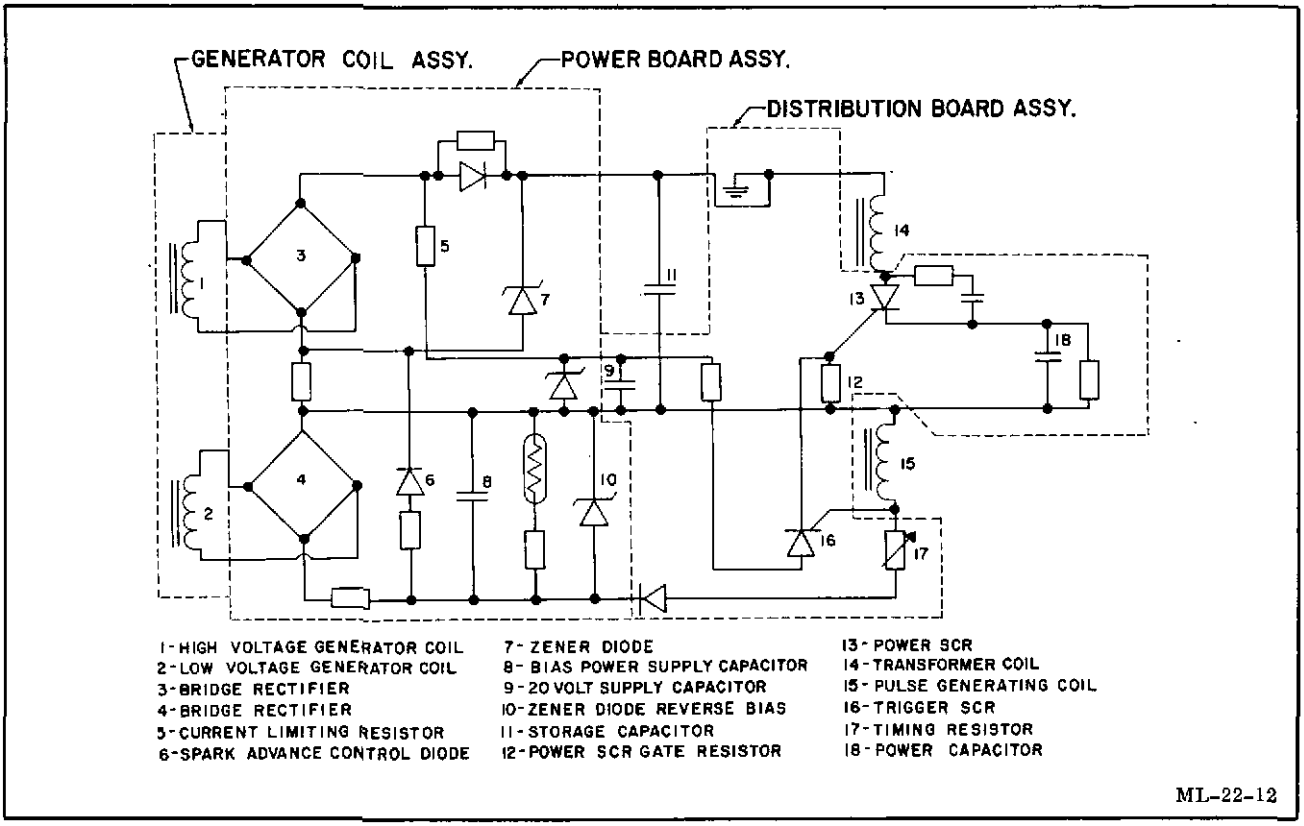
Breakerless (capacitor discharge) ignition systems consist basically of an ignition generator, transformer coils, and an interconnecting wire harness with a plug attaching to the ignition generator.

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

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.



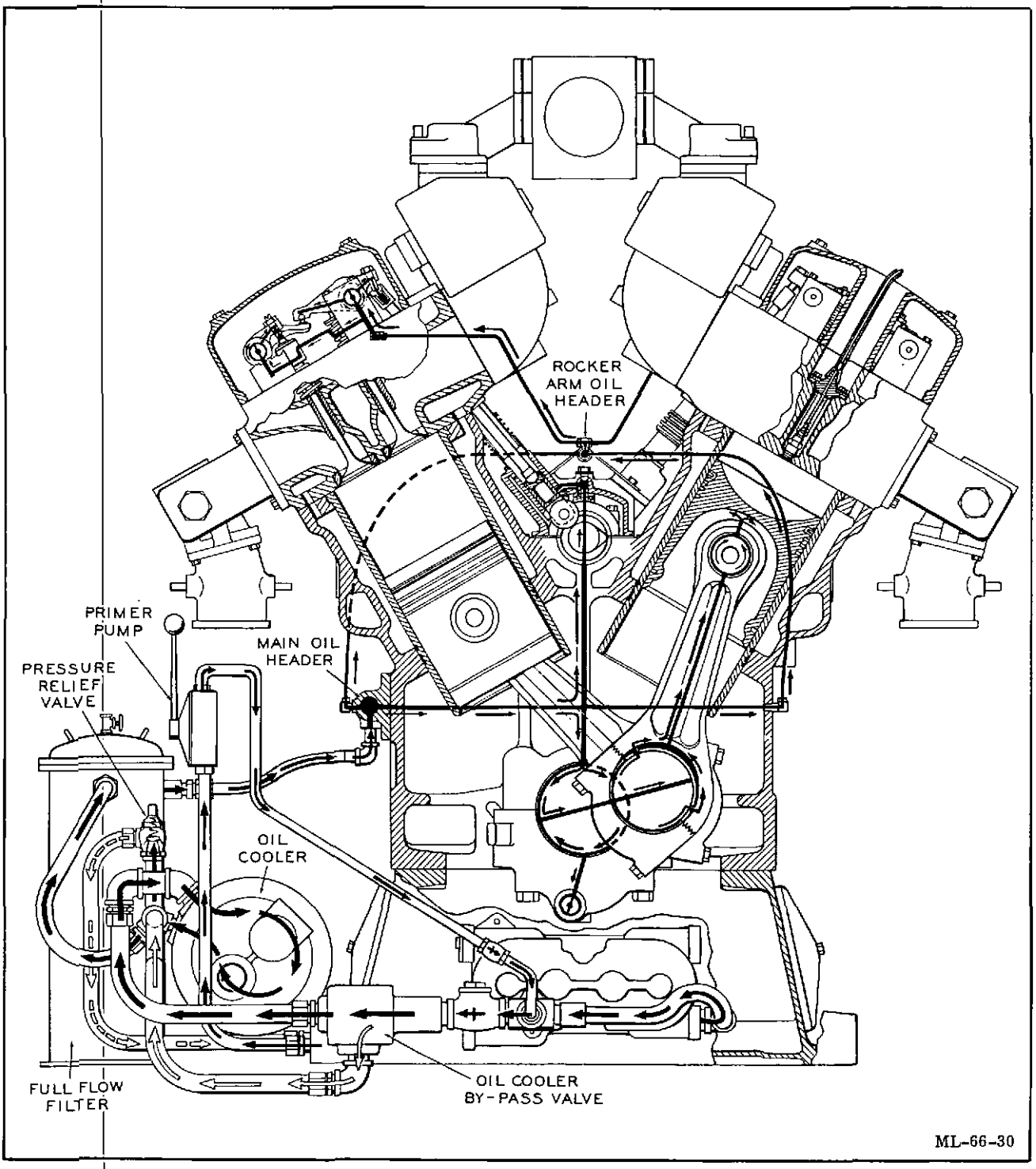
BENDIX S1800 IGNITION SCHEMATIC



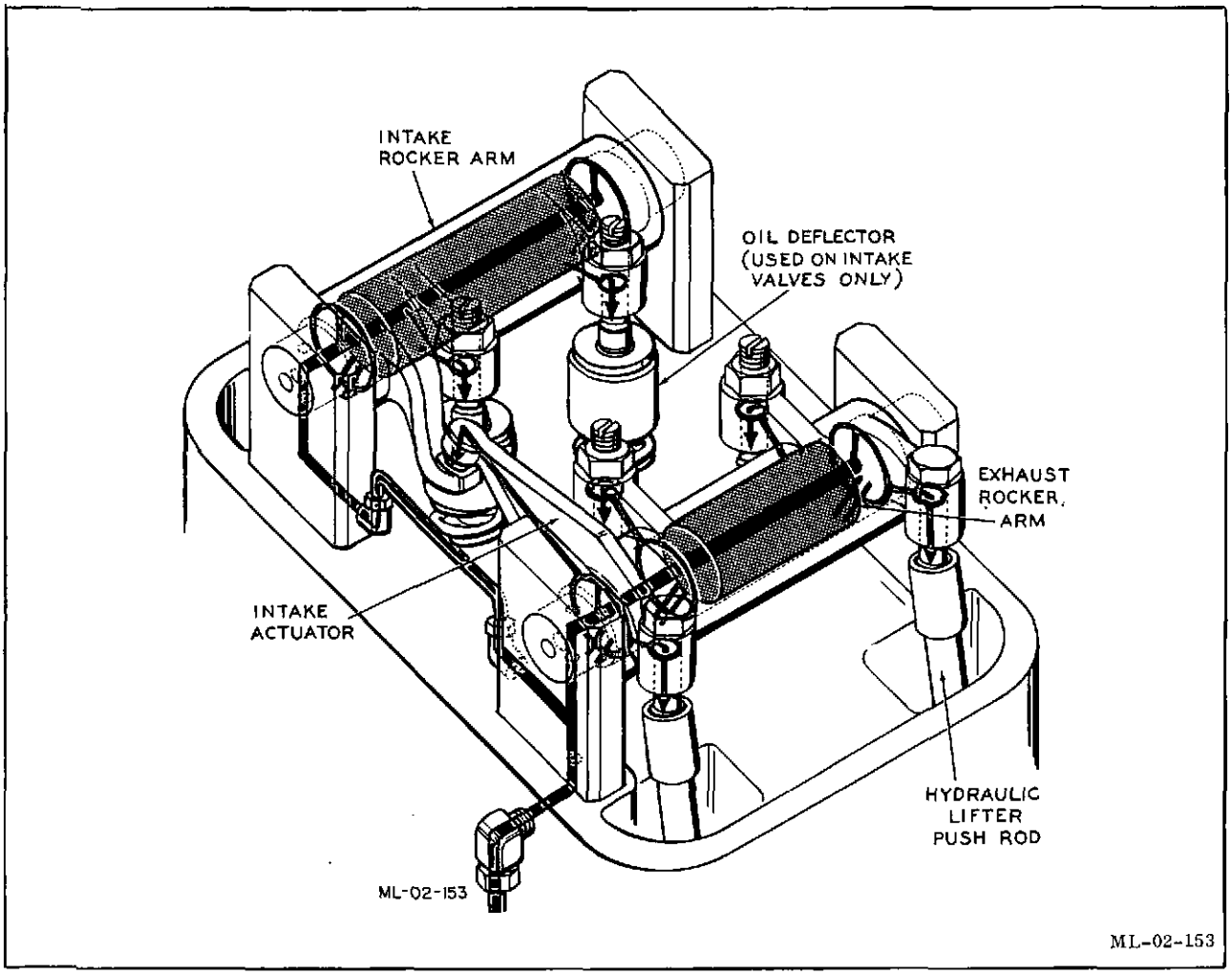
FAIRBANKS MORSE SCSA IGNITION SCHEMATIC

LUBRICATION

The gear type oil pump is externally mounted on the front of the engine. The flow of oil from the pump is routed through the oil cooler and full flow oil filter. These engines have a thermostatically controlled by-pass valve which permits oil to by-pass the cooler as necessary to hold proper oil temperature. The oil flow passes an oil pressure relief valve, which releases excess oil directly to the crankcase as required to maintain correct oil pressure, then through the oil cooler and a separately mounted oil filter. The filtered oil enters the main oil header for distribution to all working surfaces in the engine, after which it drains to the crankcase.



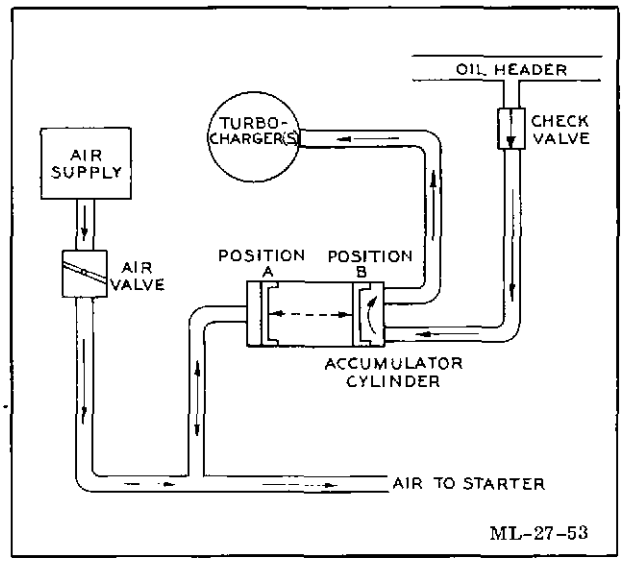
LUBRICATION SYSTEM SCHEMATIC - WITH SINGLE OIL COOLER



ROCKER ARM LUBRICATION

Turbocharger Prelubrication System

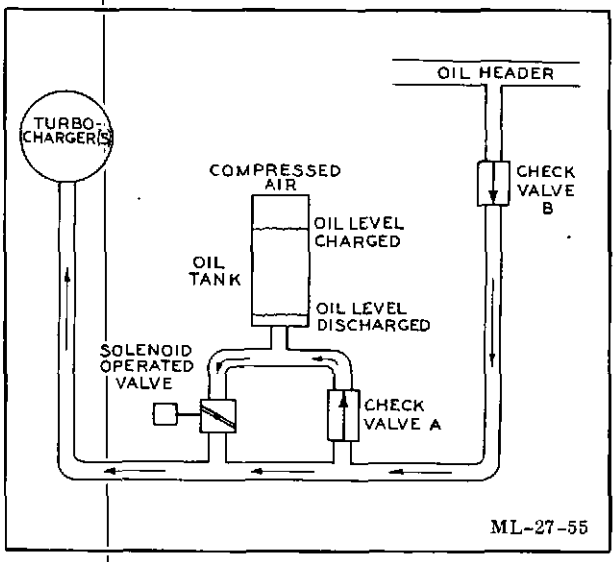
Turbocharged engines are equipped with a turbo prelube system. An accumulator is filled with oil supplied by the hand primer pump or the engine pump. On air or gas starting engines, the accumulator is pressurized when the starter is used, forcing oil into the turbocharger supply line. On electric start engines, the accumulator holds engine operating oil pressure until the starter is used. A solenoid valve, activated with the starter circuit, releases the oil to the turbocharger lines.



AIR OPERATED PRELUBRICATION SYSTEM

TURBOCHARGER

The turbocharger is an exhaust gas driven centrifugal air compressor. Its purpose is to deliver more air to the engine than is available from the pressure of the normal atmosphere (natural aspiration). The increased air supply allows the engine to burn more fuel effectively, and as a result, produce more power.



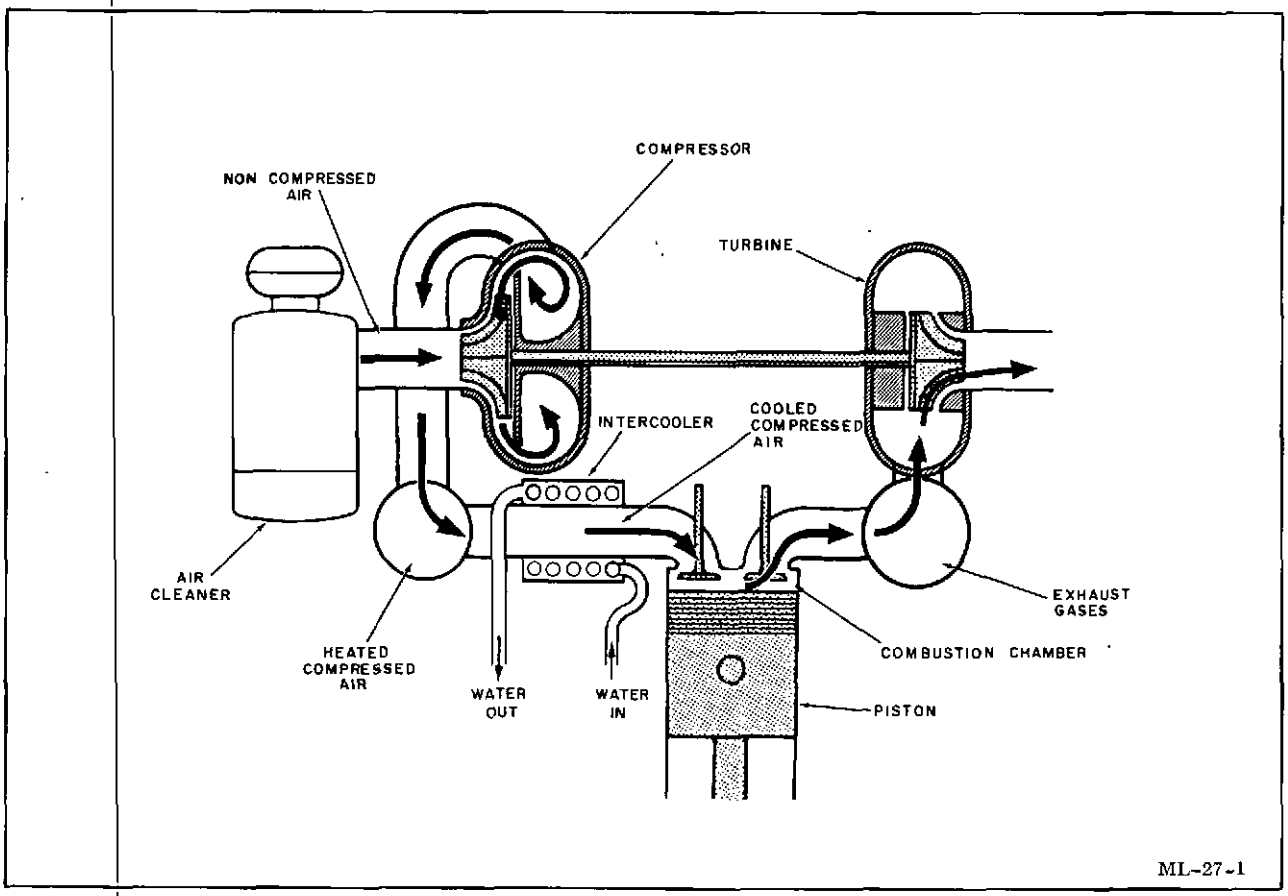
SOLENOID OPERATED PRELUBRICATION SYSTEM

The turbine uses some of the heat energy in the exhaust gas. The exhaust from the engine enters the turbine housing from the exhaust manifold. It enters the turbine wheel around its outside diameter and expands and cools while going through the turbine wheel passages. This results in energy being given to the turbine wheel, causing it to turn. This drives the centrifugal compressor mounted on the same shaft.

Air enters the spinning compressor wheel and flows radially (outward) through a diffuser section to the compressor housing. This air is now compressed above (denser than) atmospheric pressure, and is delivered to the engine air induction system. The denser air requires more fuel to maintain the correct fuel to air ratio for combustion, resulting in a greater power output from the engine.

INTER-COOLING

The density of the air discharged from the compressor section of the turbocharger can be increased by cooling. A water cooled heat exchanger, located between the turbocharger and the engine induction system, transfers heat from the compressed air stream to the heat exchanger coolant. The cooled compressed air stream increases in density, requiring more fuel than non-intercooled systems to maintain correct fuel to air ratio for combustion, resulting in a greater power output from the engine.



SCHEMATIC OF TURBOCHARGER - INTERCOOLER PRINCIPLE

TROUBLE SHOOTING CHART

SYMPTOM	PROBABLE CAUSE	REMEDY
Crankshaft cannot be barred over using barring device.		**CAUTION** DO NOT ATTEMPT TO ROTATE CRANKSHAFT WITH STARTER.
	Load not disengaged from engine.	Disengage load.
	Coolant or obstruction in cylinder:	NOTE REMOVE SPARK PLUGS OR INJECTORS TO VENT CYLINDERS OF ACCUMULATED COOLANT.
	a. Blown head gasket.	a. Replace head gasket.
	b. Blown water cooled exhaust manifold gasket.	b. Replace exhaust manifold gasket.
	c. Cracked head.	c. Replace head.
	d. Cracked sleeve.	d. Replace sleeve.
	e. Cracked crankcase.	e. Replace crankcase.
	Fuel in cylinder from leaking injector (diesels).	NOTE REMOVE INJECTORS TO VENT CYLINDERS OF ACCUMULATED FUEL. Replace or overhaul injector.
	Seized piston.	Replace piston assembly and possibly sleeve. Determine cause of seizure—insufficient ring gap, insufficient lubrication, inadequate cooling, overload.
	Bearings too tight: a. Main bearing caps installed out of location.	a. Check each bearing cap, place in proper location.
	b. Improper torque.	b. Loosen bearing caps and retorque.
	c. High spots on bearings.	c. Replace bearings.
Engine will crank but will not start.	Stop-run switch in stop position or defective.	Place switch in run position—replace defective switch.
	Fuel throttle or manual shutoff control in off position.	Place fuel throttle or manual shut-off control in on position.
	Safety shut-down control not re-set.	*Re-set safety shut-down control.*

TROUBLE SHOOTING CHART (Continued)

SYMPTOM	PROBABLE CAUSE	REMEDY
Engine will crank but will not start (continued)	Insufficient cranking speed:	
	a. Low starting air pressure.	a. Build up air pressure.
	b. Run-down battery or electric starter system malfunction.	b. Charge or replace battery; check starter system.
	c. Lube oil viscosity too high.	c. Change to lower viscosity as recommended.
	Fuel system inoperative:	
	a. Insufficient fuel supply.	a. Fill fuel tank (diesels)— check gas pressure and carburetor adjustments (gas engines).
	b. Air bound (diesels).	b. Operate hand primer pump until air is expelled. Repair source of air entering into system.
	c. Water in fuel (diesels).	c. Drain water at strainers, filters, and fuel tanks. Replace filter elements.
	d. Clogged fuel filters and strainers (diesels or LPG engines).	d. Clean strainers and replace fuel filter elements.
	e. Inoperative fuel supply pump (diesels).	e. Rebuild or replace pump.
	f. Improper control rack setting (diesels).	f. Re-set control rack linkage.
	g. Incorrect ignition or injection timing.	g. Re-time.
	h. Malfunctioning injection pump.	h. Repair or replace injection pump.
	i. Stiff carburetor diaphragm (gas engines).	i. Replace air-gas valve assembly.
	j. Worn carburetor air-gas valve assembly (gas engines).	j. Replace air-gas valve assembly.
	k. Ruptured line pressure regulator diaphragm (gas engines).	k. Replace diaphragm.
	l. Bent line pressure regulator control rod (gas engines).	l. Replace control rod.
	Faulty ignition system (gas engines):	
	a. Low tension magneto breaker points stuck open.	a. Replace breaker assembly.
	b. Low tension magneto distributor brushes stuck or damaged.	b. Free or replace brushes.
	c. Low tension magneto distributor disc loose or broken.	c. Replace distributor disc and secure.

TROUBLE SHOOTING CHART (Continued)

SYMPTOM	PROBABLE CAUSE	REMEDY
Engine will crank but will not start (continued)	d. Breakerless ignition generator power board faulty.	d. Replace power board.
	e. Breakerless ignition generator distributor pulser faulty.	e. Replace distributor pulser.
	f. Broken leads.	f. Replace leads.
	g. Drive disc broken	g. Replace disc—check timing.
	Insufficient or no intake air:	
	a. Intake air shutoff valve(s) closed (diesels).	a. Open valve(s). NOTE BAR ENGINE OVER BY HAND TO ASCERTAIN THAT CYLINDERS ARE CLEAR. INSPECT INTAKE MANIFOLDS FOR ACCUMULATIONS OF LUBE OR FUEL OIL.
	b. Clogged intake air filters.	b. Remove and clean.
	c. Clogged intercoolers (air side).	c. Remove and clean.
	Governor inoperative:	
	a. Insufficient oil:	
	(1) UG8 low oil level.	(1) Add oil.
	(2) Gasket blocks off oil supply hole (after repair).	(2) Re-position or replace gasket.
	(3) Carbon/sludge in oil passages.	(3) Clean or replace governor.
	b. Binding control linkage:	
	(1) Linkage dirty.	(1) Clean.
	(2) Linkage broken.	(2) Repair linkage.
	(3) Linkage pivot points.	(3) Re-adjust or replace pivot point bearing surfaces.
	Poor compression:	
	a. Worn rings.	a. Renew rings.
	b. Leaking valves.	b. Recondition heads and valves.
	c. Leaking head gaskets.	c. Replace head gaskets.
	Camshaft gear not in time with crankshaft gear.	Set crankshaft at T.D.C. #1 R.B. (#1 L.B. for opposite rotation engines). Align camshaft, idler and crankshaft gear match marks.

TROUBLE SHOOTING CHART (Continued)

SYMPTOM	PROBABLE CAUSE	REMEDY
Engine stops suddenly.	Fuel:	
	a. Insufficient fuel supply.	a. Fill tank (diesels)— Check gas pressure (gas engines).
	b. Air in fuel (diesels).	b. Operate hand primer pump until air is expelled. Repair source of air entering into system.
	c. Water in fuels (diesels).	c. Drain water at strainers, filters and fuel tank. Replace filter elements.
	d. Clogged fuel strainers and filters (diesels).	d. Clean strainers and replace fuel filter elements.
	e. Clogged fuel supply hose (diesels).	e. Replace hose.
	f. Fuel supply pump failure (diesels).	f. Repair or replace pump.
	g. Loose fuel control linkage.	g. Readjust and tighten.
	Low oil pressure causes safety control to shut down engine.	Inspect lubricating oil system and components—correct cause.
	High coolant temperature causes safety control to shut down engine.	Inspect cooling system and components—correct cause.
	Faulty ignition system (gas engines).	Repair or replace components as required.
	Engine overspeed causes safety control to shut down engine.	Determine and correct cause of overspeed.
	Excessive load causes engine to stall.	Determine and correct cause of overload.
	Insufficient intake air:	
	a. Intake air shutoff valves closed (diesels).	a. Open valves, determine cause of closing. **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.
	b. Clogged intake air filter(s).	b. Remove and clean.
	c. Clogged intercoolers (air side).	c. Remove and clean.

TROUBLE SHOOTING CHART (Continued)

SYMPTOM	PROBABLE CAUSE	REMEDY
Engine stops suddenly (continued)	Obstructed exhaust manifold.	Determine obstruction and remedy cause.
	Piston seizure:	
	a. Insufficient cooling.	a. Replace scored piston, sleeve and rings. Clean and/or fill cooling system, including heat exchangers.
	b. Insufficient lubrication.	b. Replace scored piston, sleeve and rings. Clean oil passages, and/or determine cause of lack of lubrication.
	c. Insufficient ring gap (applicable only immediately after overhaul).	c. Replace scored piston, sleeve and rings. Adjust ring gap.
	Obstruction in cylinder.	Replace all parts that failed.
	Seizure of bearings—main, connecting rod, piston pin or camshaft.	Replace bearings—clean up or replace crankshaft, camshaft, or piston pins as required.
	a. Lack of lubrication.	a. Check lube oil system—correct cause.
	b. Dirt in lube oil.	b. Check lube oil filters.
Engine power loss.	Insufficient fuel:	
	a. Dirty fuel filters or strainers (diesels).	a. Clean strainer and replace fuel filter elements.
	b. Low gas pressure (gas engines).	b. Check gas fuel system.
	c. Cracked fuel lines/filters (diesels).	c. Replace cracked line/filters.
	d. Worn fuel supply pump (diesels).	d. Overhaul or replace.
	e. Worn injection pump or fuel injectors (diesels).	e. Overhaul or replace.
	Air in fuel (diesels).	Operate hand primer pumps until air is expelled. Repair source of air entering system.
	Air intake system malfunction:	
	a. Dirty intake air filters.	a. Remove and clean.
	b. Clogged intercoolers.	b. Remove and clean.

TROUBLE SHOOTING CHART (Continued)

SYMPTOM	PROBABLE CAUSE	REMEDY
Engine power loss (continued)	c. Air shutoff closed on one bank (12 cyl. diesels).	c. Open valve. **CAUTION** BAR ENGINE OVER BY HAND TO ASCERTAIN THAT CYLINDERS ARE CLEAR. INSPECT INTAKE MANIFOLDS FOR ACCUMULATIONS OF LUBE OR FUEL OIL.
	Injectors malfunction (diesels):	
	a. Clogged.	a. Overhaul injector, clean tip or replace.
	b. Dirty	b. Overhaul and clean.
	Air leaks in intake system (turbo supercharged gas engines).	Correct as required.
	Turbocharger malfunction or failure:	
	a. Lack of lubrication.	a. Determine cause; repair or replace turbocharger.
	b. Foreign material.	b. Repair or replace turbocharger.
	c. Excessive back pressure.	c. Determine cause and correct.
	Engine misfiring (gas engines):	
	a. Incorrect carburetor or regulator adjustment.	a. Readjust.
	b. Faulty ignition system.	b. Repair or replace components as required.
	Ignition or injection system out-of-time.	Re-time.
	Low compression pressure:	
	a. Leaking head gasket.	a. Replace head gasket—inspect for warped cylinder head and/or crankcase—replace if necessary.
	b. Leaking exhaust; intake valves.	b. Recondition head and valves.
	c. Misadjusted intake and exhaust valves (if recently overhauled).	c. Adjust valves.
	d. Worn rings (excessive blow-by).	d. Replace rings.
	e. Worn pistons/liner.	e. Replace as necessary.
	f. Cracked piston.	f. Replace.
	g. Cracked cylinder head.	g. Replace.
	Excessive exhaust system back pressure.	Correct as required.

TROUBLE SHOOTING CHART (Continued)

SYMPTOM	PROBABLE CAUSE	REMEDY
Engine will not shut down when using normal stopping procedures.		NOTE 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.
	Defective stop-run switch.	Replace.
	Governor control linkage misadjusted (diesels).	Adjust linkage.
	Lubricating oil entering cylinder through valve guides (diesels).	Replace valve guides/recondition heads.
	Overheated combustion chamber deposits allow gas engine to "diesel".	Allow engine to cool down before attempting to stop.
Engine will not reach rated speed.	Engine overloaded.	Determine and correct cause of overload.
	Insufficient fuel supply.	Check fuel supply system.
	Restricted air intake.	Correct cause.
	Governor misadjusted.	Readjust.
	Fuel control rack linkage not properly adjusted (diesels).	Readjust linkage.
	Injectors or ignition not properly timed.	Re-time.
	One or more injectors stuck (diesels).	Replace or overhaul injectors.
	Tachometer inaccurate.	Calibrate or replace tachometer.
Engine hunts or surges.	Governor and fuel linkage sticky or sloppy.	Remove all dirt and burrs from linkage. Realign and re-set.
	Misadjusted governor compensating needle valve.	Adjust compensating needle valve. Slow reaction—open needle valve. Fast (overshooting) reaction—close needle valve.

TROUBLE SHOOTING CHART (Continued)

SYMPTOM	PROBABLE CAUSE	REMEDY
Engine hunts or surges (continued).	Dirty governor.	Clean or replace governor.
	Speed droop adjustment incorrect.	*Increase speed droop.*
Low or fluctuating lubricating oil pressure.		**CAUTION** SHUT DOWN ENGINE IMMEDIATELY.
	Insufficient oil.	Add oil as required.
	Gauge inaccurate.	Compare to master gauge—replace gauge.
	Oil gauge line plugged or valve shut.	Renew gauge line/open valve.
	Lube oil filters plugged.	*Change elements. Clean filter.*
	Lubricating oil pressure regulating valve stuck in open position.	Free valve.
	Oil pressure regulating valve set too low.	Readjust oil pressure regulating valve for 40-50 psi at governed speed.
	Lubricating oil dilution.	Change oil and filter elements. Determine and correct source of dilution.
	Lubricating oil of low viscosity.	Change to higher viscosity oil as recommended.
	Lubricating oil foaming.	Use oil grade recommended. Check for water leaks into oil.
	Clogged oil inlet screen(s).	Remove and clean screens.
	Engine operated at angles in excess of maximum safe tilt angles.	Operate within maximum safe tilt angles.
	Dirty oil cooler.	Clean.
	Worn lubricating oil pump.	Repair or replace pump.
	Worn bearings (connecting rod, main, and camshaft).	Replace worn bearings.
	Cracked or leaking lubricating oil piping.	Repair or replace piping.
Low gas pressure (gas engines).	*Incorrectly adjusted gas regulators.*	*Readjust.*
	Insufficient line pressure.	Increase line pressure.
	Incorrect orifice and/or spring in gas regulators.	Replace orifice and/or spring.
	Undersize gas regulators.	Replace with gas regulators of adequate size.

TROUBLE SHOOTING CHART (Continued)

SYMPTOM	PROBABLE CAUSE	REMEDY
Low gas pressure (gas engines) (continued).	Undersize piping.	Replace with piping of adequate size.
	Gas regulators mounted too far from engine.	Remount gas regulators as close to carburetors as possible.
High gas pressure (gas engines).	Incorrectly adjusted gas regulators.	Readjust.
	Incorrect spring in gas regulators.	Replace spring.
	Excessive line pressure.	Reduce line pressure.
Low jacket water pressure.	Low water level.	Fill cooling system.
	Clogged jacket water heat exchanger or radiator.	Clean.
	Air entering system through suction side of jacket water pump.	Repair leak—purge air from system.
	Wrong pressure cap.	Replace.
	Gauge inaccurate.	Compare to master gauge—replace gauge.
	Gauge line clogged or valve shut.	Replace line—open valve.
	Leaking pump seals.	Repair pump.
	Blown water cooled exhaust manifold gasket.	Replace gasket.
	Cracked water cooled exhaust manifold.	Replace manifold.
High lubricating oil pressure.	Misadjusted oil pressure regulating valve.	Readjust oil pressure regulating valve for 40-50 psi.
	Lubricating oil temperature too low.	Raise temperature.
	Lubricating oil of high viscosity.	Change to lower viscosity oil as recommended.
	Lubricating oil pressure regulating valve stuck in closed position.	Free valve.
	Gauge inaccurate.	Compare to master gauge—replace gauge.
High fuel oil pressure (diesels).	Defective fuel supply pump relief valve.	Free relief valve or replace pump.
	Clogged or collapsed fuel return hose.	Replace hose.
	Gauge inaccurate.	Compare to master gauge—replace gauge.

TROUBLE SHOOTING CHART (Continued)

SYMPTOM	PROBABLE CAUSE	REMEDY
Low fuel oil pressure (diesels)	Gauge inaccurate.	Compare to master gauge—replace gauge.
	Gauge line clogged or line valve shut.	Replace line or open valve.
	Fuel filters and strainers clogged.	Clean strainers and replace filter elements.
	Clogged or collapsed fuel supply hose.	Replace hose.
	Air leak on suction side of pump.	Locate and repair leak.
	Defective fuel supply pump.	Replace pump.
Low raw water pressure (marine diesels).	Clogged sea inlet strainer.	Clean.
	Gauge inaccurate.	Compare to master gauge—replace gauge.
	Clogged gauge line/gauge line valve shut.	Replace line/open valve.
	Air entering system through suction side of pump.	Repair leak—purge air from system.
	Valve closed in sea system.	Trace system—open valve.
	Worn sea water pump.	Replace or overhaul pump.
	Clogged heat exchanger/intercooler.	Clean heat exchanger/intercooler.
Low jacket water temperature.	Gauge inaccurate.	Compare to master gauge—replace gauge.
	Inoperative/malfunction thermostat(s).	Replace thermostatic element or thermostats (as applicable).
High jacket water temperature.		**CAUTION** COOL ENGINE SLOWLY.
	Gauge inaccurate.	Compare to master gauge—replace gauge.
	Low coolant level.	Fill cooling system.
	Inoperative/malfunction thermostat(s).	Replace thermostatic element or thermostats (as applicable).
	Cooling system is air bound.	Purge air from cooling system.
	Insufficient raw water pressure (marine diesels).	See Low Raw Water Pressure causes.

TROUBLE SHOOTING CHART (Continued)

SYMPTOM	PROBABLE CAUSE	REMEDY
High jacket water temperature (continued).	Engine overloaded.	Determine and correct cause of overload.
	Insufficient circulation of air (radiator cooling).	Correct as required.
	Poor coolant circulation.	Check entire cooling system.
	Worn jacket water pump or seals.	Replace or overhaul pump.
	Froozen coolant.	Completely thaw cooling system before re-starting engine.
	Blown head gasket.	Replace head gasket.
	Late ignition or injection timing.	Re-time ignition or injection pump.
	Cracked head.	Replace head.
	Cracked sleeve.	Replace sleeve.
High lubricating oil consumption.	Oil leaks in lubricating oil system.	Locate and repair leaks.
	Improper viscosity.	Change to recommended viscosity for operating temperatures.
	Leaking oil seal(s)—rear and/or front.	Change seal(s).
	Worn intake valve guides.	Change head—renew guides, or valve stem seals if used.
	Stuck/worn piston rings.	Renew rings.
	One or more pistons with rings upside down (after overhaul).	Remove piston—correct position of rings.
	Excessive connecting rod bearing running clearance.	Replace bearings.
Lubricating oil contaminated.	Lubricating oil contaminated with water:	NOTE CHANGE OIL.
	a. Sleeve seals leaking/or sleeve cracked.	a. Replace sleeve o-rings.
	b. Oil cooler leaking.	b. Replace oil cooler.
	c. Cracked crankcase.	c. Replace crankcase.
	Lubricating oil contaminated with dirt:	
	a. Lube oil filter by-pass valves opening because elements are plugged.	a. Replace elements.

TROUBLE SHOOTING CHART (Continued)

SYMPTOM	PROBABLE CAUSE	REMEDY
Lubricating oil contaminated (continued).	b. Lube oil filter elements punctured.	b. Replace elements.
	c. Air intake filters punctured.	c. Replace air intake filters.
Excessive vibration.		**CAUTION** STOP ENGINE AT ONCE—INVESTIGATE CAUSE.
	Foundation bolts:	
	a. Loose.	a. Torque.
	b. Cracked.	b. Replace bolts—torque all bolts.
	Unbalanced cylinders:	
	a. Injectors improperly set (diesels).	a. Replace injectors.
	b. One or more injectors inoperative (diesels).	b. Replace all defective injectors.
	c. Misfiring ignition system (gas engines).	c. Repair or replace components as required.
	Vibration damper:	
	a. Loose.	a. Replace all securing bolts. Torque bolts to specifications.
	b. Malfunctioning.	b. Replace damper.
	Crankshaft:	
	a. Cracked.	a. Conduct a complete investigation of entire engine for damage.
	b. Main bearing nuts loose.	b. Determine reason for loosening, investigate the entire lower crankcase before torquing and subjecting engine to use.
	Loose flywheel.	Determine cause and correct.
Blue-white exhaust (diesel).	Worn or stuck piston rings, worn sleeves.	Replace rings and/or sleeves.
	Worn valve guides.	Replace guides.
	Cracked piston.	Replace piston.
	Thermostats not maintaining engine temperature (particularly on naturally aspirated engines at start-up).	Test and replace thermostats as required.

TROUBLE SHOOTING CHART (Continued)

SYMPTOM	PROBABLE CAUSE	REMEDY
Black exhaust (diesels).	Insufficient intake air:	
	a. Intake air filters clogged.	a. Clean
	b. Malfunctioning turbocharger.	b. Replace turbocharger
	Engine overloaded.	Determine and correct cause of overload.
	Inoperative injector.	Replace or repair defective injector.
	Late injection pump timing.	Re-time.
	Low compression:	
	a. Insufficient valve clearance.	a. Re-set valves.
	b. Burned valves.	b. Replace or overhaul head.
	c. Worn/stuck rings and sleeves.	c. Overhaul.
High lubricating oil temperature.	Gauge inaccurate.	Compare to master gauge—replace gauge.
	Engine overloaded.	Determine and correct cause of overload.
	Insufficient cooling:	
	a. Low jacket water pressure.	a. See Low Jacket Water Pressure causes.
	b. Low raw water pressure.	b. See Low Raw Water Pressure causes.
	c. High jacket water temperature.	c. See High Jacket Water Temperature causes.
	d. Dirty lube oil cooler.	d. Clean or replace.
	e. Dirty jacket water heat exchanger or radiator.	e. Clean or replace.
	Low lubricating oil pressure.	See Low Lubricating Oil Pressure causes.
Knocking or unusual noises.	Low octane fuel (gas engines) or low cetane fuel (diesels).	Adjust timing for fuel being used (gas). Replace fuel with better grade (diesel).
	Engine overloaded.	Determine and correct cause of overload.
	Overly advanced ignition or injection timing.	Re-time.
	Excessive valve clearance.	Readjust valve clearance.
	Sticking valves or rocker arms.	Free up or replace.
	Damaged or excessively worn accessory drives.	Repair or replace components as required.
	Loose bearings (failed).	Replace bearings.
	Loose piston pins (failed).	Replace piston pins and/or pin bushings as required.
	Excessive crankshaft end play.	Replace main bearing thrust rings.
	Misfitted or excessively worn timing gears.	Replace.

TROUBLE SHOOTING CHART (Continued)

SYMPTOM	PROBABLE CAUSE	REMEDY
Excessive fuel consumption.	Carburetor adjusted overrich (gas engines).	Readjust.
	Leaks in fuel system.	Repair as required.
	Excessively worn fuel injectors (diesels).	Repair or replace.
	Faulty ignition system (gas engines).	Repair or replace components as required.
	Late ignition or injection timing.	Re-time.
	Engine overloaded.	Determine and correct cause of overload.
	Poor synchronization of multi-engine installations.	Balance loads.
	Improper matching of torque convertor to engine and load.	Replace torque convertor.
	Poor compression.	Determine cause(s) and effect repair.

TROUBLE SHOOTING DATA FOR WOODWARD SG AND PSG GOVERNORS

TROUBLE	CAUSE	CORRECTION
I. Engine hunts or surges.	A. Speed droop adjustment incorrect.	1. Increase speed droop.
	B. Dirty oil in governor.	1. Clean governor, change engine oil if necessary.
	C. Foamy oil supplied to governor.	1. Drain engine oil. Refill with oil of proper type.
	D. Insufficient oil supply.	1. Clean oil supply line.
	E. Lost motion in engine linkage.	1. Repair linkage.
	F. Binding in engine linkage.	1. Repair and realign linkage.
	G. Governor worn or not correctly adjusted.	1. Repair and adjust governor. See governor instruction bulletin. a. Check ballarms for sticking. b. Inspect wear on ballarm toes. c. Check pilot valve bearing. d. Pilot valve may be sticking. e. Polish pilot valve and inside of bushing. f. Inspect for excessive end play of drive shaft.

TROUBLE SHOOTING DATA FOR WOODWARD SG AND PSG GOVERNORS (Continued)

TROUBLE	CAUSE	CORRECTION
I. Engine hunts or surges (Cont.)	H. Low oil pressure.	1. Pump gear clearance incorrect. Use 0.005" gasket between case and base. No gasket used if base has rubber seal ring. 2. Lap base and case surfaces flat. 3. Relief valve plunger may be sticking. 4. Excessive end play of drive shaft.
	J. Engine misfiring.	1. Check pyrometer readings (diesel) or compression readings (gas) of each cylinder and make necessary repairs or adjustments.
	K. Voltage regulator (if used) not operating properly.	1. Adjust or repair voltage regulator.
II. Fuel pump rack (diesels) or butterfly valve (gas) does not open quickly when cranking engine.	A. Low oil pressure.	1. See IH.
III. Terminal shaft or rod and engine linkage jiggles.	A. Rough engine drive.	1. Check alignment of gears. 2. Inspect for rough gear teeth. 3. Inspect for eccentric gears. 4. Check backlash of gears.
	B. Speed droop at critical setting.	1. Reduce droop to eliminate critical, if possible. Load division will be affected if this is done. Readjust droop on units affected.
	C. Governor base not bolted down evenly.	1. Loosen bolts, realign, and secure.
IV. Load does not divide properly on interconnected engines.	A. Speed droop adjustment incorrect.	1. Readjust droop to divide load properly. 2. Increase droop to resist picking up (or dropping off) load. 3. Reduce droop to increase picking up (or dropping off) load.
	B. Speed droop adjustment vibrating out of position. NOTE: Speed droop is not essential in a D.C. electrical system. The equivalent of speed droop in a D.C. system is obtained by changing the compounding of the generators at the bus between generators. An under compounded generator is equivalent to a speed droop governor. Governors with	1. Readjust droop and tighten screw securely.

TROUBLE SHOOTING DATA FOR WOODWARD SG AND PSG GOVERNORS (Continued)

TROUBLE	CAUSE	CORRECTION
IV. Load does not divide properly on interconnected engines (Cont.).	speed droop adjustment are commonly used for D.C. service since the droop adjustment may be used to correct for errors or inequalities of generator compounding.	
	C. Slippage in hydraulic or electric couplings if used.	1. Adjust couplings.
V. Engine is slow to respond to a speed change or a load change.	A. Governor is not sensitive in measuring speed change.	1. See IG.
	B. Governor may be intentionally designed to protect engine from overloading during a load change.	1. No field correction.
	C. Low oil pressure in governor.	1. See IH.
	D. Engine may be overloaded.	1. Reduce load.
	E. Restricted fuel supply.	1. Clean out fuel supply line and filters.
VI. Engine will not pick up rated full load.	A. Fuel rack (diesel) or butterfly valve (gas) will not open far enough.	1. Adjust engine to governor fuel linkage. 2. Adjust load limiting device or fuel pump stop.
	B. Restricted fuel supply.	1. See VE.
	C. Voltage regulator (if used) not functioning.	1. Readjust or repair.
	D. Engine misfiring.	1. Check pyrometer readings (diesel) or compression readings (gas) of each cylinder and make necessary repairs or adjustments.
	E. Slipping clutch (if used) between engine and driven load.	1. Foaming oil or low oil level in hydraulic clutch. 2. See clutch instruction manual.
	F. Speed adjustment of the governor is restricted.	1. Check maximum speed limit adjustment. 2. Inspect speed adjusting linkage for interference.
VII. Governor oil overflows.	A. Drain holes plugged.	1. Clean governor. 2. The governor to engine gasket may be restricting the two drain holes at the governor pilot.
	B. Insufficient drain capacity below governor.	1. Engine to governor drive shaft (coupling, shaft, gear, etc.) not assembled properly. 2. Drain holes in engine plugged up.

TROUBLE SHOOTING DATA FOR WOODWARD UG8 GOVERNORS

TROUBLE	CAUSE	CORRECTION
Engine hunts or surges	Compensation adjustments incorrect.	Adjust needle valve and compensating adjusting pointer.
	Dirty oil in governor.	Drain oil, clean governor, and refill.
	Foamy oil in governor	Drain oil. Refill.
	Low oil level.	Add oil to correct level on gauge glass. Check for leaks, especially at drive shaft.
	Lost motion in engine linkage.	Repair linkage.
	Binding in engine linkage.	Repair and realign linkage.
	Governor worn or not correctly adjusted.	Repair and adjust governor. See governor instruction bulletin. 1. Check ballarms for sticking. 2. Inspect wear on ballarm toes. 3. Check speeder rod bearing. 4. Pilot valve or speeder rod may be sticking. See that floating lever is free. 5. Polish moving parts. 6. Inspect for lost motion of receiving compensating piston. 7. Inspect pilot valve adjustment. 8. Check for lost motion in governor internal linkage.
	Compensating spring incorrectly adjusted.	Make adjustment. See governor instruction bulletin.
	Low oil pressure. Normal operating pressure is 110 to 120 lbs. per square inch.	1. Pump gear clearance incorrect. Use 0.005" gasket between controlet and base. No gasket used if controlet has oil groove. 2. Pump check valves not seating.
	Power piston sticking.	Check alignment of piston, power link and power lever. Check for side play in terminal shaft.
	Engine misfiring.	Check pyrometer readings (diesel) or compression readings (gas) of each cylinder and make repairs or adjustments.
	Voltage regulator not operating properly.	Adjust or repair voltage regulator.

TROUBLE SHOOTING DATA FOR WOODWARD UG8 GOVERNORS (Continued)

TROUBLE	CAUSE	CORRECTION
Terminal shaft and engine linkage jiggles.	Rough engine drive.	1. Check alignment of gears. 2. Inspect for rough gear teeth. 3. Inspect for eccentric gears. 4. Check backlash of gears. 5. Compensate for the roughness by changing the flexibility of the ballhead drive shaft.
	Compensating spring adjustment at critical setting.	Change compensating spring pre-compression approximately 0.005" either way.
	Speed droop (if used) at critical setting.	Reduce droop to eliminate critical setting. Load division will be affected if this is done. Readjust droop on units affected.
	Governor base not bolted down evenly.	Loosen bolts, realign, and secure.
	Erratic action of flexible drive shaft.	If governor has laminated spring drive inspect flexible drive parts for burrs, wear, or broken laminations.
Load does not divide properly in interconnected engines.	Speed droop adjustment incorrect.	1. Readjust droop to divide load properly. 2. Increase droop to resist picking up (or dropping off) load. 3. Reduce droop to increase picking up (or dropping off) load.
	Speed droop shaft vibrating out of position.	Increase tension of speed droop friction spring.
	NOTE If droop adjustment is not provided the governor is isochronous only, and cannot be used for parallel operation. Speed droop is not essential in a DC electrical system. The equivalent of speed droop in a DC system is obtained by changing the compounding of the generators at the bus between generators. An under compounded generator is equivalent to a speed droop governor. Governors with speed droop adjustment are commonly used for DC service since the droop adjustment may be used to correct errors or inequalities of generator compounding.	
	Slippage in hydraulic or electric couplings if used.	Adjust coupling.

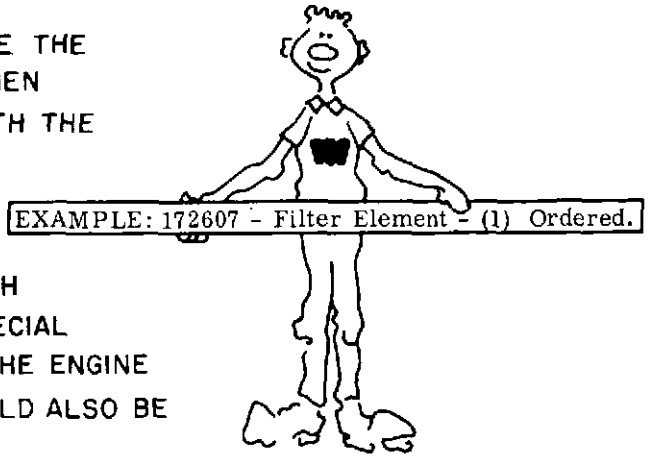
TROUBLE SHOOTING DATA FOR WOODWARD UG8 GOVERNORS (Continued)

TROUBLE	CAUSE	CORRECTION
Engine is slow to respond to speed change or a load change.	Needle valve adjustment incorrect.	Readjust compensating needle valve. Open further if possible to do so without causing instability when running without load. Compensation pointer may be too far toward maximum.
	Governor is not sensitive in measuring speed change.	See "governor worn or not correctly adjusted' cause.
	Governor may be intentionally designed to protect engine from overloading during a load change.	No field correction.
	Pilot valve not centered. It must open control ports equally in both directions.	Make pilot valve adjustment. See governor instruction bulletin.
	Low oil pressure in governor.	See "low oil pressure" cause.
	Engine may be overloaded.	Reduce load.
	Restricted fuel supply.	Clean out fuel supply line and filters.
	Load limit knob set to restrict fuel.	Open up on load limit.
Engine will not pick up rated full load.	Fuel racks (diesel) or butterfly valves (gas) will not open far enough.	1. Adjust engine-to-governor fuel linkage. 2. Adjust load limiting device. 3. Check tension of load limit friction spring. Low tension may permit load limit cam to gradually work toward reduced load position.
	Restricted fuel supply.	Clean out fuel supply line and filters.
	Voltage regulator (if used) not functioning.	Readjust or repair.
	Engine misfiring.	Check pyrometer readings (diesel) or compression readings (gas) of each cylinder and make necessary repairs or adjustments.
	Slipping clutch (if used) between engine and driven load.	1. Foaming oil or low oil level in hydraulic clutch. 2. See clutch instruction manual.
	Speed adjustment of the governor is restricted.	1. Check maximum speed limit adjustment on dial control governor. 2. Inspect speed adjusting linkage for interference on lever control governor.

REPAIR & REPLACEMENT

PARTS ORDERING

ALWAYS INCLUDE THE PART NUMBER, WHEN KNOWN, ALONG WITH THE DESCRIPTION OF THE PART, STATE THE QUANTITY OF THE PART YOU WISH TO ORDER. IF A SPECIAL PART IS NEEDED, THE ENGINE APPLICATION SHOULD ALSO BE STATED.



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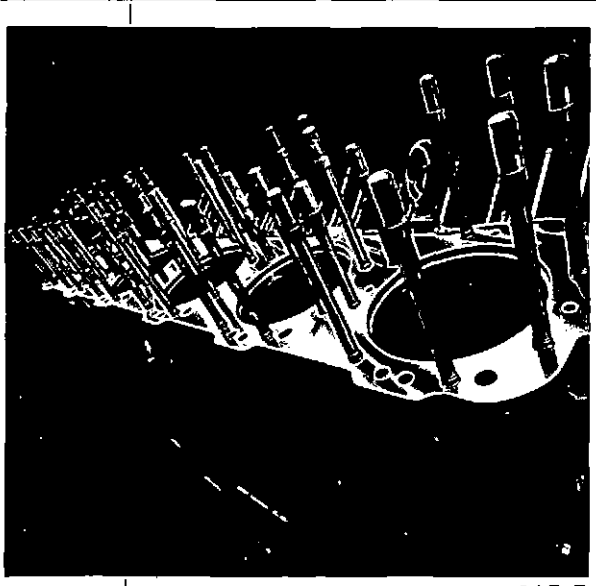
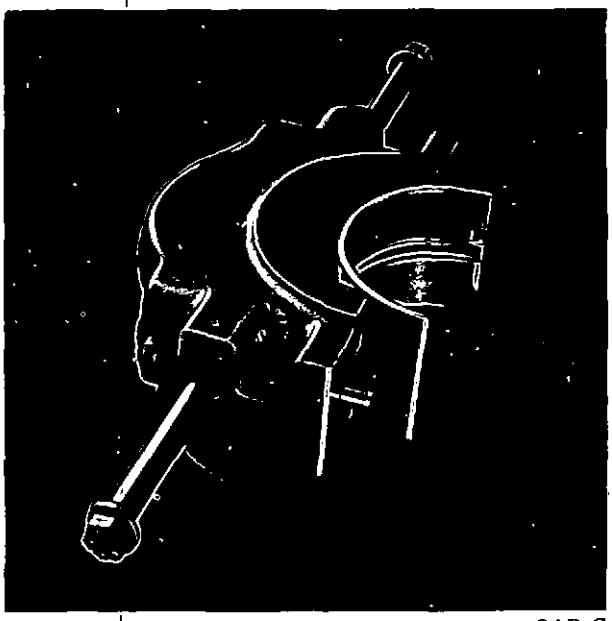


OAB-B

CRANKCASE

The crankcase and cylinder block is of one piece construction, using a ferro-alloy casting of adequate strength for heavy duty industrial use. Main bearing caps are retained by four studs and two cross bolts, providing a high degree of rigidity. An O-ring oil seal is used between the crankcase and the oil pan.

Lubrication for the various bearings is provided through drilled passages connected to the main oil header extending along the side of the crankcase. Mounting bosses and connections are provided at various points on the crankcase exterior for mounting accessories and other equipment.

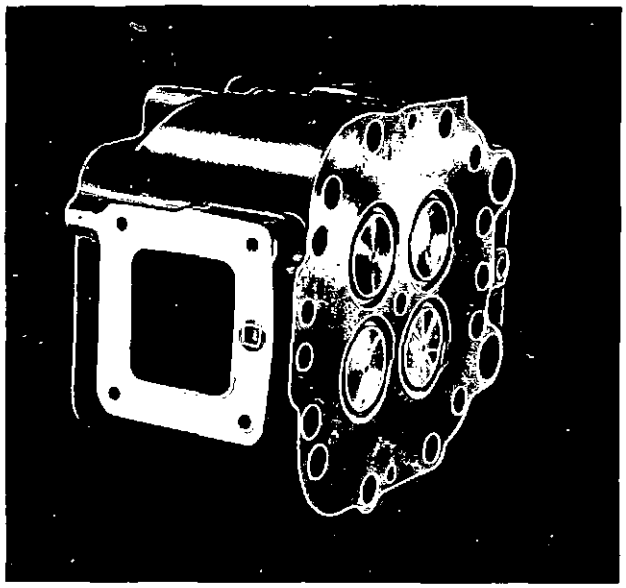


OAB-C

CYLINDER HEADS AND VALVES

Each cylinder in the engine is served by a separate four valve cylinder head. Cylinder heads are interchangeable between in-line and Vee engines and between right and left banks of Vee engines. THEY ARE NOT INTERCHANGEABLE BETWEEN GAS AND DIESEL ENGINES. Intake and exhaust valve seats are Stellite, and are a "shrink" fit in the head. Valve guides are a press fit.

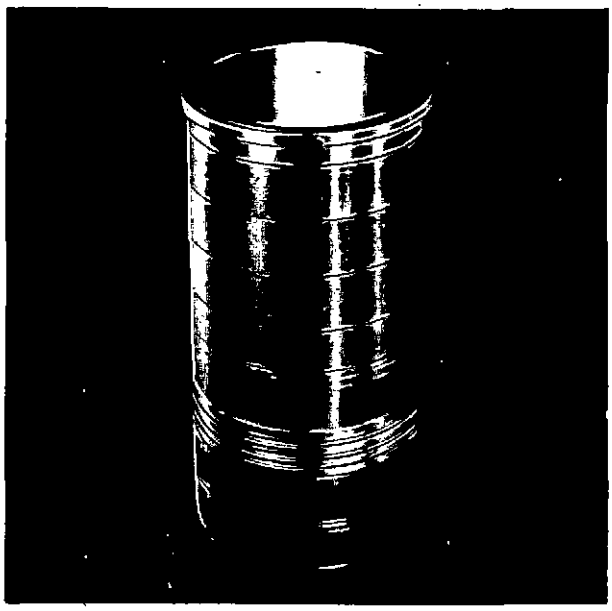
The two intake and two exhaust valves are symmetrically disposed around the spark plug. Valves are of the poppet type with hardened tips and Stellite facings. Valve operation is obtained through guided roller cam followers riding on the cam lobes. This motion is transmitted to the rocker arms through hollow push rods.



OAB-3

SLEEVES

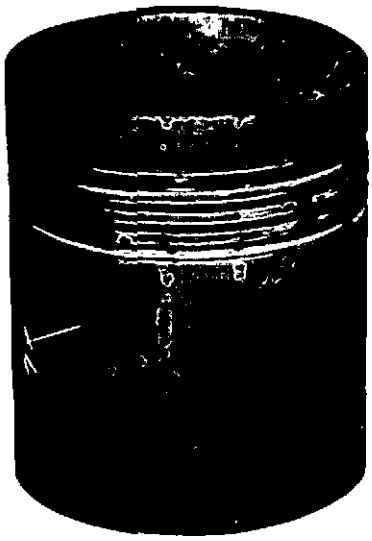
The wet-type interchangeable cylinder sleeve has a flange at its upper end to locate it in the crankcase upper deck. The sleeve flange and the crankcase recess into which it fits form a water seal. A seal ring (not on current 8-1/2" bore engines) between the sleeve flange and the crankcase recess forces the cylinder sleeve to project a few thousandths to ensure a tight crush at the head gasket joint. The sleeve carries three external grooves for the sleeve to lower crankcase deck seals. The upper two rings are of a rubberlike synthetic material. The lower ring is a Teflon ring with an internal spring (Omniseal).



OAB-D

PISTONS

The pistons are heavy-duty castings, cam-ground, tapered full skirt type, and carry four piston rings. The upper three are compression rings; the lower one is an oil control ring. The piston pin is full floating, retained by spring clips in the piston. Pistons are cooled by oil carried through the connecting rod.



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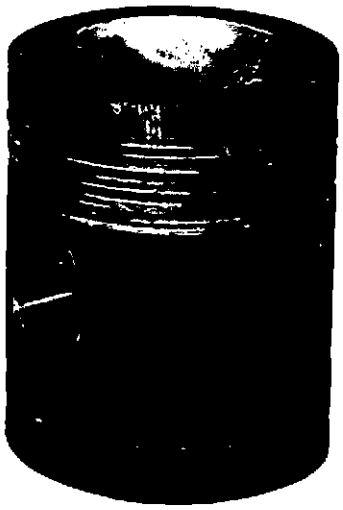

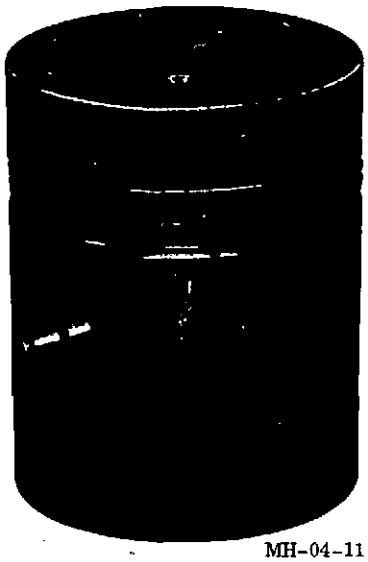

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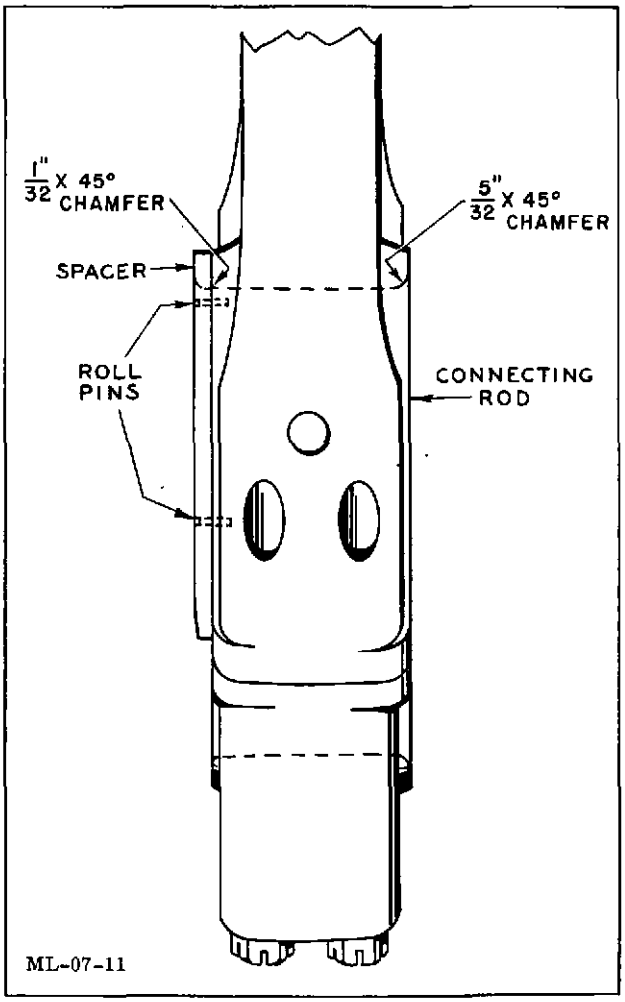
CONNECTING RODS

Drop-forged connecting rods are of I-section design. They are split at a 30° angle at the crankpin end to make piston removal thru the cylinder sleeve possible. One of the four rod cap bolts is of the close fitting type, which, together with the serrated faces between cap and rod, assures proper alignment. Two hard bronze bushings are press fitted in the piston pin end. Rods are stamped to identify their cylinder location.

Four place type bolts retain the rod caps. It is important to install the "body bound" bolt to full depth before torquing the other three rod cap bolts. The special size bolt hole is identified by an "X" mark on the surface of the connecting rod cap, which is machined flat for cap screw head seating in the immediate area of the special bolt hole.

NOTE

Twelve cylinder rods can be used in six cylinder engines by adding spacer, while removal of spacers allows use of six cylinder rods in twelve cylinder engines. Rods in six cylinder engines must be installed with spacers towards front of engine.



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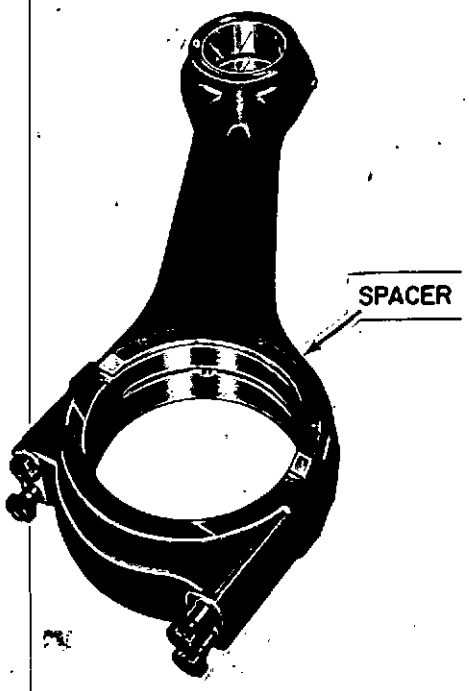

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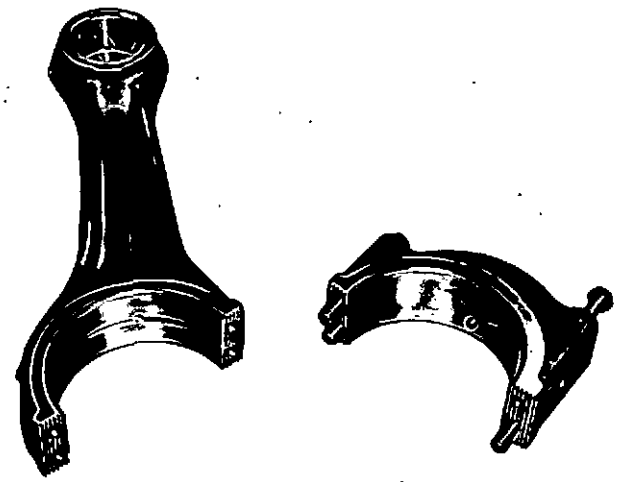

MH-07-18

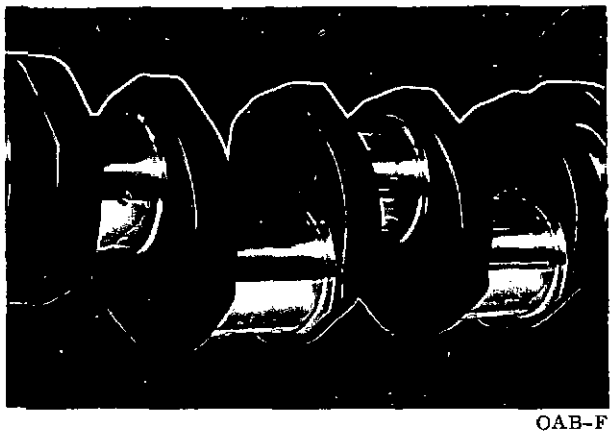
CRANKSHAFT

The crankshaft has seven hardened main bearing journals which run in steel-backed tri-metal bearing shells. Drilled passages, running diagonally from the main-bearing journals through the crankcheeks, carry pressure oil to the connecting rod bearing. In addition to the spiral grooves which reverse the rearward flow of oil, a graphite coated packing type rear oil seal protects against oil leakage at the flywheel end of the crankshaft.

The front crankshaft journal controls end play. Thrust bearings are two piece bronze thrust rings doweled in place on each side of the front main bearing. Thrust forces acting to move the crankshaft rearward are absorbed by a steel thrust washer bearing against the front thrust ring. The crankshaft drive gear is located directly ahead of the thrust washer and is keyed to the crankshaft. A dish-shaped oil slinger rides against the outer face of the crankshaft drive gear.

CAUTION

When performing any repair work on counterbalanced crankshafts do not remove counterweights for any reason.



OAB-F

GAS CYLINDER HEADS

Refer to Service Bulletin No. 7-1890 to clarify interchangeability requirements for the gas cylinder heads.

CAUTION

Be sure that the deflectors, o-rings, and retainer rings are NOT installed on turbocharged gas engines which operate with intake manifold pressures from "0" to POSITIVE pressure. These oil control parts are intended for use only when engine operates with negative intake manifold pressure. Current cylinder head assemblies are without deflectors and o-rings, but include new intake valve guides and seals.

DIESEL CYLINDER HEADS

Refer to Service Bulletin No. 7-1967 to clarify interchangeability requirements for diesel cylinder heads.

NOTE

Starting with Serial No. 297506, all production VHP diesel engines will have oil deflectors installed on all four intake and exhaust valves in each cylinder head. VHP diesel engines manufactured prior to Serial No. 297506 had these oil deflectors installed on the intake valves only. Oil deflectors should be installed on all four valves on all VHP diesels at the time of the first top overhaul. O-rings and retainer rings are also used on all four intake and exhaust valves in each diesel cylinder head.

CYLINDER HEAD GASKETS

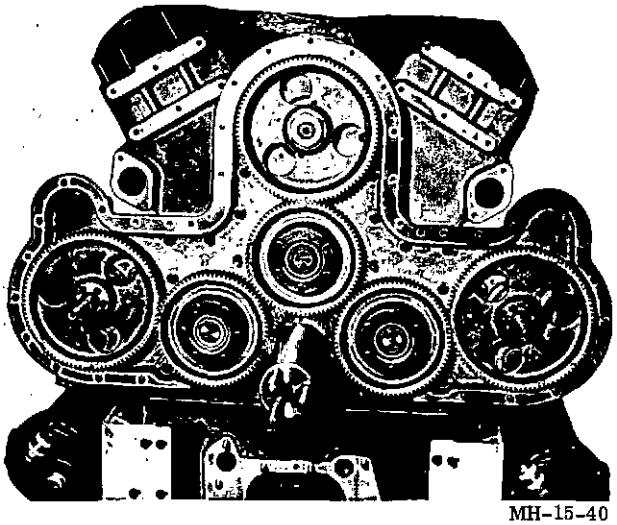
Always select and use only the correct cylinder head gasket. Installation of an incorrect gasket could result in ruined parts or engine failure.

Because cylinder head gasket selection is determined by cylinder sleeve flange design, please refer to Service Bulletin No. 1933 when replacement is required.

TIMING GEARS

It is necessary to mate one of the "x" marks on the idler gear between the camshaft and the crankshaft with the "x" mark on the crankshaft gear. With these "x" marks in line, mate the other "x" mark on the idler gear with the "x" mark on the camshaft gear. Nominal backlash at these points is 0.008" to 0.012". Other gears which mesh with the crankshaft gear may be assembled without regard for the "x" marks on them.

The oil pump idler gear runs between the crankshaft gear and the oil pump drive gear and is mounted on



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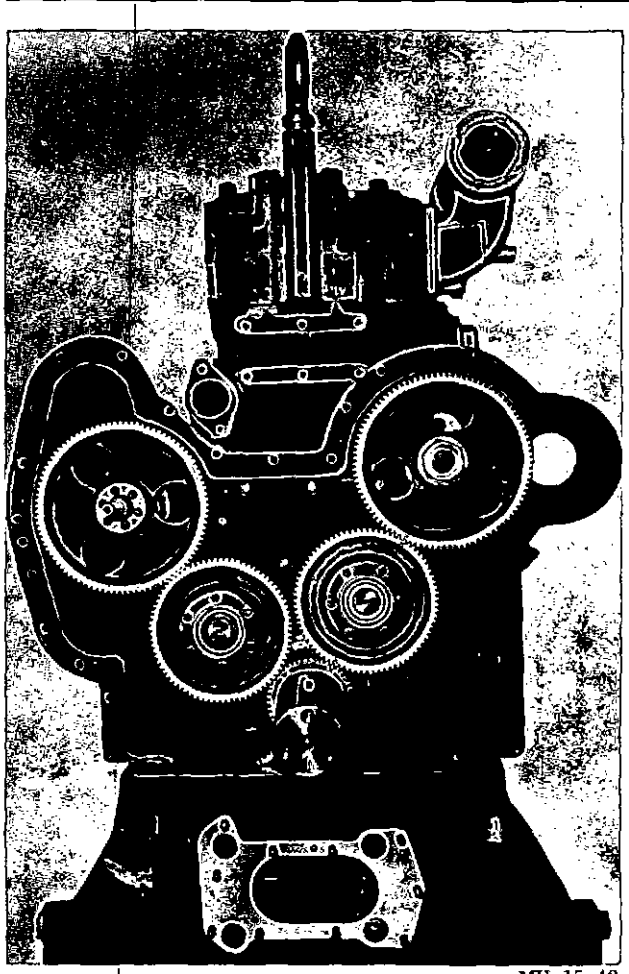
TIMING GEARS - 12 Cylinder Engines



MH-15-42

TIMING GEARS - 6 Cylinder Engines

an idler spindle which is locked into the front main bearing cap. The proper backlash between the crankshaft gear and the oil pump idler gear is 0.008" to 0.012". The proper backlash between the oil pump idler gear the oil pump drive gear is 0.015" to 0.020".

The gear cover seals off the front end of the housing and since the forward extension of the crankshaft extends through the cover, a front oil seal is provided here. The gear cover embodies mounting provisions for the high capacity water pump.

The self-locking nut securing the camshaft or accessory drive idler gear spindles to the crankcase has been superseded by a steel nut, Part No. 207329. This is a left hand 1-1/2-12 thread nut (class 3 fit) used on the current production engines and available for field service when a new idler gear spindle nut is required.

NOTE

(V-12 only) Either the left or the right bank number one piston, rod assembly, and cylinder sleeve must be removed to get clearance for wrench on center spindle nut.

Use Loctite 271 or 277 (equivalent to Stud-lock) on clean spindle threads before installing washer and nut. Loctite primer is not required. The recommended torque value is 750-780 lb. ft. (103,73 - 107,88 kgm).

FUEL INJECTION PUMP DRIVE

The flywheel formerly mounted on the fuel injection pump drive shaft is no longer required.

Replacement drive shafts, without the flywheel, are interchangeable with the flywheel type.

Fuel Injection Pump Repair

The precision construction and accurate calibration of the Bosch fuel injection pump make it mandatory that all repair work be accomplished under conditions of utmost cleanliness and with instruments of laboratory type. Hence, if it becomes necessary to repair a fuel injection pump, contact an authorized Waukesha Distributor who will usually have exchange equipment available, or an authorized Robert Bosch service station. The only exception to this is the fuel transfer pump which may be cleaned and repaired in the field provided that cleanliness precautions are observed rigorously.

Fuel Injection Pump Removal and Installation

Whenever a line is disconnected or when installing the pump, make every effort to keep even minute particles of dirt from entering the openings exposed. Before disconnecting a line, or opening the vent cap, go over pump with a small paint brush and fuel oil to wash away accumulated dirt. Wipe outside surfaces clean and dry before starting work and keep them that way until the job is sealed up. Use particular care to protect the delivery valve openings with tape or caps whenever fuel lines must be disconnected. Also cover ends of fuel lines. Be sure to fill pump sump with lube oil to overflow level whenever reinstalling or replacing a pump.

Injection Pump Calibration Fluid

This specification covers one grade of calibration and flushing fluid for use by the Waukesha Motor Company manufacturing, laboratory, and field personnel for flow bench testing, leakage tests, and flushing injection pumps. This fluid is recommended for use in all bench testing of injection pumps, especially when such pumps are stored or unused for indefinite periods of time before being placed in service.

1. Property Requirements

The material purchased to this specification shall conform to the requirements listed in the following table.

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	

Fuel Injection Pump Linkage and Discharge Lines

The continued long-time service built into the injection pump is directly dependent upon the preservation of its precision parts through intelligent care and maintenance.

Careful attention to details in connecting and adjusting the control rack linkage is necessary. Check all ball joints, clevis pins, and clevises for wear, binding, or misalignment. Replace all worn or questionable linkage parts.

When attaching discharge lines always center each line over its delivery valve holder before tightening the union nut. This will prevent initial stresses that might cause tubing to break during operation.

A few instances have been reported of fuel leakage at the inlet and outlet bushings used on injection pumps. In the event that they are found to be loose or leaking, it is suggested that they be re-installed with a suitable thread seal such as LocTite.

Overflow Valve

Supplementary to the fuel supply pump is an overflow valve mounted at the front of the injection pump.

The overflow valve serves two purposes. First, it maintains uniform supply pressure in the sump (reservoir around the pump plungers) at a value high enough for optimum performance without being so high as to force excessive quantities of fuel oil into the lower portion of the injection pump. In addition, this valve provides a constant escape path for trapped air or fuel vapor which is returned to the tank and vented. The bleed lines from the injectors return the injector bleed-off fuel into the intake manifold ports.

NOTE

Under no circumstances should the overflow or bleed line fuel be taken directly back to the fuel supply pump inlet. This will result in recirculation of air and vapor until eventually enough air will accumulate to reduce engine output or stop the engine.

The overflow valve may become gummed or dirty and need an occasional cleaning. This is easily accomplished with benzol or similar solvent and should be all that is required to make the valve operate freely. Again, observe cleanliness precautions.

Occasional replacement of the valve will be necessary. A solid delivery stream from the overflow

valve without excessive air bubbles is indicative of proper operation of the fuel supply and fuel injection pumps.

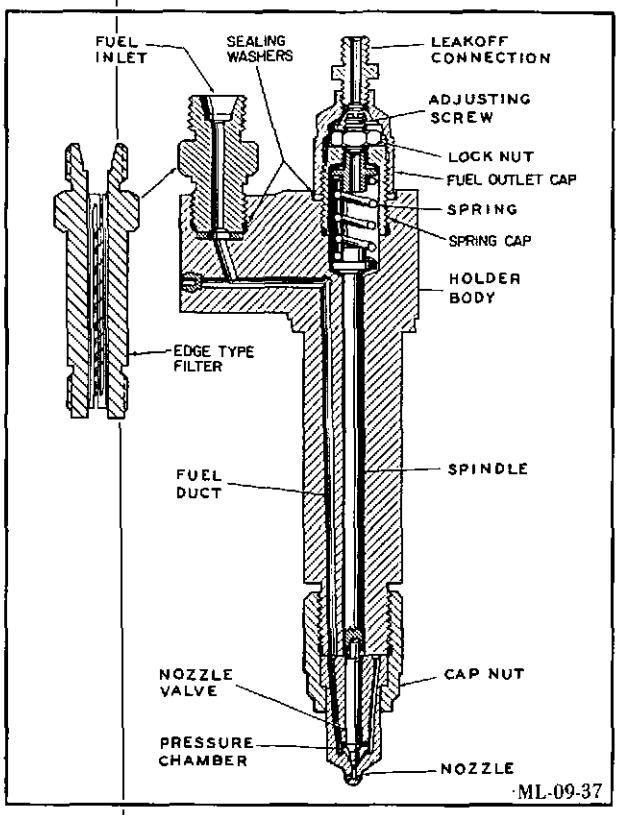
FUEL INJECTORS

The fuel injectors are of the inward opening multiple hold type. Opening pressure settings are listed in the FITS AND CLEARANCES at the end of this section.

This opening pressure is adjustable providing the injectors are taken to a Robert Bosch service station where injector testing equipment is available. DO NOT UNDER ANY CIRCUMSTANCES ATTEMPT TO ADJUST INJECTORS WITH MAKESHIFT EQUIPMENT IN THE FIELD.

Removing Fuel Injectors

Before removing an injector, remove the rocker arm cover and disconnect the drain-back line and the fuel supply line at the couplings. To prevent the entrance of dirt to either the nozzles or the tubing, cap the openings with suitable caps or masking tape. Remove the two screws and lockwashers and the injector clamp and lift out the injector. Remove and discard the nozzle gasket and the nozzle holder o-ring and use a new gasket and o-ring when replacing the injector. Clean the nozzle recess before reinstalling the injector. A seat cleaning tool is available for carbon removal. On engines which have been operating for some time, it may be necessary to tap the injector very lightly with a soft-face hammer. Do not use violent methods to loosen stuck injectors, but work carefully and evenly on all sides to prevent cocking. Use caution to avoid dropping dirt into the injector opening, and plug it to prevent any dirt from entering while the injector is not in place.



On current diesel engines an edge type filter is used to filter fuel before it enters the injector (see illustration). The element in this filter is not replaceable; only the complete filter can be purchased. The filter does not require servicing due to its self cleaning action.

Servicing Injectors

Unless service station equipment is available and the operator is skilled in its use, there is little actual repair work that can be accomplished on injectors. If an injector is suspected of improper operation, however, it may be given a general test by allowing it to spray into the atmosphere while cranking the engine over. Experience is the best indication of what may be considered a satisfactory spray pattern.

WARNING

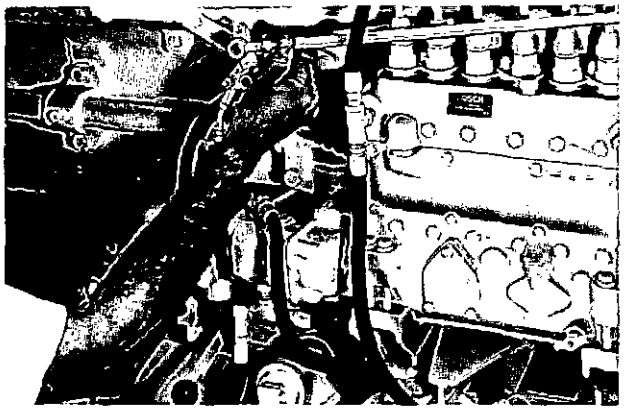
Never allow an injector to spray against the skin. The fuel oil may penetrate the flesh and cause serious infection and injury.

In checking multiple hole injectors for spray pattern, an attempt should be made to visualize what the spray pattern will look like if all the orifices are clear and delivering an equal quantity of fuel. Each orifice should deliver about the same quantity of fuel and there should be no coarse drops in the pattern. A distorted pattern indicates a clogged or eroded orifice. Comparison of the spray pattern with that of a similar nozzle known to be in good condition will resolve any doubts. Undesirable injector operation is usually characterized by dribbling, sprays of badly distorted patterns, sprays projected sideways, or up, or down, from the nozzle, and other rather self-evident troubles. The best remedy is replacement with another nozzle and return of the old one for repair.

When handling injector nozzles remember their precision construction and avoid gripping in a vise or similar abuses. When storing or shipping nozzles, always make provision for moisture protection to prevent corrosion.

DIESEL EXHAUST TEMPERATURE PYROMETERS

Diesel engines are equipped with exhaust temperature pyrometers. The dial of this instrument has a selector switch permitting checking individual cylinder exhaust temperatures as desired. The pyrometer also permits checking exhaust temperature to the turbocharger. The pyrometer serves two basic purposes.



MH-08-80

First, the exhaust temperature readings may be compared with the temperature Vs. horsepower curve and the approximate power output of the engine thus established and maintained for any given conditions. Overloading may be avoided and engine life prolonged by due regard for the pyrometer readings. In this respect, the pyrometer serves much the same purpose as the vacuum gauge on spark ignited gas engines.

In addition, the pyrometer offers a readily available means of checking individual cylinder performance. Here a variation between one or two cylinders and the others indicates some service problems needing attention. Stuck or leaking injectors, leaky valves and low compression, delivery valve difficulty, and similar conditions will often be revealed by the pyrometer.

It must be remembered that the horsepower Vs. exhaust temperature curves are not accurate unless the engine is operating properly. Retarded timing, low nozzle pressure settings, rack adjustment errors, and other factors subject to servicing and installation mistakes will raise or lower the exhaust temperature and at the same time reduce the horsepower available from the engine.

Mounting the Thermocouple

The thermocouple assembly must not protrude into the exhaust manifold so far as to strike the metal of the manifold. Metal contact with the thermocouple unit will definitely give an inaccurate reading at the pyrometer. Normal practice is to install one thermocouple in each exhaust outlet. Pyrometer assemblies using a single thermocouple unit are available. This would, of course, read only the average exhaust temperature for all of the engine cylinders.

Connecting the Pyrometer and Thermocouple

The pyrometer operates on the thermo-electric principle, is actually a rugged galvanometer which measures the voltage generated by a juncture of two dissimilar metals termed a thermocouple. Since this voltage is of minute value it is most imperative to provide for perfect electrical connections throughout the entire system. All wire ends and terminal connections must be clean, bright and dry. Both the pyrometer and the thermocouple terminals are marked (+white) for positive and (-red) for negative. The lead wires must be connected positive to positive and negative to negative. Do not, under any circumstances, use a battery powered test light or similar device to "ring out" the circuit without completely disconnecting the instrument. Uncontrolled voltage applied to the pyrometer will cause severe damage. Even the small battery in a volt-ohmeter will damage the instrument.

Wiring

Either of two types of connecting wires may be used between the thermocouple and the pyrometer. Alloy connecting wires may be identified by the color code; white for positive and red for negative. Iron-constantan wire on the other hand, if it is not color coded, may be identified by using a magnet. The positive iron wire is attracted to the magnet while the negative constantan wire is non-magnetic.

Checking the Wiring

After the wiring is completed the pyrometer should read up scale when the selector switch is positioned to indicate the temperature of a heated thermocouple. The indicator will read in the opposite direction when the wiring is reversed between the indicator or the thermocouple. As noted before, the iron wire may be identified by the use of a magnet but alloy wires are non-magnetic. In this instance, remove the wires from the thermocouple terminals and twist them together. Applying the heat of a match flame to the wire at this point will cause the indicator to read up scale if the connections are correct. If not, reverse the lead wires at the pyrometer.

If necessary, additional cables leading from the thermocouple elements to the indicating dial may be installed to relocate the dial where desired.

Adjustment

After all connections have been made and it is determined that the scale reads in the upwards direction with application of heat at the thermocouple note the temperature indicated with the selector in the OFF position. It should read ambient air temperature. Minor corrections may be made with a small screw provided on the dial face of some instruments.

Maintenance

When the pyrometer fails to respond to sudden changes in exhaust temperature such as after load application, or at the time of engine overhaul it is advisable to remove the thermocouple and clean any carbon which has accumulated on the stem. The thermocouple assembly consists of two wires of dissimilar metals which are connected within a protecting tube or stem. After extensive use it may not be feasible to clean this unit and it should be replaced. Give complete data when ordering, serial number, type of thermocouple, etc.

TURBOCHARGER

Turbocharger Installation

The turbocharged engine is normally shipped with the turbochargers in position on the engine. If a turbocharger is to be installed on an engine in the field, please refer to the following operating instructions and to these mounting instructions. Information on Waukesha installation prints, if supplied, takes precedence over these instructions.

The turbocharger is shipped assembled. Do not remove covers or plugs until immediately prior to installation, and use extreme care to ensure no dirt enters the unit.

The turbine housing and/or compressor housing may be rotated with respect to the center housing. Increments of orientation vary as to the method of housing attachment. The center line of the oil drain in the center housing should be within 35 degrees of vertical after the turbocharger has been installed.

Immediately prior to mounting the unit, prime the lubrication system as follows: Invert turbocharger, fill center housing with new, clean oil through oil inlet. Turn rotating assembly by hand to coat bearings and thrust washer with oil.

Coat threads of attaching bolts or studs with high temperature thread lubricant. Secure turbocharger to its mount. Connect ducts and make sure all connections are air tight.

Flush oil through oil inlet line and ensure that line is clean and unobstructed. Fill engine and oil inlet line with new, clean lubricating oil, and connect line. Connect oil return line. A check valve is installed in the oil inlet line to maintain an oil supply, thereby minimizing the possibility of oil starvation upon engine start up while oil pressure is building up. A good flow of warm oil must be going to the turbocharger before loading the engine. Current turbocharged engines are equipped with a turbocharger pre-lube system which is actuated during cranking to supply the turbocharger bearings with lubricating oil prior to sustained engine operation.

CAUTION

Connect turbocharger ducts so as to impose no compressive bending, or torsional loads on turbocharger.

All air duct connections must be air tight. Inlet air to compressor must be free of dirt and protected from contamination.

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

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

Turbocharger Operating Instructions

If the turbocharger(s) are to be installed on a new or newly overhauled engine, operate the engine for approximately one hour without the turbocharger installed, or use a separate oil filter in the oil supply line to the turbocharger during the first hour of operation. This must be done to ensure that no metal particles are carried from the engine into the turbocharger lubrication system. The turbocharger oil supply lines are equipped with magnetic plugs as a precautionary measure.

CAUTION

Before starting the engine, ensure that the turbocharger and oil supply lines have been filled with oil as directed in the turbocharger installation paragraph.

Make sure there is oil in the turbocharger before allowing the rotor assembly to turn (oil pressure should be 10 psig minimum). Disconnect the supply line at the turbocharger, then hold the compressor impeller from turning and start the engine. As soon as oil appears at the end of the supply line, attach the line. After the line is attached, release the impeller.

Check all ducts and gaskets or leaks. Repair all leaks before proceeding.

Operate engine at rated output and listen for sounds of metallic contact from the turbocharger. If any such noise is apparent, shut down immediately and correct the cause.

Turbocharger Low Output Operation

The turbocharger is intended to increase engine power output. Do not operate at low power more than necessary or for prolonged periods. DO NOT IDLE TURBOCHARGED ENGINES FOR EXTENDED PERIODS! This type of operation will foul the turbocharger and make expensive disassembly and cleaning necessary.

Air Leaks

Since the turbocharger is basically a centrifugal air pump driven by a gas turbine, anything which causes leakage or impedes the air flow will reduce the efficiency and power output. In all cases where engine

supercharging and power output seem to be less than normal, check first for possible leaks in the connections at the intake manifold and exhaust manifold. Very slight leaks are sometimes serious contributors to low efficiency. The next point to check under these conditions would be the possibility of a partially clogged air cleaner. It is essential that the air cleaners be as efficient as possible in order to prevent substantial amounts of dirt from reaching the impeller. Proper and regular air cleaner maintenance helps greatly.

Cleaning the Turbocharger

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

Turbocharger Maintenance

If the machine is to be shut down for an extended period of time, the turbocharger must be protected Ideally, where corrosion is troublesome, the unit should be dismantled and the shaft surfaces and all bearings thoroughly covered with vaseline for protection. All exposed surfaces should be slushed with rust preventive compound. Before placing the unit in operation again, it must be dismantled to permit thorough cleaning and removal of the protective coating. In less severe conditions, running the engine as outlined under Conventional Storage on page 2-33 may provide adequate protection; or, removal of the turbocharger to a clean, dry place may be best.

The turbocharger is designed and constructed to elinimate hand fitting of moving parts. All repair parts should be entirely interchangeable without forcing or fitting. It is essential in assembly and repair of the turbocharger that parts be handled carefully and kept clean since tolerances on some parts are such that nicks, burrs or dirt will interfere with the proper operation of the machine.

Determining Turbocharger Repairability

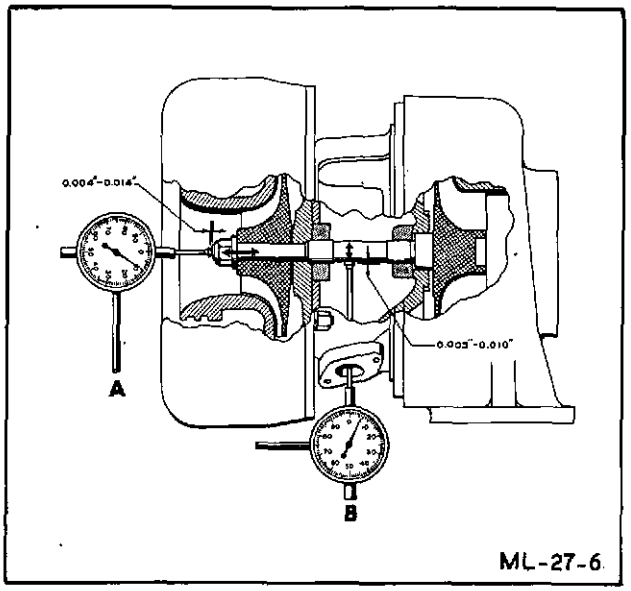
A bearing clearance inspection procedure is used to determine whether it is necessary to replace or repair a turbocharger. In most cases this bearing check can be made while the turbocharger is still mounted.

Prepare for bearing clearance inspection by fastening a dial indicator (plunger type with one inch travel) using a mounting plate and a two inch extension rod, to the turbocharger oil drain mounting pad. The mounting plate and indicator can be secured with the bolts which were removed to gain access to the oil drain hole.

Turbocharger Radial Bearing Check

Mount the dial indicator through the oil hole as illustrated at "B". Grasp each end of the rotating assembly and applying equal pressure at each end move the rotating shaft toward and then away from the dial indicator pin. The total dial indicator reading should be between .005 and .010. The unit must be repaired if not within these limits.

These checks can be made with the housing attached. A magnetic base for the dial indicator is also helpful.



TURBOCHARGER BEARING CHECK

Turbocharger Axial Bearing Check

Mount the dial indicator on the compressor side of the turbocharger as illustrated at "A". Move the shaft axially back and forth by hand. The total indicator reading should be between .004 and .014. The unit must be repaired if not within the limits.

Daily Turbocharger Service and Maintenance Inspection

1. Inspect mounting and connections of turbocharger for security, lubricant leakage, or air leakage.
2. Check engine crankcase breather for restrictions to air flow.
3. Operate engine at rated output, and listen for unusual turbocharger noise. If a shrill whine (over and above normal turbine whine) is heard shut down immediately. Whine is indicative of imminent turbocharger bearing failure. Remove turbocharger for overhaul. Other unusual noises would result from improper clearance between turbine wheel and turbine housing. If such noises are heard, turbocharger must be removed from the engine, disassembled and inspected.
4. Check turbocharger for unusual vibrations while operating engine at rated output. If excessive vibration is evident remove turbocharger, disassemble, and inspect.
5. Inspect and service the engine air cleaner if required.
6. Check engine under loaded conditions. Excessive exhaust smoke indicates improper fuel-air mixture and could be a result of either engine overloading or turbocharger malfunction.

Periodic Turbocharger Service and Maintenance Inspection

In addition to daily inspection, periodic inspection should be made in conjunction with engine periodic inspection.

Inspect all air ducting and connections for leaks. Make inspection both with engine shut down, and with engine running. Check at manifold connections to turbine inlet and at engine exhaust manifold gasket.

CAUTION

Do not operate the turbocharger if leaks exist in the ducting, or if air cleaner is not filtering efficiently. Dust leaking into air ducting can damage turbocharger and engine.

Remove air inlet duct and compressor housing and check for dirt or dust buildup. Remove all such foreign matter, determine and correct cause. Uneven deposits left on impeller can affect balance and cause premature bearing failure.

With compressor housing removed, push impeller toward turbine end and turn rotating assembly by hand. Check for binding or rubbing. Listen carefully for unusual noises. If binding or rubbing is evident remove turbocharger for disassembly and inspection.

If shims were removed for inspection, use same thickness of shims at reassembly.

Turbocharger Trouble Shooting

Refer to the trouble shooting table for aid in determining the cause of turbocharger malfunction.

Summary of Turbocharger Operation and Maintenance

The points below represent the main factors in operating and maintaining a turbocharged engine.

1. Do not operate engine under load until a flow of warm oil is available to the turbocharger.
2. Do not exceed recommended speed of the turbine and impeller.
3. Idle engine before shutdown.
4. Be sure oil line to turbo and its return are clear before starting.
5. Be sure the oil in the engine is clean and filters are well maintained.
6. Pre-oil new or stored turbochargers before starting.
7. Do not be alarmed by slight oil leakage at idling speeds.
8. Always check for tight air and exhaust connections before going further if the turbo output seems low.
9. Keep air cleaner serviced.
10. Clean turbo impeller carefully as needed.
11. NEVER use cutting, scraping, abrasives, or corrosives on impeller or turbine.
12. Avoid restrictive mufflers or exhaust pipes.
13. Do not idle for prolonged periods.

Turbocharger Overhaul Instructions

The following tools should be available.

1. A furnace, oven, or hot oil bath which can be temperature controlled between 350 and 375°F (177 and 191°C).
2. A fixture or stand which will prevent the rotating assembly from turning while tightening or loosening the impeller nut.
3. A sleeve which can be assembled on the rotating assembly shaft in place of the impeller.

TROUBLESHOOTING DATA FOR AIRESEARCH TURBOCHARGERS

TROUBLE	CAUSE	REMEDY
Excessive noise or vibration.	Lube oil pressure low. Improper bearing lubrication. Loading engine before warm oil is supplied to turbo.	Provide required oil pressure. Clean or replace oil line. If trouble persists, overhaul turbocharger.
	Leak in engine intake or exhaust manifold.	Tighten loose connections or replace manifold gaskets as necessary.
Engine will not deliver rated power.	Clogged air filter.	Clean air filter.
	Foreign material lodged in compressor impeller or turbine.	Disassemble and clean. Overhaul turbocharger.
	Excessive dirt build-up in compressor.	Thoroughly clean compressor assembly. Service air cleaner and check for leakage.
	Leak in engine intake or exhaust manifold.	Tighten loose connections or replace manifold gaskets as necessary.
	Rotating assembly bearing seizure.	Overhaul turbocharger.

4. A fixture or stand which will hold the assembly in a vertical position.

The part, serial and model numbers and other pertinent information appears on the nameplate attached to the turbocharger. Include this information in all correspondence with the Service Department of the Waukesha Engine Division.

Prepare to disassemble the unit by cleaning the exterior with a pressure spray of cleaning solvent.

WARNING

Use cleaning solvent in a well-ventilated area. Avoid breathing fumes. Keep away from open flames.

Disassemble only as required to make necessary inspections or repairs. As each part is removed place it in a clean protective container.

NOTE

Measure the thickness of the compressor housing and the turbine housing shims as they are removed. Record the measurements so that the same thicknesses can be used at reassembly.

Remove the bolts and lock plates which hold the compressor and turbine housings to the center housing group. Tap housing with a soft headed hammer if force is needed for removal. Then remove the nozzle and diffuser.

NOTE

Exercise care when removing housing to prevent damage to compressor or turbine wheel. Once damaged they cannot be repaired.

Place the center housing group in a suitable fixture, which will hold the turbine wheel from turning. Remove the impeller nut. Heat the remainder of the assembly in a furnace, oven or oil bath, to a temperature of 350 to 375°F (177 to 191°C) for no longer than ten minutes. If hot oil is used, immerse impeller only. Do not use direct flame heating in the impeller.

CAUTION

Do not overheat the impeller.

Press the rotating assembly from the impeller using an arbor press. Keep the shaft centered with the bearings until the shaft is clear of the center housing.

CAUTION

Be careful to avoid scuffing bearing journal surfaces of the rotating assembly and inner surface of bearings with the diamond knurl located on the shaft between the bearing journals.

Remove thrust plate screws and lock tabs. Tap the thrust plate lightly to remove from recess in the center housing.

Before cleaning, inspect parts for signs of burning, rubbing, or other damage which might not be evident after cleaning. Then soak all parts in clean carbon solvent for about 25 minutes.

WARNING

Use cleaning solvent in a well ventilated area. Avoid breathing fumes. Keep away from open flames.

After soaking use a stiff bristle brush and remove all dirt particles. Dry parts thoroughly with filtered, moisture-free, compressed air at approximately 20 psig pressure.

NOTE

Normally, a light accumulation of carbon deposits will not affect turbine operation.

General inspection requirements are given in the table at the bottom of this page.

Replace any part which fails to meet inspection requirements.

Replace the following parts: thrust plate o-ring and lock plates, nozzle retaining nut gaskets, piston ring, and bearings.

Replace all damaged studs and nuts.

Check each part prior to installation to ensure cleanliness. As parts are assembled, cover openings to prevent entry of dirt or other foreign material.

NOTE

If any particle falls into the turbocharger during assembly, remove the particle immediately, even though extensive disassembly is required.

Lubricate o-rings with a light coat of liquid soap or "Molykote, Type Z" before installation.

Assemble in reverse order of disassembly, noting the following:

1. Align diaphragm on center housing, install shim and back plate. Torque back plate to 25 to 30 foot pounds. Secure back plate with tabs of lock plates.
2. Lubricate OD of bearings and insert in center housing. Install snap ring.
3. Lubricate bearing journals of rotating assembly shaft. Guide assembly straight through bearings, using care not to scuff or scratch bearing journal surfaces with threads of turbine and seal on center housing. Extreme care must be exercised while pushing shaft assembly through bearings in order to prevent corner at compressor end journal as well as diamond knurl on shaft between bearing journals from scuffing or scoring inner surface of bearings.
4. Ensure that hole and cutout in thrust washer engage pins in center housing, and that washer is seated flat against the housing.
5. Install thrust plate washer and thrust ring with piston ring in thrust plate. Ensure that cutouts in washer mate with ribs in thrust plate and that washer is seated flat against thrust plate. Slide assembly over shaft and tighten thrust plate bolts evenly to 80 to 100 inch pounds torque.

INSPECTION TABLE FOR AIRESEARCH TURBOCHARGER

ITEM	TURBOCHARGER INSPECTION REQUIREMENTS
GENERAL	Parts must not show signs of damage, corrosion, or deterioration. Threads must not be nicked, crossed, or stripped.
ROTATING ASSEMBLY	Turbine wheel must show no signs of rubbing, and vanes must not be eroded. Shaft must show no signs of scoring, scratches, or seizure with the bearings.
IMPELLER	Must show no signs of rubbing and must be completely free of dirt or other foreign material. Impeller bore must not be galled.
HOUSINGS	Must show no signs of contact with rotating parts, except at slinger grooves. Oil and air passages must be clean and free of obstructions.
NOZZLE	Vanes must not be eroded and must not be bent to a different nozzle area.
DIFFUSER	Must be completely free of dirt and foreign material.

6. Make a sleeve which will fit over shaft of rotating assembly and bear against face of thrust ring. Length of sleeve must be same as length of bore of impeller. Install sleeve over shaft and secure firmly with plain washer and nut. Check axial (thrust) play of rotating assembly. Play should be 0.003 to 0.010 inch. Remove nut, washer and sleeve.

7. If the same compressor housing, diffuser, impeller, and rotating assembly are being reassembled into same center housing, use same thickness of shims for diffuser as recorded at disassembly. Install same shims onto the center housing. Install diffuser plate assembly and secure with lock washers and nuts. Tighten nuts evenly to 12.5 to 16.6 foot pounds torque.

8. Heat impeller in furnace, oven, or hot oil bath to 350°F, 177°C, for no longer than ten minutes. Install impeller. While impeller is still hot, install washer and nut. Ensure that orientation marks on rotating assembly, thrust ring, impeller, and washer are aligned. Tighten nut to 30 to 35 foot pounds torque. After impeller cools to less than 150°F, 66°C, tighten nut to 40 to 50 foot pounds torque. Clean impeller of oil if hot oil bath was used for heating.

CAUTION

Impeller nut must be tightened in such a manner as to apply no bending loads on shaft. It is recommended that a wrench with a double universal joint be used.

9. Secure nozzle to turbine housing, and tighten nuts to 35 to 45 inch pounds torque.

NOTE

Nozzle retaining bolts may be rotated 180 degrees to facilitate assembly. Bolt heads must bear on nozzle and not on turbine housing.

10. Apply a thin coat of Permatex Super 300 to diffuser mating face and bolt holes of compressor housing, install compressor housing on diffuser and secure with bolts and lock washers. Tighten bolts evenly to a torque of 150 to 200 inch pounds.

11. If same housings, diffuser, impeller, and rotating assembly are being reassembled, use same thickness of shims as recorded at disassembly. Install correct shims, orient turbine and compressor housings with center housing and carefully install each housing in position. Tighten nuts center housing to turbine housing evenly to 300 to 350 inch pounds torque and secure with lockplates. Tighten nuts center housing to diffuser evenly to 150 to 200 inch pounds torque.

NOTE

If any parts listed in step 11 are new, select shims which will give correct turbine wheel and compressor impeller clearance. Determine correct shim thickness in accordance with steps 12 through 16. If impeller, thrust ring, or rotating assembly require replacement, center housing rotating assembly must be replaced entirely. This is a factory balanced assembly and interchanging of rotational parts is not recommended due to possible loss of balance.

12. Assemble center housing assembly as outlined in steps 1 through 7, using 0.045 inch shims when installing the diffuser assembly.

13. Place center housing assembly upright with turbine wheel resting on surface plate or similar parallel surface.

14. Place parallel bar across diffuser vanes. Measure depth from top of bar to face of thrust ring with a depth micrometer. Record depth reading. Measure from top of parallel bar to face of diffuser vane and record depth reading. Subtract readings. Difference indicates height of diffuser vanes above thrust ring face. Rotate parallel bar 180° and take second set of readings. Agreement within 0.001 inch maximum is desired.

15. Place impeller face up on gage block, on flat parallel surface. With vernier height indicator, measure height of blade tip. Measure at least one-eighth inch back from tip edges. Record height reading. Remove impeller from gage block and measure height of gage block. Record height reading. Subtract readings. Difference indicates height of impeller. Rotate impeller 180° and repeat measurements. Agreement of within 0.001 inch maximum is desired.

16. Subtract impeller height from diffuser vane height. A difference of 0.013 to 0.017 inch is required. Select shims to add or subtract from shims previously placed under diffuser in order to gain proper dimension.

17. Heat impeller in furnace, oven, or hot oil bath and install as outlined in step 8. If properly shimmed, diffuser vanes will be from 0.013 to 0.017 inches higher than impeller blade tips.

18. Use feeler gage to measure clearance at three equidistant points between nozzle, turbine vane ends, and inner shroud of turbine housing. Note clearance. Maximum tolerance is 0.003 inch.

19. Place turbine housing assembly face up so that it rests on turbine exhaust flange. Install combination of shims to provide thickness of 0.040 inch. Install center housing rotating assembly, check turbine wheel for free spin. Tighten nuts to 25 to 30 foot pounds torque.

20. If turbine spins freely, remove nuts, separate unit and remove 0.010 inch shim. Repeat procedure until turbine rubs lightly on turbine housing.

21. Separate unit and add combination of shims to provide additional 0.019 to 0.029 inch. This is required face clearance tolerance.

22. Install selected shims. Orient turbine housing to center housing as required. Tighten nuts to torque of 25 to 30 foot pounds and secure lockplates. Rotate shaft to check for binding.

23. Orient compressor housing to diffuser assembly and secure with bolts and lock washers. Ensure that mating surfaces of compressor housing and diffuser assembly have been thinly coated with Permatex 300. Torque bolts to 12.5 to 16.6 foot pounds. Rotate shaft and check for binding.

After assembly, push the rotating assembly as far as possible from the turbine end, turn, and check for binding. Repeat check pushing from the compressor end.

If unit is to be stored, lubricate internally, install protective covers on all openings.

Turbocharger Testing

Turbocharger does not require testing after overhaul. After turbocharger is reinstalled, inspect the installation following recommendations in paragraphs titled "Daily Turbocharger Service and Maintenance Inspection", "Periodic Turbocharger Service and Maintenance Inspection", and "Turbocharger Operating Instructions".

VALVE SERVICING AND ADJUSTMENT

Servicing Roller Type Valve Tappet Assemblies

Waukesha Motor Company has revised the method of fabricating the roller type valve tappets used in this engine. Because these methods cannot be duplicated effectively in field shops, only complete assemblies can be used for service replacement purposes.

Servicing Hydraulic Push Rods

Any of the following may be encountered when troubleshooting a malfunctioning hydraulic push rod system.

1. Complete failure (all or most of the push rods are noisy).
2. Single push rod failure.
3. Intermittent failure.
4. Starting noise.

Analysis and Correction of Hydraulic Push Rod Failures

1. COMPLETE FAILURE

This type of failure is caused by interruption of the oil supply to the hydraulic push rods.

A. An example would be the loss of engine oil pressure because of line breakage.

B. Too much oil in the crankcase can cause a similar condition. The entire oil supply can be whipped into foam with excessive air in the oil making the fluid so compressible that the hydraulic push rods are inoperative.

C. Complete failure may be caused by water leaking into the oil supply (especially where permanent antifreeze such as ethylene glycol is used). The push rods would gradually become noisier if most or all were affected. Starting the engine in cold weather would be very difficult since a similar coating would be formed in the engine requiring considerably more torque to turn the engine over.

D. Complete failure can also be caused by a leak on the inlet side of the oil pump. Intake of air can make the fluid compressible enough to cause noise and can cause valve seating before it has slowed down (resulting in broken valves among other things) because of loss of dampening action.

E. Anything causing oil pressure drop, such as burned out bearings or any unusual loss of oil can cause push rod malfunction. A clattering noise may result at idling after long hard running. This is due to high oil temperature or thinning oil so that pressure cannot be maintained when there is an excessive loss of oil due to worn parts. As can be seen, generally these failures are due to some unfavorable condition in the oiling system.

2. SINGLE PUSH ROD FAILURE

A. A faulty hydraulic unit, such as one having a fast leak-down usually would not show up with cold oil or during normal operation, but a slight noise would be heard at idling or when the oil is hot. This is not dangerous, does not affect operation or cause breakage, but because it does produce annoying noise at idling with hot oil, the unit should be replaced.

Locate the noisy push rod by pressing against the upper end of the valve spring with fingers (if oil is hot, use a hammer handle or similar wooden handle). The shock of the valve seating will be clearly felt. Also, the noisy push rod can be located with a listening device by comparing it with the sounds of other push rods.

B. The push rod hydraulic valve may be stuck at the bottom of the body allowing the intake or exhaust valves to operate at full dry clearance (approximately 1/8 inch). IT IS DANGEROUS TO OPERATE AN ENGINE AT HIGH SPEED IN THIS CONDITION--VALVE BREAKAGE IS PROBABLE.

Stop the engine with the valve lifter on the base circle of the cam. Manually press down on the rocker arm. There should be no interference from the push rod, indicating the stuck hydraulic valve. Sticking may be due to excessive dirt or a trace of ethylene glycol in the oil. Determine the cause so that proper steps can be taken to prevent a recurrence. Examine the oil filter for unusual amounts of dirt, and if found, replace the filter elements and oil. Examine the hydraulic unit for cause of failure. Burned bearings or scored engine parts fill the oil with particles of metal, necessitating a thorough engine cleaning plus parts replacement.

C. A sticking rocker arm can cause single push rod noise. Locate the noisy push rod, then hold the engine valve end of the rocker arm down, forcing the arm against the valve stems. Normally, the hydraulic unit spring with a four to six pound force, moves the rocker arm, but the rocker sticking on the shaft can prevent its action and thus prevent refilling the hydraulic unit. Holding down on the rocker arm assists the spring, causing the unit to fill with oil and become quiet.

D. A worn valve guide or misalignment of the valve seat can cause push rod noise. Rotate the valve spring about 180 degrees. If the noise stops temporarily but returns after the spring works back to the original position something is wrong with the valve seating. A worn guide, bent valve, or misaligned seat is usually the cause, so a replaced push rod will not correct the trouble. This noise isn't usually loud and should do no harm at high speed operation.

E. When engine valves or stems are gummed or sticking, preventing full valve closing, it may sound like a push rod noise accompanied by irregular engine operation due to the valve holding open. High fuel consumption may indicate that a valve overhaul is necessary. This can also be caused by wrong lubricating oil or fuel type used.

F. Any condition preventing oil delivery to a single push rod will cause noise. Check each part removed to determine that there are no restricted passages.

G. Some conditions cause scoring between the cam and the lifter roller, in turn causing an irregular profile on the roller/cam surface. It can sound like a noisy push rod. Measure the lift of the valve by shimming between the rocker arm and the valve stems until the hydraulic unit bottoms and the valves are held off the seat slightly.

CAUTION

Do not cause valves to be held off seats more than .005" to preclude possibility of bending valve heads by striking the piston.

Compare the lift to other valves or to the height given in the fits and clearances section.

3. INTERMITTENT FAILURE

Intermittent noise, such as a clatter at idling after hard running, may be caused by excessive or too little oil in the crankcase. An air leak on the inlet side of the oil pump or low pressure (due to worn pump or bearings) may cause excessive loss of oil pressure, noticeable in the hydraulic units. See paragraph 1 for these conditions. Of course intermittent noise may be caused by a push rod unit which is sticking part of the time, by a tight rocker arm or by a tight lifter in its guide.

4. STARTING NOISE

Starting noise may be due to slight sticking of the hydraulic unit. A little time and warm-up is required to move the plunger into operating position, however, note that this may be the beginning of trouble from antifreeze leaking into the oil. Starting noise due to antifreeze in the oil may quiet as soon as the oil reaches a temperature where the deposit softens.

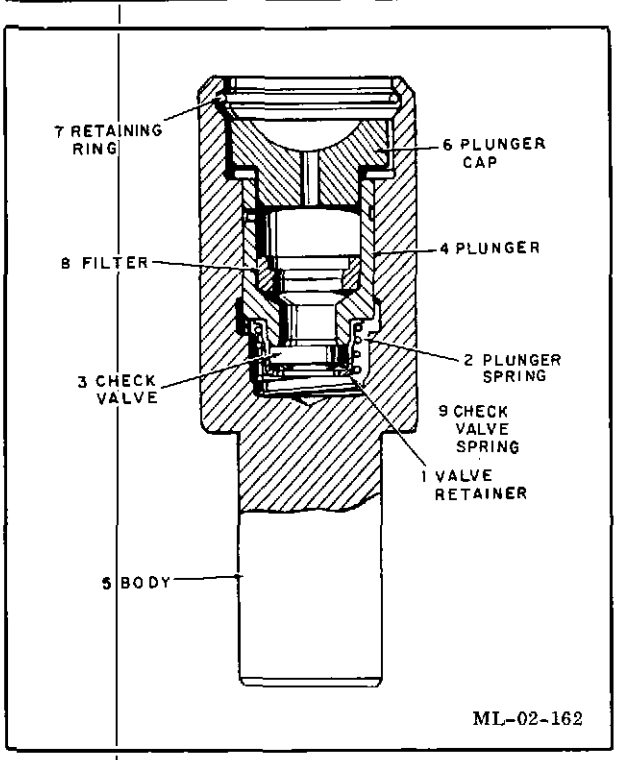
Hydraulic Push Rod Overhaul

CLEANING

During engine valve overhaul, clean and inspect the hydraulic units. After long operation, a deposit forms above the operating position of the plunger, so the plunger cannot move above this position. The hydraulic units fill with oil to this point, so as they are removed, they will go down slowly, appearing to be stuck, but they are not. When a hydraulic unit sticks, it sticks at the bottom of travel. In handling and cleaning hydraulic push rods, provide for a clean working area, free from splinters or filings. Cover the working area with paper. Keep the parts for each unit separate to avoid misassembly (and noisy push rods) later. Clean all ports and inspect contact surfaces for wear, pitting, corrosion, and other appearances of deterioration. The filter (8) must be replaced as required.

ASSEMBLY

Assemble the plunger sub-assembly by placing the cup-shaped valve retainer (1) in an open end up position. On early engines insert the thin wave washer curved spring (9) into the retainer (spring curvature can be up or down). On later engines install conical



PUSH ROD TYPE HYDRAULIC VALVE LIFTER

coil spring with small end towards check valve. Place the check valve (3) into the retainer, either side up. Insert the nose end of the plunger (4) into the retainer and press it all the way in. The plunger sub-assembly is now complete.

To assemble the component parts into the push rod unit, it will be necessary to use an arbor press and a fixture to hold the unit. Place the push rod with the hydraulic unit body (5) up in a vertical position in the fixture. Drop the plunger spring (2) into the body making sure that it goes into the spring cavity. Fill the body approximately 1/2 full of clean kerosene and carefully insert the plunger sub-assembly into the body with a slight rotating motion. Do not force the plunger into the body. The air being trapped between the oil in the body and the bottom of the plunger will leak out slowly if the plunger is held down by hand for a short period of time. Fill the plunger inside diameter with clean kerosene and place the plunger cap (6) in position on top of the plunger. With the unit in the fixture plate and in position on the arbor press directly under the arbor press ram, place a short length of 7/16" diameter rod between the arbor ram and the socket of the plunger cap. Apply downward pressure on the plunger cap and move the plunger into the body until the top surface of the plunger cap is slightly below the retaining ring groove in the body. Insert the retaining ring (7) into the groove on the ID of the body using a small screw driver. Raise the arbor press ram up and observe that the plunger spring forces the plunger and the plunger cap up against the retaining ring. The assembly is now complete and the unit ready to be installed in the engine.

CAUTION

In handling the hydraulic units, cleanliness and good inspection procedures must be practiced. Care must be exercised to assemble the parts properly. There is no interchangeability of parts. Hydraulic valve lifters should never be installed dry. Always prime the lifters with clean recommended oil.

After filling, determine whether unit is holding properly by comparing with another unit. Although unit may be compressed, it will resist rather than collapsing quickly.

Valve Removal and Replacement

Using a valve spring compressor, compress the valve springs and remove the retaining ring, o-ring, split taper keepers, and valve spring retainer.

NOTE

Mark each valve for identification so that it is installed in its original position. Inspect the valve, the valve guide and valve insert for wear, etc.

Inspect each valve carefully for warpage, cracking, scoring and stem wear. Inspect the valve faces for pitting, cracks and evidence of burning. Excessive wear of either the stem or the guide will make it impossible to secure a tight seat by grinding unless the valve or guide, or possibly both, are replaced. Make sure valves are marked for reassembly in the same guides.

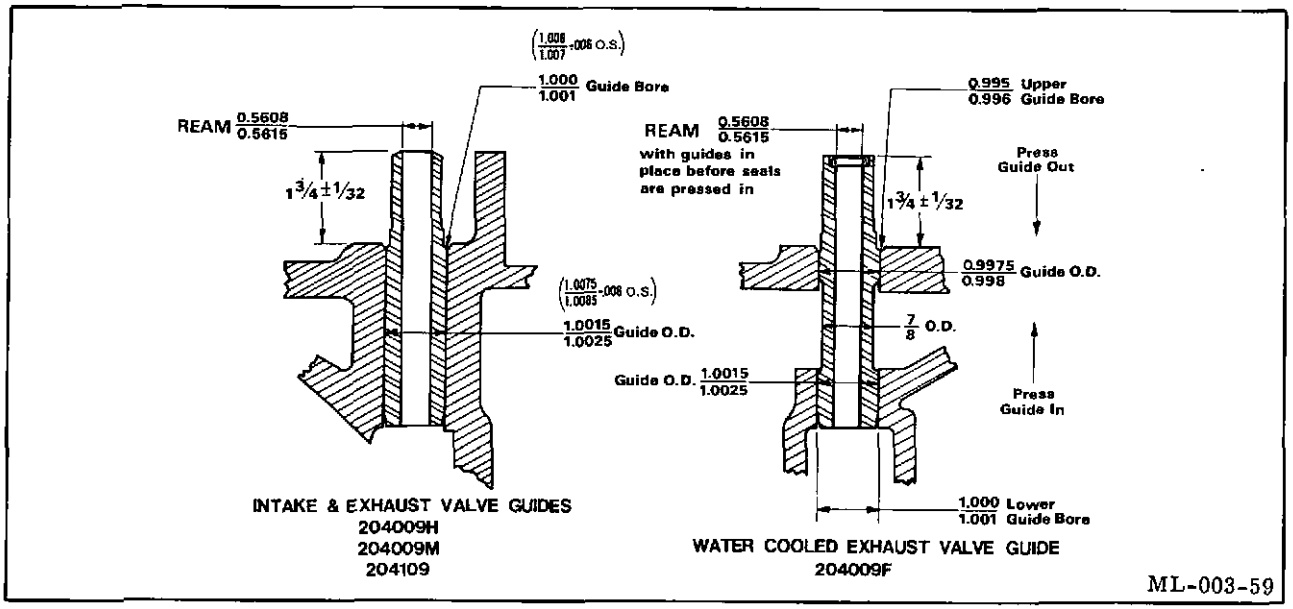
CAUTION

Do not use a stiff wire brush. Examine the springs for any sign of pitting, corrosion, damage or bright spots. Replace any spring which shows any of these conditions, regardless of degree. Compare spring length to that of a new spring. If it is more than 3 percent shorter, replace it. Spring failure can cause extensive damage to the engine. Check spring specifications in the fits and clearances section.

Inspect valve guides. Use a Dial Bore Gauge or similar instrument to check the bore of valve guide and dimensions against those specified in the fits and clearances at the end of this unit.

Valve Guide Removal and Replacement

Remove worn valve guides with a suitable press. Press new guides into place on an arbor press with a mandrel of the proper size to prevent damage. Guides should extend 1-3/4 ± 1/32 inches above the face of the cylinder head.



CAUTION

Care must be taken when replacing water cooled exhaust valve guides. The outside diameter at the valve head end of the guide is larger than the outside diameter at the valve stem end of the guide; therefore, the guide must be pressed out toward the valve seat insert and must be pressed in from the valve seat insert side of the head.

Apply a good heavy body lubricant, such as white lead mixed with SAE 30 lube oil, to the outside diameter of the valve guide before pressing into the cylinder head. When pressed into the head, the guide has a tendency to work harden. For this reason, the guide must be reamed in place. Always start the reamer from the valve seat insert side of the head. A carbide faced reamer with a No. 2 Morse taper is available from Waukesha under part number 499953.

The exhaust valve stem seal must be installed flush with the end of the guide after the guide has been reamed in place. The seal is a light press fit, and must be installed with the seal lip facing down toward the valve seat.

NOTE

Install valve carefully to avoid moving seal in exhaust valve guide.

The piston ring type valve guide seal used in the 204109 intake valve guide must also be installed after the guide has been reamed in place. Refer to Service Bulletin No. 7-2021 for installation instructions.

DAMAGED VALVE GUIDE BORES IN CYLINDER HEAD

Some valve guide bores in the cylinder head are damaged when valve guides are removed. These heads may continue to be used if the bores are cleaned up with a reamer and the new valve guides are reworked by one of the following methods:

NOTE

The O.D. of reworked valve guides should result in a .0005" to .0025" press fit.

ELECTRO-COPPER PLATING (RECOMMENDED)

This process is available at most bright chrome plating shops. It is accurate, requires no clean up work, and provides good heat transfer quality. Thicknesses up to .005" on a side (.010" O.S.) can be obtained with good adhesion.

SPRAY COPPER COATING (ALTERNATE)

This process is available at certain specialty shops. It provides good heat transfer quality. Some machining is necessary to obtain concentricity and required outside diameters.

KNURLING (NOT RECOMMENDED)

Knurling can be used with limited success on non-water cooled guides (use a 45° diamond shaped cut).

CAUTION

Guides, if knurled, will probably shear the metal from the head casting when being installed. This may lead to premature loosening of the guide and induce higher valve stem temperatures due to poor heat transfer between the guide and the head.

FLYWHEEL AND FLYWHEEL HOUSING

Flywheel and Flywheel Alignment

A major factor in obtaining long service life from any engine and clutch or power take-off assembly is the proper alignment of the flywheel housing, flywheel, and pilot bearing bore. Distortion or lack of a common center on any of these parts will set up forces which will 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 take-off 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.

Distortion or misalignment of the flywheel, housing, or both may occur because of a number of reasons, even though the alignment is carefully checked before the engine leaves the factory. Some of these reasons are listed below.

1. Rough handling in shipping or storage. Jolting and roughness in railway shipment will definitely cause this trouble.

2. Improper loading or unloading techniques. The use of fork trucks, lift trucks, bulldozers and similar equipment to bump or skid an engine from a freight car or truck, or for pushing in a warehouse or on a loading dock is a common source of misalignment trouble.

3. Dropping, sliding violently down skids, tipping the engine on end for repair work, prying against wheel or housing with bars, or uneven mounting surfaces during operation will also produce misalignment.

4. Removal of the flywheel, the housing, the crankcase, or the crankshaft for service and maintenance operations always introduces the possibility of misalignment.

Flywheel Housing Mounting

The machined contact surface of the flywheel housing mounts on the machined rear surface of the crankcase.

Before installing the flywheel housing, use a straight edge to check the housing rear surface for high spots around the bolt holes and burrs or pick ups that might prevent accurate seating. Dress these off if found. When the housing has been installed and the bolts snugged up just enough to hold it in place make the following check for concentricity before installing the dowels.

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.

2. Use a soft-face hammer as shown to correct misalignment until the run-out does not exceed 0.015" total indicator reading.

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

4. Before starting the dressing operation, check to make certain the housing bolts are snug and the dowel holes are aligned. Unless the dowel holes are in perfect alignment, it will be necessary to ream them for an oversize dowel or re-drill and ream in a new location. Do not force the dowels into a misaligned hole since this will definitely spoil the alignment job. If the bolts and dowels are not snug, the tool may cause the housing to shift during the cutting operation and this, of course, will produce a very unsatisfactory job.

After tightening bolts to final tension, relocate the dial indicator to indicate the flywheel housing face.

1. Housing face run-out should be confined to 0.010" or less. Although under emergency conditions it may be possible to correct minor distortions by means of a block of hard wood and a hammer, this procedure is definitely not recommended as good operating practice. If correction is required, it should be done with a cutting tool mounted on a radius arm and firmly attached to the flywheel or flywheel flange. 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.

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. Do not pry against the housing or crankshaft flange. Work through the side door and insert the bar carefully between the crank throw and a main bearing cap. If inspection does not reveal any other reason for excessive run-out, it will be necessary to mount a cutting tool on the wheel and face off the housing slightly to bring the two surfaces into the correct relationship. Machining of the housing bore may also be accomplished at this time if needed.

As with the flywheel housing, the mounting surface of the flywheel and the crankshaft flange must be free of burrs and conditions which would prevent accurate seating.

1. The drilling of the flywheel holes prevents the wheel from being located improperly. With the aid of adequate hoisting equipment, lift the wheel and align the offset hole so that the wheel mounts on the flange.

2. Use a torque wrench to apply the correct tightening value to all bolts evenly, working across the wheel from one to another in several stages. Refer to the table of tightening torque values in the back of this unit.

Mount a dial indicator on a bar extending across the flywheel housing and check the run-out of the pilot bearing bore. Run-out should not exceed 0.005".

Remount the dial indicator to measure the run-out 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 dirt or burrs have prevented the flywheel from seating, or rough handling has somehow distorted the wheel or crankshaft flange, maximum run-out should not exceed 0.015".

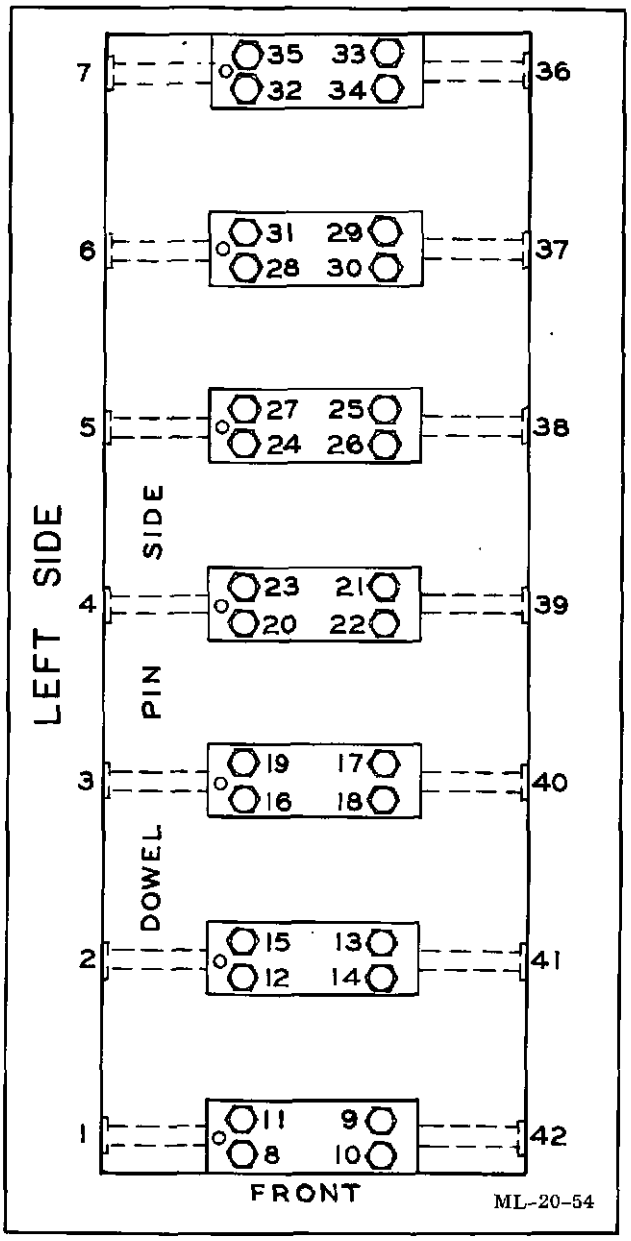
LIFTER REPLACEMENT

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

MAIN BEARING CAP TORQUE

1. Generously apply engine oil to main bearing studs and nuts immediately before installing nuts.
2. Turn main bearing cap nuts until bearing caps are held firmly against engine block. Follow the crossover sequence as shown in the illustration, starting with number 8.
3. Apply 3M Scotch Grip Industrial Adhesive EC 847, or equal, to both sides of the crosstie cap screw washers. Install cap screws and turn in until seated following the number sequences 1 thru 7 and 36 thru 42.
4. Tighten the crosstie cap screws and the bearing cap nuts in the steps of increasing torque values given in table below.

	TORQUE VALUES		
	CROSSTIE CAP SCREWS LEFT SIDE	MAIN BEARING CAP NUTS	CROSSTIE CAP SCREWS RIGHT SIDE
STEP 1	60 lbs. ft. (8,35 kgm)	68 lbs. ft. (9,5 kgm)	60 lbs. ft. (8,35 kgm)
STEP 2	120 lbs. ft. (16,60 kgm)	136 lbs. ft. (19,00 kgm)	120 lbs. ft. (16,60 kgm)
STEP 3	180 lbs. ft. (24,90 kgm)	205 lbs. ft. (29,00 kgm)	180 lbs. ft. (24,90 kgm)
FINAL	242-250 lbs. ft. (33,34-34,59 kgm)	271-279 lbs. ft. (37,48-38,58 kgm)	242-250 lbs. ft. (33,34-34,59 kgm)



BOTTOM VIEW OF CRANKCASE

INSTALLATION OF SPRING-LOADED TEFLON SLEEVE SEAL RINGS

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. Lu-

bricate 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 tapered sleeve installation tool and the compression tool can be purchased from your authorized Waukesha distributor.

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.

6. Lubricate the seal with liquid soap or other lubricant in the conventional manner and install and inspect the sleeve as uaual. Check for leakage and bore roundness.

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.

WATER PUMP SEAL

When installing a new water pump seal, carefully wipe the carbon or teeplelite 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.

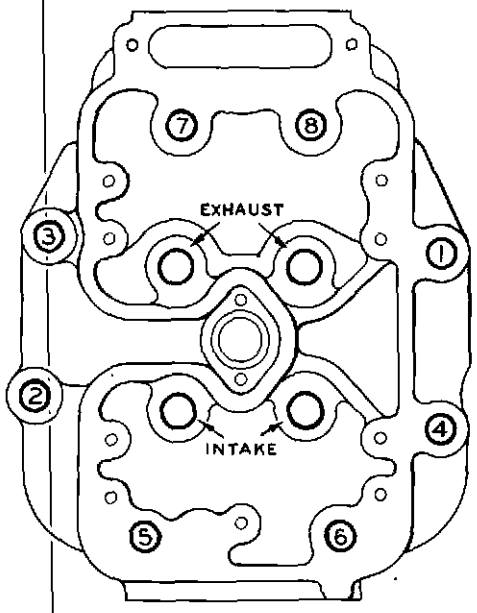
Lubrication of the seal after installation is provided by the engine coolant. When using only water as the engine coolant, about 1% soluble oil should be added as a seal lubricant and cooling system corrosion inhibitor.

GENERAL TORQUE RECOMMENDATIONS

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

HEAT TREATED MATERIAL SAE GRADE5 & GRADE 8				
	NOTE: INCREASE VALUES 1/3 FOR DRY THREADS			
	GRADE 5 (3 radial dashes on bolt or cap screw head)		GRADE 8 (6 radial dashes on bolt or cap screw head)	
THREAD SIZE	U.S. Pounds-Feet	Metric Kgm	U.S. Pounds-Feet	Metric Kgm
1/4-20	6	0,8	9	1,2
1/4-28	7	0,9	11	1,5
5/16-18	13	1,8	18	2,5
5/16-24	15	2,1	21	2,9
3/8-16	24	3,3	34	4,7
3/8-24	27	3,7	38	5,3
7/16-14	38	5,3	54	7,5
7/16-20	42	5,8	60	8,7
1/2-13	58	7,9	82	11,3
1/2-20	65	8,9	90	12,4
9/16-12	84	11,7	120	16,6
9/16-18	93	12,9	132	18,3
5/8-11	115	15,7	165	22,8
5/8-18	130	17,9	185	25,6
3/4-10	205	28,4	290	40,1
3/4-16	230	31,8	320	44,3
7/8-9	305	42,2	455	62,9
7/8-14	335	46,3	515	71,2
1-8	455	62,9	695	96,1
1-14	510	70,5	785	108,6
1-1/8-7	610	84,4	990	136,9
1-1/8-12	685	94,7	1110	153,5
1-1/4-7	860	118,9	1400	193,6
1-1/4-12	955	132,1	1550	214,4
1-3/8-6	1130	156,3	1830	253,1
1-3/8-12	1290	178,4	2085	288,4
1-1/2-6	1500	207,5	2430	336,1
1-1/2-12	1690	233,7	2730	277,5
1-3/4-5	2370	327,8	3810	526,9
2-4-1/2	3550	490,9	5760	796,6

FITS AND CLEARANCES



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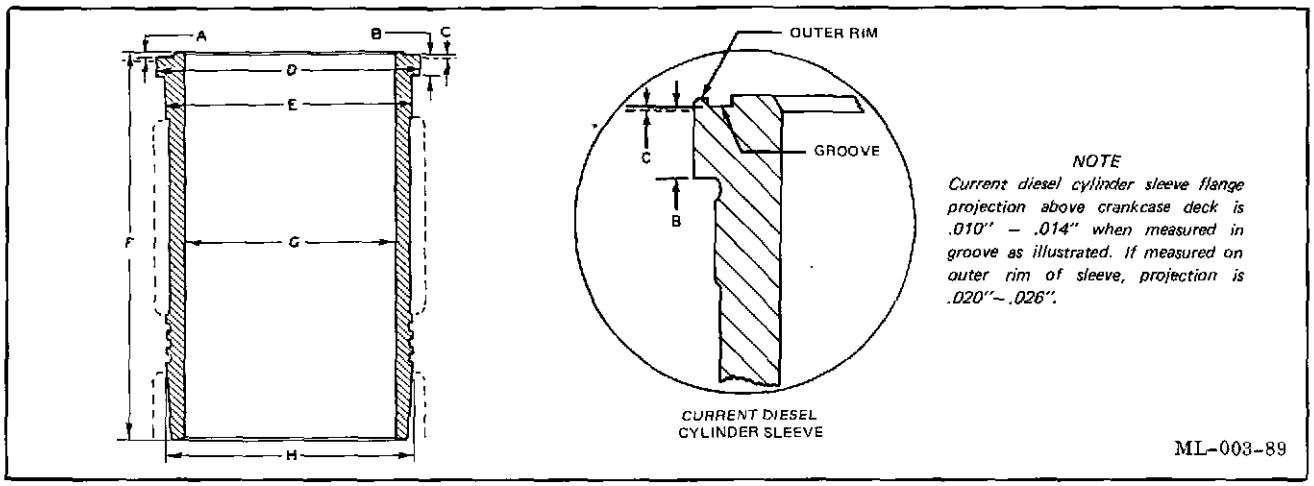
Cylinder heads should always be torqued in the proper sequence as illustrated. Lubricate studs, nuts, and flat washers with SAE 30 engine oil. First hand secure nuts in positions 1 and 2, making sure that the head dowels are seated. Hand start the remaining nuts. The first time through the torque sequence use 25 percent of the total torque value; each succeeding time through the torque sequence increase the torque setting by 25 percent of total torque value until final torque is reached. In order to be sure of proper torque, the torque sequence should again be repeated with the torque wrench set to the total torque value. Do not overtorque. If any nuts are overtorqued by 15 lbs. ft. (2,1 KGM) on 7/8" studs, or 20 lbs. ft. (2,8 KGM) on 1" studs, reduce torque on all nuts to 75% of total torque and repeat entire torquing sequence.

TORQUING CYLINDER HEAD STUD NUTS. ILLUSTRATION ALSO SHOWS LOCATIONS OF INTAKE AND EXHAUST VALVES.

TORQUE RECOMMENDATIONS (VALUES STATED ARE FOR OILED THREADS)

	U.S. Pounds-Feet	Metric Kgm
Cylinder head (Consult the illustration on this page for the stud nut tightening sequence.)		
1 inch studs (current design)	625-650	86,4-89,9
7/8 inch studs	446-450	61,7-62,2
Consult the Repair and Replacement unit for the proper main bearing cap nut and bolt tightening sequence.		
Elastic stop nuts	271-279	37,5-38,6
Cross-tie cap screws	242-250	33,5-34,6
Connecting rods	175-192	24,2-26,6
Edge type filter to injector	65-72	8,9-9,9
Injector fuel outlet cap	45-50	6,2-6,9
Injector spring cap	58-72	8,0-9,9
Injector adjusting screw lock nut	7-8	0,96-1,1
Injector nozzle cap nut	75-100	10,4-13,8
Injector to cylinder head	19-23	2,63-3,18
Camshaft gear nut	433-450	59,8-62,2
Idler stud nut (in crankcase, LH thread) Self-locking	667-683	92,2-94,5
Standard	750-780	103,7-107,8
Idler stud nut (in bearing cap, solid idler spindle)	175	24,2
Idler stud nut (in bearing cap, hollow idler spindle)	300-320	41,5-44,3
Vibration damper	87.5-92	12,1-12,7
Flywheel	171-175	23,6-24,2
Oil Pan 3/4-10	204-208	28,2-28,8
1/2-13	83-87.5	11,5-12,1
Rocker arm cover screws	30-35	4,15-4,84
Valve lifter screws (fixed type only)	60	8,3
*Crankshaft counterweights	483-500	66,8-69,2
Oil filter (4 element) shell bolts	60	8,3
Oil filter (7 & 14 element) cover bolts	35-37	4,84-5,11
Spark plugs	30-34	4,15-4,70

*NOTE: Check counterweight torque 30 to 60 days after start up and then annually.



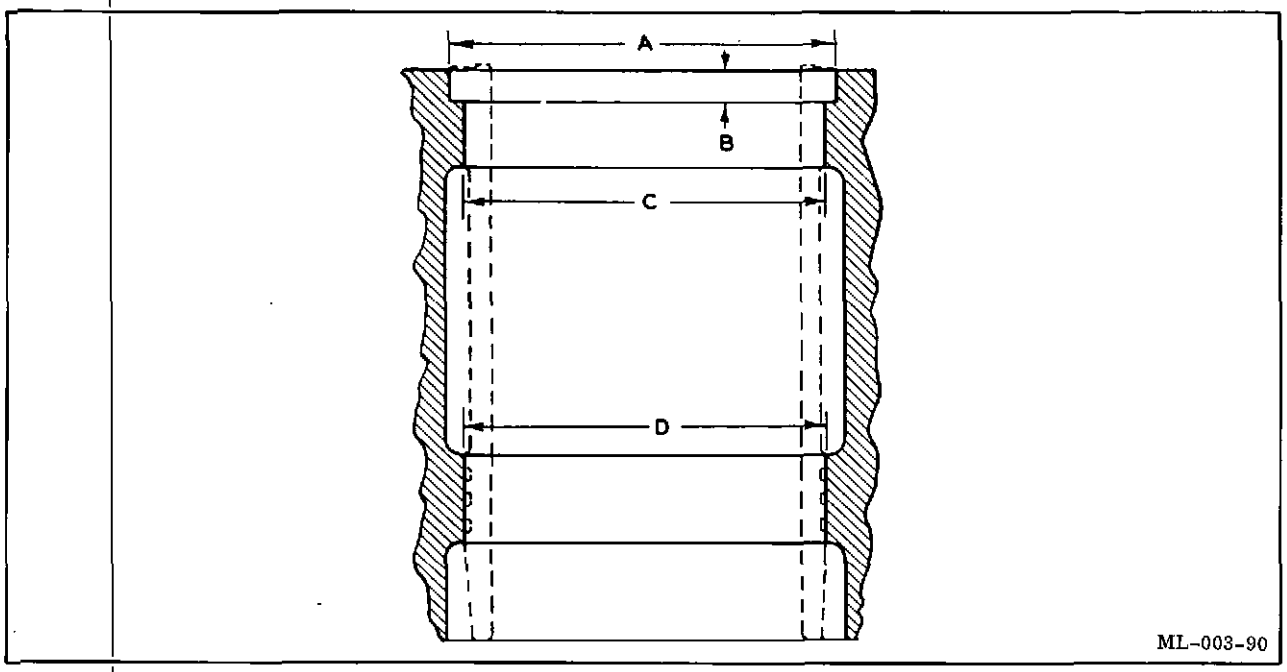
TYPICAL CYLINDER SLEEVE

CYLINDER SLEEVES - DIESEL

	U. S. inches	Metric mm
Type . . . . . Wet type, replaceable		
(A) Heat dam projection of original sleeves with 9.864-9.868" flange OD	.045-.049	1,143-1,245
(B) Flange height of current sleeve with 10.188-10.190" flange OD . . .	.5725-.5745	14,542-14,592
Flange height of original sleeves with 9.864-9.868" flange OD	.5345-.5365	13,576-13,627
(C) Sleeve projection above crankcase: Current sleeves	.010-.014	0,254-0,356
Original sleeves	*0.000-0.006*	0,000-0,152
(D) Flange OD of current sleeve	10.188-10.190	258,775-258,826
Flange OD of original sleeve	9.864-9.868	250,546-250,647
(E) Sleeve OD (below flange) of current sleeve	9-11/16	246,050
Sleeve OD (below flange) of original sleeve	9-7/16	239,725
(F) Sleeve length	18-5/8	473,075
(G) Sleeve ID	8.5003-8.5008	215,908-215,920
(H) Sleeve OD (lower seal area) of current sleeve	9.675-9.677	245,745-245,796
Sleeve OD (lower seal area) of original sleeve.	9.4345-9.4380	239,636-239,725
Sleeve out of round limit (measured in place)	.001	0,025
Sleeve seal area to crankcase clearance	0.000-0.0055	0,000-0,140

CYLINDER SLEEVES - GAS

Type . . . . . Wet type, replaceable		
(A) Heat dam projection	.045-.049	1,143-1,245
(B) Flange height (sleeve used with flange sealing ring)	.5345-.5365	13,576-13,627
Flange height (current 8-1/2" bore sleeve used without flange sealing ring)	.5635-.5655	14,313-14,364
(C) Sleeve projection above crankcase (with .028-.030" flange sealing ring)	.000-.006	0,000-0,152
Sleeve projection above crankcase (current 8-1/2" bore engines *without flange sealing ring*)	.001-.005	0,025-0,127
(D) Flange OD: F2895, L5108G and L5790G (original sleeve)	9.864-9.868	250,546-250,647
Flange OD: F2895, L5108G and L5790G (current sleeve)	10.188-10.190	258,775-258,826
Flange OD: F3521, L7042G	10.616-10.618	269,646-269,697
(E) Sleeve OD (below flange) F2895, L5108G and L5790G (original sleeve)	9-7/16	239,725
Sleeve OD (below flange) F2895, L5108G and L5790G (current sleeve)	9-11/16	246,050
Sleeve OD (below flange) F3521 and L7042G	10-1/4	260,350
(F) Sleeve length	18-5/8	473,075
(G) Sleeve ID: F2895, L5108G and L5790G	8.5003-8.5008	215,908-215,920
Sleeve ID: F3521 and L7042G	9.3753-9.3758	238,133-238,145
(H) Sleeve OD lower seal area: F2895, L5108G and L5790G (original sleeve)	9.4345-9.4380	239,636-239,725
Sleeve OD lower seal area: F2895, L5108G and L5790G (current sleeve)	9.675-9.677	245,745-245,796
Sleeve OD lower seal area: F3521 and L7042G	10.243-10.245	260,172-260,223
Sleeve out of round limits	.001	0,025
Sleeve seal area to crankcase clearance	.000-.0055	0,000-0,140



TYPICAL SECTION THROUGH CRANKCASE

CRANKCASE - DIESEL

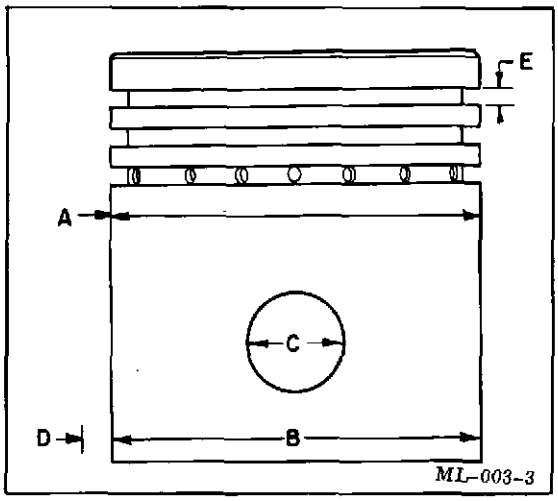
	U.S. inches	Metric mm
(A) Sleeve counterbore diameter of current sleeve	10.199-10.202	259,055-259,130
Sleeve counterbore diameter of original sleeve	9.875-9.877	250,825-250,876
(B) Sleeve counterbore depth	.5605-.5625	14,237-14,288
(C) Crankcase upper bore of current crankcase	9.750-9.760	247,650-247,904
Crankcase upper bore of original crankcase	9.500-9.510	241,300-241,554
(D) Crankcase lower bore of current crankcase	9.678-9.680	245,821-245,872
Crankcase lower bore of original crankcase	9.438-9.440	239,725-239,776
Crankcase main bearing journal bore	6.6615-6.6630	169,202-169,402
Crankcase camshaft bushing bore (6 cylinder engines)	3.7495-3.751	95,237-95,276
(12 cylinder engines)	3.752-3.753	95,301-95,326

CRANKCASE - GAS

(A) Sleeve counterbore dia.: F2895, L5108G and L5790G (original sleeve).	9.875-9.877	250,825-250,858
F2895, L5108G and L5790G (current sleeve).	10.199-10.202	259,055-259,130
F3521 and L7042G	10.625-10.628	269,875-269,951
(B) Sleeve counterbore depth	.5605-.5625	14,237-14,288
(C) Crankcase upper bore: F2895, L5108G and L5790G (original sleeve) .	9.500-9.510	241,300-241,554
F2895, L5108G and L5790G (current sleeve) .	9.750-9.760	247,650-247,904
F3521 and L7042G	10.312-10.317	261,924-262,051
(D) Crankcase lower bore: F2895, L5108G and L5790G (original sleeve) .	9.438-9.440	239,725-239,776
F2895, L5108G and L5790G (current sleeve) .	9.678-9.680	245,821-245,872
F3521 and L7042G	10.246-10.248	260,248-260,299
Crankcase main bearing journal bore	6.663-6.6615	169,240-169,202
Crankcase camshaft bearing bore (6 cylinder engines)	3.7495-3.751	95,237-95,276
(12 cylinder engines)	3.752-3.753	95,301-95,326

PISTON PIN - GAS

	U.S. inches	Metric mm
Piston pin diameter		
Red	2.9991-2.9994	76,1771-76,1848
Blue	2.9994-2.9997	76,1848-76,1923
Piston pin length		
F2895, L5108G and L5790G	7.33375-7.34375	186,27725-186,53125
F3521 and L7042G	8.33375-8.34375	211,67725-211,93125
Piston pin fit: Pin selected (color) to provide a loose hand push fit at normal room temperature	.0010-.0015	0,0254-0,0381



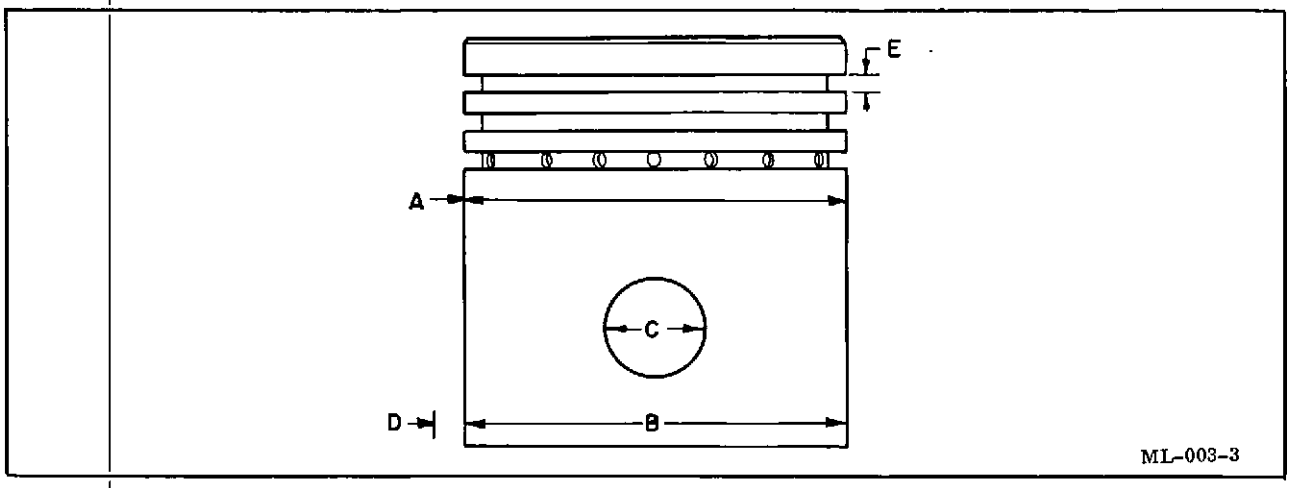
TYPICAL PISTON

PISTON - GAS

	U.S. inches	Metric mm
Piston material	Tin plated aluminum alloy	
Piston type	Cam ground	
Pistons are removed from	Top of crankcase	
Permissible weight variation per set	8 ounces (203 grams)	
Piston hole center to piston crown standard compression ratio:		
L5108G (8.25 to 1)	6.245-6.255	158,623-158,877
F2895, L5790G (8.25 to 1)	5.620-5.630	142,748-143,002
F3521, L7042G (8.0 to 1)	5.465-5.475	138,811-139,065
10.0:1 Compression ratio:		
F2895, L5108G	6.587-6.597	167,310-167,564
F3521, L5790G and L7042G	6.087-6.097	154,610-154,864
(A) Piston skirt diameter (top) in line with pin hole:		
F2895, L5108G and L5790G	8.461-8.462	214,909-214,935
F3521, L7042G	9.336-9.337	237,134-237,160
90° from pin hole:		
F2895, L5108G and L5790G	8.477-8.478	215,316-215,341
F3521, L7042G	9.352-9.353	237,541-237,566
(B) Piston skirt diameter (bottom) in line with pin hole:		
F2895, L5108G and L5790G	8.480-8.481	215,392-215,417
F3521, L7042G	9.354-9.355	237,592-237,617
90° from pin hole:		
F2895, L5108G and L5790G	8.488-8.489	215,595-215,620
F3521, L7042G	9.362-9.363	237,795-237,820
(C) Piston pin hole bore		
Red	3.0004-3.0006+	76,2102-76,2152
Blue	3.0007-3.0009	76,2178-76,2229
(D) Piston skirt to sleeve clearance (thrust area)		
F2895, L5108G and L5790G	.0113-.0128	0,2870-0,3251
F3521, L7042G	.0123-.0138	0,3124-0,3505
(E) Groove width:		
Top, 2nd and 3rd:		
F2895, L5108G and L5790G	.189-.190	4,801-4,826
Top:		
F3521, L7042G	.1915-.1925	4,8641-4,8895
2nd and 3rd:		
F3521, L7042G	.190-.191	4,826-4,8514
4th and 5th:		
F2895, L5108G and L5790G	.313-.314	7,950-7,9756
F3521, L7042G	.376-.377	9,550-9,576

PISTON PIN - DIESEL

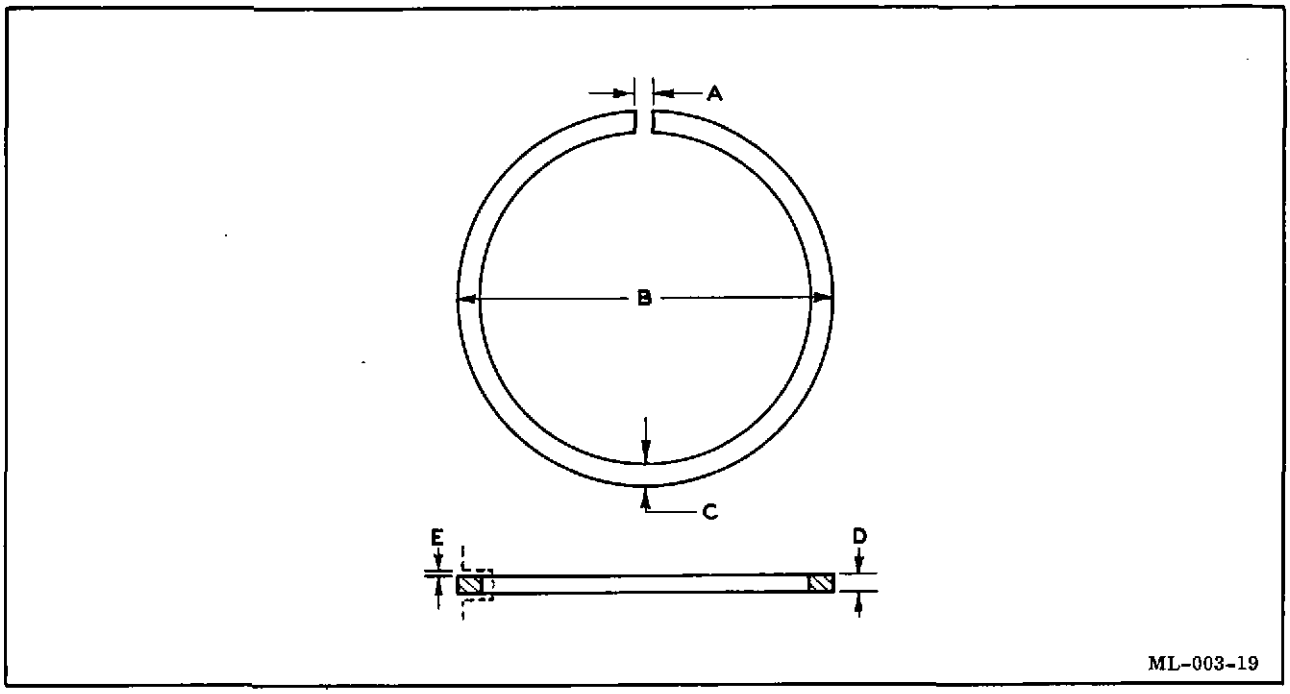
	U.S. inches	Metric mm
Piston pin diameter:		
Red	2.9991-2.9994	76,1771-76,1847
Blue	2.9994-2.9997	76,1847-76,1923
Piston pin fit: Pin selected (color) to provide a loose hand push fit at normal room temperature	.0010-.0015	0,0254-0,0381
Piston pin length	7-11/32	186,529



TYPICAL PISTON

PISTON - DIESEL

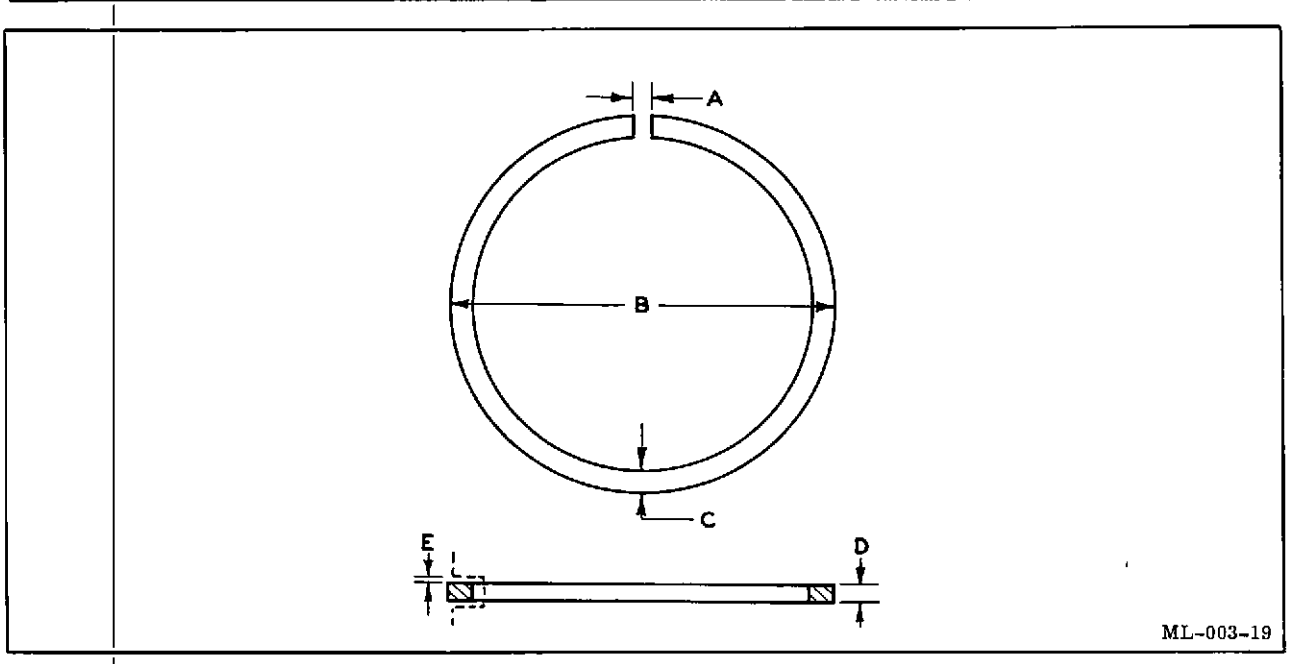
	U.S. inches	Metric mm
Piston material	Parko Lubrite finished cast iron	
Piston type	Cam ground	
Pistons are removed from	Top of crankcase	
Permissible weight variation per set	2 ounces (56,7 grams)	
Piston hole center to piston crown	6.095-6.097	154,813-154,864
Top of piston below top of crankcase	.016-.033	0,406-0,838
(A) Piston skirt diameter (top)		
In line with pin hole	8.475-8.477	215,265-215,315
90° from pin hole	8.488-8.489	215,595-215,621
(B) Piston skirt diameter (bottom)		
In line with pin hole	8.490-8.492	215,646-215,697
90° from pin hole	8.495-8.496	215,773-215,798
(C) Piston pin hole bore		
Red	3.0004-3.0006	76,2102-76,2152
Blue	3.0007-3.0009	76,2178-76,2229
(D) Piston skirt to sleeve clearance (thrust area)	.0043-.0058	0,1092-0,1473
(E) Groove width - Top	Wedge type	
2nd and 3rd	.189-.190	4,801-4,826
4th	.251-.252	6,375-6,401



TYPICAL PISTON RING

PISTON RINGS - DIESEL

	U.S. inches	Metric mm
Top ring . . . . . Chrome plated wedge type compression		
Second and third rings . . . . . Tapered face compression (top marked "Top" or "Up")		
Fourth ring . . . . . Conformable grooved oil ring with expander (top marked "Top" or "Up")		
(A) Ring gap		
Top	.035-.050	0,889-1,270
2nd and 3rd	.025-.040	0,635-1,016
4th	.030-.050	0,762-1,270
(B) Ring diameter		
Top	8.500" at 17 lbs. minimum	215,9 @ 7,71 kg
2nd and 3rd	8.500" at 15 lbs. minimum	215,9 @ 6,80 kg
4th	8.500" at 28 lbs. minimum	215,9 @ 12,70 kg
(C) Ring wall		
Top	.280-.295	7,112-7,493
2nd and 3rd	.300-.315	7,620-8,001
4th	.185-.200	4,699-5,080
(D) Ring width		
Top	Wedge type	
2nd and 3rd	.1835-.1850	4,6609-4,6990
4th	.2475-.2490	6,2865-6,3246
(E) Side clearance		
Top	Wedge type	
2nd and 3rd	.0040-.0065	0,1016-0,1651
4th	.0020-.0045	0,0508-0,1143



TYPICAL PISTON RING

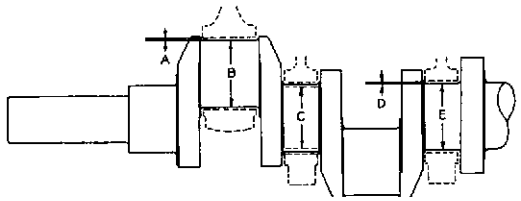
PISTON RINGS - GAS

Top ring . . . . . Crowned plasma coated compression
Second and third rings . . . . . Tapered face compression (top marked "Top" or "Up")
Fourth ring . . . . . Conformable grooved oil ring with expander (top marked "Top" or "Up")
Fifth ring (when used) . . . . . Grooved oil ring (top marked "Top")

NOTE: Metric measurements given in parenthesis below U.S. inches measurement.

	Top	2nd and 3rd	4th	5th (when used)*
(A) Ring gap				
F2895, L5108G, L5790G	.040"-.055" (1,016-1,270)	.025"-.040" (0,635-1,016)	.015"-.035" (0,381-0,889)	.025"-.040" (0,635-1,016)
F3521, L7042G	.045"-.060" (1,143-1,397)	.030"-.045" (0,762-1,143)	.015"-.035" (0,381-0,889)	.015"-.035" (0,381-0,889)
(B) Ring diameter				
F2895, L5108G, L5790G	8.500"@30# Min. (215,900@13,6)	8.500"@15# Min. (215,900@6,80)	8.500"@28.5 Min. (215,900@12,93)	8.500@17# Min. 215,900@7,71)
F3521, L7042G	9.375"@22# Min. (238,12@9,98)	9.375"@15# Min. (238,12@6,80)	9.375"@24# Min. (238,12@10,88)	9.375@25# Min. (238,12@11,34)
(C) Ring wall				
F2895, L5108G, L5790G	.300-.315" (7,62-8,00)	.300-.315" (7,62-8,00)	.225"-.240" (5,715-6,096)	.304"-.319" (7,721-8,102)
F3521, L7042G	.302"-.317" (7,670-8,051)	.302"-.317" (7,670-8,051)	.290"-.310" (7,366-7,874)	.327"-.342" (8,305-8,687)
(D) Ring width				
F2895, L5108G, L5790G	.185"-.1865" (4,699-4,7371)	.1835"-.185" (4,6609-4,699)	.3085"-.310" (7,8359-7,874)	.3095"-.3110" (7,8613-7,8994)
F3521, L7042G	.185"-.1865" (4,699-4,7371)	.185"-.1865" (4,699-4,7371)	.372"-.3735" (9,449-9,4869)	.372"-.3735" (9,4488-9,4869)
(E) Side clearance				
F2895, L5108G, L5790G	.0025"-.005" (0,0635-0,127)	.004"-.0065" (0,1016-0,1651)	.003"-.0055" (0,0762-0,1397)	.002"-.0045" (0,051-0,1143)
F3521, L7042G	.005"-.0075" (0,127-0,1905)	.0035"-.006" (0,0889-0,1524)	.0025"-.005" (0,0635-0,127)	.0025"-.005" (0,0635-0,127)

*Not used on production engines and not supplied in service kits.



ML-003-5

TYPICAL CRANKSHAFT

CRANKSHAFT

	U.S. inches	Metric mm
Crankshaft end play	.005-.016	0,127-0,406
End play adjustment (oversize thrust rings)	.010	0,254
Thrust ring thickness (standard)	.216-.218	5,486-5,537
(A) Connecting rod bearing running clearance (theoretical)	.0026-.0060	0,0660-0,1524
(B) Connecting rod bearing journal diameter	6.2485-6.250	158,725-158,790
Early Model L5108G	5.749-5.750	146,024-146,050
Connecting rod bearing journal maximum undersize	.040	1,016
(C) Main bearing journal maximum undersize	.040	1,016
(D) Main bearing running clearance (theoretical)	.0035-.0074	0,0889-0,1880
(E) Main bearing journal diameter	6.2485-6.250	158,725-158,750

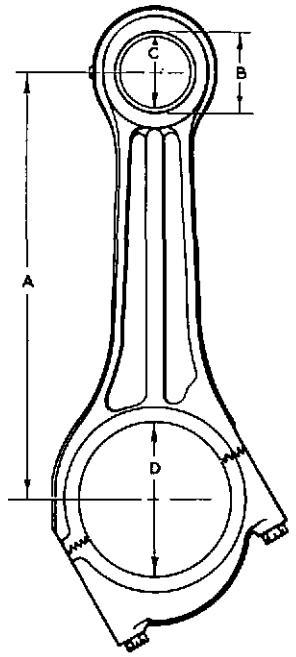
CAMSHAFT

Camshaft journal diameter	3.498-3.499	88,849-88,875
Camshaft service bushing assembled ID - (6 cylinder engines) (bushings to be assembled as indicated by word "FRONT" and arrow)	3.501-3.5035	88,925-88,989
Camshaft journal running clearance (theoretical) (6 cylinder engines)	.002-.0055	0,051-0,140
(12 cylinder engines)	.003-.0056	0,076-0,142
Camshaft end play (6 cylinder engines)	.005-.017	0,127-0,432
(12 cylinder engines)	.005-.008	0,127-0,203
End play adjustment (6 cylinder engines)	Replace thrust plate	
(12 cylinder engines)	.002 shims	
Thrust plate thickness (6 cylinder engines)	.515-.525	13,081-13,335
Thrust ring thickness (standard) (12 cylinder engines)	.154-.156	3,911-3,962
Cam lift (Intake and Exhaust)	.670	17,018
Rocker arm ratio	1.0926 to 1	

Camshaft coupling must never be loose.

FLYWHEEL AND HOUSING

	Total Indicator Reading	
Pilot bearing run-out	.005	0,12
Face run-out on wheel	.016	0,40
Housing bore run-out	.012	0,30
Housing face run-out	.012	0,30

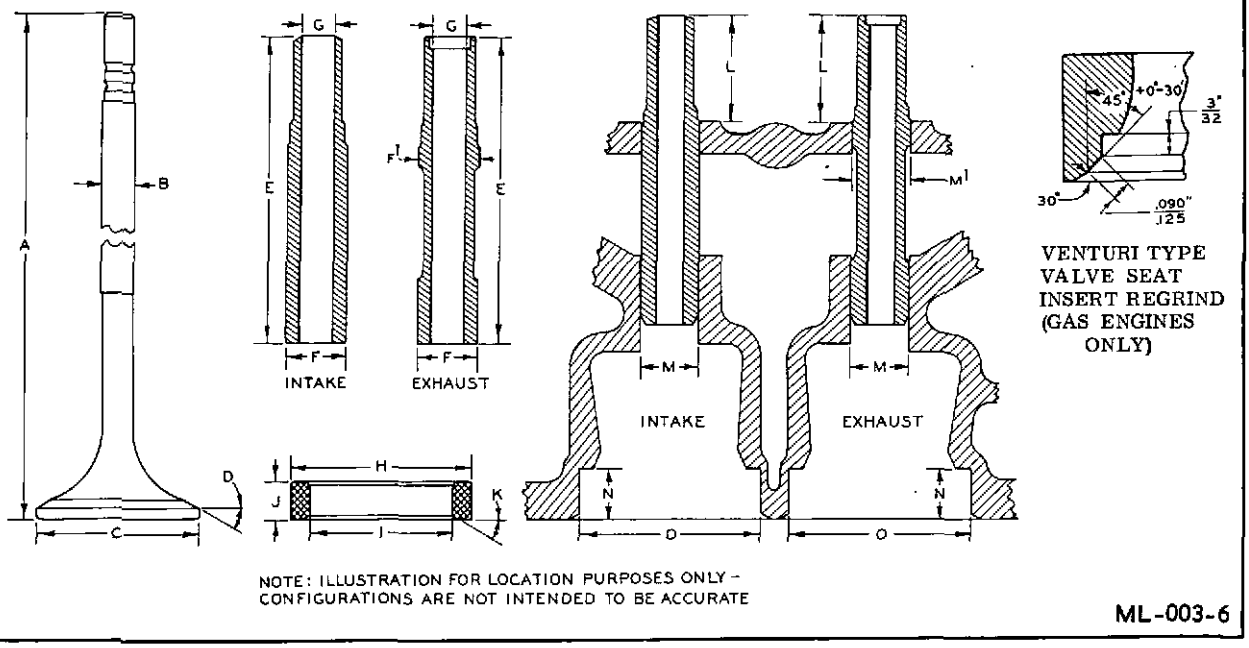


ML-003-62

TYPICAL CONNECTING ROD AND BUSHINGS

CONNECTING ROD, BUSHING AND BEARING

	U.S. inches	Metric mm
Rod material . . . . . Heat treated steel forging		
Permissible weight variation per set	2 ounces	56,7 grams
(A) Rod length, center to center	18.001-18.003	457,225-457,250
(B) Rod small end finish size	3.250-3.251	82,550-82,575
(C) Bushing bore diameter (diamond bored) (Assemble 2 bushings with open ends of grooves toward inside)	3.0015-3.002	76,238-76,508
Bushing press in rod	.0035-.0065	0,0889-0,1651
Pin clearance in bushing	.0018-.0029	0,0457-0,0736
(D) Rod large end finish size	6.625-6.626	168,275-168,300
Rod large end width (12 cylinder engines)	2.799-2.802	71,095-71,171
(6 cylinder engines)	3.065-3.074	77,851-78,079
Rod side clearance (12 cylinder engines)	.021-.033	0,533-0,838
(6 cylinder engines)	.011-.025	0,279-0,635
Bearing running clearance (theoretical)	.0026-.006	0,0660-0,1524
Actual running clearance	.003-.0064	0,076-0,162



VENTURI TYPE VALVE SEAT INSERT REGRIND (GAS ENGINES ONLY)

VALVE TRAIN, VALVE PORT CLEARANCES - DIESEL AND GAS

VALVE TRAIN, VALVE PORT CLEARANCES - DIESEL

		Intake and Exhaust	
		U.S. inches	Metric mm
(A)	Valve length	10-57/64	276,62
(B)	Valve stem diameter (intake)	.557-.558	14,147-14,706
	(exhaust)	.5593-.5598	14,206-14,219
	taper to	.5575-.558	14,1605-14,173
(C)	Valve head diameter	2.825-2.835	71,755-72,009
(D)	Valve face angle	44° 30' ± 15'	44° 30' ± 15'
(E)	Guide length	5-3/16	131,7625
(F)	Guide outside diameter	1.0015-1.0025	24,4381-25,4635
(F)[1]	Exhaust guide upper outside diameter	.997-.998	25,324-25,3492
(G)	Guide inside diameter (ream)	.5608-.5615	14,2443-14,2621
	Guide ID to stem OD clearance (intake)	.0028-.0045	0,0711-0,1143
	(exhaust)	.001-.004 (taper)	0,025-0,107
(H)	Insert outside diameter	3.128-3.129	79,451-79,476
(I)	Insert inside diameter	2.360-2.365	59,944-60,071
(J)	Insert depth	.706-.710	17,932-18,034
(K)	Insert seat angle	45° +30' -0'	45° +30' -0'
(L)	Guide extends above head	1-3/4 ± 1/32	44,45 ± 0,792
(M)	Guide bore in head	1.000-1.001	25,4-25,425
(M)[1]	Exhaust guide upper bore in head	.995-.996	25,273-25,298
(N)	Insert counterbore depth	.8245-.8285	20,942-21,044
(O)	Insert counterbore diameter	3.124-3.125	79,349-79,375
Valve insert seat width (minimum)		5/32	3,969
Valve face width		5/32 ± 1/32	3,969 ± 0,794
Valve spring free length	204035 (inner)	3-25/32 ± 1/16	96,04248 ± 1,587
	204135 (outer)	4-9/32 ± 1/16	108,74248 ± 1,587
Valve closed spring length	204035 (inner)	3" @ 56.7 ± 3 lbs.	76,2 @ 25,72 ± 1,36
	204135 (outer)	3-27/64" @ 111 ± 5 lbs.	86,91 @ 50,35 ± 2,27
Valve open spring length	204035 (inner)	2-17/64" @ 110 ± 5 lbs.	57,6 @ 49,80 ± 2,27
	204135 (outer)	2-11/16" @ 205 ± 10 lbs.	68,3 @ 92,99 ± 4,54
*Rocker arm bushing ID (see note on next page) (Press fit in arm and diamond bored)		1.375-1.376	34,925-34,950
Rocker arm shaft OD		1.3735-1.3745	34,8869-34,9123
Running clearance, rocker arm bushing to shaft		.0005-.0025	0,0127-0,0635

*NOTE: The intake rocker arm bushing must be installed flush with the hub with the grooves in the bushing located at the bottom of the rocker arm (notch in bushing on horizontal centerline). Also, with the lifter adjusting screw removed, the oil holes must be drilled through the bushing before the bushing is diamond bored. The flatted ball oiling hole and the lifter adjusting screw oiling hole are both #11 drill (.191") (4,851 mm) but are plugged with rivets and must be reopened before drilling through the bushing. These must be plugged again after the oil holes are drilled through the bushing. Similarly, the exhaust rocker arm lever has a #11 drill (.191") (4,851 mm) oil hole to the lifter adjusting screw which is plugged with a rivet and this hole and the 1/8" (3,2 mm) diameter oiling hole through the valve adjusting screw hole at the other end of the lever must be drilled through the bushings (with the screws removed) before the bushings are diamond bored. Be sure to plug the lifter adjusting screw oiling hole after the bushing is drilled through. The bushings in the exhaust and intake rocker arm levers must be installed flush with the hub ends and with the grooves in the bushings located at the bottom of the levers with the open ends of the grooves towards the center of the lever (notch in bushing on horizontal centerline). The intake rocker arm lever bushings do not require any oiling holes to be drilled before the bushings are diamond bored.

VALVE TRAIN, VALVE PORT CLEARANCES - GAS

		Intake and Exhaust	
		U.S. inches	Metric mm
(A)	Valve length	10-57/64	276,62
(B)	Valve stem diameter (intake)	.557-.558	14,148-14,173
	(45° exhaust on nat. aspirated)	.555-.556	14,098-14,122
	(45° exhaust on turbo. and all 30° exhausts)	.5593-.5598	14,206-14,2189
	taper to	.5575-.558	14,1605-14,173
(C)	Valve head diameter	2.825-2.835	71,755-72,009
(D)	Previous valve face angle	44° 30' ± 15'	44° 30' ± 15'
	Current valve face angle	30° ± 15'	30° ± 15'
(E)	Guide length	5-3/16	131,8
(F)	Guide outside diameter	1.0015-1.0025	25,4381-25,4635
(F)[1]	Exhaust guide upper outside diameter	.997-.998	25,323-25,349
(G)	Guide inside diameter (ream)	.5615-.5608	14,2621-14,2443
	Guide I.D. to stem O.D. clearance (intake)	.0028-.0045	0,0711-0,1143
	(45° exhaust on nat. aspirated)	.0048-.0065	0,1219-0,1651
	(45° exhaust on turbo. and all 30° exhausts)	.001-.004 (taper)	0,0254-0,102
(H)	Insert outside diameter (45°)	3.128-3.129	79,451-79,477
	Insert outside diameter (30°)	3.126-3.127	79,400-79,426
(I)	Insert inside diameter (45°)	2.640-2.650	67,056-67,310
	Insert inside diameter (30°)	2.441-2.451	62,001-62,255
(J)	Insert depth (45°)	.605-.610	15,367-15,494
	Insert depth (30°)	.550-.555	13,970-14,097
(K)	Insert seat angle (previous)	45° 30' ± 15'	45° 30' ± 15'
	Insert seat angle (current)	30° +30' -0'	30° +30' -0'
(L)	Guide extends above head	1-3/4 ± 1/32	44,5 ± 0,742
(M)	Guide bore in head	1.000-1.001	25,400-25,425
(M)[1]	Exhaust guide upper bore in head	.995-.996	25,273-25,298
(N)	Insert counterbore depth	.8245-.8285	20,942-21,043
(O)	Insert counterbore diameter	3.124-3.125	79,350-79,375
	Valve insert seat width (45°)	5/32 ± 1/64	3,969 ± 0,397
	Valve insert seat width (30°)	6/32 ± 1/64	4,763 ± 0,397
	Valve face width (45°)	5/32 ± 1/64	3,969 ± 0,397
	Valve face width (30°)	17/64	6,747
	Valve spring free length 204035 (inner)	3-25/32 ± 1/16	96,0 ± 1,6
	204135 (outer)	4-9/32 ± 1/16	108,7 ± 1,6
	Valve closed spring length 204035 (inner)	3" @ 56.7# ± 3#	76,2 @ 25,72 ± 1,36
	204135 (outer)	3-27/64" @ 111# ± 5#	86,9 @ 50,35 kg ±2,27

(Continued on next page)

	U.S. inches	Metric mm
Valve open spring length (204035 inner)	2-17/64" @ 110# ± 5#	57.5 @ 49,80 kg ± 2,27
(204135 outer)	2-11/16" @ 205# ± 10#	68,3 @ 92,99 kg ± 4,54
*Rocker arm bushing I.D. (Press fit in arm and diamond bored)	1.375-1.376	34,925-34,950
Rocker arm shaft O.D.	1.3735-1.3745	34,8869-34,9123
Running clearance, rocker arm bushing to shaft	.0005-.0025	0,0127-0,0635

*NOTE: The intake rocker arm bushing must be installed flush with the hub with the grooves in the bushing located at the bottom of the rocker arm (notch in bushing on horizontal centerline). Also, with the lifter adjusting screw removed, the oil holes must be drilled through the bushing before the bushing is diamond bored. The flatted ball oiling hole and the lifter adjusting screw oiling hole are both #11 drill (.191") (4,851 mm) but are plugged with rivets and must be reopened before drilling through the bushing. These must be plugged again after the oil holes are drilled through the bushing. Similarly, the exhaust rocker arm lever has a #11 drill (.191") (4,851 mm) oil hole to the lifter adjusting screw which is plugged with a rivet and this hole and the 1/8" (3,2 mm) diameter oiling hole through the valve adjusting screw hole at the other end of the lever must be drilled through the bushings (with the screws removed) before the bushings are diamond bored. Be sure to plug the lifter adjusting screw oiling hole after the bushing is drilled through. The bushings in the exhaust and intake rocker arm levers must be installed flush with the hub ends and with the grooves in the bushings located at the bottom of the levers with the open ends of the grooves towards the center of the lever (notch in bushing on horizontal centerline). The intake rocker arm lever bushings do not require any oiling holes to be drilled before the bushings are diamond bored.

VALVE CLEARANCE - GAS

Valve clearance	Hydraulic lifters
Cam lift (measured at push rod)	.670" (17,018 mm)

VALVE LIFTERS - GAS

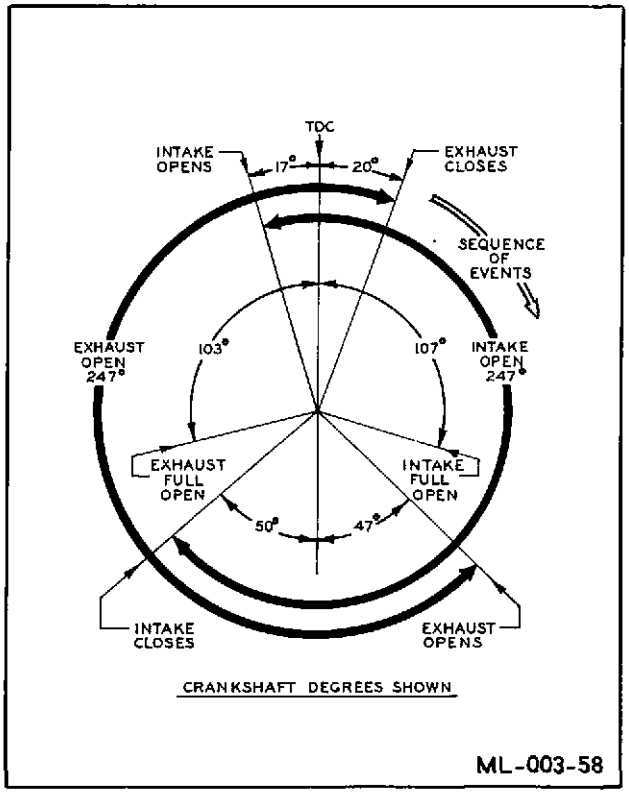
Valve lifter body to valve lifter guide clearance	.002"-.004" (0,051-0,101 mm)
Valve lifter body O.D.	1.4965"-1.4975" (38,0111-38,0365 mm)
Valve lifter guide I.D.	1.5005"-1.4995" (38,1127-38,0873 mm)

VALVE CLEARANCE - DIESEL

Valve clearance	
Hydraulic valve lifters	Not applicable
Solid push rods (intake)	.004"-.006" (0,102-0,152 mm)
(exhaust)	.020"-.022" (0,508-0,558 mm)
Cam lift (measured at push rod)	.670" (17,018 mm)

VALVE LIFTERS - DIESEL

Valve lifter body to valve lifter guide clearance	.002"-.004" (0,051-0,101 mm)
Valve lifter body O.D.	1.4965"-1.4975" (38,0111-38,0365 mm)
Valve lifter guide I.D.	1.4995"-1.5005" (38,0873-38,1127 mm)



VALVE SEQUENCE

OIL PUMP

	U.S. Measurement	Metric Measurement
Backlash oil pump pressure gears	.012"-.015"	0,305-0,381 mm
Pressure gear(s) to cover end play	.005"-.011"	0,127-0,279 mm
Drive shaft bushing ID (ream) In cover	1.2515"-1.2525"	31,7881-31,8135 mm
In body	1.376"-1.377"	34,950-34,976 mm
Drive shaft running surface OD In cover	1.248"-1.2485"	31,699-31,712 mm
In body	1.372"-1.3725"	34,849-34,862 mm
Drive shaft running clearance In cover bushing	.003"-.0045"	0,076-0,1143 mm
In body bushing	.0035"-.005"	0,0889-0,127 mm
Idler gear bushing ID	1.0005"-1.0015"	25,4127-25,4381 mm
Idler shaft OD	.998"-.9985"	25,348-25,3619 mm
Idler gear running clearance on shaft	.002"-.0035"	0,051-0,0889 mm
Radial clearance between pumping gear teeth and pump chamber wall	.002"-.003"	0,051-0,076 mm
Space drive gear at assembly 1/32" (0,79 mm) from body. Drill through 1/4" (6,35 mm).		
Press driven gear on shaft 1-1/2" (38,1 mm) from end. Drill and ream 1/4" (0,79 mm) at assembly.		
Assemble drive shaft bushing in body so that hole in bushing lines up with hole in bore.		
Crankshaft to oil pump drive idler gear bushing ID	1.4995"-1.5005"	38,0873-38,1127 mm
Idler gear stud OD (Running surface)	1.4975"-1.498"	38,0365-38,049 mm
Crankshaft to oil pump drive idler gear running clearance	.0015"-.003"	0,0381-0,076 mm
Crankshaft to oil pump drive idler gear end play	.010"-.016"	0,254-0,406 mm

TIMING GEAR BACKLASH

Between oil pump drive idler gear and oil pump drive gear	.015"-.020"	0,381-0,508 mm
Between all other timing gears	.008"-.012"	0,203 - 0,305 mm

CAPACITIES

OIL (Fill engine to capacities shown—run engine, then check dipstick; add oil to bring level to full mark; record for future oil changes.)		
Oil pan (low level depth gauge)	35 gallons	132.5 liters
Oil pan (high level depth gauge)	43 gallons	163 liters
Oil pan for Marine engine	120 gallons	454 liters
Lubricating oil filter (4 element)	9 gallons	34 liters
Lubricating oil filter (7 element)	23 gallons	87,1 liters
Lubricating oil filter (14 element)	30 gallons	113,6 liters
Lubricating oil filter, Marine engine	13.5 gallons	51 liters
Fuel injection pump(s) Fill before new engine start-up	1 quart	.9463 liter
Oil cooler (6 inch)	2.5 or 5.0 gallons	9,46 or 18,9 liters
Oil cooler (8 inch)	8 gallons	30,3 liters

Lubrication System, Pressures

Oil pressure recommended before releasing safety valve handle at start-up	20 to 30 psig	1.41 to 2.11 kg per sq cm
Normal stabilized oil pressure at idle speeds	15 to 40 psig	1.05 to 2.80 kg per sq cm
Low oil pressure (safety control valve will shut off engine)	10 psig	0,70 kg per sq cm
Normal stabilized oil pressure with engine loaded	45 ± 5 psig	3,16 ± 0,35 kg per sq cm
Minimum oil pressure at the turbocharger	10 psig	0,70 kg per sq cm
FC Starting engine normal oil pressure	15 psig	1,05 kg per sq cm

Lubrication System, Temperatures

Minimum stabilized low oil temperature	160°F.	71°C.

BASIC DATA

Type of cylinder sleeves . . Wet type, replaceable
Flywheel housing size . . . . . SAE No. 00
Main bearing number and type . . . Seven precision
Camshaft bushing number
and type . . . . . 7 steel-backed, lead base
Timing gears, face width . . . . . 2.25" (57,15 mm)

Lubrication System, Engine Transient Tilt Angles

Permissible engine transient tilt angles at low oil mark, based on keeping suction screen submerged.

	Standard Engine	Marine Engine
Front down	4°	9°
Rear down	2°	10°
Left side down . . .	8°	28°
Right side down . . .	8°	28°
360° rotation	2°	-

COMPRESSION PRESSURE - DIESEL

RPM	PSI
110	415 (29,175)
150	440 (30,932)
600	470 (33,041)
900	490 (34,447)

INJECTION PUMP TIMING

Current turbocharged engines:

RPM	TIMING
To 800	30° BTDC
801-1000	32° BTDC
1001-1200	34° BTDC

Current naturally aspirated engines:

SPEED	RPM	TIMING
Constant	To 800	36° BTDC
	801-1000	38° BTDC
	1001-1215	40° BTDC
Variable	All Speeds	36° BTDC

CAUTION: Refer to engine timing plate, especially for turbocharged engine(s).

FUEL INJECTORS

Opening pressure setting for turbocharged engine injectors used with injection pumps equipped with standard delivery valves:
(service) 4000 ± 50 psi (281,2 ± 3,5 kp/cm^2)
(production) 4200 ± 50 psi (295,2 ± 3,5 kp/cm^2)

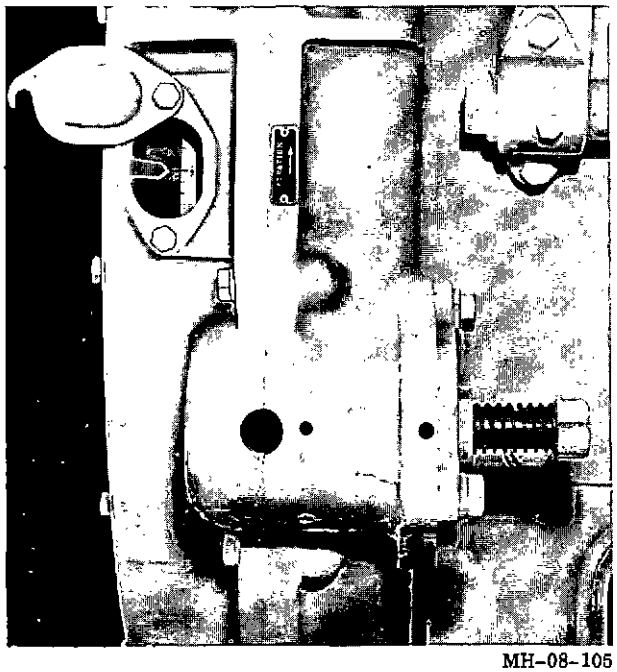
Opening pressure setting for all naturally aspirated engine injectors and for turbocharged engine injectors used with injection pumps equipped with double check delivery valves:
(service) 3500 ± 50 psi (246 ± 3,5 kp/cm^2)
(production) 3600 ± 50 psi (253,1 ± 3,5 kp/cm^2)

INJECTION PUMP CALIBRATION DATA AND RACK SETTINGS

CALIBRATION DATA
Pump:
Right bank and 6 cylinder standard rotation (D and DS) A69564C
Right bank and 6 cylinder standard rotation (DSI) A69564F
Right bank and 6 cylinder opposite rotation (D and DS) A69564D
Right bank and 6 cylinder opposite rotation (DSI) A69564G
Left bank standard rotation (D and DS) A69565C
Left bank standard rotation (DSI) A69565F
Left bank opposite rotation (D and DS) A69565D
Left bank opposite rotation (DSI) A69565G

Drive at right hand end (Right Bank)
Drive at left hand end (Left Bank)
Rotation: Standard . . . . . Clockwise
Opposite . . . . . Counterclockwise

Right bank and 6 cylinder firing order:
Standard Rotation 1-5-3-6-2-4
Opposite rotation 6-3-5-1-4-2
Left bank firing order:
Standard rotation 6-2-4-1-5-3
Opposite rotation 1-4-2-6-3-5



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TOP DEAD CENTER "TDC" MARK

No. 1 outlet is at right hand end of right bank pump.
No. 6 outlet is at right hand end of left bank pump.
Control rack shuts off to the right (right bank).
Control rack shuts off to the left (left bank).
Supply pump pressure: 21 psi (1,47 kp/cm^2).
Port closure at plunger lift 2.0 + 0.1 mm from bottom dead center
Test Instructions . . . . . Robert Bosch BT 113-6

Tubing size: 2mm I.D. x 8mm O.D. x 1500 mm long
Test oil . . . . . Per Waukesha Specification see page 4-7

Test oil temperature . . . . . 105 °F (40 °C)

Injectors: Test nozzles EFEP 216A, nozzle holder EFEP 215, opening pressure set at 2500 psi (175 kp/cm^2)
These injectors are standard Robert Bosch injectors.

Fuel Delivery:

Pump Rpm	Rack Setting (in. -mm)	Qty. cc/100 Strokes	Allowable Delivery Tolerance cc/100 Strokes
Used Pump Test			
600	23/64—9	19.5—22.2	
Equal Delivery			
600	*45/64—18*	*68.5—69.5*	2.8
600	61/64—24	97.0—103.0	
200	23/64—9	12.5—15.8	

FULL LOAD RACK SETTING

Set control rack to dimension shown for required horsepower, either naturally aspirated, turbocharged, or turbocharged intercooled. All rack settings are measured from the "rack stop" position (see illustration).

INJECTION PUMP RACK TRAVEL DATA

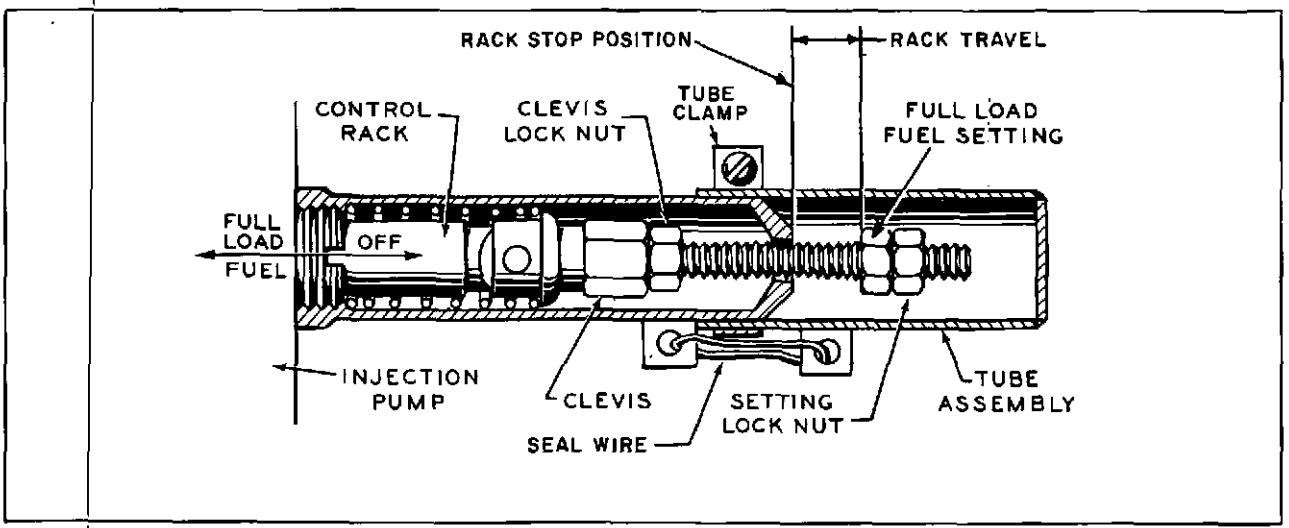
Rack settings are compiled from our own test room and laboratory figures for bare engines and this must be recognized since normal field conditions would involve such things as altitude, air intake temperature, barometric variations, and accessories. All of these influence power available.

The horsepower values listed are for intermittent duty and are corrected to sea level barometric pressure of 29.92" (760 mm) hg. and standard temperature of 60°F (16°C). For DSI engines, horsepower values are based on 85°F (29°C) intercooler inlet water temperature.

Moreover, the exact value of the rack setting for any given load may vary from pump to pump and engine to engine. For this reason, it is very important that the user of these rack settings understand their limitations. Failure to produce the expected power with a given setting may reflect any number of factors ranging from pump timing and primary supply pressure problems to improper turbo performance. Thus, it is expected that the person using the rack setting data given in this tabulation will use good judgment, both in the mechanical sense and in his evaluation of the performance obtained.

NOTE

Rack travel is adjusted at the factory before shipping. The adjustment made is predicated upon engine load requirements which are specified at the time the engine is ordered. Normally, adjustment of rack travel is not necessary unless engine requirements have been changed.



SETTING RACK TRAVEL

RACK TRAVEL SETTINGS (FROM RACK STOP TO FULL FUEL)

ENGINE RPM	CURRENT DIESEL ENGINE SERIES			PREVIOUS DIESEL ENGINE SERIES		
	ENGINE MODEL	HORSEPOWER	RACK TRAVEL IN. —MM	ENGINE MODEL	HORSEPOWER	RACK TRAVEL IN. —MM
900	L5792DSI	1184	49/64—19,5	L5790DSI	890	38/64—15,1
1000	L5792DSI	1315	50/64—19,8	L5790DSI	1200	45/64—17,9
1200	L5792DSI	1579	52/64—20,6	L5790DSI	1300	46/64—18,3
900	L5792DS	947	47/64—18,5	L5790DS	940	45/64—17,9
1000	L5792DS	1052	44/64—17,4	L5790DS	1150	53/64—21,0
1200	L5792DS	1263	48/64—19,1	L5790DS	1250	50/64—19,8
900	L5792D	720	39/64—15,5	L5790D	730	44/64—17,4
1000	L5792D	794	39/64—15,5	L5790D	810	41/64—16,3
1200	L5792D	921	37/64—14,8	L5790D	925	42/64—16,7
900	F2896DSI	592	49/64—19,5	F2895DSI	427	36/64—14,3
1000	F2896DSI	658	50/64—19,8	F2895DSI	570	40/64—15,9
1200	F2896DSI	789	52/64—20,6	F2895DSI	625	40/64—15,9
900	F2896DS	474	47/64—18,5	F2895DS	387	44/64—17,4
1000	F2896DS	526	44/64—17,4	F2895DS	429	51/64—20,2
1200	F2896DS	631	48/64—19,1	F2895DS	512	48/64—19,1
900	F2896D	360	39/64—15,5	F2895D	293	42/64—16,7
1000	F2896D	397	39/64—15,5	F2895D	321	39/64—15,5
1200	F2896D	463	37/64—14,8	F2895D	371	40/64—15,9

IGNITION DATA

Spark plug size . . . . . 18 mm with 1/2" reach
Torque to 40 to 45 lbs. ft. dry
Torque to 30 to 34 lbs. ft. oiled

Spark plug type:
(standard - for all applications) 69512
(platinum tip - for all applications except generator sets) . . 60999B
(shielded - for all applications except generator sets) . . 60999E
(shielded - for generator set applications only) 167037

Spark plug gap:
(standard) . . . . . .020"
(platinum tip) . . . . . .011"
(shielded - except gen. sets) . . . . . .015"
(shielded - gen. sets only) . . . . . .025"

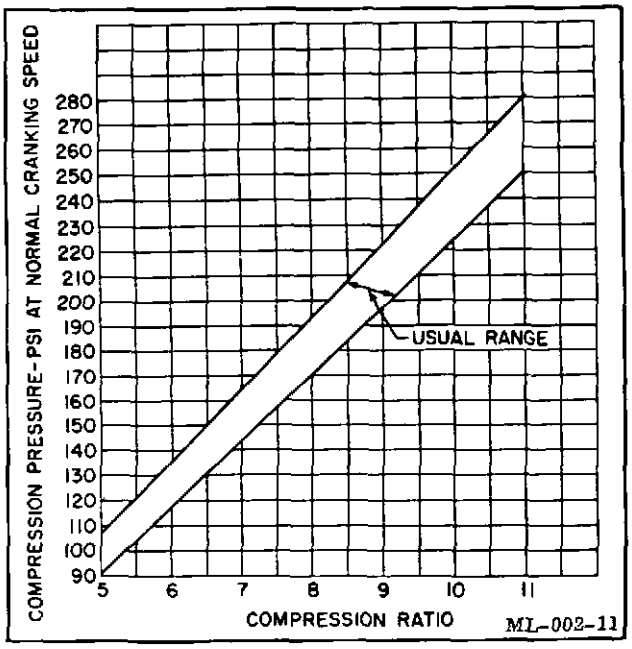
Magneto point clearance . . . . . .016"-.018"

When a shielded ignition system is used, tighten all connector nuts and spark plug extensions finger tight plus 1/8 to 1/4 turn. Do not touch terminal connectors with bare fingers and make sure all parts are clean before assembling them.

IGNITION TIMING

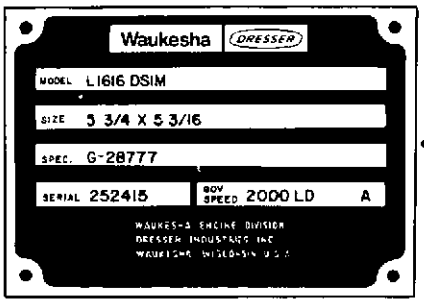
Compression Ratio	RPM	Natural Gas	LPG
7.0:1	600–899	24° BTC	CAUTION
7.0:1	900–1200	28° BTC	For LPG ignition timing refer to Service Bulletin No. 14-2149.
8.0:1	600–899	20° BTC	
8.0:1	900–1200	24° BTC	
8.25:1	600–899	21° BTC	
8.25:1	900–1200	24° BTC	
10.0:1	600–899	22° BTC	
10.0:1	900–1200	24° BTC	

GAS ENGINE COMPRESSION PRESSURE

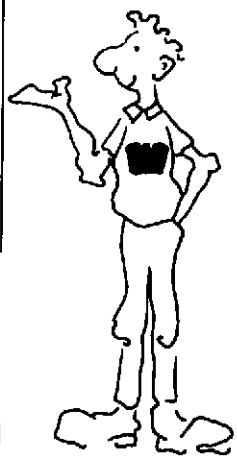


COMPRESSION PRESSURE VS RATIO

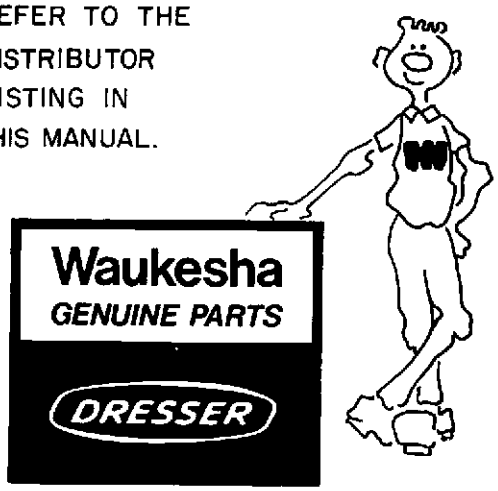
INSTALLATION



ALWAYS SPECIFY THE ENGINE MODEL DESIGNATION, SPECIFICATION NUMBER, AND SERIAL NUMBER, AS FOUND ON THE ENGINE NAMEPLATE.



GENUINE WAUKESHA PARTS ARE AVAILABLE WORLDWIDE AND MUST BE ORDERED THROUGH YOUR LOCAL WAUKESHA DISTRIBUTOR. FOR THE DISTRIBUTOR CLOSEST TO YOU, REFER TO THE DISTRIBUTOR LISTING IN THIS MANUAL.



PARTS ORDERING

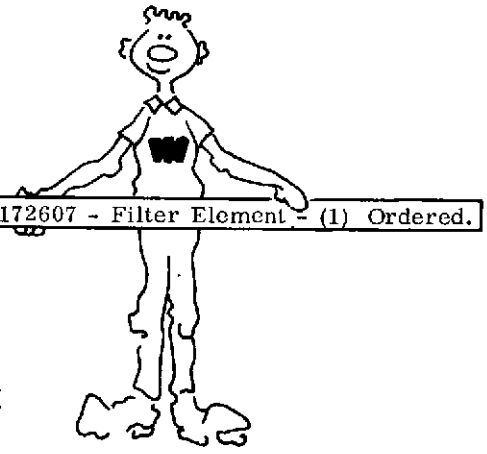
ANTICIPATE YOUR PARTS REQUIREMENTS:

a) ORDER PARTS EARLY IN THE DAY.

b) KEEP A SUPPLY OF NORMAL MAINTENANCE PARTS IN STOCK.

c) OBTAIN A PARTS STOCKING RECOMMENDATION FROM YOUR DISTRIBUTOR.

ALWAYS INCLUDE THE PART NUMBER, WHEN KNOWN, ALONG WITH THE DESCRIPTION OF THE PART, STATE THE QUANTITY OF THE PART YOU WISH TO ORDER. IF A SPECIAL PART IS NEEDED, THE ENGINE APPLICATION SHOULD ALSO BE STATED.



EXAMPLE: 172607 - Filter Element - (1) Ordered.

ML-003-25

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 Waukesha 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 for a maximum of 5 psi oil header pressure. 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.

The engines described in this manual require a minimum of 36" between engines or between engine and wall. End clearance required to remove camshaft is 48 inches. Sufficient overhead clearance is required to permit the use of a chain hoist for removal of heavy engine parts. The heaviest part of these engines is the cylinder block which weighs 1080 lbs. The cylinder heads weigh 124 lbs. each.

WARNING

Use only engine lifting eyes to position the engines. 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.

STATIONARY INSTALLATIONS

Engine Foundations

Nearly all stationary 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.

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.

VHP series engines may be either four point or six point mounted. Refer to Service Bulletin No. 14-1563C for six point mounting procedures.

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 prob-

lems 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 readings 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 shimming 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 counterbore. The discs provide for a number of important functions as follows:

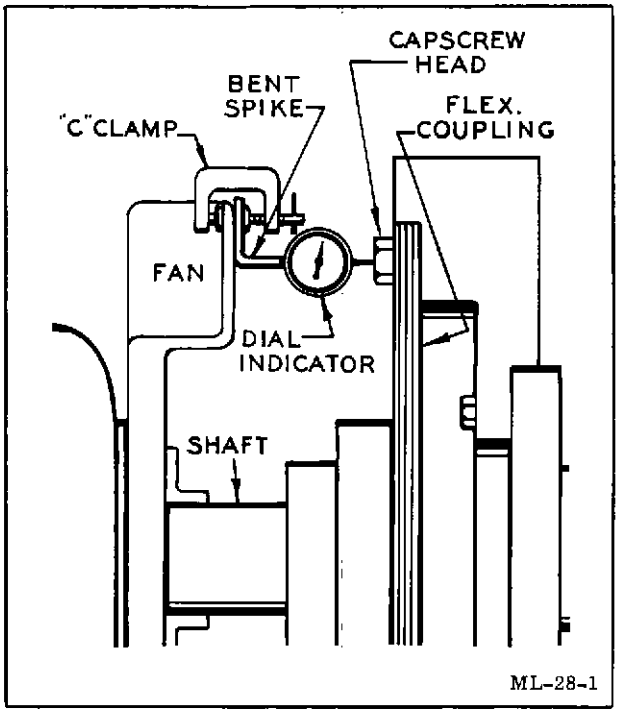
1. Pilot and support the front end of the generator rotor.
2. Eliminate the need for a generator drive end bearing.
3. Permit some minor angular misalignment because of the laminated construction.
4. Permit engine crankshaft end play and some minor longitudinal movement of the rotor.

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.

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 capscrew. 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.

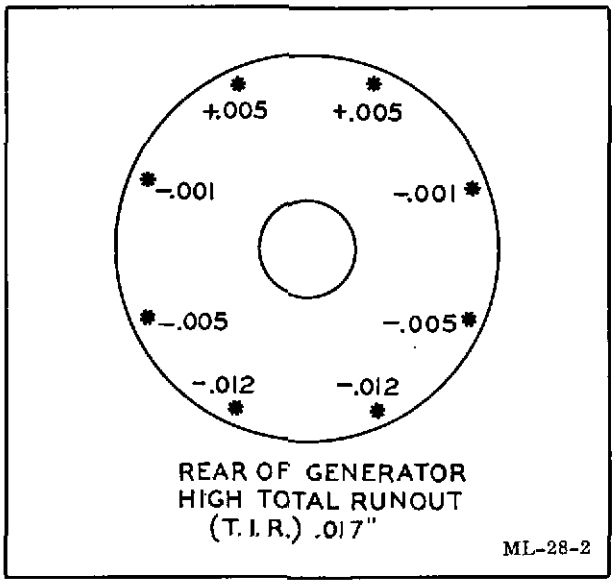


MOUNTING OF GENERATOR COUPLING ALIGNMENT DIAL INDICATOR

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.

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 capscrew 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 reduced 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



EXAMPLE OF GENERATOR COUPLING ALIGNMENT RUN-OFF

.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 engines described in the manual require a 3/4" diameter pipe to supply compressed air for air starters. Compressed air regulators should be set for 150 psi maximum, with a minimum 60 psi.

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. 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.
2. Base water flow and temperature rise across radiator core or cooler on jacket water pump curve.
3. Pressure drop through radiator core or cooler with full water flow at rated speed must not exceed 3 to 5 psi.
4. Allow 15% reserve for variations in application and environmental conditions, i.e., wind direction, dirt and debris. This is in addition to normal *design fouling factors.*
5. When possibility of using 50-50 solution of ethylene glycol exists, radiator core or cooler area should be sized 15% larger since there is a 15% reduction in heat transfer coefficient for ethylene glycol when compared with water.
6. Select radiator or cooler for highest ambient or sea water temperature that will be experienced in operation. For radiators, allowance must be made for air temperature rise across engine with blower fan, or in engine room if suction fan is used.
7. Radiators and surge tanks must have 7 psi pressure caps.
8. Provision must be made for de-aeration of coolant, such as divided top tank or separate surge tank.
9. Provision must be made for balance line connection to engine pump suction to prevent pump cavitation.
10. Adequate expansion volume for complete cooling system must be provided in radiator or separate surge tank.
11. Provisions must be made for connecting auxiliary pump to circulate water through oil cooler and/or intercooler where applicable.
12. Maximum back pressure, feeding into radiator or cooler, should not exceed 5 psi at 2000 RPM.
13. 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:

1. Use 200° F. (instead of 185° F.) engine outlet *temperature.*

2. Allow 5% (instead of 15%) reserve for variations in application and environmental conditions.

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

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

Cooling System Capacity

The cooling system capacity is approximately 48 gallons (181.7 liters) for all 6 cylinder VHP engines and 107 gallons (405 liters) for all 12 cylinder VHP engines. These capacities are for the engine only and do not take into account radiators or other cooling 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 cathodes protection.

AIR INTAKE SYSTEM

Huge quantities of combustion air are required for all internal combustion engines. Combustion air requirement for engines described in this manual may be obtained from your Waukesha Distributor.

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 3% of fuel input for all engines described in this manual. 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 15 inches of water for naturally aspirated engines and 12 inches of water for turbocharged 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.

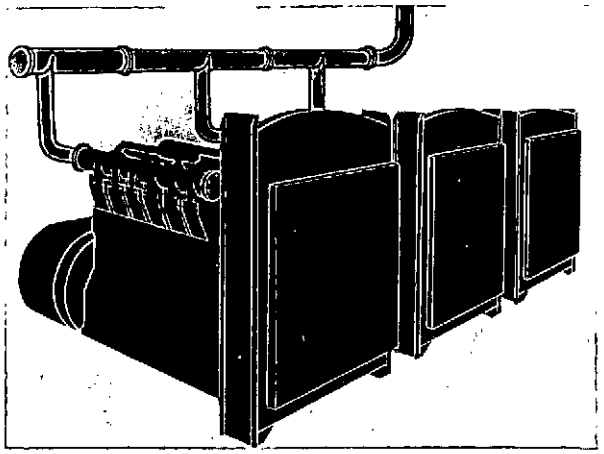
2. Install a tubing connector and a length of copper tubing (to permit dissipation of heat) in each tapped hole and connect a manometer hose and manometer. To ensure accurate measurement, it is important that the manometer line fitting does not protrude beyond the inner surface of the exhaust elbow or 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.

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.



MH-88-1

MULTIPLE EXHAUST CONNECTIONS TO A COMMON HEADER ARE VERY POOR PRACTICES

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. Multipls exhaust connections to a common header are not recommended, as this can result in erratic operation and damage.

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

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

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

Exhaust flow requirements for engines described in this manual may be obtained from your Waukesha Distributor.

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

The exhaust outlet diameter is 5" on six cylinder naturally aspirated engines and 6" for six cylinder turbocharged engines. On the twelve cylinder engines the exhaust outlet diameter is 8" for both turbocharged and naturally aspirated engines.

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 ±1/4 INCH OFFSET AND ±1/4 INCH AXIAL DEFLECTION.

GAS FUEL SYSTEM

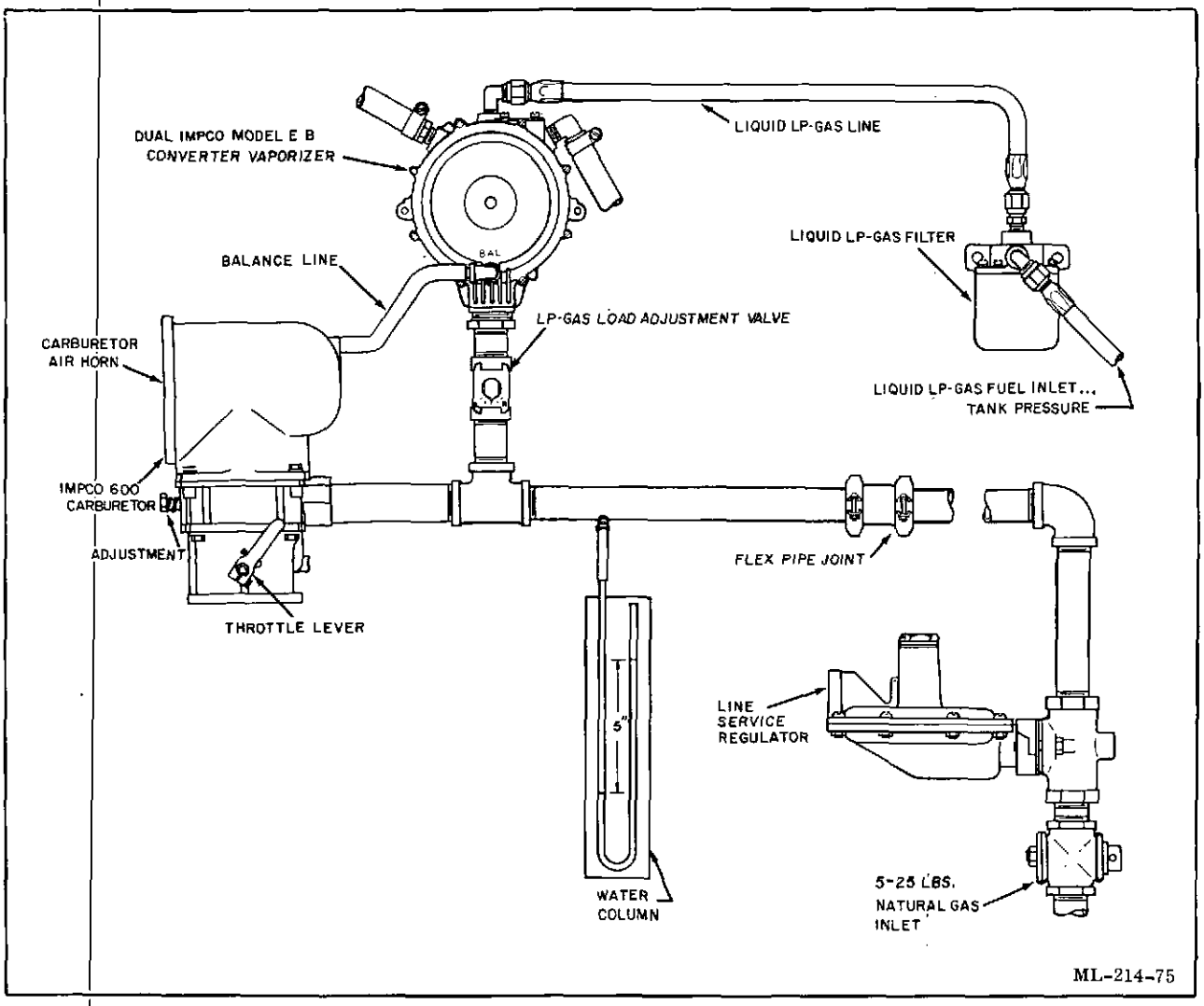
Natural gas inlet pipe is 2 inches. Required natural gas pressure to the line pressure regulators is 10-25 psi (nat. asp) or 20-25 psi (turbo).

WARNING

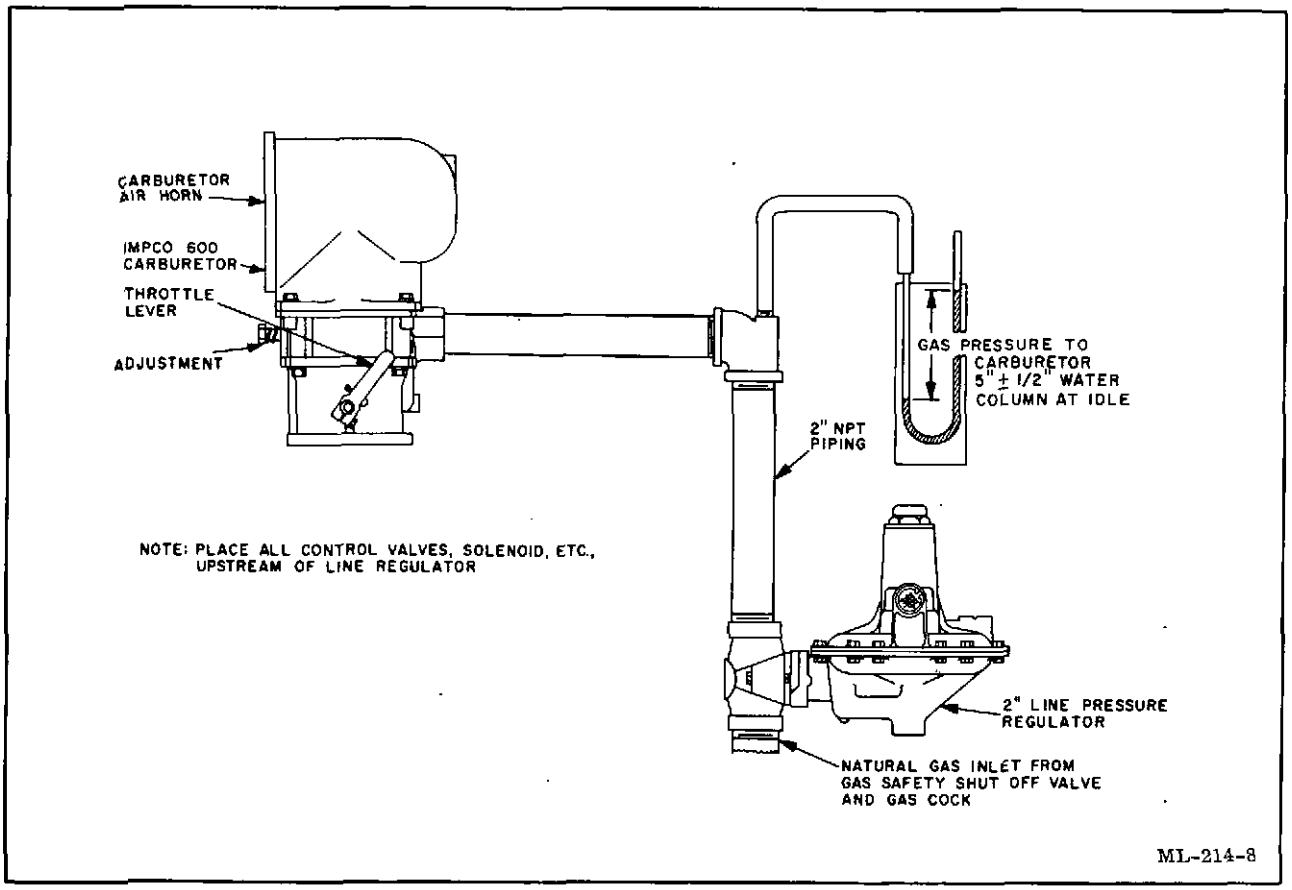
For reasons of safety.....ALL GAS INSTALLATIONS IN CLOSED AREAS OR BUILDINGS SHOULD HAVE A POSITIVE SHUTOFF VALVE TO PREVENT GAS LEAKAGE WHEN THE ENGINE IS AT REST.

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 turbocharged engines from the pressurized air at the carburetor air horn to the atmospheric vent in the regulator.



TYPICAL IMPCO COMBINATION LP AND NATURAL GAS INSTALLATION



TYPICAL IMPCO NATURAL GAS INSTALLATION - NATURALLY ASPIRATED

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.

LUBRICATING OIL SYSTEM

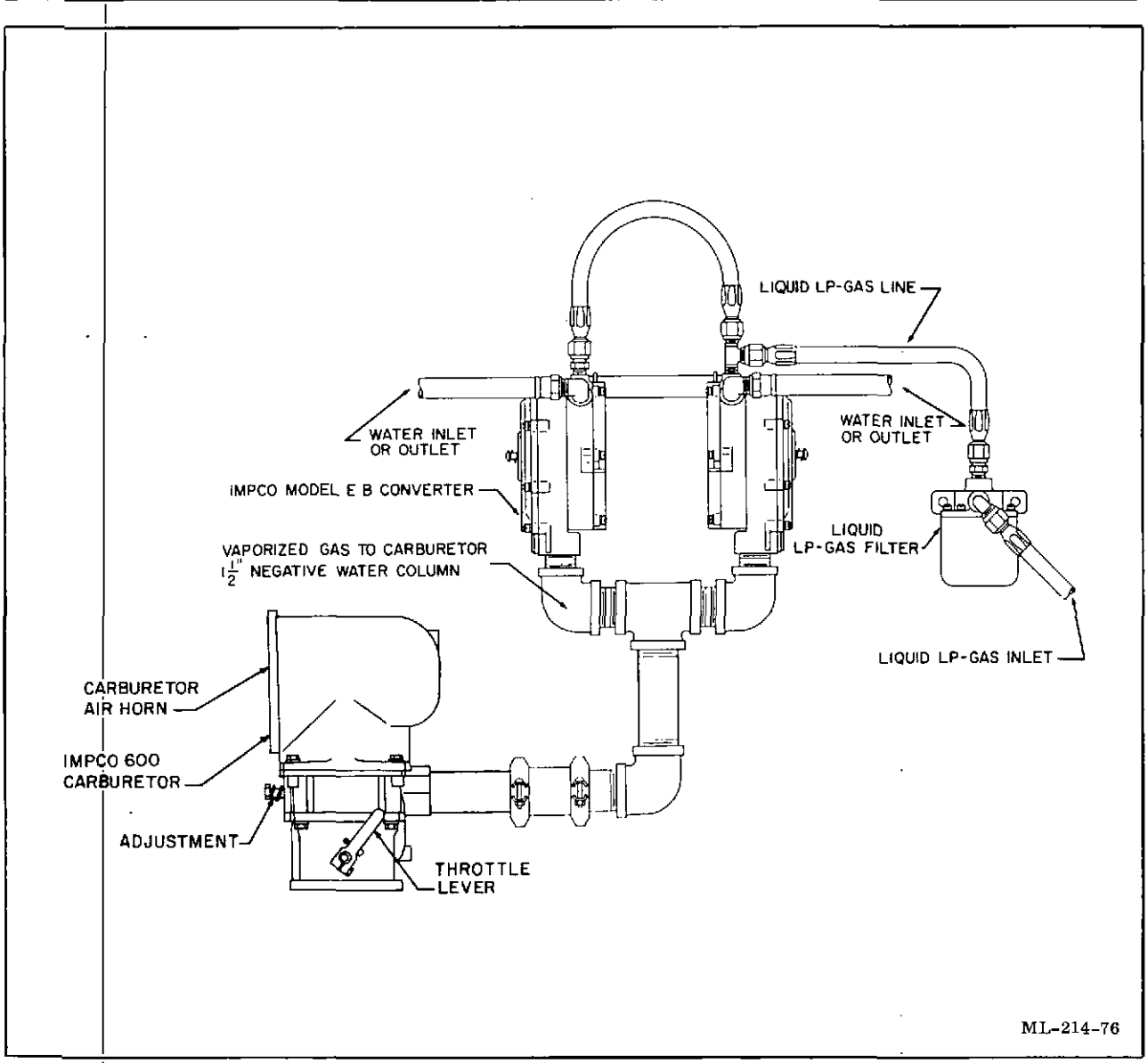
Lubricating oil specification recommendations as well as oil sump and filter capacities are contained in the front portion of the "Preventive Maintenance" unit. The installation should include adequate provisions for draining lube oil.

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 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. Refer to Service Bulletin No. 14-1629 for maximum safe tilt angles.

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.



TYPICAL IMPCO LP GAS INSTALLATION

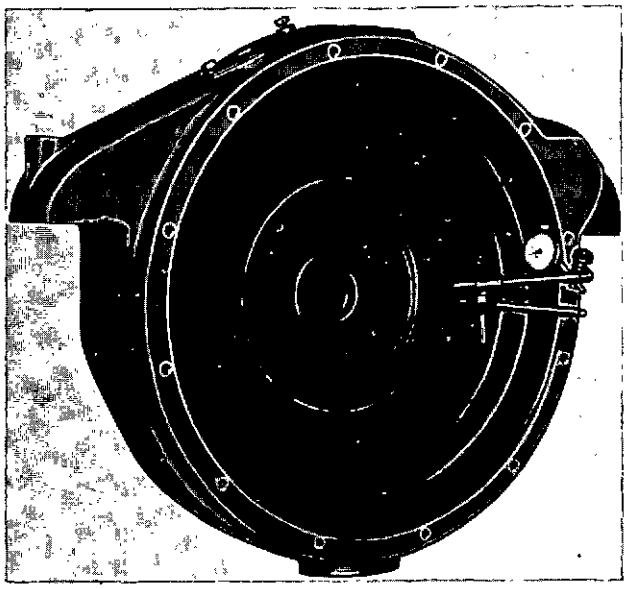
CHECKING FLYWHEEL AND HOUSING RUN-OUT AND CRANKSHAFT ENDPLAY

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

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



MH-13-4

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 .012" total indicator reading.

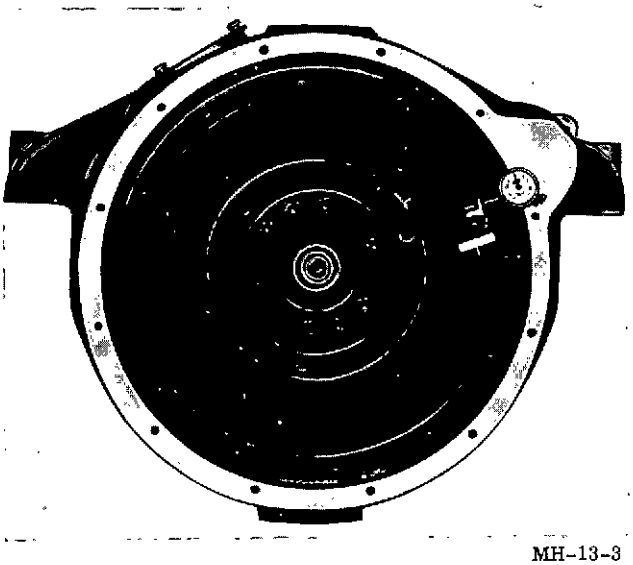
4. Tighten bolts partially, working back and forth across the housing. Recheck bore concentricity with dial indicator.

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 .012" 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.

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.

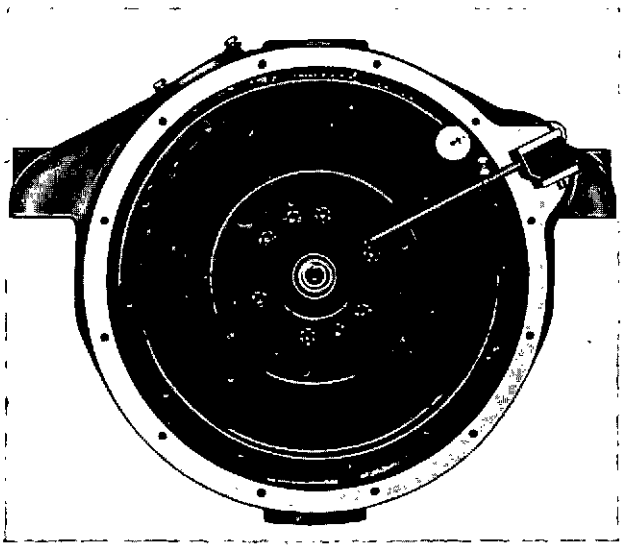


MH-13-3

CHECKING HOUSING FACE RUN-OUT

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

Remount the dial indicator as shown to measure the runout of the flywheel face. Again, it is emphasized that each reading must be taken with the crankshaft moved all the way forward to contact the thrust bearing. Unless rough handling has somehow distorted the wheel or crankshaft flange, maximum runout should not exceed .016" total indicator reading.



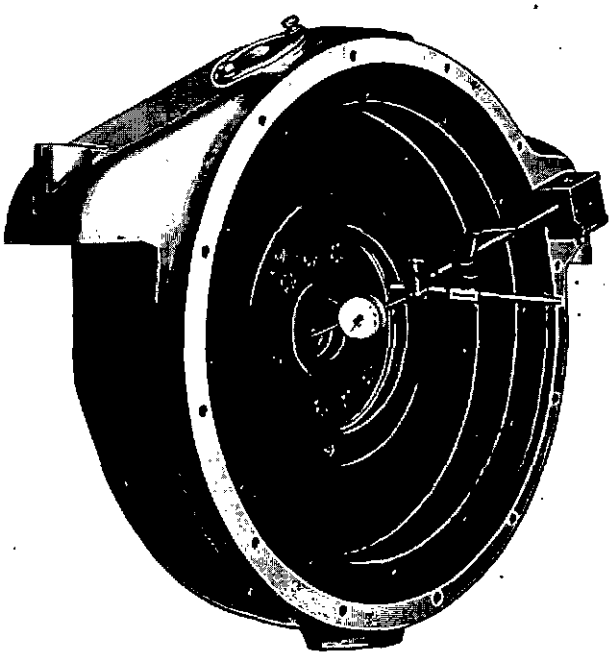
MH-13-2

CHECKING FLYWHEEL FACE RUN-OUT

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" - .016".

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.



CHECKING PILOT BEARING BORE RUN-OUT MH-13-1

Waukesha DRESSER