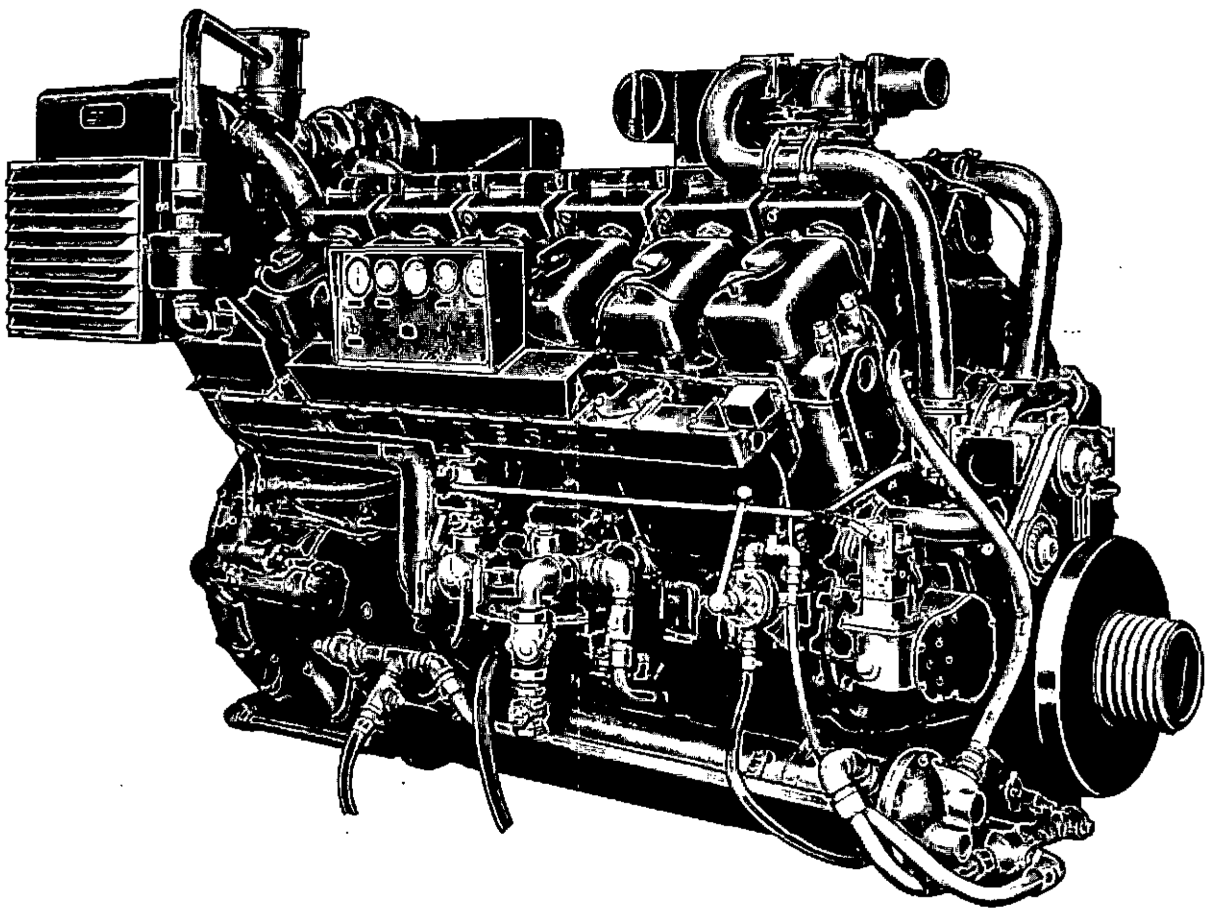
# WAUKESHA ENGINES

SUPERCHARGED AND NATURALLY ASPIRATED

## Models L-5108-G, L-5790-G & L-7042-G



# OPERATORS MANUAL

WAUKESHA MOTOR COMPANY • WAUKESHA, WIS.

PUBLICATION 4722 EDITION 4

Eastern Office: 485 Washington Ave., Carlstadt, New Jersey 07072
Mid-Continent Office: 5000 S. 45th West Ave., Tulsa, Okla. 74107
Pacific Coast Office: P.O. Box 2146, Huntington Park, Calif. 90255
Alaskan Office: 239 E. International Airport Road, Anchorage, Alaska 99502

# WAUKESHA MODELS L-5108G, L-5790G AND L-7042G GAS ENGINES

## SUPERCHARGED AND NATURALLY ASPIRATED

REG. U.S. PAT. OFF.

EDITION FOUR

F-4722

**WAUKESHA MOTOR COMPANY**

WAUKESHA, WISCONSIN, U. S. A.

**Main Office**
Waukesha, Wis. 53186

**Factories**
Waukesha, Wis. 53186
Clinton, Iowa 52733

**Branch Offices**
485 Washington Ave.
Carlstadt, N.J. 07072

5000 S. 45th West Ave.
Tulsa, Okla. 74107

P. O. Box 2146
Huntington Park, Calif. 90255

239 E. International Airport Road
Anchorage, Alaska 99502

# SAFETY PRECAUTIONS

The exhaust products of an internal combustion engine are toxic and may cause injury to health 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 open air.

All internal combustion engine fuels are highly combustible and may explode under certain conditions. Fuels must be conducted to the engine with secure piping, free from leaks, properly designed to resist breakage from vibration.

All engine installations should be equipped with a means of positive fuel shutoff for emergency use when fuel is conducted to the engine from a remote source. In addition, fuels under pressure such as natural gas or liquified petroleum gas, should be controlled by a positive shutoff 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.

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 minimize spark hazard and it is the responsibility of the engine owner to specify or provide such connections and equipment.

Internal combustion engines must be properly provided with guards against hazard 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.



4722-2500-6/69-MB-ZP

# INTRODUCTION

The Waukesha Motor Company supplies this handbook as a guide to those operating and servicing Waukesha Model L-5790-G series engines. In most cases, the procedures in the following pages are to be regarded as recommendations -- they should be combined with good judgment and common sense on the operator's part. It is emphasized, however, that these recommendations are based on many years of practical experience with internal-combustion engines, and are generally applicable under average conditions. Occasionally, unusual or extreme circumstances may appear to justify some degree of variation in operating or maintenance technique. In such cases, it is urgently requested that the problem be submitted to the Service Department, Waukesha Motor Company, Waukesha, Wisconsin.

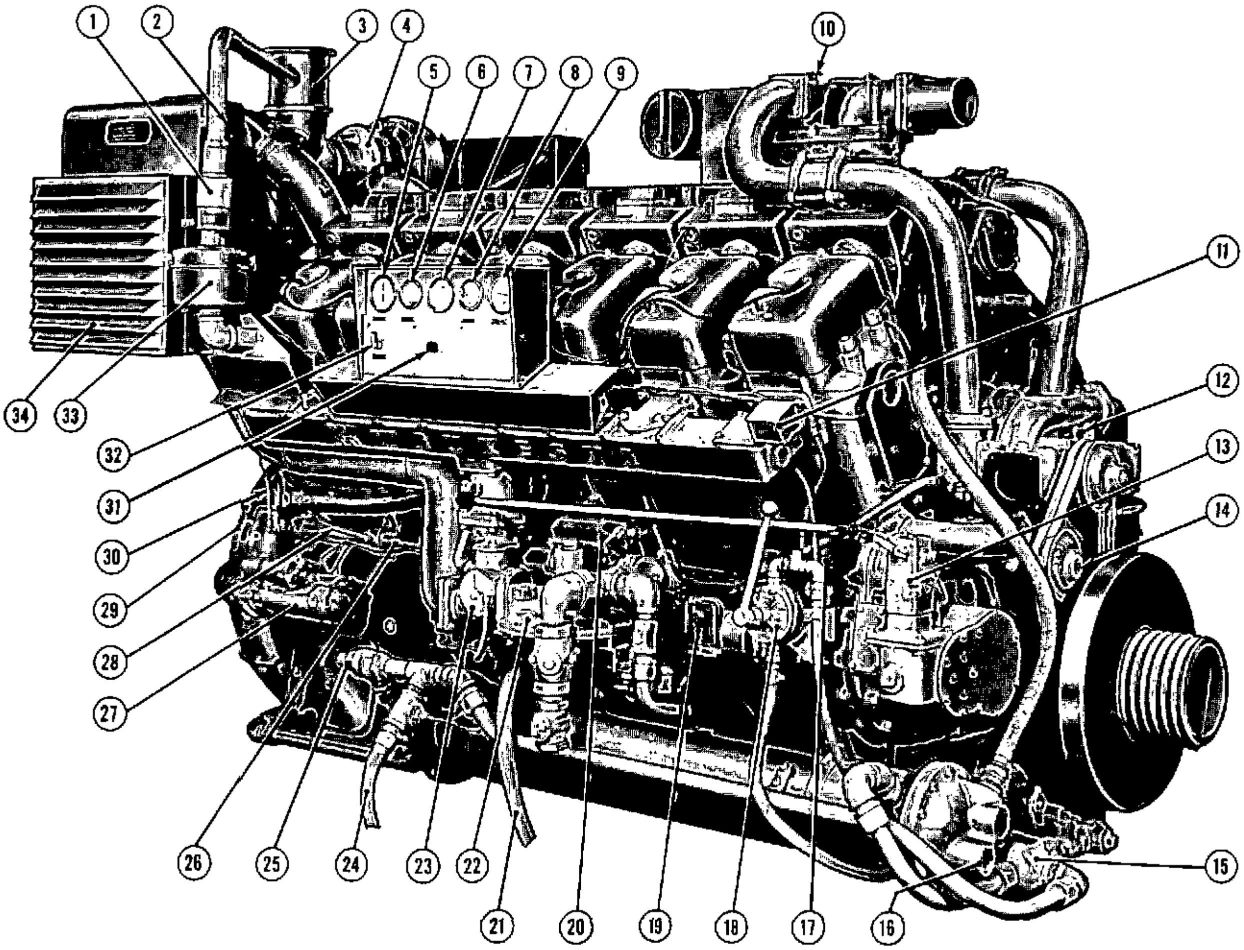
When requesting information from the manufacturer, include the engine model and serial number found on the engine name plate. In addition, any conversions or changes from the original design made by the engine owner should be mentioned.

# CONTENTS


| Title | Page |
|---|---|
| DESCRIPTION | 1 |
| General | 1 |
| Crankcase | 1 |
| Cylinder Heads | 3 |
| Sleeves | 4 |
| Crankshaft | 4 |
| Connecting rods | 6 |
| Pistons | 7 |
| Valve Mechanism | 7 |
| Camshaft | 8 |
| Oil Pump | 10 |
| Lubrication System | 10 |
| Oil Coolers | 14 |
| Water Pump | 14 |
| Cooling System | 14 |
| Accessory Drives | 18 |
| Starting Engine | 18 |
| SERVICE | 19 |
| General | 19 |
| Lubrication | 19 |
| Oil Capacity | 20 |
| Oil Changes | 20 |
| Oil Screens and Magnetic Plugs | 20 |
| Selecting Oil Viscosity | 21 |
| Operating Temperatures | 21 |
| Break-In | 21 |
| Oil Consumption | 21 |
| Warm Oil For Cold Weather Starting | 22 |
| Oil Filter | 22 |
| Use Genuine Filter Elements | 22 |
| Technical Data | 22 |
| Oil Pressure Control | 24 |
| Oil Cooler | 25 |
| Crankcase Ventilation | 25 |
| Greasing | 26 |
| Accessory Lubrication | 26 |
| Air Starter Lubrication | 27 |
| Air Cleaners | 27 |
| Dry Type Air Cleaners and Condition Indicator | 27 |
| Cooling System | 28 |
| Cooling and Anti-Freeze | 28 |
| Thermostatic Valve Assembly | 28 |
| Cleaning Cooling System | 28 |
| Commercial Cleaners | 29 |
| Cooling Fans | 30 |
| Fan Belts | 30 |
| Greasing Fan Hub | 30 |
| Valve Adjustment | 30 |
| General | 30 |
| Adjustment | 32 |
| Governor Linkage | 33 |
| Flywheel and Flywheel Housing Alignment | 34 |
| Flywheel Housing Mounting | 34 |
| Engine Storage | 36 |
| Nucle-Oil Storage (Recommended Procedure) | 37 |
| Conventional Storage | 38 |
| Gas or Gasoline Engines | 38 |
| Storing Engines That Have Been In Service | 39 |
| Preservation Equipment and Materials | 39 |
| Sprays and Atomizers | 39 |
| Heating Compounds | 39 |
| Preparing Engine for Operation | 39 |
| Woodward Governor, UG-8 | 40 |
| Oil Trouble, Governor | 40 |
| Dirty Oil Causes Approximately 50% of All Troubles | 40 |
| Governor Oil Level | 42 |
| Compensating Adjustment | 42 |
| Analysis And Correction of Governor Trouble | 42 |
| OPERATION | 46 |
| Safety Controls | 46 |
| Pre-Starting Checks | 47 |
| Starting Procedure | 48 |
| Starting Engine Clutch Engagement | 48 |
| Low Speed Operation | 48 |
| Stopping Procedure | 48 |
| Inspection | 49 |
| Daily Inspection | 49 |
| Weekly Inspection | 49 |
| Monthly Inspection | 50 |
| 100-Hour Inspection | 50 |
| 500-Hour Inspection | 50 |
| Trouble Shooting | 50 |
| Engine Fails to Start or Starts with Difficulty | 50 |
| Failure of Engine to Develop Power or Irregular Running | 53 |
| Engine Stops | 53 |
| Engine Misfires | 53 |
| Knocking or Unusual Noises | 54 |
| Excessive Fuel Consumption | 54 |
| Overheating | 55 |
| Low or Fluctuating Oil Pressure | 56 |
| SERVICE MAINTENANCE | 57 |
| Fuel System | 57 |
| Line Size | 58 |
| LPG Fuel Systems | 58 |

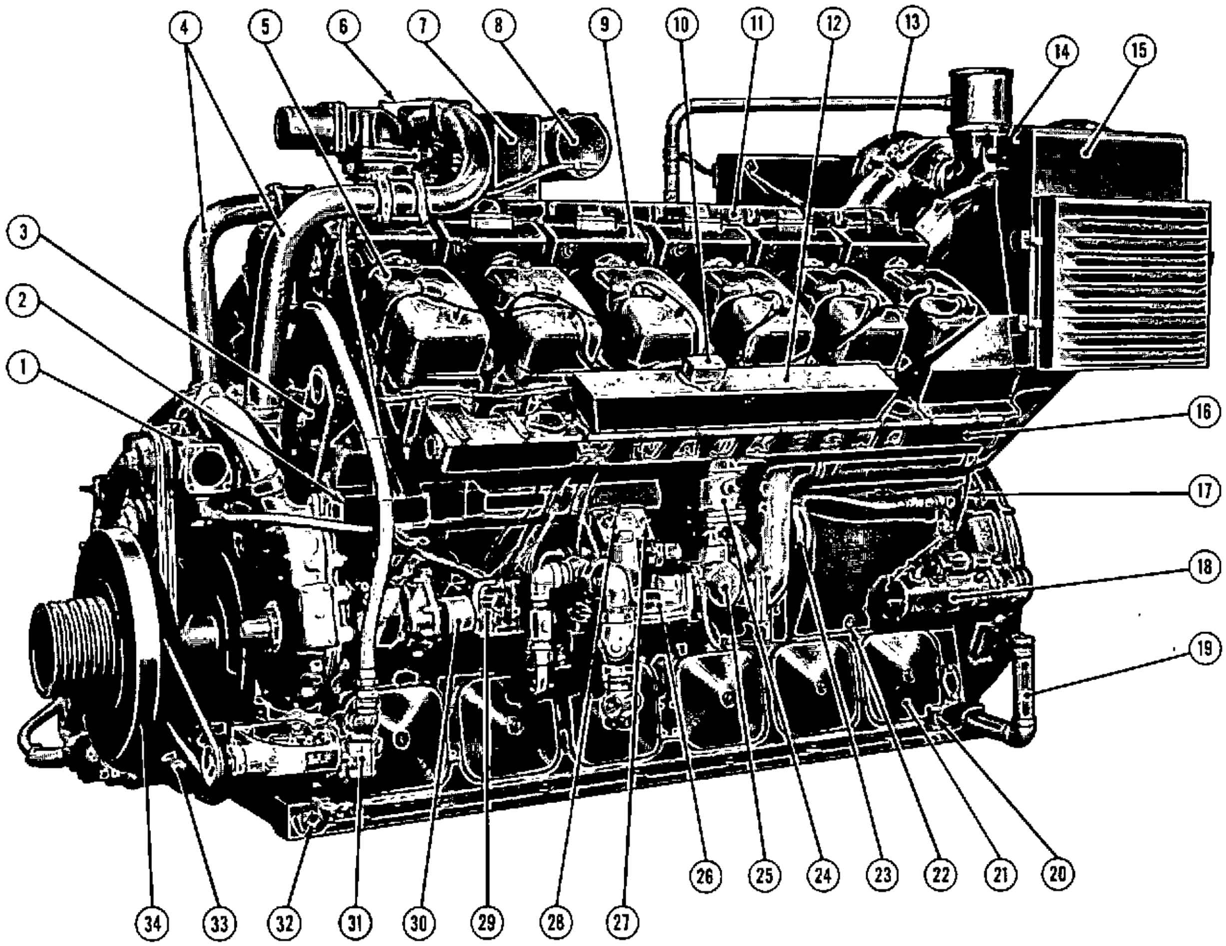
# CONTENTS


| Title | Page |
|---|---|
| SERVICE MAINTENANCE (Cont.) | |
| Vaporizer | 58 |
| Synchronization Procedure | 58 |
| Scrubber Tanks | 59 |
| Impco Carburetors | 59 |
| Operation | 59 |
| Installation | 60 |
| General Impco Service Instructions | 60 |
| Natural Gas | 60 |
| Adjustment | 61 |
| Thermac Pressure Reduction Valve | 63 |
| LP Gas | 63 |
| Balance Lines | 63 |
| Turbocharged Engines | 63 |
| Turbocharging and Intercooling | 63 |
| Turbocharging | 63 |
| Air Leaks | 64 |
| Turbo Cleaning | 64 |
| Mufflers | 64 |
| Low Output Operation | 65 |
| General Maintenance Comments | 65 |
| Summary | 65 |
| Installation | 65 |
| Lubrication Requirements | 65 |
| Air Duct Requirements | 66 |
| Mounting | 66 |
| Initial Run-in | 66 |
| Daily Service and Maintenance Inspection | 66 |
| Periodic Service and Maintenance Inspection | 67 |
| Trouble Shooting | 67 |
| Bearing Inspection | 67 |
| Radial Bearing Check | 67 |
| Axial Bearing Check | 68 |
| Intercooler | 68 |
| Maintenance | 68 |
| Impco Carburetor-Adjustment | 68 |
| Power Limiter | 69 |
| Servicing Hydraulic Push Rods | 70 |
| Hydraulic Push Rod Overhaul | 72 |
| Cleaning | 72 |
| Assembly | 72 |
| Testing | 73 |
| Crankcase Ventilation System | 73 |
| Ignition Systems | 73 |
| Mag-Tronic Ignition System | 73 |
| Installation | 75 |
| Final Timing | 75 |
| Periodic Inspection | 75 |
| Safety Shut Downs | 75 |
| Low Tension Ignition | 76 |
| Timing | 76 |
| Adjustable Drive Members | 77 |
| Installation Instructions | 78 |
| Bendix Breakerless Ignition | 79 |
| Description | 79 |
| Preliminary Timing and Installation | 79 |
| Final Timing | 80 |
| Maintenance | 81 |
| Timing Tapes and Charts | 81 |
| Cross-Bolted Bearings | 82 |
| Crankshaft Gear Removal | 83 |
| Camshaft Gear Removal | 83 |
| Servicing Roller Type Valve Tappet Assemblies | 83 |
| Left Hand Rotation Engine Data | 84 |
| Installation of Spring-Loaded Teflon Sleeve Seal Rings | 84 |
| FITS AND CLEARANCES | 85 |
| General | 85 |
| Torque Value Recommendations | 85 |
| General Torque Value Recommendations | 85 |
| Cylinder Sleeves | 86 |
| Crankcase | 86 |
| Piston Pin | 87 |
| Piston | 87 |
| Piston Rings | 88 |
| Crankshaft | 88 |
| Camshaft | 88 |
| Flywheel and Housing | 89 |
| Connecting Rod, Bushing and Bearing | 89 |
| Valve Train, Valve Port Clearances | 89 |
| Valve Clearance | 90 |
| Valve Lifters | 90 |
| Oil Pump | 91 |
| Timing Gear Backlash | 91 |
| Capacities | 91 |
| Ignition Data | 91 |
| Timing | 92 |
| DISTRIBUTORS AND SERVICE | 93 |
| WARRANTY | 94 |



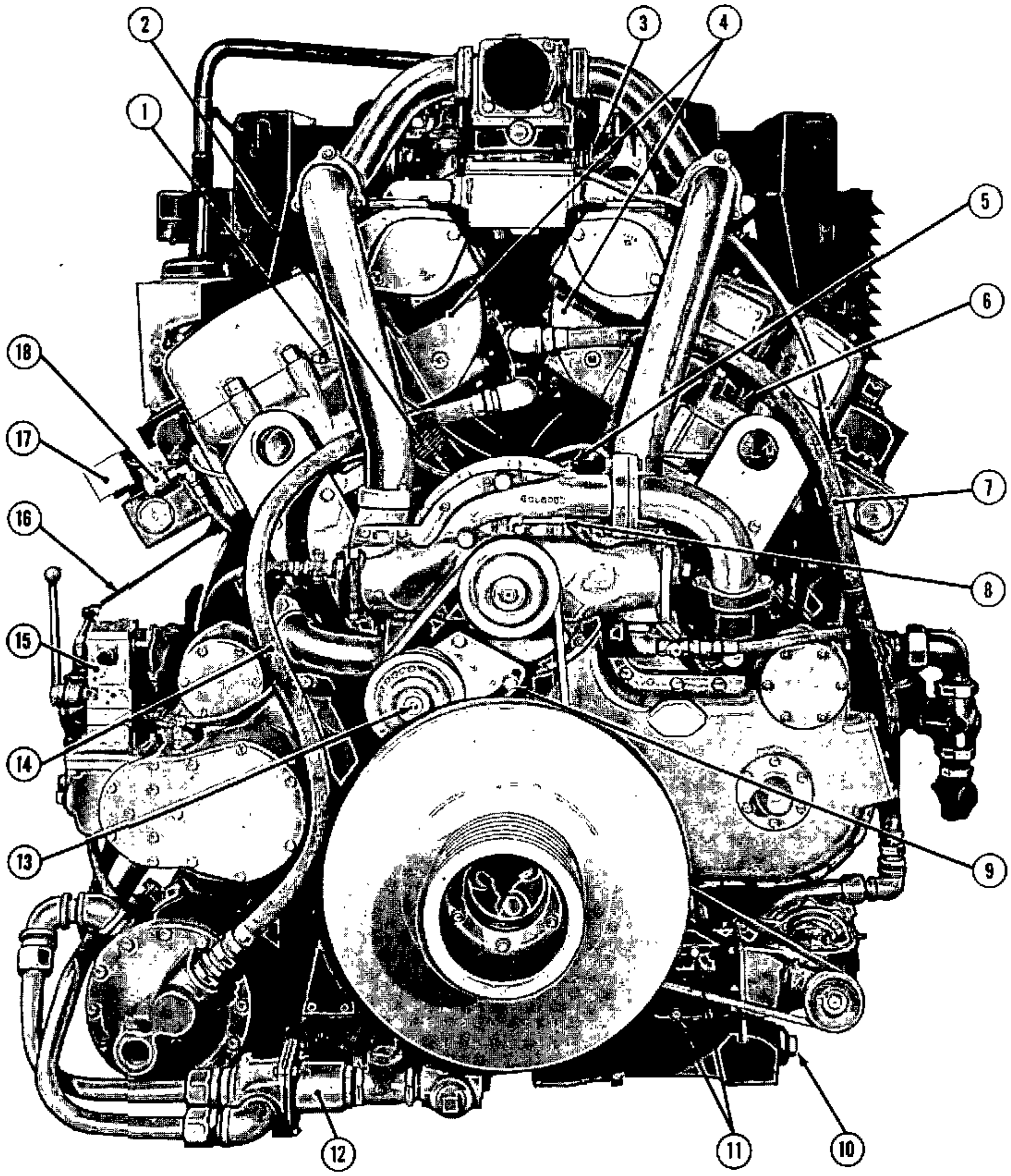
WAUKESHA MODEL L-5790-GSI - RIGHT SIDE VIEW

1. Breather Regulator
2. Air Cleaner Resistance Indicator
3. Exhaust Outlet Venturi
4. Left Bank Turbocharger
5. Vacuum-Pressure Gauge
6. Water Temperature Murphy Swichgage
7. Tachometer
8. Oil Pressure Murphy Swichgage
9. Oil Temperature Gauge
10. Air Bleed Vent Cock
11. Overspeed Shutdown Switch
12. Water Pump Grease Fitting
13. Woodward Governor
14. Idler Pulley Grease Fitting
15. Oil Cooler Bypass Valve
16. Oil Cooler-Intercooler Coolant Outlet
17. Overspeed Governor Adjustment
18. Lubricating Oil Primer Pump
19. Low Tension Magneto
20. Safety Shutdown Control
21. Hose from Lubricating Oil Filter
22. Gas Pressure Regulator
23. Carburetor
24. Hose to Lubricating Oil Filter
25. Oil Pressure Relief Valve
26. Main Oil Header
27. Starting Motor
28. Oil Line to Rocker Arm Oil Header
29. Timing Mark Access Cover
30. Oil Line to Right Bank Turbocharger
31. Ignition Switch
32. Vacuum-Pressure Gauge Selector Valve
33. Crankcase Breather
34. Air Cleaner




WAUKESHA MODEL L-5790-GSI - LEFT SIDE VIEW

1. Water Pump
2. Engine Nameplate
3. Lifting Bracket
4. Cooling System Bypass Lines
5. Rocker Arm Cover
6. Air Bleed Vent Line
7. Thermostatic Controls
8. Expansion Tank
9. Water Cooled Exhaust Manifold
10. Safety Shutdown Control Junction Box
11. Top Water Manifold
12. Ignition Coils Assembly
13. Right Bank Turbocharger
14. Air Cleaner Resistance Indicator
15. Air Cleaner
16. Intake Manifold
17. Oil Line to Left Bank Turbocharger
18. Starting Motor
19. Oil Filler
20. Leveling Bolt
21. Oil Pan and Bearing Access Door
22. Main Bearing Cap Lateral Bolt
23. Power Limiter
24. Butterfly Valve Housing
25. Carburetor
26. Gas Pressure Regulator
27. Safety Control Manual Trip Button
28. Safety Control Reset Button
29. Low Tension Magneto
30. Magneto Drive Coupling Guard
31. Oil Cooler-Intercooler Coolant Pump
32. Oil Pan Drain Plug
33. Oil Pump
34. Vibration Damper




WAUKESHA MODEL L-5790-GSI - FRONT VIEW

1. Rocker Arm Oil Line
2. Push Rod Cover
3. Water Temperature Sensing Element
4. Water Cooled Exhaust Manifolds
5. Water Pump Air Bleed Vent
6. Spark Plug Insulator
7. Coolant Line to Intercoolers
8. Water Pump Grease Fitting
9. Water Pump Belt Tension Adjustment
10. Oil Pan Drain Plug
11. Belt Tension Adjustment
12. Oil Cooler Bypass Valve
13. Idler Pulley Grease Fitting
14. Coolant Line from Intercoolers
15. Woodward Governor
16. Governor Control Rod
17. Overspeed Shutdown Switch
18. Overspeed Shutdown Switch Actuator

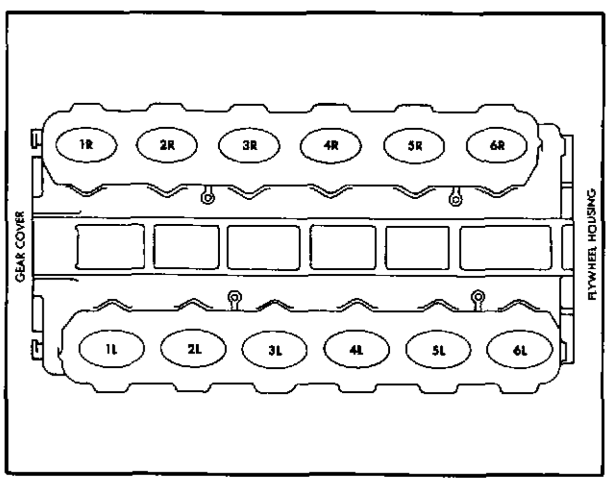
# DESCRIPTION

## GENERAL

The Waukesha Model L-5790-G series are twelve cylinder, four-stroke cycle, overhead valve, spark ignition, gaseous fuel engines.

The information in this manual applies to the Waukesha Model L-5108-G, L-5790-G and L-7042-G engines, both naturally aspirated and turbo supercharged. These model designations may be interpreted as follows. The prefix letter "L" as the 12th letter of the alphabet indicates 12 cylinders. The numbers 5108, 5790 and 7042 indicate the nominal displacement in cubic inches. The suffix letters indicate the type of fuel ("G" gaseous) and if the engine is turbo supercharged and intercooled ("SI"). Thus, a Model L-5790-GSI is a 12-cylinder, 5788 cubic inch displacement engine, operates on gaseous fuel, and is turbo supercharged and intercooled.

Since the Model L-5790-G is the basic model in this series, references to this model will be made throughout this manual. However, unless specifically pointed out, the information in this manual applies equally to all the engine models in this series and variations of these models. The major difference between the models in this series is the displacement, which is 5100 cubic inches for the L-5108-G, 5788 cubic inches for the L-5790-G, and 7040 cubic inches for the L-7042-G. The bore and stroke is 8-1/2 by 7-1/2 inches for the L-5108-G, 8-1/2 by 8-1/2 inches for the L-5790-G and 9-3/8 by 8-1/2 inches for the L-7042-G.




CYLINDER NUMBERING DIAGRAM

Since these engines are used in many different applications with numerous engine equipment variations, this manual will cover only the standard engine and the most commonly used optional equipment and accessories.

The following operational and service data have been prepared from a practical viewpoint. There are no special techniques or "tricky" adjustments necessary to keep the unit in good operating condition. Consistently careful maintenance of the engine and its fuel, oil, and coolant, will more than pay for itself in prolonged good performance and reliability. Never overlook the great contribution that properly serviced air cleaners can make to engine life. In addition, reasonable storage care, especially of the precision parts is extremely important.

For purposes of discussion or correspondence, the following reference points should be established.

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

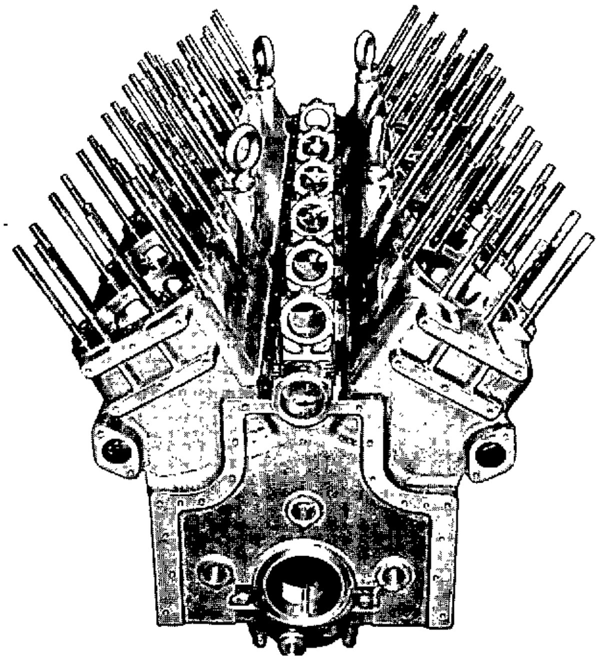
FRONT and REAR -- References to various locations on the engine shall be interpreted as meaning from the gear-cover (front) and flywheel (rear) ends, respectively.

RIGHT and LEFT -- Shall be interpreted as meaning from the right and left of a viewer facing the rear (flywheel) end of the engine.

Major parts are interchangeable between right and left cylinder banks. Since many of the parts described contain complex oil or water passages, no mention has been made of these passages except as is necessary to avoid uncertainty.

## CRANKCASE

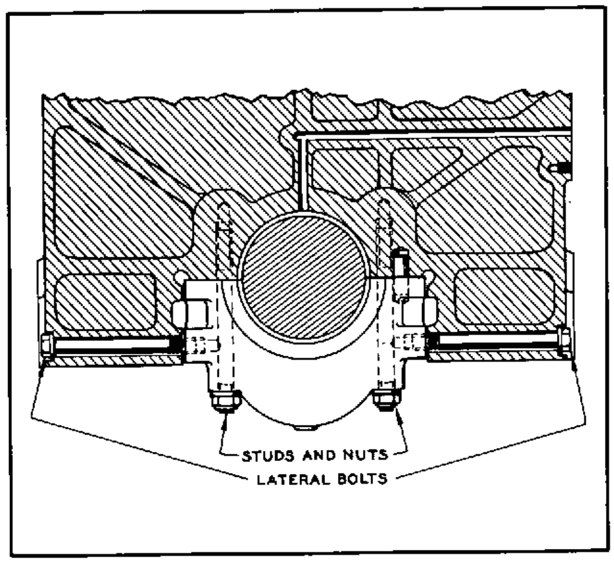
The cooling water passages are formed between the side-wall structures of the crankcase and the cylinder sleeves. Thus, the sleeves are always in direct contact with the coolant. Since the cylinder sleeves are of the removable type, it is necessary to maintain a seal at the upper and lower sleeve-to-crankcase contact surfaces.



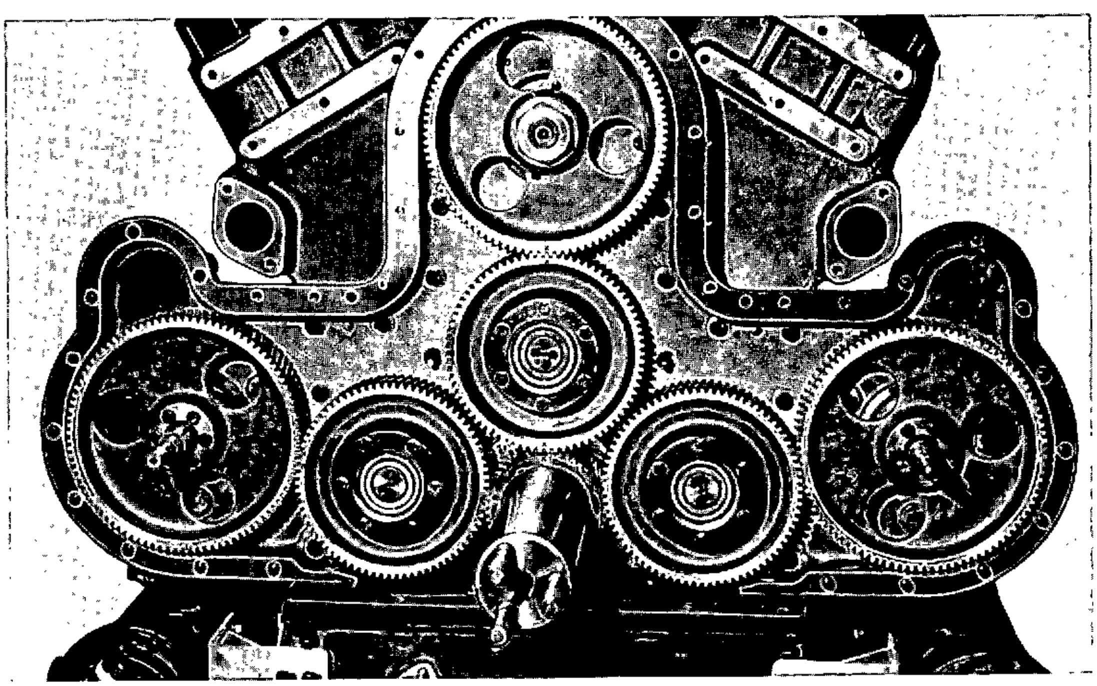
CYLINDER BLOCK - CRANKCASE

This is accomplished in the upper contact area by the head gasket which seals the accurately finished mating surfaces at the joint between the grooved sleeve flange and the cylinder head and with copper sealing rings used between the sleeve flange and the crankcase recess for added sealing efficiency. Three seal rings are utilized in the crankcase to lower cylinder sleeve sealing area.

Permanent, postive alignment of all parts of the power train is assured by thick top decks and heavy webs between seats for the camshaft and crankshaft. Each main bearing cap is supported, in addition to four studs and elastic stop nuts, by two place type bolts which secure




BEARING CAP SUPPORT



TIMING GEAR INSTALLATION

it laterally to provide additional rigidity of main bearing alignment. The lower surface of the crankcase is finish machined to form a seal with the box type oil pan upon which it mounts. An O-ring type oil seal is utilized between the crankcase and the oil pan, with the seal recess in the mating surface of the oil pan.

To insure correct valve timing of the Model L-5790-G engine, 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". The two lower idler gears which mesh with the crankshaft gear may be assembled without regard for the "x" marks on them. (Refer to illustration on page 2.)

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

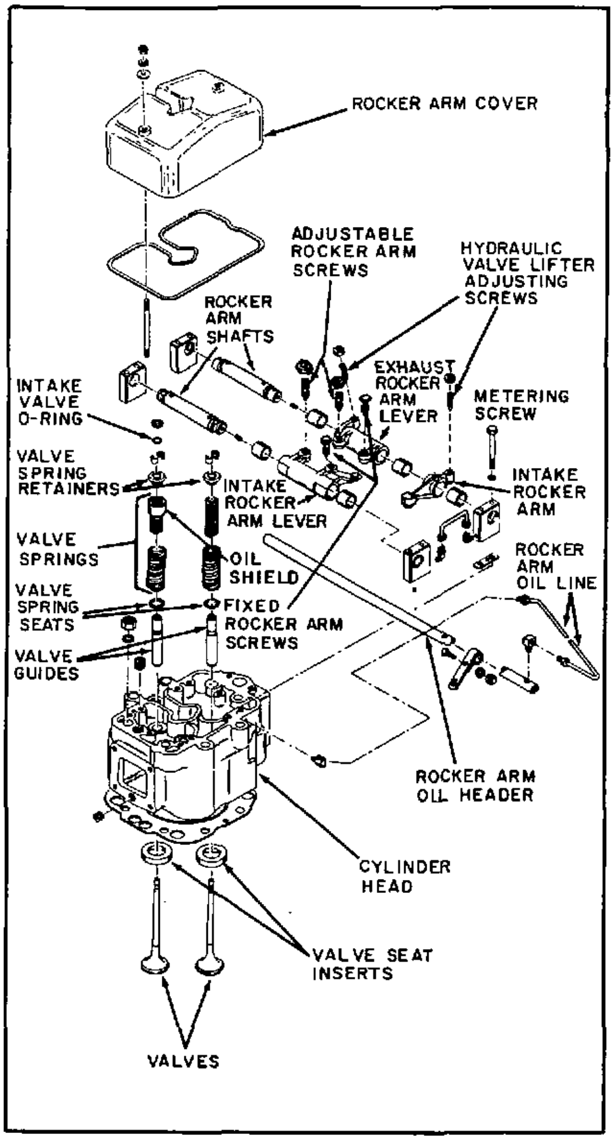
At the rear end of the crankcase is a mounting surface for a flywheel housing of the specified size and two (upper and lower) packed-type crankshaft oil retainers. To ensure accurate mounting of the clutch or other drive unit in the flywheel housing, the rear surface of the engine is held to very close tolerances, and when a flywheel housing is specified, the housing itself is machined true after it is assembled to the engine. Whenever the power takeoff, the flywheel, or flywheel housing are removed, the run-out and eccentricity of the related parts should be checked and adjusted to the following limits: flywheel housing should not be eccentric more than 0.015-in. total indicator reading; nor should there be more than 0.010-in. indicator reading for the face runout. The most important flywheel limit is: 0.005-in. indicator reading for the clutch pilot bearing eccentricity.

Lubrication for the various bearings throughout the crankcase is provided by drilled passages directly or indirectly connected with the external main oil header extended along the right side of the crankcase. The main oil header is a rigid tube with connection fittings spaced to match the passages extending inward to the main bearing locations.

Faced mounting bosses and connections are provided at various points on the crankcase exterior for mounting accessories, lines and other equipment as may be selected by the operator.

## CYLINDER HEADS

The twelve interchangeable alloy iron cylinder heads are especially designed and fabricated for the temperatures and pressures of industrial use. Each head carries complete rocker arm and valve mechanism for one cyl-



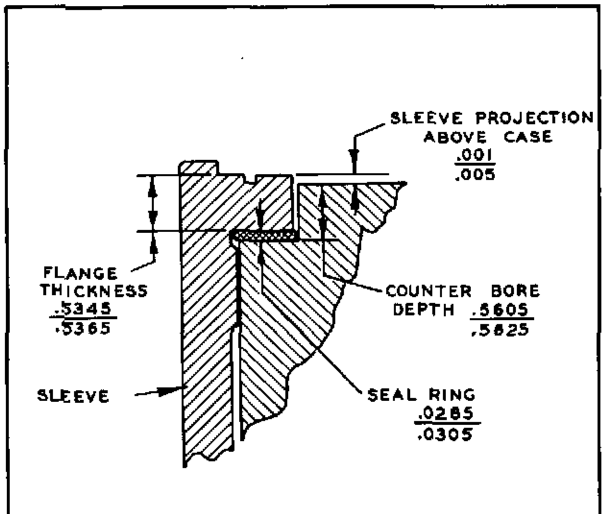

CYLINDER HEAD - EXPLODED VIEW

inder. Cast aluminum rocker arm covers are interchangeable. However, if the rocker arm covers are interchanged, new rocker arm cover gaskets must be used. Hard Stellite seat inserts are shrunk into place in both intake and exhaust valve seats. The intake manifolds are mounted on the right and left sides of the right and left cylinder banks, respectively, and the exhaust manifolds are mounted between the two cylinder banks. Each head has mount pads for this purpose. In addition, a smaller exit from the head in the pad area above the exhaust port provides a water inlet to the water cooled exhaust manifolds which are used as an upper collection point for cooling water after the water has passed through the engine. Water passages in the heads are arranged for directional coolant flow to eliminate hot spots.

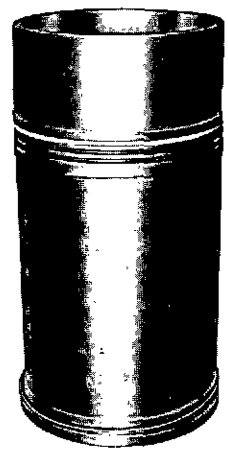
When replacing cylinder heads or after overhaul, the cylinder head hold down stud nuts should be retightened to the proper torque values after running the engine either idle or after load testing if possible. It is equally important that the stud nuts be tightened in the proper sequence as illustrated in the fits and clearances section at the rear of this manual.

## SLEEVES

The wet-type, interchangeable and easily replaceable cylinder sleeves are cast from close grained alloy iron especially selected and machined for oil retention, long wearing qualities, and resistance to distortion. Each sleeve has a shoulder and grooved flange at its upper end to locate it in the crankcase upper deck and prevent shifting and leakage when the cylinder head and gasket are secured above it. The sleeve flange and the crankcase deck recess into which it fits both have precision finished mating surfaces to form a water seal at this point. Additional sealing efficiency is achieved through the usage of a copper sealing ring between the sleeve flange and crankcase recess. The cylinder sleeve flange projects a few thousandths above the deck to ensure a tight crush at the gasket joint. Whenever sleeves are installed a check should be made to be sure that this projection is present.




SLEEVE PROJECTION WITH SEALING RING

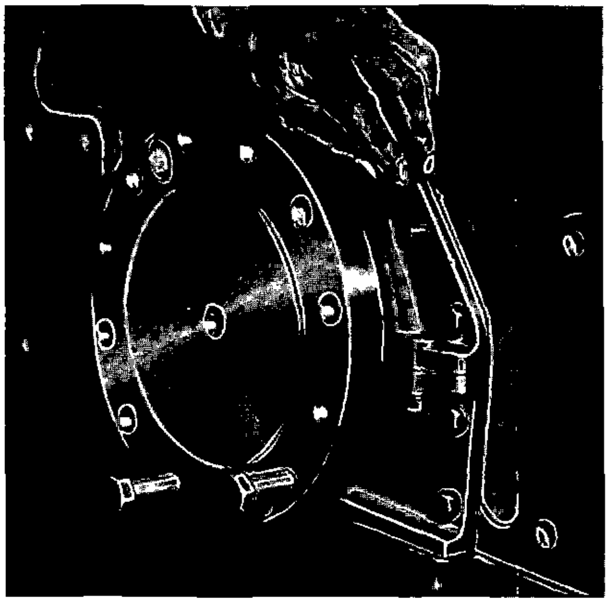


CYLINDER SLEEVE WITH SEALING RINGS

The outer surface of the sleeve lower end is tapered, and immediately above the taper are three grooves for the seal rings. Two synthetic rings of like color are used in the two upper sleeve grooves while a ring of different color is installed in the bottom groove. Engines with special cooling use a Teflon seal ring in the bottom groove.

## CRANKSHAFT

The Model L-5790-G dynamically balanced crankshaft is precision ground from drop-forged, heat-treated steel and gains unusual operating smoothness from a torsional vibration damper. Crankcheeks are of massive design to provide ruggedness for hard, continuous service. The crankshaft has seven locally-hardened main bearing journals which run in precision-type steel-backed, aluminum bearing shells. Connecting rod bearings are of similar construction for maximum serviceability. Drilled passages, running diagonally from the main-bearing journals through the crankcheeks, carry

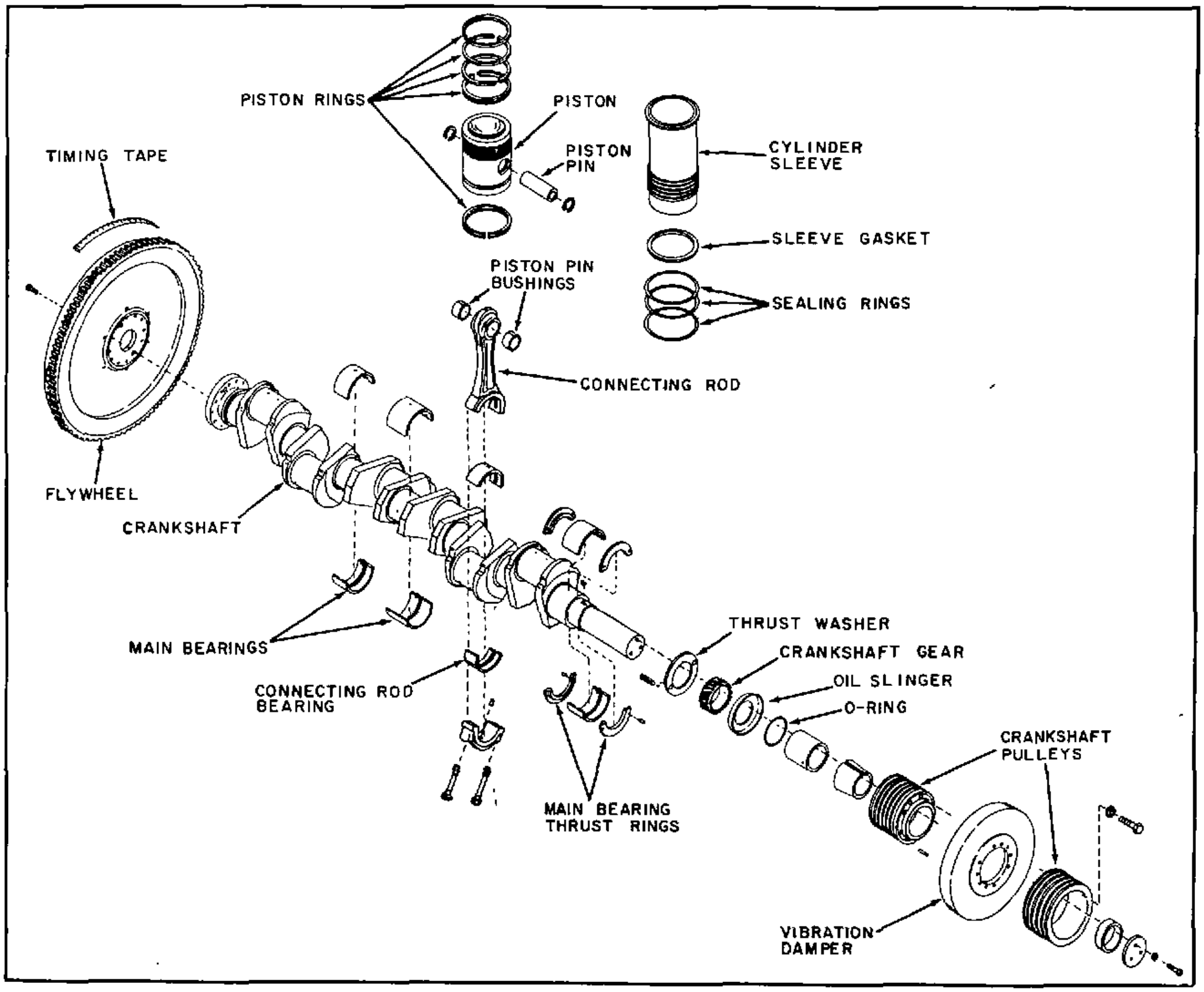


REAR OIL RETAINER INSTALLATION

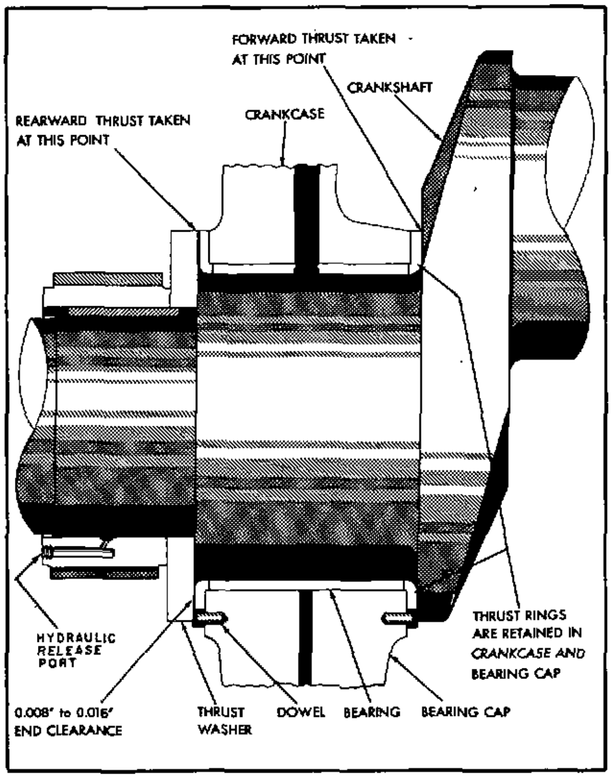
pressure oil to the connecting rod bearing areas. In addition to the spiral grooves which reverse the rearward flow of oil, a graphite coated packing type rear oil seal protects against oil leakage at the flywheel end of the crankshaft. The oil seal, which is split for replacement purposes, is held securely in position by grooves in the removable rear oil seal retainer upper and lower halves.

The rear extremity of the shaft has an integral mounting flange for the flywheel. This flange is drilled and tapped for twelve 5/8 - 18 flywheel mounting bolts. One bolt hole, opposite number six crankpin, is offset 1/8 inch in order to ensure the installation of the flywheel in the proper relationship to the crankshaft.

The front crankshaft journal blends into a finished shoulder designed to absorb thrust loads. This shoulder bears against a two piece bronze thrust ring which is one of two rings




CRANKSHAFT - PISTONS - CONNECTING RODS - BEARINGS



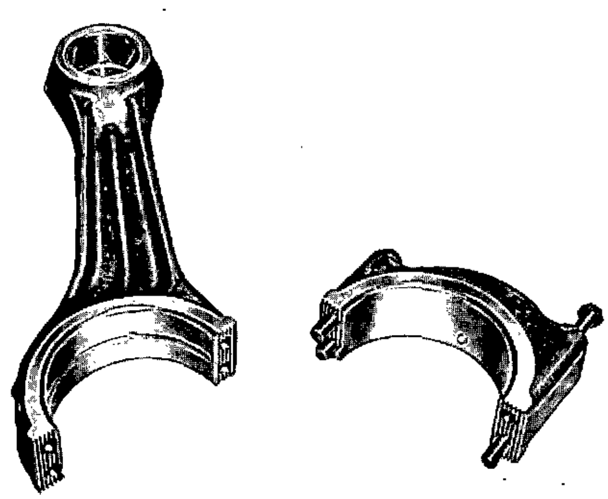

CRANKSHAFT END PLAY

doweled in place on each side of the front main bearing. Thrust forces acting to move the crankshaft rearward are absorbed by a polished steel thrust washer bearing against the front thrust ring. The crankshaft end play is controlled by the amount that the crankshaft can move before either one of the thrust surfaces contacts the front or rear thrust ring. Oversize thrust rings are available. The crankshaft drive gear is located directly ahead of the thrust washer and is keyed to the crankshaft. A dish-shaped oil slinger ring rides against the outer face of the crankshaft drive gear.

The front crankshaft extension supports a fan and water pump drive pulley and a vibration damper.

## CONNECTING RODS

Twelve drop-forged connecting rods of I-section, rifle-drilled design, are employed in the L-5790-G. The rods are forged and heat treated in one piece, then separated and serrated at the crankpin end before being assembled and machined to accommodate the steel-backed precision type aluminum bearings. The serrations ensure positive alignment. Hard bronze bushings are press-fitted and broached in the piston pin end and then diamond bored

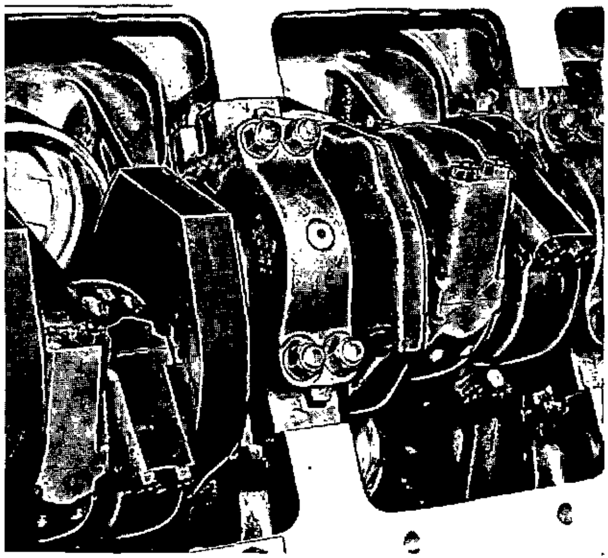


CONNECTING ROD WITH CAP REMOVED

for precise size and alignment. These bushings are used as a master reference for finish boring the large end bearing seat. For this reason the connecting rods are never bent for alignment either at the factory or in the field.

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. A recent change in production engines identifies the special size bolt hole by an "X" mark on the surface of the connecting rod cap where it is machined flat for cap screw head seating and in the immediate area of the special bolt hole. A similar mark should be applied during overhaul to engines in the field if they have not been marked in this manner. The serrations on one side of the rod and cap are offset from the serrations on the other side of the rod and cap, so that it will be immediately apparent if an attempt were made accidentally to install a cap and bearing shell in reverse position on the rod. Whenever reinstalling connecting rods, inspect serrations just prior to installation of cap to ensure that serrations are free of chips, dirt particles, and burrs.

It will be noted that the split line of the rod and cap is not at a right angle with the rod center line, but is at a 30° angle. The connecting rod arrangement is of the side-by-side type, with opposing connecting rods operating from a single wide-area crankpin. The right bank cylinders are slightly ahead of the left bank cylinders and therefore the right bank connecting rods are towards the front of each crankpin with the rod cap angled towards the left bank. The reverse



CONNECTING RODS CORRECTLY INSTALLED

is true for the left bank connecting rods. The rods must be installed correctly or they will interfere with the crankpin fillets. Rods are stamped (1R, 1L, etc.) to identify their cylinder bank location.

Early Model L-5108-G connecting rods have the split line of the rod at a right angle with the rod centerline and are marked "CHEEK SIDE" for installation, use bolts with self-locking nuts to retain the cap, and utilize dowels for cap locating purposes.

## PISTONS

The tin plated aluminum alloy pistons are heavy-duty castings of the cam-ground, tapered full skirt type. The five ring grooves are rectangular, with the top groove incorporating a ni-resist iron insert. The top ring is a crowned, plasma coated compression ring. The second and third rings are tapered face compression rings. The fourth ring is a conformable grooved oil ring with expander. The fifth ring (when used) is a grooved oil ring located below the piston pin. The two oil ring grooves have a number of drain passages leading to and providing oil control in the piston skirt area. The full floating tubular piston pin is hardened and lapped, and is a hand press fit in the piston bosses at room temperatures. Current Model L-5108-G and L-5790-G engines use a pin with a 1 inch ID while earlier models used a pin with a 1-1/2" ID. These piston pins are interchangeable in sets only. Spring clip retainers control the end travel of the pins.

## VALVE MECHANISM

There are four valves for each cylinder, two intake and two exhaust, symmetrically disposed around the spark plug to provide maximum breathing. The valves are of the poppet type with hardened tips. Stellite seat facings are employed on the valves and the valve seat inserts are Stellite. The valve guides are a special alloy. When replacing valves, valve seat inserts or valve guides, exercise caution to use service parts of the correct material. The valve seat inserts are retained by a shrink fit in the cylinder head and the intake and exhaust guides are a press fit in the cylinder head, but inserts and guides may be pulled and replaced if necessary. Valves and springs are retained by hardened washers stepped to center the springs and incorporating split-taper keepers. The intake valves utilize o-rings and oil shields for oil control. The oil shields should not contact the cylinder head walls. The o-rings and their lock rings are not reusable after removal and must be replaced with new parts. Intake and exhaust valves are identified by INT and EX. Do not interchange intake and exhaust valves.

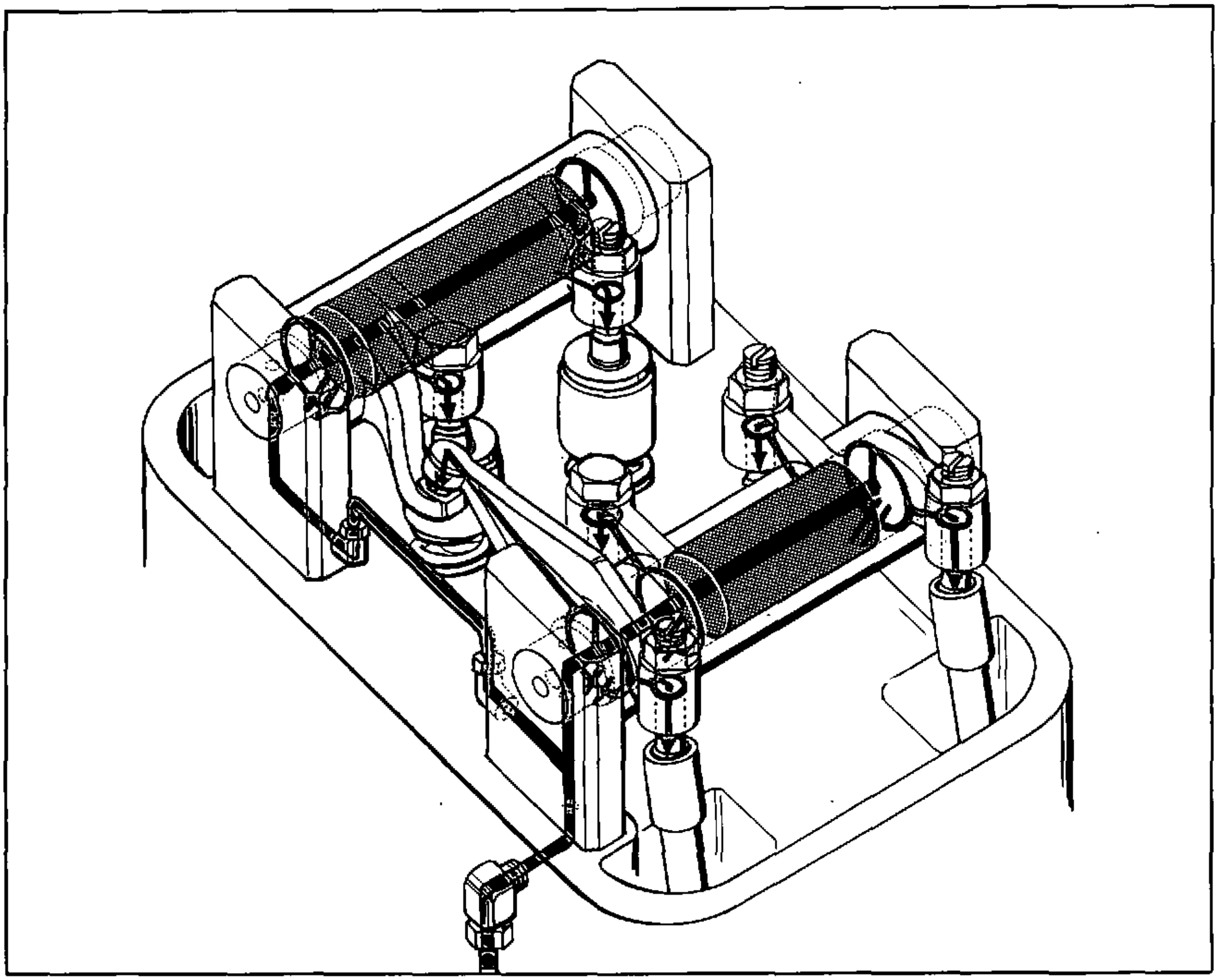
Valve actuation is obtained through guided roller cam followers riding on the cam lobes. This motion is transmitted to the rocker arms through tubular steel push rods which incorporate hydraulic valve lifters at the upper end.

The cam followers are firmly seated in cam follower guides, which are assembled to the camshaft covers. Two-piece hollow tubular steel push rod covers are retained by spring action. They are easily removed by hand, as they are located outside of the crankcase and in the "V" formed by the cylinder banks.

The exhaust rocker arm lever for each cylinder is equipped with rocker arm and hydraulic valve lifter adjusting screws and actuates both of the exhaust valves for the cylinder. The intake rocker arm is equipped with a hydraulic valve lifter adjusting screw and pivots on the same shaft as the exhaust rocker arm lever, but in turn actuates the intake rocker arm lever which is equipped with rocker arm adjusting screws to actuate both of the intake valves for the cylinder. The rocker arm adjusting screws incorporate a pivoting flatted ball to maintain constant non-sliding contact with the valve stem tips. The flatted balls are lubricated through passages in the rocker arm levers.

The ductile iron rocker arms and levers pivot on split-type, steel-backed, leaded bronze bushings riding on a hardened hollow steel shaft. The bronze bushings are pressed in place, lubrication passages are drilled, and the bushings are then reamed.

Full pressure lubricating oil from the rocker arm oil header is fed through a passage in the

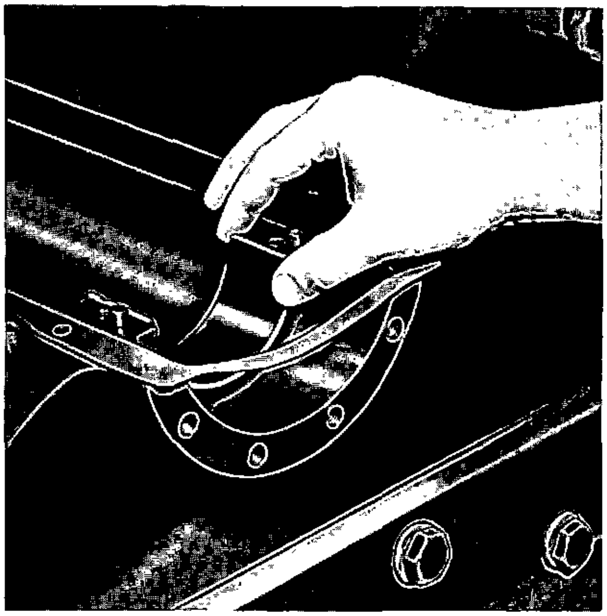


VALVE MECHANISM LUBRICATION SCHEMATIC

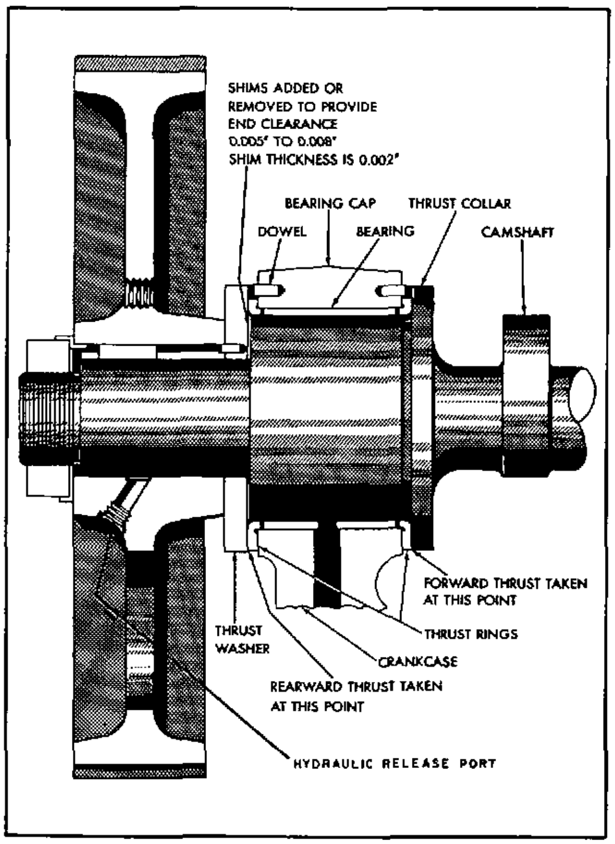
cylinder head which connects to an oil passage in the right hand exhaust rocker arm shaft support. The lubricating inlet passage in the plugged exhaust rocker arm shaft mates with the oil passage in the exhaust rocker arm shaft support. An oil tube connects the oil passage in the right hand intake rocker arm shaft support to the oil passage in the right hand exhaust rocker arm shaft support. The lubricating inlet passage in the plugged intake rocker arm shaft mates with the oil passage in the intake rocker arm shaft support. Both rocker arm shafts have oil passages to lubricate the intake rocker arm and the rocker arm levers. The intake rocker arm has an oil passage to lubricate the mating surfaces of the intake rocker arm and the intake rocker arm lever, as well as an oil passage to the hydraulic lifter adjusting screw to supply oil to the hydraulic lifter in the end of the intake push rod. A metering screw in the top of the intake rocker arm prevents over oiling of the mating surfaces of the intake rocker arm and the intake rocker arm lever. Current production engines utilize a slightly different lubricating passage without a metering screw. The exhaust rocker arm lever has oil passages to the hydraulic lifter adjusting screw to supply oil to the hydraulic lifter in the end of the exhaust push rod and to lubricate the rocker arm adjusting screw balls and the exhaust valve stems and guides. The intake rocker arm lever has oil passages to lubricate the rocker arm adjusting screw balls and the intake valve stems and guides.

### CAMSHAFT

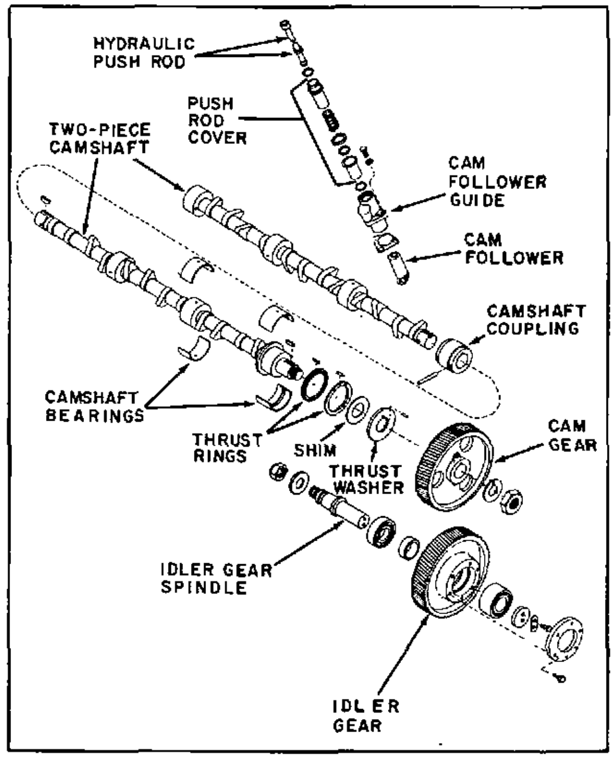
A single camshaft mounts in the "V" of the engine. Seven steel-backed babbitt-lined type bearings, aligned in this "V", support the camshaft at each end, at the center, and at four intermediate points. They are easily removed for inspection or replacement. The bearings are secured by cam bearing caps.



CAMSHAFT BEARINGS ARE REPLACEABLE




SHIM ADJUSTMENT FOR CAMSHAFT END PLAY

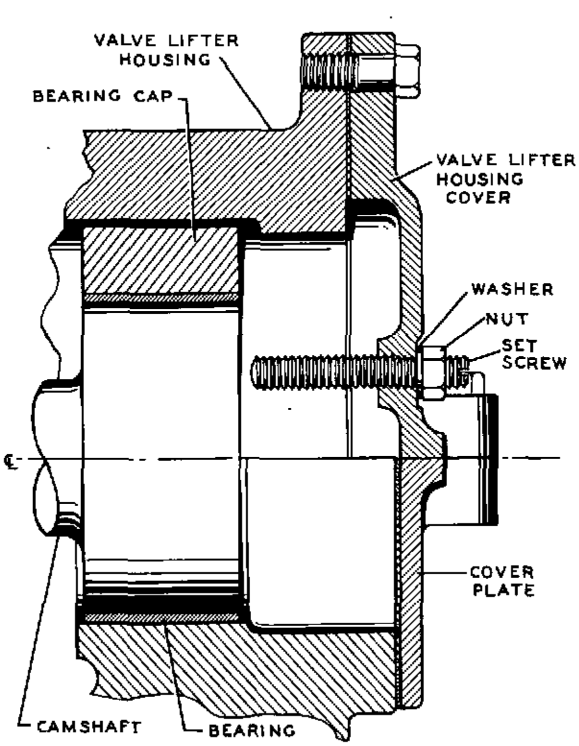



IDLER SHAFT, CAMSHAFT, AND VALVE OPERATING PARTS

Individual, hardened cams actuate each of the twenty-four cam followers. The forward end of the camshaft is keyed and threaded for the retention of the cam drive gear. Thrust and end play are absorbed by a steel thrust collar and a steel thrust washer which ride against bronze thrust rings. These thrust rings are doweled and piloted in the bore of the crankcase and the front camshaft bearing cap on each side of the front camshaft bearing. The camshaft end play is controlled by adding or removing selected shims between the forward thrust ring and the thrust washer as illustrated in the diagram. A two piece aluminum camshaft cover is drilled for lubrication of the cam followers and is finish machined to form a seal with the crankcase. A separate oil header, mounted above the camshaft cover, is supplied with full pressure oil at both ends from the main oil header and supplies oil to the overhead valve members.

Replacement of the gears in the cam drive-accessory drive set up is not recommended as a field procedure.

To facilitate cam gear removal without disturbing end play of the camshaft, a setscrew is provided at the flywheel end of the rear camshaft cover. As this setscrew is only for cam gear removal, it must not contact the camshaft while the engine is operating.




CAMSHAFT SETSCREW FOR GEAR INSTALLATION

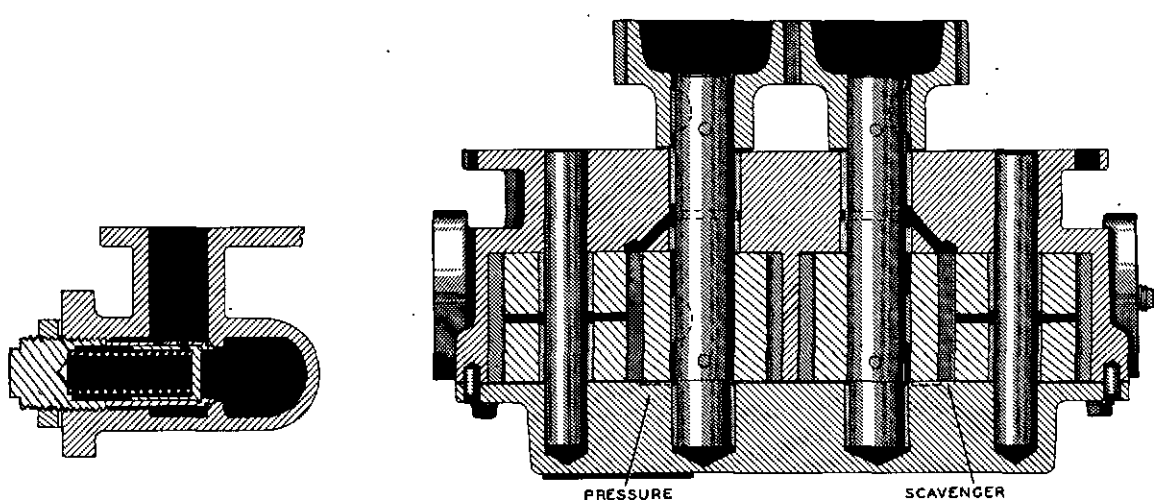
## OIL PUMP

The Model L-5790-G uses an externally mounted, gear-type, pressure oil pump with a large reserve capacity. The pump consists of a cast body unit and removable cover, which together act as a housing for the two oil pump gears. The oil-pump drive gear is keyed and pinned to the heat-treated drive shaft which runs in replaceable bushings in the housing and cover. The oil-pump idler gear, like the drive shaft, has replaceable bushings for long wear and continued accuracy of displacement. Combination pressure and scavenger type oil pumps and low speed dual capacity oil pumps both utilize two sets of pumping gears.

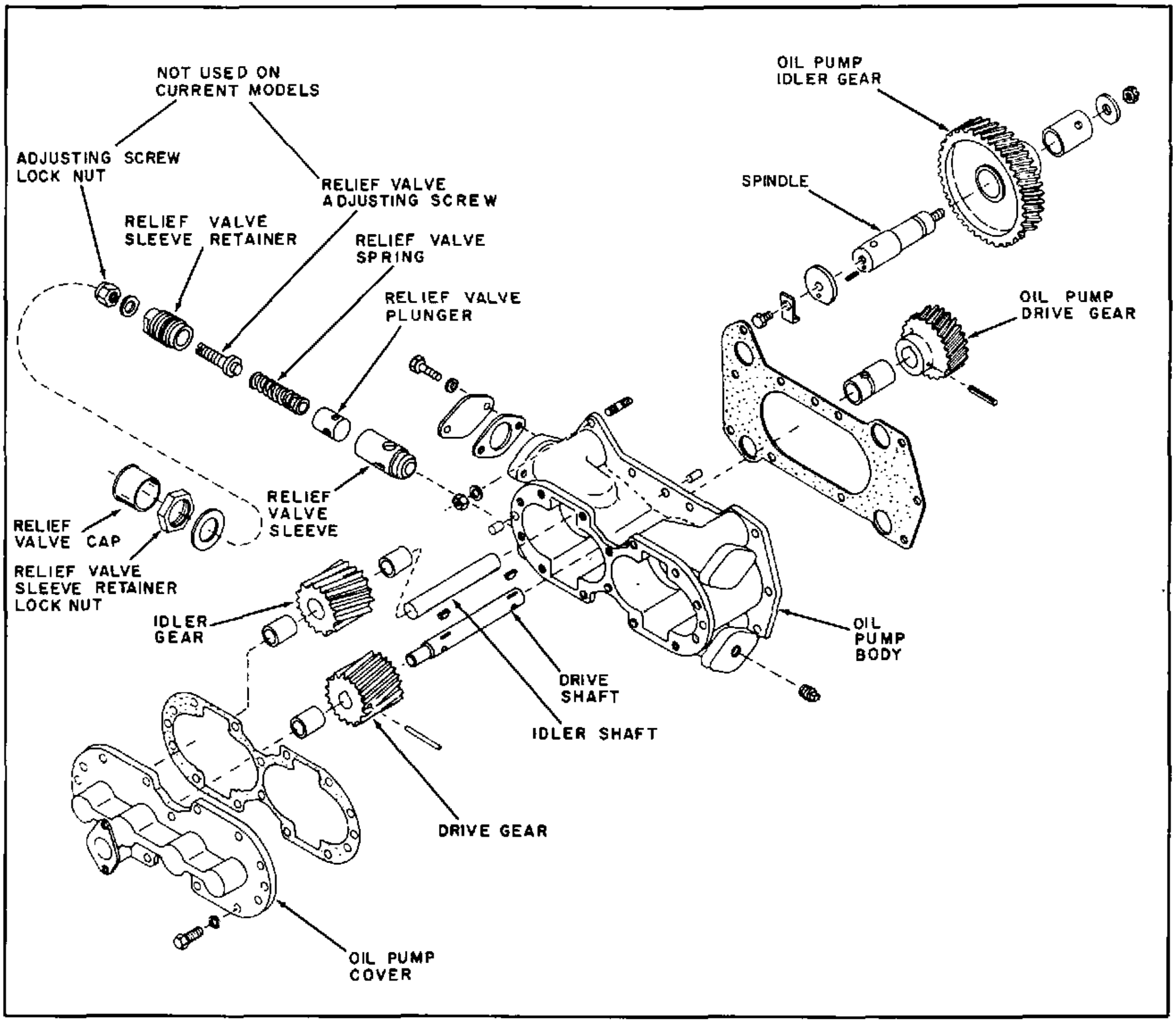
The oil-pump cover to oil-pump body seal is effected by a paper gasket of 0.017 to 0.019 inch thickness. Substitution of thinner or thicker gasket materials will disturb the end-clearance relationship of the pump gears.

## LUBRICATION SYSTEM

The Model L-5790-G uses a wet-sump, pressure lubrication system with the additional feature of oil cooling. With the exception of the oil that normally remains in the lines, filters, and passages, the entire oil supply of the engine is retained in the engine base.




OIL PUMP - SECTIONAL VIEW

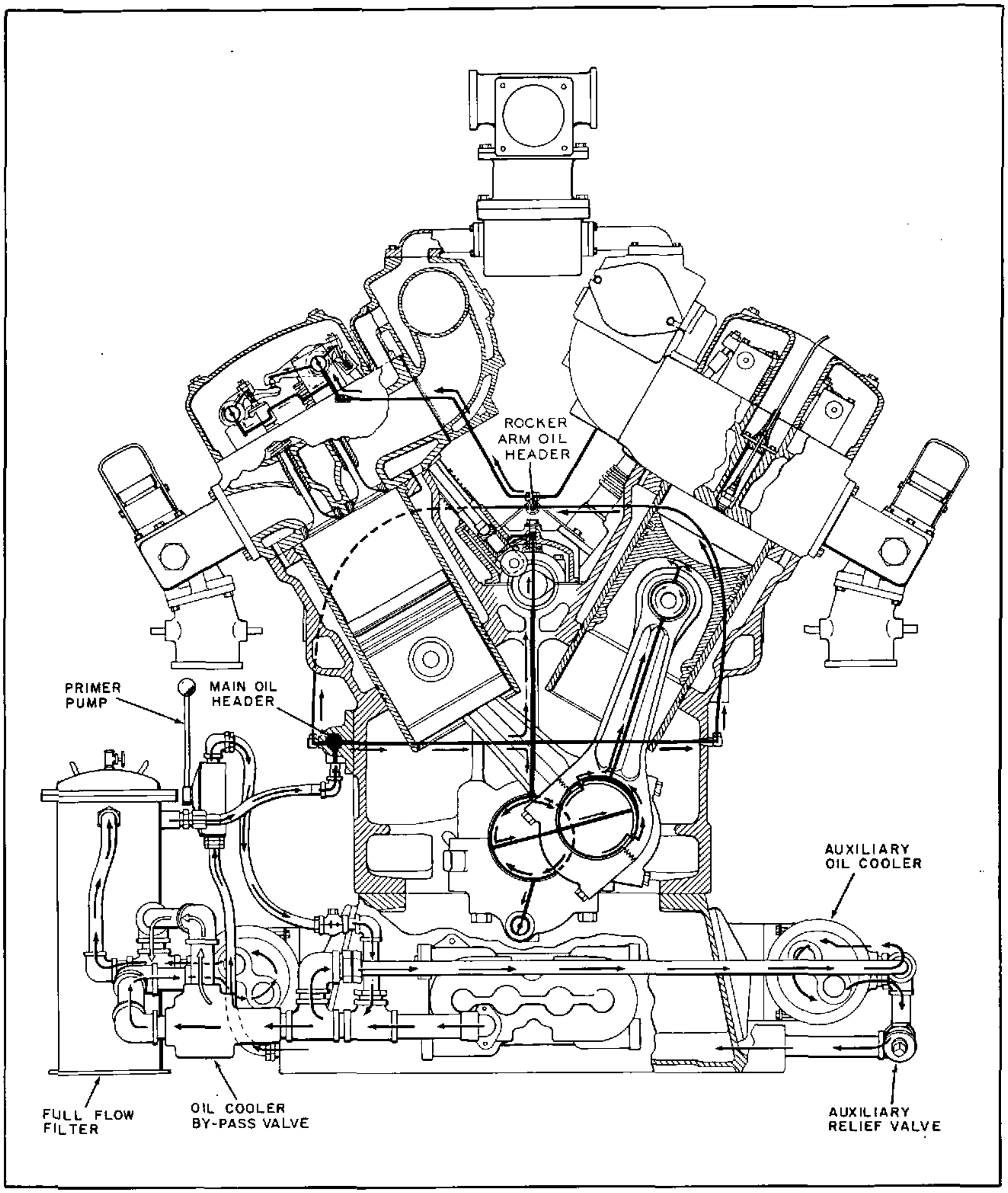



OIL PUMP - EXPLODED VIEW

The suction produced on the inlet side of the oil pressure pump gears draws the oil into the oil-level equalizers and screens in the sump, from which it passes to connections on the lower rear face of the pump. Having entered the oil pump, the oil is carried around the space between the gear teeth and the pump walls by the mechanical action of the oil pump gears and is discharged under pressure at the front of the pump.

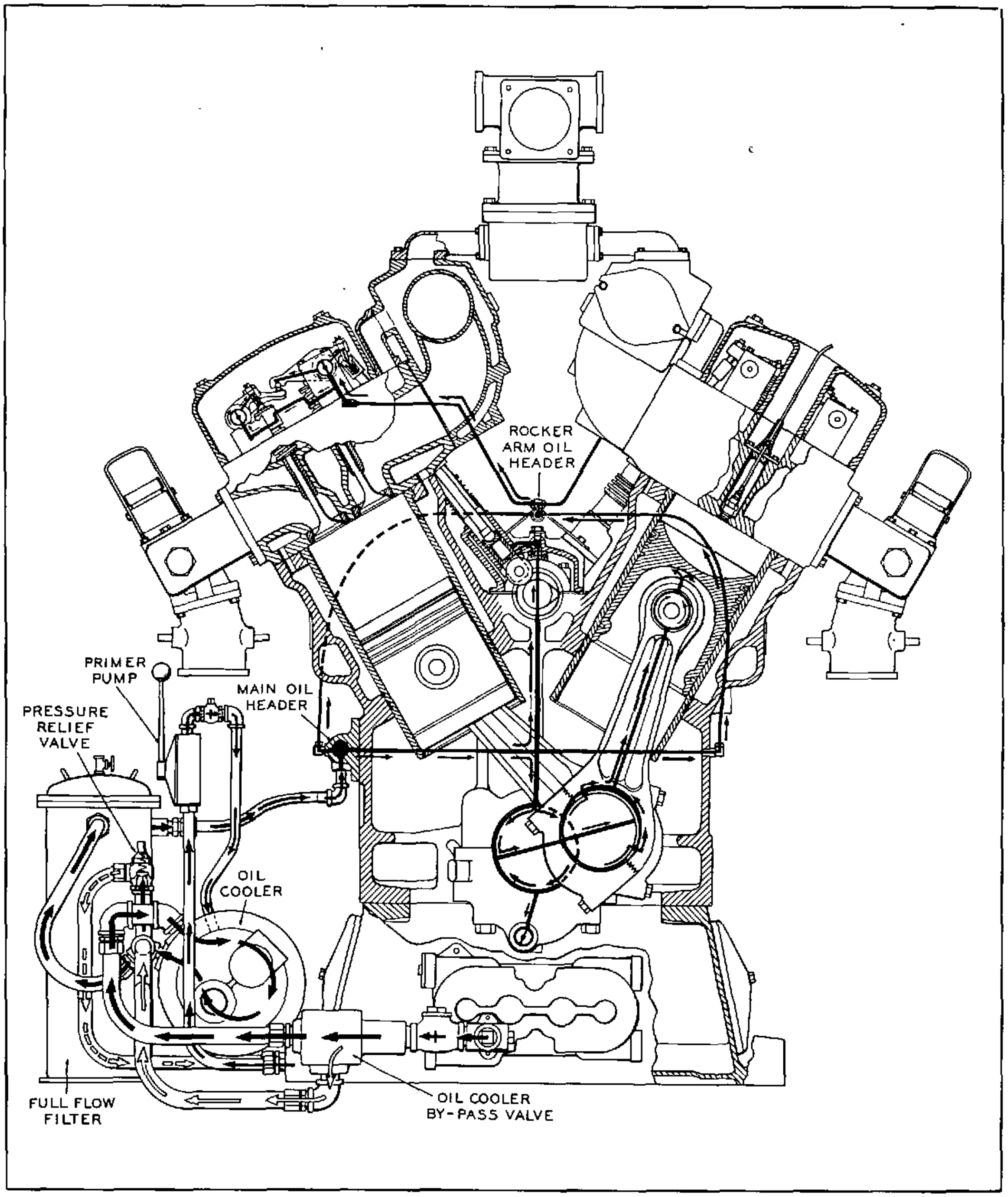
After being discharged from the pump, the oil passes through a short line to the oil cooler on the right side of the engine where it flows around the cooling tubes, giving up heat to the water. A temperature control valve in the oil line allows the oil to by-pass the cooler as necessary to maintain a nominal temperature of 170°F. From the cooler, the oil enters the top of the full flow filter through a flexible line and after being filtered, returns from the top of the filter through a flexible line to the main oil header which extends lengthwise along the right side of the engine. Oil under pressure is therefore distributed the full length of the header.

A portion of the oil is continuously shunted through the auxiliary oil cooler which mounts on the left side of the engine, and is then returned to the oil sump. This oil cooler is equipped with a separate relief valve so that it doesn't by-pass oil to the sump until engine oil pressure has built up to a sufficient value. Current Model L-5790-G engines utilize only a single large oil cooler which mounts on the right side of the engine with a relief valve to control oil header pressure and to continuously by-pass a portion of the cooled oil to the engine sump.




LUBRICATION SYSTEM SCHEMATIC - WITH DUAL OIL COOLERS

The oil pump pressure relief valve opens off the main oil passage of the pump. A spring-loaded piston of conventional design moves outward to relieve oil pressure through a spill-back to the sump. The pressure at which this occurs is controlled by the screw adjustment regulating spring tension on the valve. The pressure relief valve is adjusted at the factory and




LUBRICATION SYSTEM SCHEMATIC - WITH SINGLE OIL COOLER

should not require attention for a long period of service unless disturbed. Current Model L-5790-G engines incorporate a non-adjustable oil pump pressure relief valve.

The oil, with the exception of that by-passed through the pressure relief valve, flows through the main oil gallery under controlled pressure and enters the drilled passages through the crankcase webs to each crankshaft main bearing journal and camshaft bearing. Each journal is drilled diagonally to provide a passage leading through the crankcheek and emerging at the crankpin to lubricate the connecting rod bearings. Some of this oil leaves the connecting rod bearings through the bearing side clearance, the remainder passes upwards through the rifle-drilled connecting rods to lubricate the piston pin bushing. Oil from both of these sources sprays or splashes on the cylinder walls and is metered by the rings for piston lubrication. In addition, a jet of oil from the upper end of the connecting rod is directed at the lower side of the piston crown, thus providing a cooling action and preventing heat concentration in this area.

Drilled passages from the front main bearing journal provide, through oil tubes, for oiling the gear train and the accessory drives.

A separate oil header, mounted above the camshaft cover, is supplied with full pressure oil at both ends from the main oil header and supplies oil to the overhead valve members. Both ends of this oil header are equipped with magnetic plugs as a precautionary measure. The cylinder heads are equipped with fittings and tubes leading to the rocker arm lubricating system. Scavenger oil drains back through passages in the heads and through the tappet compartments via the space around the push rods.

The oil filter system is full-flow, and, with full-flow filtering, all oil in the pressure system must go through the filter or its by-pass valve before entering the engine bearings. A dirt-clogged filter will cause the dirty oil to by-pass and enter the engine.

Oil for the turbochargers is piped directly from the main oil header under full pressure and is returned to the rear valve tappet housing which drains to the oil pan. Both turbocharger oil supply lines are equipped with magnetic plugs as a precautionary measure.

## OIL COOLERS

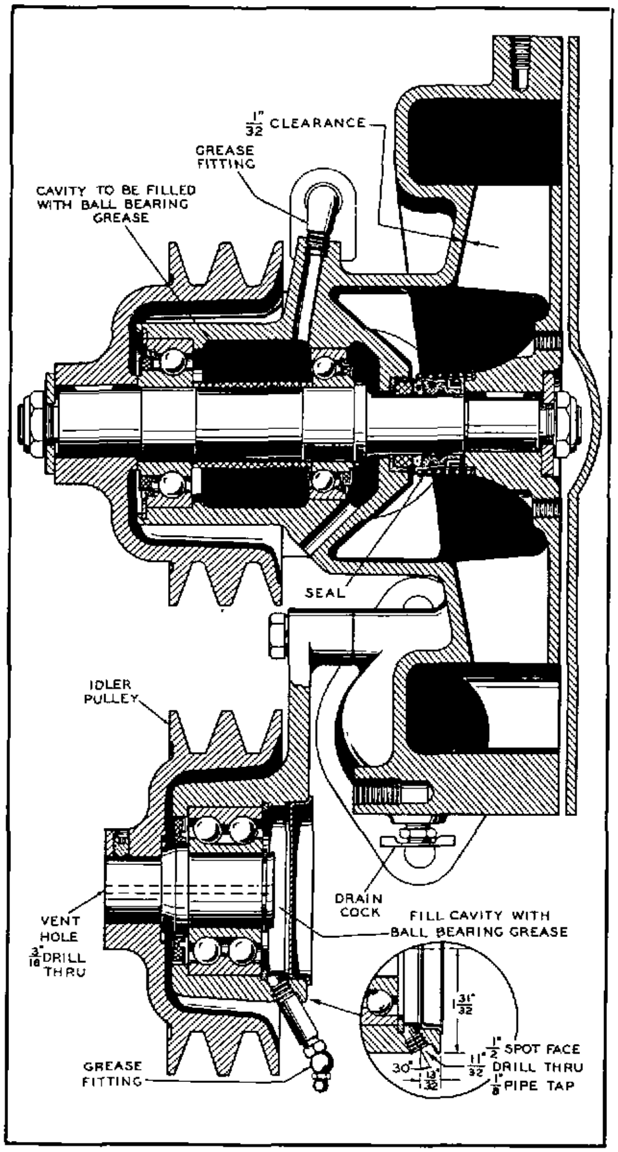
To assist in maintaining proper oil temperature and viscosity, the Model L-5790-G engines are equipped with an oil cooler located on the right front side of the oil pan, with an auxiliary cooler mounted on the left front side of the oil pan. Current engines use only a large single oil cooler which is mounted on the right front side of the engine. A belt driven auxiliary water pump, mounted at the left front of the engine, supplies coolant to the oil cooler(s) and to the intercooler (when applicable). There are provisions for draining both the oil and water from the coolers. The interior of the cooler provides a tube and baffle heat exchanger into which oil enters from the pump. Oil leaving the right side oil cooler passes through the full flow filter and then into the engine main oil header. A portion of the oil pump output is by-passed to the auxiliary cooler for additional cooling. Since two pressure relief valves are installed in the dual cooler installation, proper adjustment of the valves must be made to prohibit excessive oil by-pass to the auxiliary cooler. Refer to the service section for adjustment of relief valves. The large single oil cooler returns part of its output to the engine oil sump.

## WATER PUMP

Model L-5790-G engines use a single centrifugal type water pump which is mounted on the center of the gear cover and is driven by two belts from the crankshaft pulley. The pump itself is a vaned impeller, mounted on a hardened shaft, and operating in the chamber formed between the cast water-pump body and the water-pump cover. This is a self-contained pump with a ball bearing supported shaft and a spring packed carbon type seal on the pump shaft to prevent water seepage. When replacing the water pump seal, carefully wipe the carbon 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. Do not lubricate or grease the seal mating surfaces. The pump is lubricated with ball and roller bearing grease. To insure complete draining of the cooling system, a drain cock is provided at the bottom of the pump casting. For venting the pump when filling the cooling system, an air bleed vent is provided at the top of the pump casting. An adjustable idler pulley provides the belt tension adjustment. The idler pulley is lubricated with ball and roller bearing grease.

## COOLING SYSTEM

The cooling system used on the Model L-5790-G is of the pressure circulating type and can be connected to a variety of external cooling devices such as radiators, cooling towers, heat exchangers, and so on. Maximum back pressure, feeding into the cooling devices, should not exceed 4 lb.




WATER PUMP - SECTIONAL VIEW

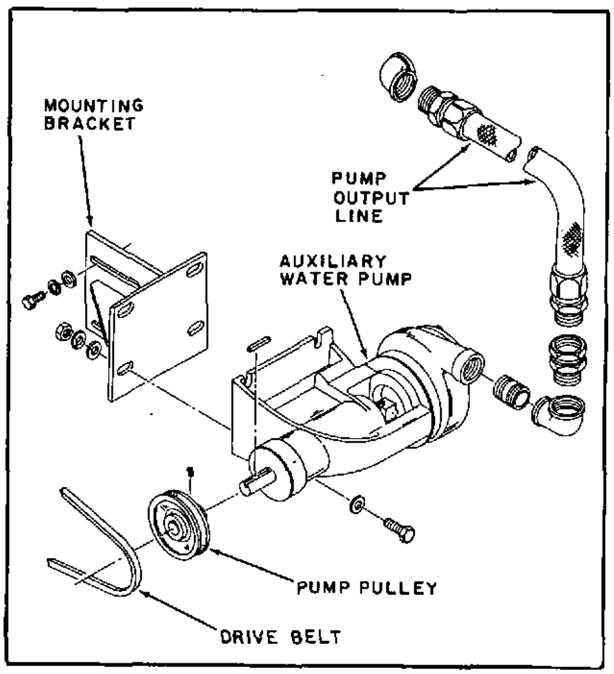
per square inch at 900 rpm. The water enters through the water pump inlet on both sides of the engine. The centrifugal pump causes the supply of cooling water to pass directly into the engine cylinder jacket through the water headers which extend on each side of the crankcase for its entire length. Here, heat is picked up from the cylinder sleeves which are surrounded for nearly their entire length by circulating water. Carefully located holes allow the water to enter the cored cylinder heads in the desired pattern. To ensure effective cooling of the cylinder head between the intake and exhaust valve seats, the flow of water is accurately directed in this area. The water cooled manifolds which are located between the cylinder banks of the engine collect the water at each cylinder head and feed it through the thermostat housing to the radiator or other cooling system.

The thermostat housing is a butterfly design which has all vital components outside of the water flow. Thus, only the butterflies are subjected to the possible corrosive effect of the coolant. When the engine is cold, most, or all, of the water will by-pass to enter the water pump for re-circulation. When the engine is warmed up and operating normally, the entire flow passes out of the engine for cooling, unless temperatures are marginal, in which case occasional by-passing will occur.

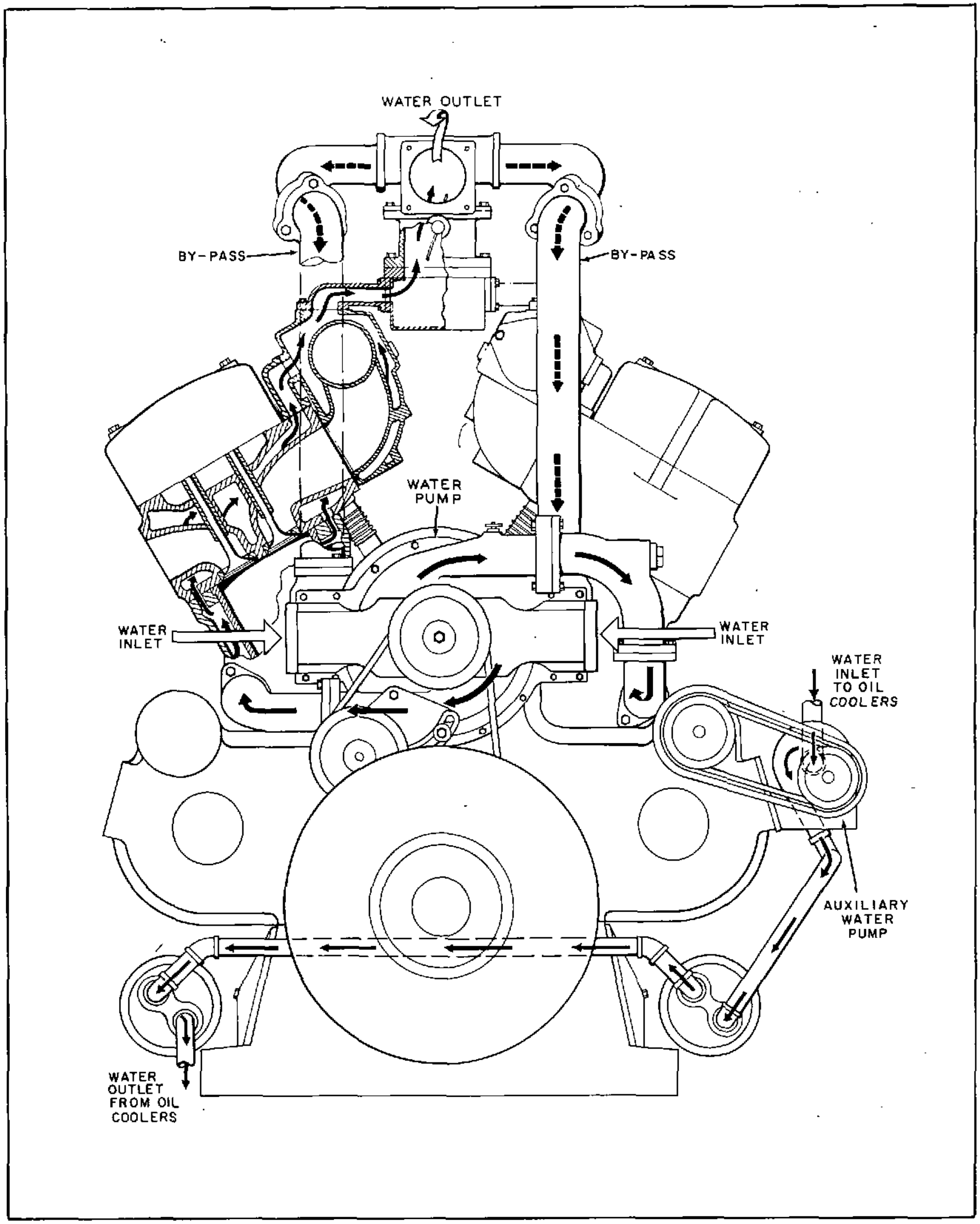
A belt driven auxiliary water pump, mounted at the left front of the engine, supplies coolant to the oil cooler(s), and when applicable, to the intercooler.

For the FC starting engine, cooling water is tapped off from a fitting at the rear of the crankcase, passed through the FC, and returned to the main engine system through a line leading to the water cooled exhaust manifold. If the main engine is cold, heated water from the FC passes through the by-pass and back into the circulating system of the main engine as an aid to warming prior to starting.

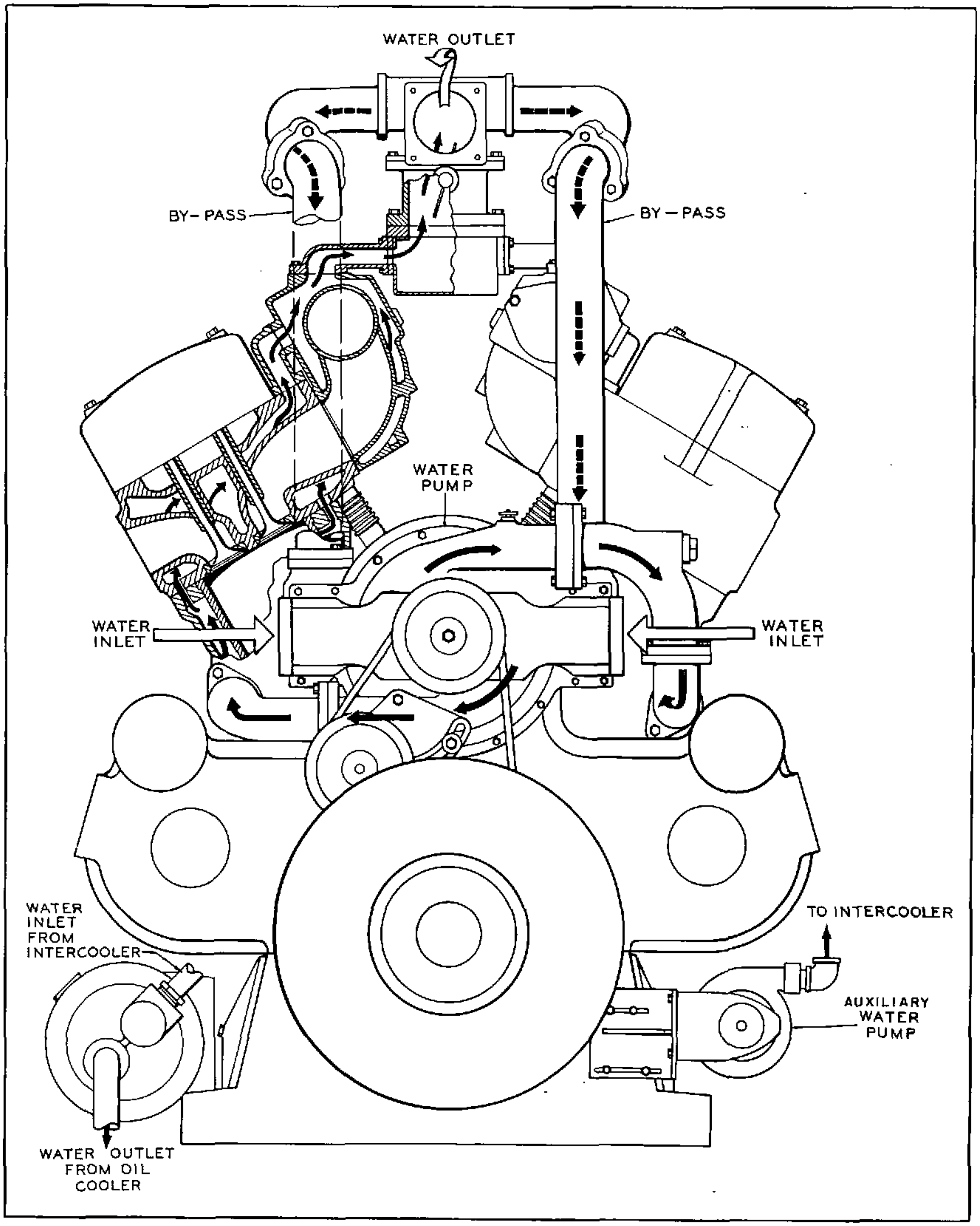
Perfect cooling system performance requires a clean cooling system without leaks. When filling the cooling system of an engine which



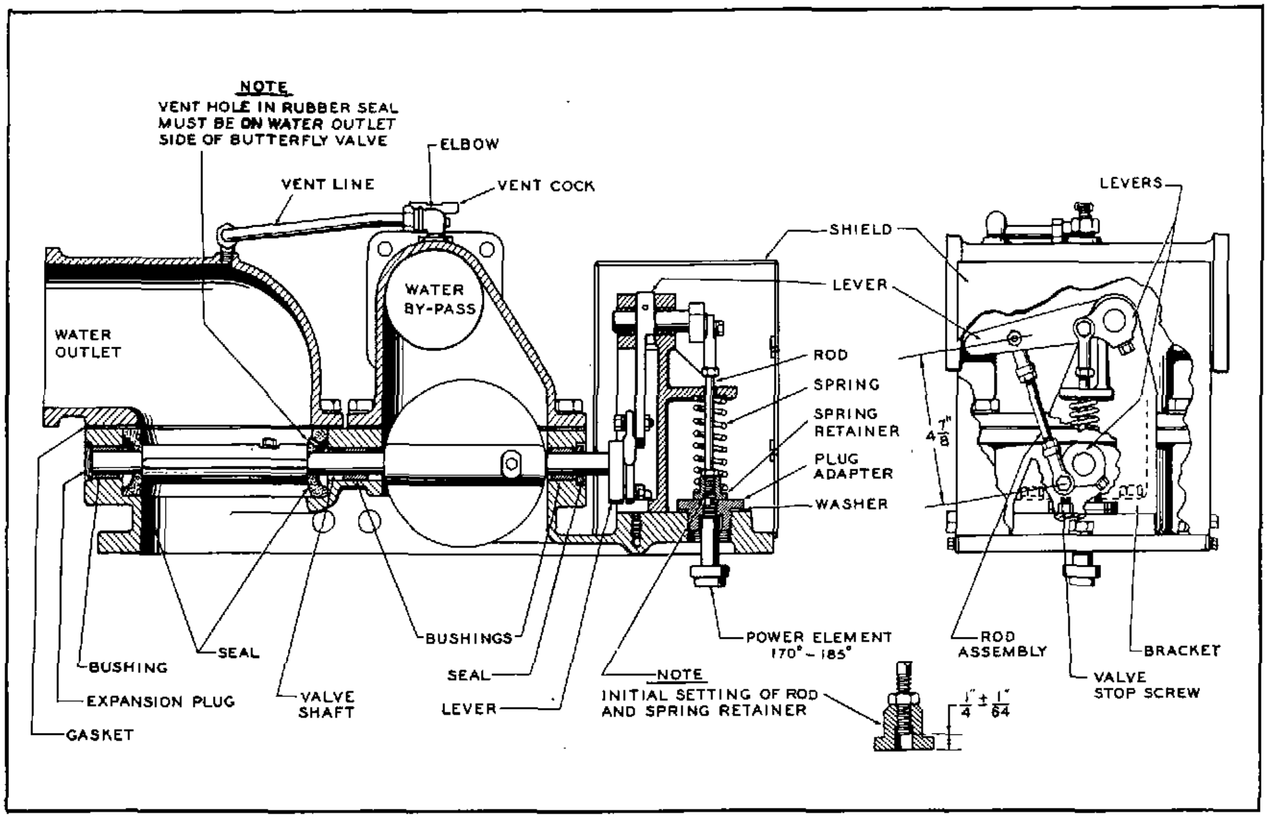

AUXILIARY WATER PUMP




*COOLING SYSTEM SCHEMATIC – WITH DUAL OIL COOLERS*




COOLING SYSTEM SCHEMATIC – WITH SINGLE OIL COOLER




THERMOSTATIC VALVE ASSEMBLY

has been drained, be sure to open the air bleed vent in the thermostat housing to allow any air trapped in the system to escape. Close the air bleed vent when air has been purged and a solid stream of water begins to flow. The water pump is also equipped with an air bleed vent which should be opened when filling the cooling system until any air trapped in the pump has escaped.

## ACCESSORY DRIVES

The magnetos (or one breakerless ignition generator, when applicable) used on the Model L-5790-G engines are coupled to and driven by the magneto drive shafts which are driven by the accessory drive shafts. Both the magneto drive shafts and the accessory drive shafts ride in ball bearings in the accessory drive housings. The accessory drive shafts are driven by the accessory drive gears in the engine gear train.

The governor and the overspeed governor are driven off the right hand accessory drive, while the hour meter and the tachometer can be driven off either the right hand or the left hand accessory drive.

## STARTING ENGINE

The Model FC starting engine commonly employed on the Model L-5790-G is a conventional four-stroke cycle gasoline engine with magneto ignition. This engine uses a manually operated Bendix device for driving the starter pinion.

# SERVICE

## GENERAL

The service life of any engine can be greatly extended if a regular and complete maintenance program is established and strictly adhered to. Even with the best maintenance, however, an engine can encounter trouble if such things as proper mounting, alignment with other equipment, flywheel run-out and sufficient crankshaft endplay are disregarded in the initial installation or in subsequent relocations of the engine. Although flywheel run-out and crankshaft endplay are firmly established within limits at the factory such things as rough handling or improper installation of power take-offs or clutches may adversely affect these clearances and lead to serious engine damage. These things should be checked prior to operation. A well established maintenance program ensures that all of the following factors are prevalent throughout an engine's normal service life.

1. Clean lubricant of proper grade and viscosity for the operating conditions.
2. Clean fuel of proper net BTU content.
3. Clean air and correct fuel-air mixture.
4. Correct valve adjustments.
5. Hot, properly timed ignition system.
6. Even, high compression pressures.
7. Operation within proper temperature range.
8. Proper engine timing.

Attention to the above and the many related factors can often spell the difference between good performance and trouble.

## LUBRICATION

The performance of a lubricant, like that of any manufactured product, is the responsibility of the refiner and producer. Also, the engine operator, to a large degree, controls the oil's performance, for he is the one who must make decisions on oil changes, filter changes, loads, general maintenance, and operating conditions. A tabulation of lubricant producers and marketers, together with the performance grades for which the producers have indicated their products are qualified, is available from the Engine Manufacturers Association (EMA), 333 North Michigan Avenue, Chicago, Illinois - 60601. The Waukesha Motor Company has made it a practice not to recommend oil by brand name.

NOTE

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

For Class B engines operating on gaseous fuels, Waukesha Motor Company recommends oils compounded for gas engine operation. In addition, the oil shall have 5,000 PPM of barium, calcium, or combination of both with a maximum of .03 percent zinc. In addition the sulfated ash level should be 2 to 3.4% by weight. Some lower ash oils give satisfactory performance, but experience shows that valve and valve seat wear are improved when oils having a high ash level are used.

We have seen considerable evidence, pointing to failure of some low ash and ashless lube oils, compounded especially for natural gas engines, to retard valve and seat wear.

Our inspection of a considerable number of cylinder heads has also revealed the formation of lacquer on valve stems that could be avoided, providing the oil is changed more frequently.

Waukesha laboratory tests, conducted over a period of several years and verified by some of the major oil companies, have indicated a dramatic reduction in the rate of valve and seat wear when lube oils, with 5,000 parts per million of Barium, Calcium or combination of both is used. There is now a feeling that the Zinc content of these Series 3 lube oils should be held to a minimum, especially when the gas engines are turbocharged, to reduce fouling of turbo rotating parts and nozzle rings.

Our experience during the past year has influenced us to again specify lube oils containing 5,000 parts per million of Barium, Calcium or combination of both for Waukesha gas engines.

We are completely aware that some suppliers of lube oil will prefer to disregard our recommendation and may continue to use special gas engine oils in their engines. In addition, we are aware that some engines will not tolerate Series 3 lube oils, due to build-up of deposits in combustion chamber areas. This problem does not exist in our L-5790-G engines.

It is necessary for us to emphasize the importance of our recommendation. Waukesha will not accept responsibility for excessively rapid valve and seat wear unless these new recommendations are followed.

Many owners will request a list of lube oils that meet our recommendation and we have contacted many of the lube oil suppliers, to obtain their reaction and their reference to the specific oils that do conform. A list of such oils is available from the Waukesha Motor Company or any of its field agencies.

Multi-viscosity oil should be used only where cold starting conditions make it necessary. The oil supplier should assume full responsibility for satisfactory performance of the multi-viscosity oil at both low and normal engine operating temperatures.

## OIL CAPACITY

The oil capacity of the Model L-5790-G *with-out filters or other equipment is specified* in the fits and clearances section. When the large capacity Waukesha 14-element full-flow filter is used an additional 30 gallons of oil will be required. If additional filters or other engine lubricated equipment is used, the capacity should be determined and the correct amount added. Engines operating with a full-flow type oil filter must have the filter prefilled. Prefilling the filter is necessary because the engine will be starved for oil until the filter and lines are filled. Use the lubricating oil primer pump and open the filter vent cock when prefilling the filter.

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

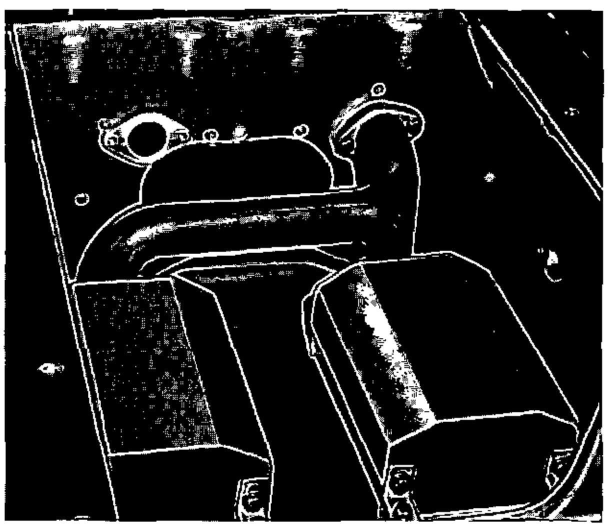
## OIL CHANGES

The crankcase level should be checked prior to each day's engine operation and at the same time the condition of the oil as revealed on the bayonet gauge should be observed carefully. Replace oil at any time it is plainly diluted, broken down, thickened by sludge, or otherwise deteriorated. Remember that some modern oils cannot be judged on the basis of color alone because the additives are intended to hold carbon particles in suspension. The standard filter supplied will not remove these particles. The dark appearance of the oil is not necessarily an indication that the oil should be changed. Whenever oil is changed, the filter must be serviced, unless the filter is equipped with pressure gauges to indicate differential pressure, and the filter must then be serviced when a 15 psi drop across the filter is indicated. 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 indicates the suitability of a shorter or longer change period. One part of this analysis is monitoring the viscosity change, which should not exceed two SAE grades from the new oil. When extended drain periods are contemplated, the supplier's analysis, or that of a reputable laboratory, should determine the suitability of oil for further service. Not all oils in every type of engine will give maximum service, therefore be careful to examine the oil after the first draining to determine whether it is standing up in service. Trial periods of ten hours are suggested and at the end of such periods make careful inspection of the oil depth gauge for sludging, frothing, and emulsification. Such conditions call for more frequent changes or a different oil. In winter operation, low oil temperatures (below 160° F.) are particularly likely to cause sludge formation. Temperature-control devices—curtains, shutters, and so on—should be used if needed in order to hold the oil temperature around 180° F.

## OIL SCREENS AND MAGNETIC PLUGS

Incidental to changing the oil, and very important to maintaining proper lubrication, is the removal and cleaning of the screen mesh strainers below the oil-level equalizers in the oil sump. These screen strainers are readily removed through the handholes in the sides of the box base. To remove any accumulation of sludge and carbon gum from the screen mesh, it is recommended that the screen be soaked in a suitable solvent, such as benzol or lacquer thinner. Soaking should continue until softening

CLEANING OIL INLET SCREEN



OIL SCREENS INSTALLED IN OIL PAN

of the deposit permits easy removal without damage to the screen. Remove and clean the magnetic plugs at the inlets to the rocker arm oil header (2) and the turbocharger (2).

## SELECTING OIL VISCOSITY

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

1. Make one or more check runs under actual operating conditions of speed and load. Use SAE 40 oil for this test. Note the temperature range of the oil in the crankcase by means of an accurate oil temperature gauge immersed in the oil.

2. Find the temperature range noted in the above test in the tabulation below. The proper oil viscosity for these operating conditions will be found directly to the right. If different kinds of service cause the loads and operating conditions to vary, re-check the oil temperature as above and select an oil of lighter or heavier viscosity as required by the new conditions.

CLASS "B" ENGINES
OIL TEMPERATURE METHOD

| Oil Operating Temperatures | SAE Viscosity Numbers |
|---|---|
| 190° - 210° F. | 40 |
| 150° - 180° F. | 30 |

## OPERATING TEMPERATURES

Engines operated with low oil temperatures below 160°F. can be expected to show excessive sludging and wear. Engines operated with high oil temperatures above 230° may experience lacquering and ring sticking. The undesirable effects of operating at abnormally low or high oil temperatures can be alleviated to some extent by the use of additive type oils.

## BREAK-IN

New or overhauled engines should be "broken-in" to seat piston rings properly on a low additive type oil for the first 100 hours of operation. (NOTE: Stand-by engines should have a specific break-in cycle before being put into service). Never idle for more than 15 minutes. Load and unload procedure is best. Repeated loading with equal idle periods in 5-minute intervals for a period of one hour results in more rapid break-in of the engine.

## OIL CONSUMPTION

Acceptable oil consumption should range from 0.002 to 0.004 pounds per horsepower-hour. To figure use—

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

## WARM OIL FOR COLD WEATHER STARTING

In winter operation low temperatures congeal oil and increase engine internal friction greatly. With below zero temperatures the engine sometimes cannot be started even though it fires on each cylinder while the starting engine is cranking it over. This results from the cold, heavy oil on the bearing surfaces raising the friction load to a higher value than the torque the engine is able to develop at starting speeds. It has been determined by dynamometer tests that SAE 30 oil, at 30 below zero, may require more than three times the torque the engine is able to develop to overcome friction and maintain running. Under such conditions, the engine may be cranked over almost indefinitely with intermittent firing without actually starting. At the same time, the oil temperatures reached once the engine is started prevent the use of light oils. In such cases, the problem centers around providing a means of warming the oil before starting or a policy of removing the oil during shut-down periods and warming it before refilling the crankcase.

Oil heater pipes can be installed as optional equipment on engines used in colder climates or where warm oil is required prior to starting. On these engines, warming the oil before starting can best be accomplished by circulating hot water or steam through the "U" shaped oil heater pipe assembly which is installed in and clamped to the floor of the oil pan. The open ends of this pipe assembly extend out through the lower rear sides of the pan.

## OIL FILTER

Model L-5790-G engines are factory equipped with a large capacity full-flow oil filter. When a condition arises where neglect of the filter or an unusually rapid accumulation of sludge tends to bring about filter element clogging, the engine will not be starved of oil because of this condition, but it is very important to remember that the dirty oil that brought about the filter element clogging is now passing through the engine itself, and may reduce engine life materially.

Because of the above possiblity, the recommendations made for filter change periods coincide with the recommendations for oil change. However, if the filter is equipped with pressure gauges to indicate differential pressure, the filter must be serviced when a 15 psi drop across the filter is indicated, as this indicates the elements are clogged and the filter is by-passing the oil. If the oil shows evidence of sludge formation or improper filter operation, it should be changed and the filter elements as well. Also a check should be made to see that the oil and water temperatures are within the desired range of 160° - 180° F.

If experience indicates the practicality of running the lubricating oil for maximum periods between changes, then the filter may be considered as satisfactory for this period of operation. In all cases, the filter elements should be changed at the time of oil change, except as indicated above. When changing full flow filter elements, be sure to prefill the filter.

Be sure that all oil lines and pipes installed between the oil filter outlet and the oil header are clear and free from scale, rust and dirt.

## USE GENUINE FILTER ELEMENTS

The genuine dual density filter elements are of a patented type and are designed to continuously self-adjust the pressure within the filter and allow for a full stream of filtered oil to the bearings without opening by-passes.

The two different filtering materials are in series rather than in parallel. Effective filtering is accomplished at all times, yet the flow characteristics of the filter remain constant over a long period of service. This reduces the possibility of operating with a partially open by-pass valve because of pressure drop across the filter resulting from inadequate filter maintenance. The by-pass valve, now provided, however, is especially positioned to avoid plugging under such conditions and will, of course, open if necessary.

We are not aware than any "replacement" element, other than the genuine element will provide the "controlled pressure" in this full flow system. It is urged that no chance of damage to these engines be risked through an attempt to use any except genuine filter elements.

## TECHNICAL DATA

Selection of the correct filter element is important and the following description is provided to avoid confusion.

Element No. 167602. Dual density standard element. Used in single and dual element filters and in fourteen element filter only for L-5100 and larger engine models.

Element No. 167602-A. Dual density treated element. Used when high sulphur fuels are involved. Same application as indicated for part number 167602.

Element No. 167603. Single or constant density standard element. Used in fourteen element filter on engines smaller than L-5100 model. Not used on larger engines because of insufficient flow capacity for oil volume required.

Element No. 167603-A. Single or constant density treated element. Used when high sulphur fuels are involved. Same application as indicated for part number 167603. Also used in seven, fourteen and twenty-one element gas conditioners.

To replace filter elements, refer to filter illustration and proceed as follows:

1. Remove drain plug; drain filter. Release the swing-bolts securing cover; remove cover taking care not to damage the "O" ring. Place a suitable mark on both cover and filter body before removing cover so that "O" rings which are re-used will seat in any minor irregularities in the seating surface. Filters are now being built with index marks.

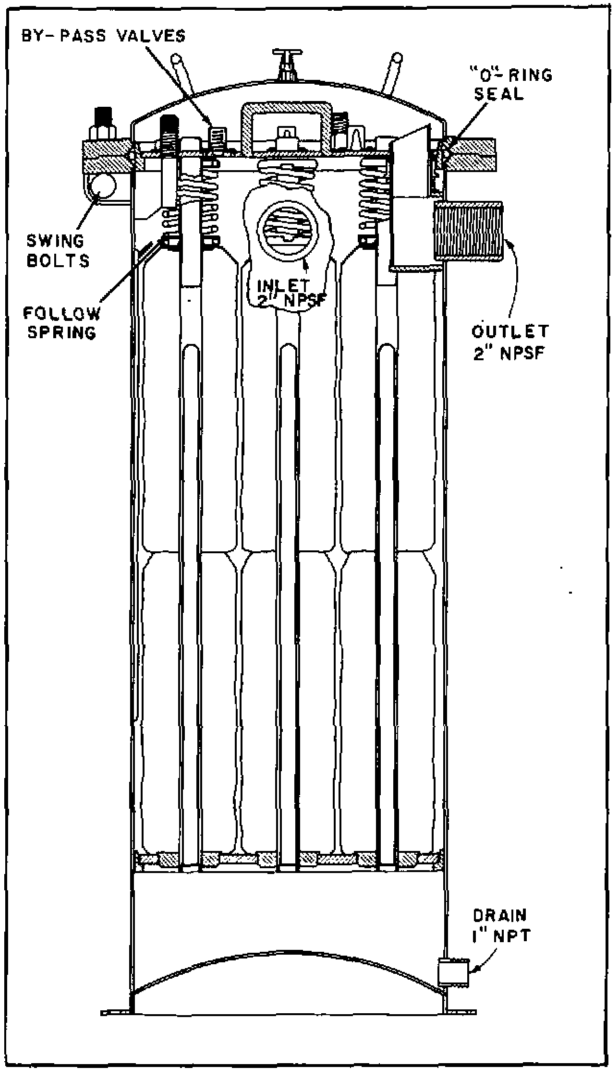
NOTE

As a general service recommendation, it is suggested that the large, cover "O" ring be replaced at least every fourth filter change and possibly more often if inspection shows signs of hardening, cracking, or other deterioration. The small ring on the standpipe should be replaced when necessary. It should be carefully inspected at each filter change.

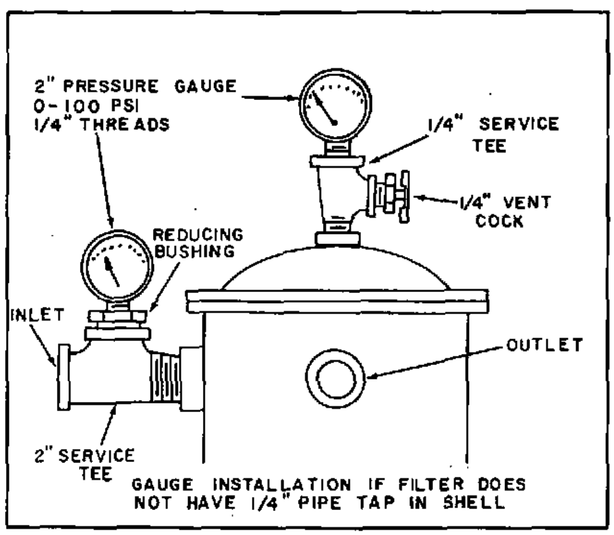
2. Remove cap screw and washer securing spider; remove spider and follower springs. Remove old elements and clean shell thoroughly. Install drain plug.

3. Install new elements over center tubes. Install follower spring assembly, spider, washer, and cap screw.

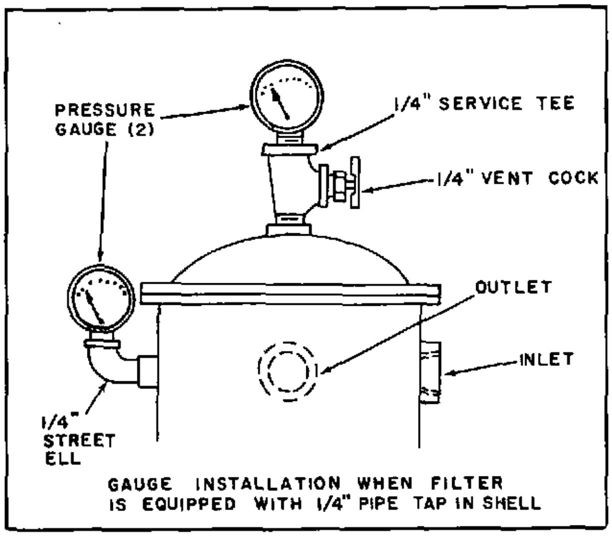
4. Install cover with cover "O" ring; secure with swing-bolts.




WAUKESHA OIL FILTER




GAUGE INSTALLATION WITHOUT PIPE TAP




GAUGE INSTALLATION WITH PIPE TAP

CAUTION

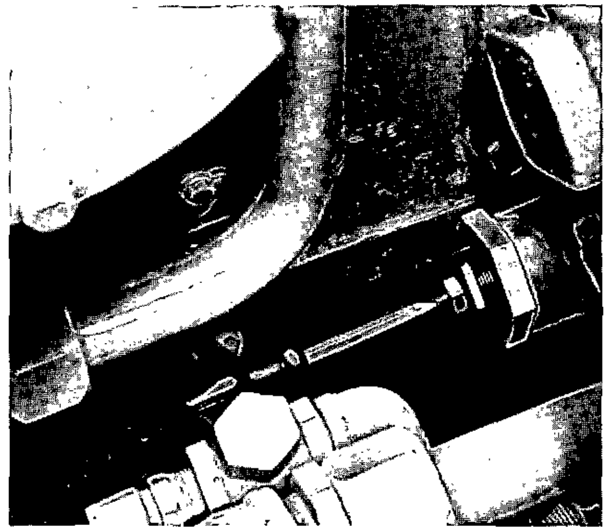
*Tighten the bolts progressively until* snug; then pull down in place to 35 to 37 foot pounds.

5. Add oil to the system to replace that lost with element change; check for leaks.

## OIL PRESSURE CONTROL

Under all normal operating conditions, the high-capacity pump used on the Model L-5790-G will maintain the oil pressure within the specified limits. A cold engine, or the addition of cold oil to the crankcase of a warm engine, will cause high oil pressure until the oil temperature stabilizes in the proper range. A warm engine will normally carry a low oil pressure at idle speeds, and no alarm should be felt under these circumstances if it does not fall below 15 pounds. When starting up, if pressure still fails to register after the engine has run for 25 to 30 seconds, the engine should be shut down and the cause determined. Excessive damping of the gauge may cause this. Oil pressure will be about 40 psi at engine governed speed.

Adjustment of the oil-pressure relief valve is seldom necessary. This operation should always be done AFTER the engine and oil temperatures have stabilized at normal levels. It is equally important that all other factors--proper grade of clean oil, bearing clearances, no leakage, and so on, be satisfactory before attempting to adjust the oil pressure.



OIL PRESSURE ADJUSTMENT (Early Models)

Field reports have indicated that some operators have been attempting to adjust oil pump 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. Current engines are equipped with a non-adjustable oil pump pressure relief valve which is pre-set for approximately 80 psi. This non-adjustable relief valve must also have the relief valve sleeve bottomed and its threaded retainer drawn down snugly and locked. 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.

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

On engines equipped with an adjustable oil pump pressure relief valve, it is imperative that proper relief valve adjustments are made so that one valve does not impair operation of the other. Proper adjustment can be made as follows:

CAUTION

It is stressed that the following procedure is based on fairly cold oil. If the initial setting of 75 to 80 pounds were made with hot oil, the relief valve would probably be bottomed solidly and cause oil pump damage on cold start.

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 screw 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. Reduce oil pressure indicated on oil gauge to 40 psi by adjusting auxiliary relief valve.

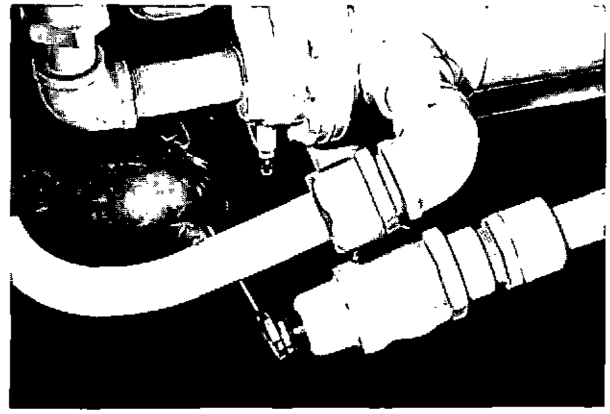
5. Operate engine until oil is up to normal engine operating temperature (minimum 160°), then readjust auxiliary relief valve to 40 psi header pressure if required.

FOR ENGINES WITH DOUBLE CAPACITY OIL PUMP AND NO OIL COOLERS, use same procedure as in 1 through 5, except close the oil pump valve (step 2), adjust auxiliary valve for 75 to 80 psi (step 3), adjust the oil pump valve for 40 psi (step 4), and readjust the oil pump valve if required for 40 psi (step 5).

On engines equipped with a non-adjustable oil pump pressure relief valve, proceed as follows:

1. Start engine and adjust relief valve at oil cooler outlet to 40 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°), then readjust relief valve at oil cooler outlet to 40 psi header pressure if required.



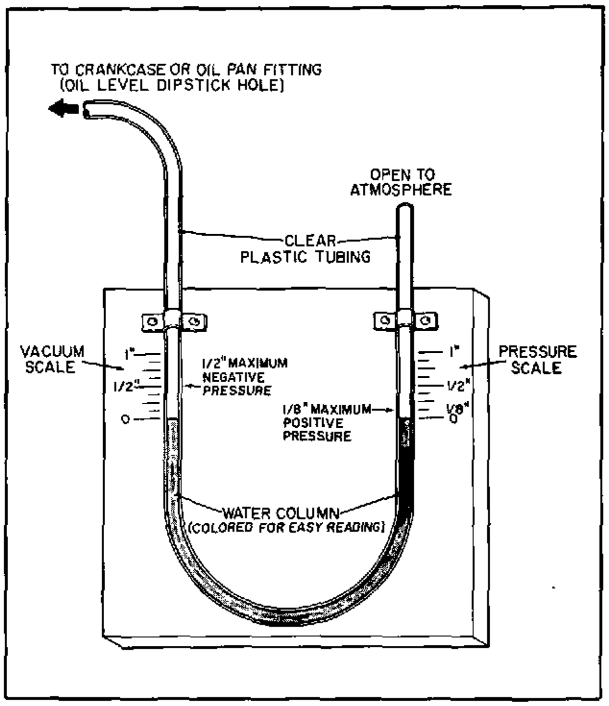
ADJUSTING AUXILIARY RELIEF VALVE
(Early Models)

## OIL COOLER

Maintenance of the oil cooler unit(s) consists largely of periodic cleaning and inspection for clogging or corrosion. Improper or fluctuating oil pressure, or an undesirable increase in oil temperature, may indicate the need for servicing the cooler more frequently. In general, the cooler should be removed from the engine, disassembled, and cleaned after each 500 hours of operation. All rust and lime deposits should be removed from the water passage tubes of the cooler at this time. The sludge deposits within the cooler body may be cleaned out by several solvents and methods, but in all cases, it is recommended that cleaning take place as quickly as possible after removing the cleaner from the engine. Ordinarily, benzol, lacquer thinner, or a commercial sludge and carbon remover will be effective if pumped vigorously through the cooler body. Observe fire and safety precautions.

## CRANKCASE VENTILATION

Regular maintenance of the crankcase ventilation system is very important. Excessive crankcase pressure caused by a poorly maintained system can result in severe lubricating oil leakage especially around the crankshaft oil seal areas. On the other hand, excessive vacuum or negative pressures can cause small dirt particles to be drawn into the crankcase around these seals. Crankcase pressure should therefore be kept within the limits of 1/8" positive to 1/2" negative pressure measured in inches of water. A simple method of measuring pressure can be devised by tapping a crankcase door to receive a brass elbow fitting to which a length of clear plastic tubing can be connected.




MANOMETER USED TO CHECK CRANKCASE PRESSURE

Bend the plastic tube into a "U" shape and clip to a section of wood to make a manometer with negative and positive pressure scales as shown on the illustration. Water added to the manometer tube should just reach the zero mark on both positive and negative pressure scales. A *dye or ink added to the water aids in reading* the manometer when the engine is in operation.

Components of the ventilation system should be serviced on a monthly basis or more often if unusual conditions are encountered.

## GREASING

Use a good grade of cup grease to lubricate the Bendix outboard bearing and steady-rest bearing. Fill cups and turn down as needed. A good grade of ball bearing grease is needed for cooling fan bearings when a fan is used. See "GREASING FAN HUB." Grease water pump fitting every 500 hours and idler pulley fitting and auxiliary water pump fittings (2) every 100 hours with a good grade of ball and roller bearing grease. Add water pump grease to the auxiliary water pump stuffing box fitting every 100 hours.

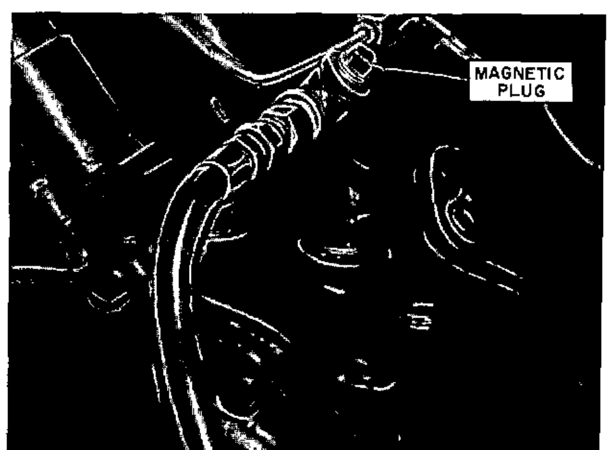
## ACCESSORY LUBRICATION

Those accessories not directly involved in the operation of the Model L-5790-G are generally selected to fill the specific needs of the engine operator. For this reason the variety of types and models of accessory devices becomes so large that the engine manufacturer must necessarily refer the operator to the *recommendations of the accessory manufacturer* for service data. Commonly, however, the lubrication of accessories follows certain basic rules that may be used as a guide, but should not be construed as over-riding or substituting for exact instructions from the accessory manufacturer.

Electrical equipment of the "motor" type—generators, and so on, ordinarily requires a minimum of lubrication. At each oil change, a few drops of light oil should be placed in the cups provided for this purpose. Over-lubrication of electrical equipment is usually harmful and should be avoided. Never oil commutators or brushes.

Lubricate power take-off units according to the instructions of their manufacturers. Apply a good grade of grease to the pilot bearing with a pressure gun capable of forcing the grease the length of the hollow shaft and into the pilot hole. Remember, however, that these shafts are filled before installation at the factory, and should also be filled when installed in the field; hence great quantities of grease are not desirable.

Starter engine transmissions carry a small amount (about 1/2 pint) of oil in the housing. Use SAE 10 oil of good quality and fill through




ROCKER ARM OIL HEADER MAGNETIC PLUG

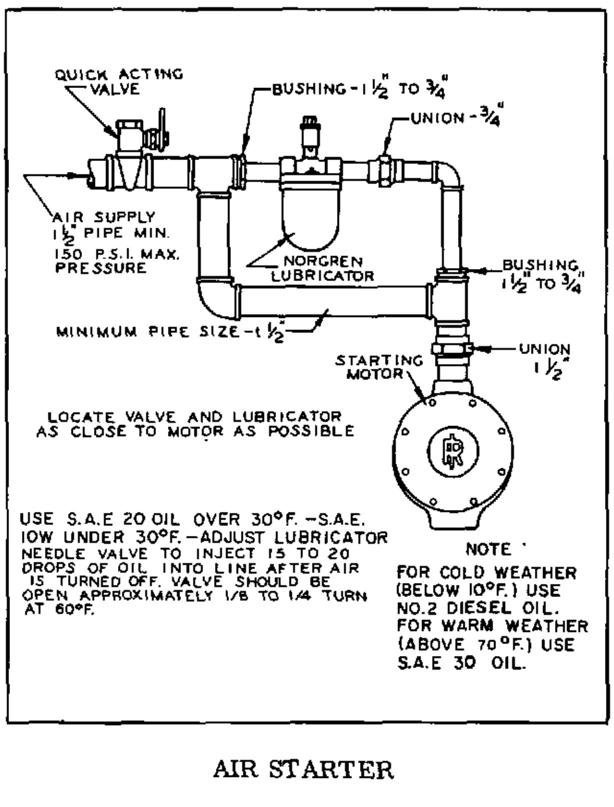
the opening in the upper side of the transmission case until the oil reaches the level of the drain fitting on the side of the case. Do not over-oil since this may cause clutch trouble. The starter engine crankcase requires 4 quarts of SAE 10 oil.

### AIR STARTER LUBRICATION

Maintain the proper oil level as marked on the "Lubricator" bowl. Use SAE 20 oil above 30° F. and SAE 10W oil below 30° F. For cold weather (below 10° F.) use No. 2 Diesel oil. For warm weather (above 70° F.) use SAE 30 oil.

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

Whenever the air starting motor is removed from the engine, unscrew the bushing oiler plug at the end of the drive housing and saturate the felt bushing oiler with SAE 20 motor oil.




AIR STARTER

### AIR CLEANERS

Model L-5790-G engines are factory equipped with dry type air cleaners. It is important for the operator to appreciate that the purpose of air cleaners is to collect dirt and grit and so keep it out of the engine working parts. As a result the cleaner units must themselves be cleaned, sometimes several times each day if operating conditions are particularly bad.

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

### DRY TYPE AIR CLEANERS AND CONDITION INDICATOR

The two dry type air cleaners are mounted separately at the rear of the engine. Each air cleaner services one bank of the engine.

An air cleaner condition indicator gauge mounted in the air duct for each bank serves as positive evidence that air cleaner service is necessary.

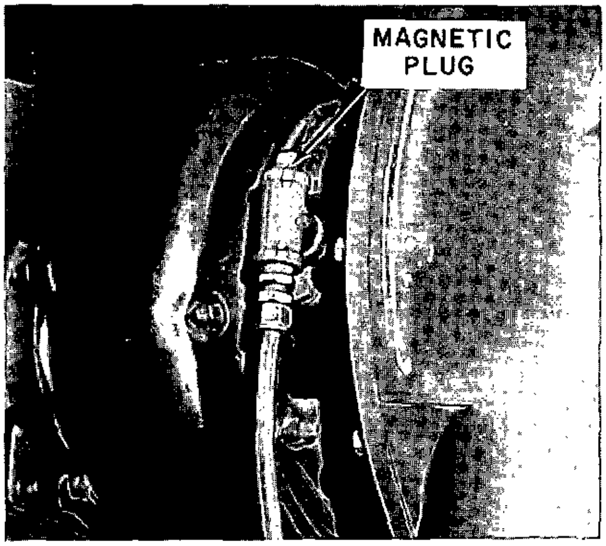
As dirt trapped by the air cleaner gradually restricts the flow of air, the condition indicator signal, which is preset for a maximum restriction, rises within the gauge. When the maximum restriction is reached, the signal locks into full view indicating the need for servicing the air cleaner element.

CAUTION

Unless the signal is locked in view indicating a clogged element, it will return to a normal setting upon engine shut-down. Normally the element is serviced long before the gauge indicates a need, but the operator is cautioned to check the gauge every day while the engine is running.

When removing the filter element, use care to avoid spilling dust in the air duct.

When dirty, elements can be cleaned with compressed air (moderate pressure). The preferred method of cleaning is to wash them in clear water or a solution of water and a mild detergent to remove excessive dirt. Reverse washing from the down-stream side is recommended where water nozzles are used; however, high pressure nozzles should never be used. Elements should be completely dried before placing back in service.




TURBOCHARGER INLET MAGNETIC PLUG

## COOLING SYSTEM

### Cooling and Anti-freeze

The cooling system of the bare Model L-5790-G engine holds 90 gallons of water without provision for radiators or other equipment. When adding anti-freeze compounds on a percentage basis therefore, remember to include the coolant volume of the radiator or other external parts of the cooling system. The following table may be used as a guide.

| Pure Methyl Wood Alcohol | Denatured Wood Alcohol | Ethylene Glycol "Prestone" | Radiator Glycerine (G. P. A.) | Freezing Points °F. | °C. |
|---|---|---|---|---|---|
| 13% | 17% | 16% | 37% | 20 | -7 |
| 20% | 26% | 25% | 55% | 10 | -12 |
| 27% | 34% | 33% | 70% | 0 | -18 |
| 32% | 40% | 39% | 81% | -10 | -23 |
| 37% | 46% | 44% | 92% | -20 | -29 |
| 40% | 53% | 48% | 100% | -30 | -35 |

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

Never fill an engine with straight water after it has been exposed to sub-freezing temperatures for any length of time. This applies even when warm water is used because the water in the radiator and jacket passages cools rapidly and is likely to freeze before the engine can be started. If it is planned to leave the coolant in the engine at the next shutdown, then mix the proper proportion of soluble oil, anti-freeze and water before filling the engine. If water alone is to be used, then be sure that enough water to fill the entire system is immediately available; start the engine; and add water quickly before over-heating can occur. This last method requires, of course, that the water be drained immediately when the engine is shut down.

Periodic additions of anti-freeze will be required to compensate for evaporation. Use a hydrometer type test gauge to ensure that the anti-freeze solution is maintained at its proper strength.

### Thermostatic Valve Assembly

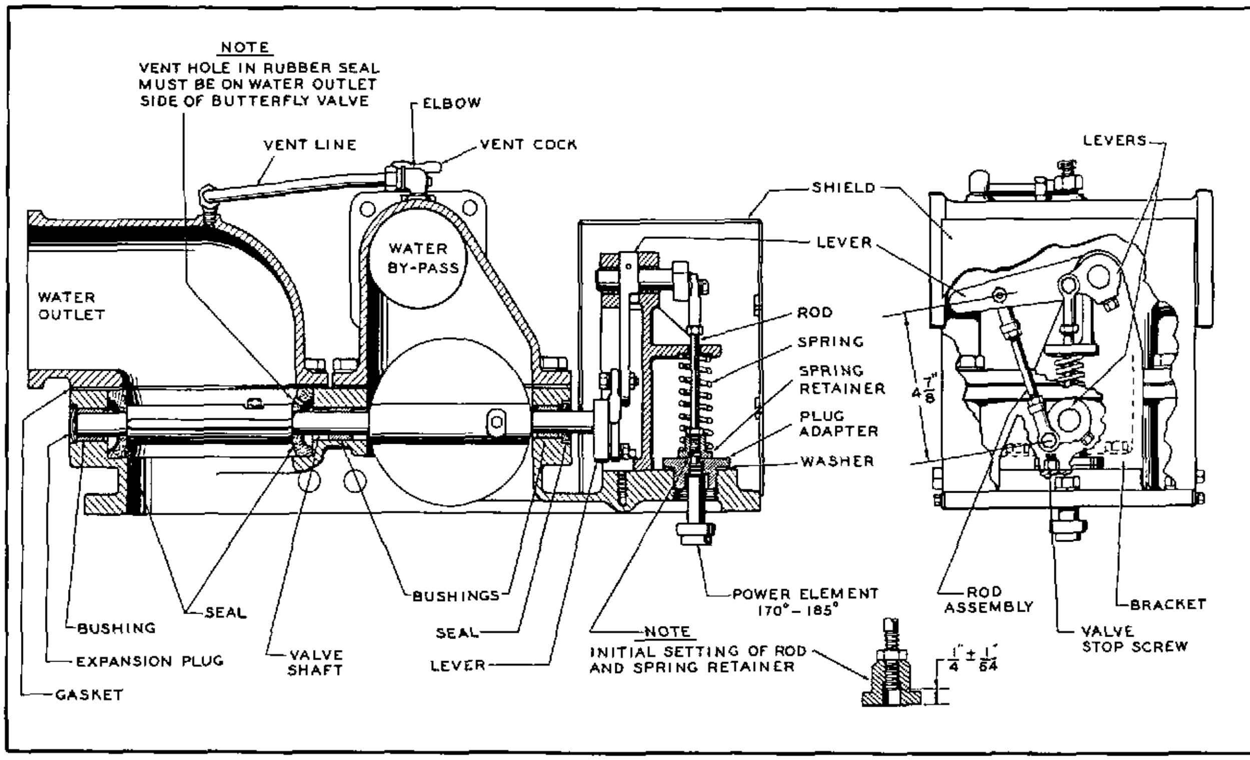
Model L-5790-G engines employ a single pellet type power unit to actuate butterfly valves in the engine water discharge housing. The two valves operate in such a manner as to divert the water to the radiator, through the by-pass, or partially through each as needed to control the engine water temperature.

Adjustment of the control assembly is seldom required in the field. The main requirement, in the event it becomes necessary to replace the power element or associated components, is to provide approximately 1/4" clearance between the face of the spring retainer and the operating rod. It is very important to note, however, that the power element as received, with the plunger in the element hole more or less loosely, must be forced by hand until the plunger bottoms. This can be done by pressing the plunger very firmly against a bench top until the plunger feels solid in the power element. The element may then be screwed into the plug adapter. With the spring retainer and rod seated over the plunger tip, the tip should not quite reach up into the retainer far enough to touch the rod end. The power element must be at room temperature when making this check. The adjustment of the rod (as described and illustrated) to provide approximately 1/4" clearance between it and the face of the spring retainer will effect the proper plunger tip and rod end clearance.

Do not attempt to change the linkage otherwise unless it is required to alter the 4-7/8" dimension slightly to provide the best positioning of the butterfly valves.

### Cleaning Cooling System

When clean, soft water is used as a coolant, and when the proper inhibitors and anti-freeze solutions are used, radiator and cooling passage accumulations will not be excessive. About




THERMOSTATIC VALVE ASSEMBLY

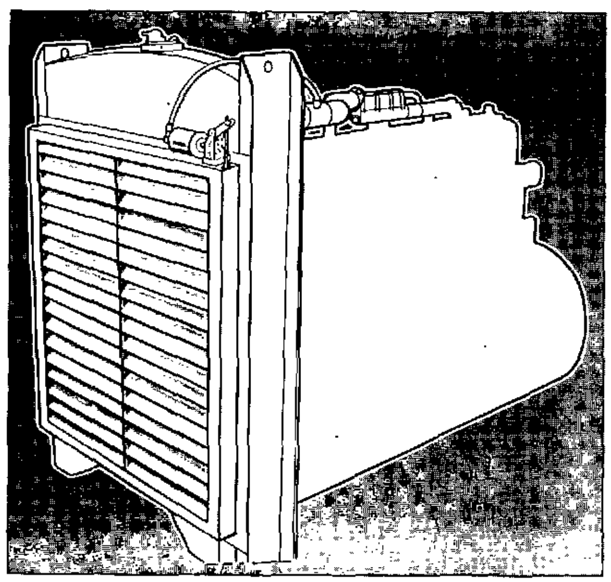
once each year, however, the engine will benefit if the cooling system is cleaned of sludge and sediment. A washing soda solution will ordinarily do this job satisfactorily.

To clean the cooling system . . .

1. Drain system and measure water volume.
2. Replace half of measured volume with fresh water.
3. Boil other half of volume and add washing soda until no more will dissolve.
4. Add hot soda solution to cooling system (fill up).
5. Operate engine normally for 24 hours.
6. Drain, flush, refill with clean water to which a soluble oil has been added in a proportion of 1 ounce per gallon of water.

### Commercial Cleaners

It is recognized that a number of excellent commercial cooling system cleaners are available. The WAUKESHA MOTOR COMPANY suggests, however, that an operator considering the use of such a cleaner first investigate its possible reaction with the copper and bronze parts in the engine. If such a cleaner is used, follow the manufacturer's recommendations carefully.



USE AUTOMATIC RADIATOR SHUTTERS IF NECESSARY TO MAINTAIN CORRECT ENGINE TEMPERATURE

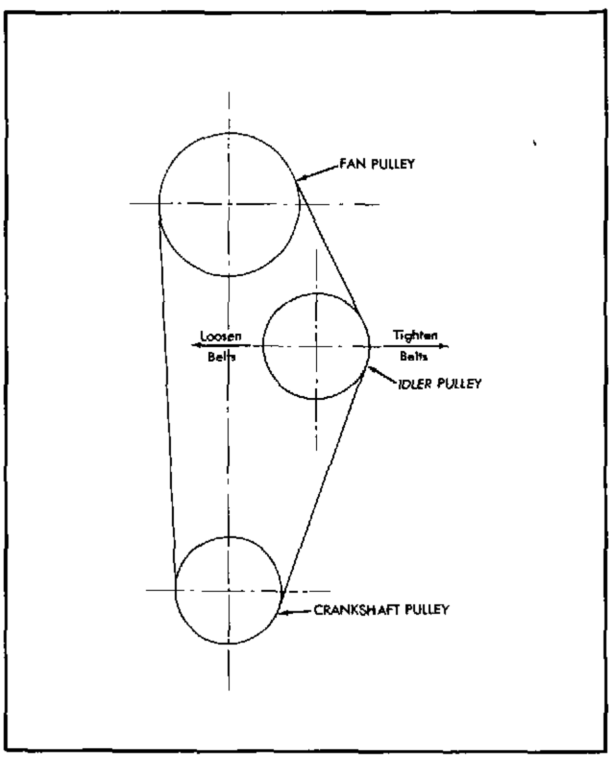
### Cooling Fans

About the only maintenance work encountered in connection with cooling fans will be lubrication and the occasional straightening of a blade damaged in some manner and the replacement of fan belts. In the case of slightly bent blades, it is important to remember that inaccurate blade alignment can cause considerable roughness and vibration as well as inefficient cooling and bearing wear. Hence, bent blades should be brought into track, adjusted to the same angle as the other blades, and examined for security of the hub attachment and possible cracks in the spider area.

### Fan Belts

Periodic replacement of fan belts is good insurance against damaged radiators and inopportune shut downs. Provision has been made to reduce the stretch between the fan pulley and the drive pulley of the engine by moving the idler pulley and this adjustment should be used to install the belts. Attempting to force a belt over the pulleys while it is under tension is almost certain to damage the belt.

To install new fan belts, (all should be replaced at the same time), follow the procedure below:



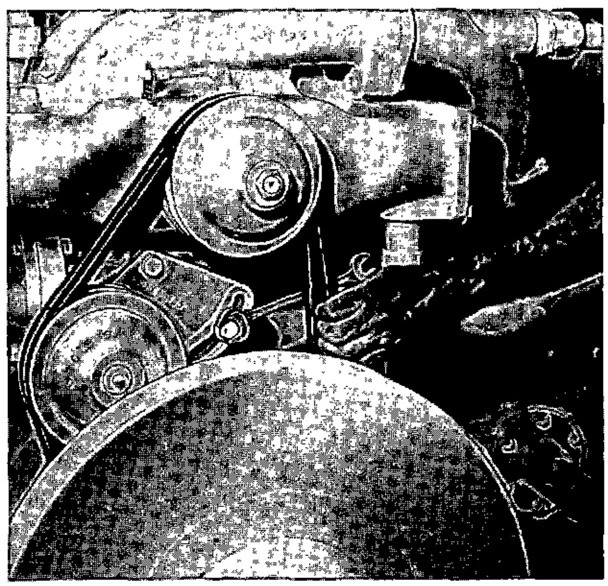

CHECKING FAN BELT TENSION

1. Loosen the bolts which secure the idler pulley and its mounting bracket to the radiator.

2. Turn the idler pulley adjusting screw to move the idler pulley assembly towards the center of the radiator until the belt tension is completely relieved and the old belts can be slipped free.

3. Slip the new belts over the pulleys and by using the adjusting screw again move the idler pulley assembly back towards the side of the radiator until the belts show some tension but are not so tight as to prevent movement with the thumb and the forefinger for about one-half inch to either side.

4. Retighten the idler pulley assembly bolts.



ADJUSTING WATER PUMP BELT TENSION

### Greasing Fan Hub

Sixty inch fan: Repack fan bearing every 10,000 hours (Idler bearing is permanently packed). Seventy-two inch fan: Repack fan and idler bearings every 10,000 hours. Use soda-soap type grease. (Over-greasing may cause seals to blow out.)

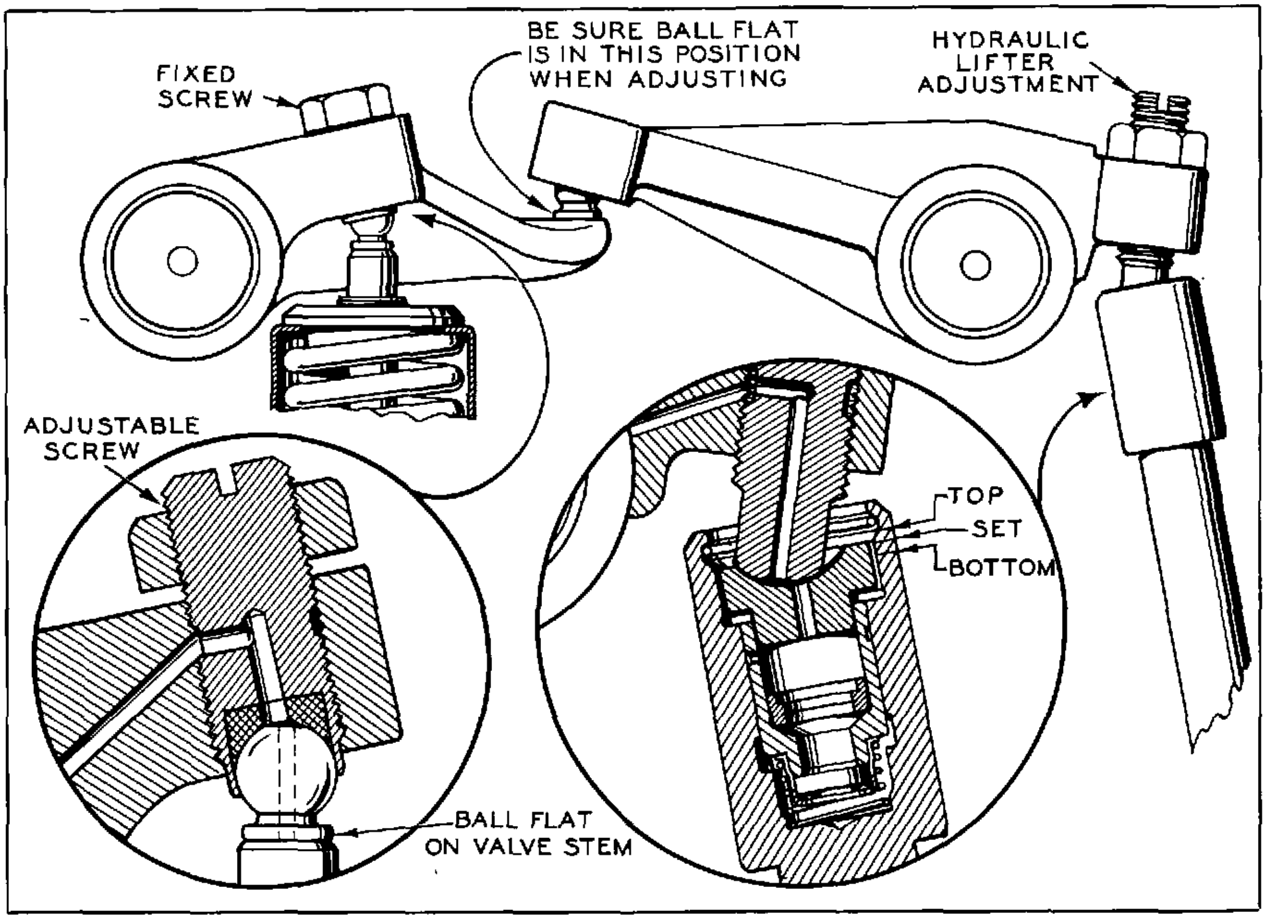
## VALVE ADJUSTMENT

### General

Hydraulic push rods maintain constant and uniform valve adjustment, automatically, at all

# LUBRICATION GUIDE

| | |
|---|---|
| ENGINE CRANKCASE | Check oil level and condition daily. Lubricating oil capacity is specified in the fits and clearances section. Change oil as chemical analysis indicates necessity or at regular intervals. |
| ENGINE OIL PAN | Clean and inspect oil pan at each oil change or less frequently as experience shows is required. |
| OIL SCREENS AND MAGNETIC PLUGS | Clean at each oil change, or less frequently as experience shows is required. |
| FILTERS (Waukesha Elements) | Replace filter elements at each oil change. If the filter is equipped with pressure gauges to indicate differential pressure, the filter must be serviced when a 15 psi drop across the filter is indicated. (Use genuine Waukesha elements.) Inspect used elements for unusual conditions. Large capacity filter requires additional 30 gallons oil. |
| GOVERNOR (Woodward) | Check oil level in sight gauge daily. Change oil every 500 - 1000 hours depending on operating condition. Oil must be changed every six months regardless of hours of service. Use neutral (non-acid, non-alkali) petroleum oil. |
| AIR CLEANERS | Check and clean as required or as indicated by air cleaner condition indicator (daily or more often in unusual operating conditions). |
| FAN & IDLER | Repack bearings with soda-soap type grease every 10,000 hours (60" fan idler permanently packed). Avoid over greasing. |
| WATER PUMPS | Add soluble oil to cooling system occasionally, grease water pump fitting every 500 hours, auxiliary water pump fittings (2) every 100 hours (1 good stroke—DO NOT OVER-GREASE) and idler pulley fitting every 100 hours with a good grade of ball and roller bearing grease. Add water pump grease to the auxiliary water pump stuffing box fitting every 100 hours. |
| STARTING ENGINE | Check oil level daily, change oil at least 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. |
| AIR STARTER | Lubricate every 3 months with #2 cup grease through the grease fittings. Keep Norgren Lubricator filled to level (SAE 30,SAE 20 or SAE 10W oil or No.2 Diesel oil). |
| CRANKCASE BREATHER | Inspect each time oil is changed. Don't allow dirt to accumulate. Rinse in gasoline as required, allow to dry, and then re-oil breather mesh with engine oil. |




VALVE ADJUSTING COMPONENTS

loads and speeds. Basically the same as hydraulic valve lifters, these units are located at the top end of the push rods. Hydraulic push rods will also run more quietly, and the hydraulic dampening effect prolongs valve and associated valve train part life.

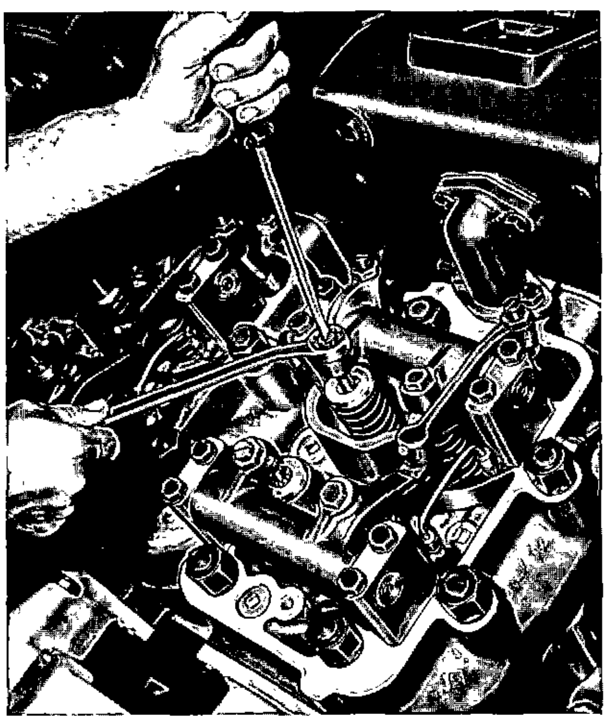
Whenever the rocker covers are removed, the valve and spring mechanism should be examined for evidence of inadequate lubrication due to sludging or plugged oil lines. Excessive sludge in the rocker area is an indication of too low oil operating temperatures, poor filtering action, or an oil that breaks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

### Adjustment

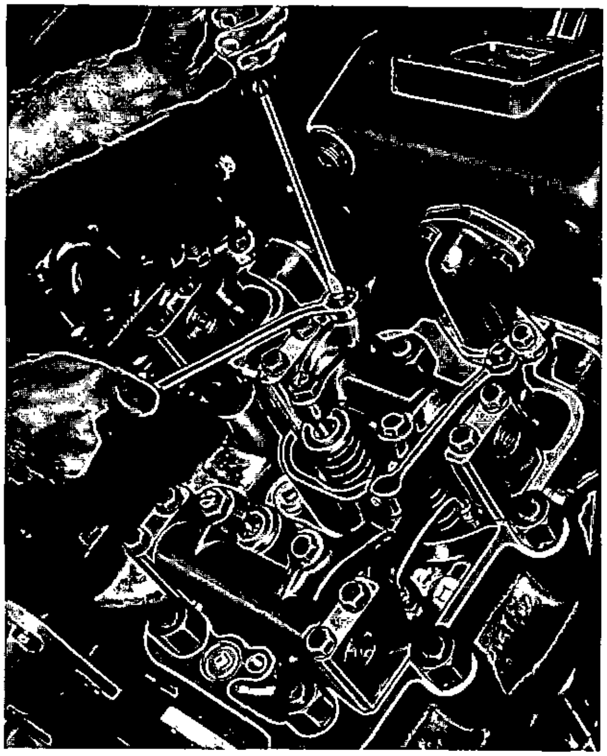
The following adjustment procedure should be followed at all times as normal service procedure and after removing or replacing a cylinder head or rocker assembly.

Place the piston of each cylinder in turn on T.D.C. compression stroke before proceeding.

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



ADJUSTING VALVE ACTUATING SCREW



ADJUSTING HYDRAULIC LIFTER SCREW

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 adjustable 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. This adjustment must be repeated occasionally as a service measure to compensate for slight differences in valve and seat wear between the two valves.

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 and filled with engine oil.

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 adjustment 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.

The above procedure must be carried out in sequence on each cylinder head with each piston brought into approximate top center position, compression stroke, as in any conventional valve adjustment operation.

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 down the rocker 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. Current production rocker arms do not have this adjustment but utilize a different oiling passage to lubricate the intake rocker arm contact shoes.

NOTE: Fill lifters with oil and check manually for "pump up" at step 6.

## GOVERNOR LINKAGE

If it should be necessary to remove the governor at any time, there are some basic requirements which should be observed. Most important, make sure that the operating linkage and the adjusting nuts are accurately assembled exactly as before to prevent improper positioning of the butterfly valves. Also, be sure the lock nuts are in place and securely tightened to prevent change in the length of any of the linkage. Notice carefully, and mark, the position of the butterfly valves so that they go back exactly as before. Also notice that they close against the sharp edge. Close them, and with a pencil, mark the top sides and the adjacent walls of the intakes so that they are not reassembled upside down, or backwards. If these precautions are followed, the governor should operate exactly as before when it is again put into service provided the setting of the governor and the length of the operating rods have not been changed. To secure the best operation, make sure that the length of the operating rod is adjusted so that the butterflies stand a trifle towards the closing position when the engine is stopped. Simultaneous operation of the butterfly valves is assured by a butterfly valve cross shaft which passes directly through the crankcase.

## FLYWHEEL AND FLYWHEEL HOUSING 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 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 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.

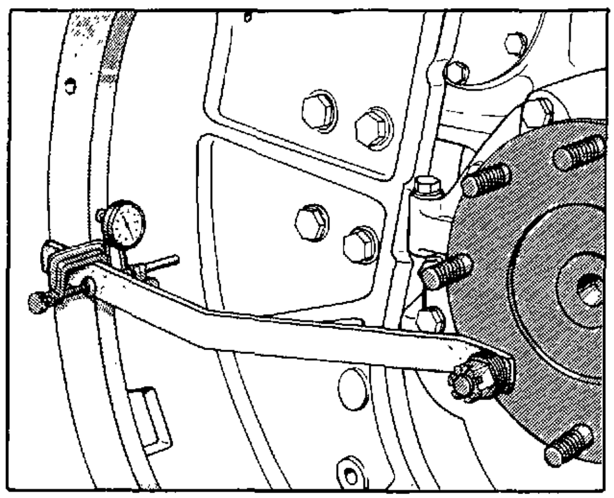
4. Removal of the flywheel, the housing, the crankcase, or the crankshaft for service and maintenance operations always introduces the possibility of misalignment.

## 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.



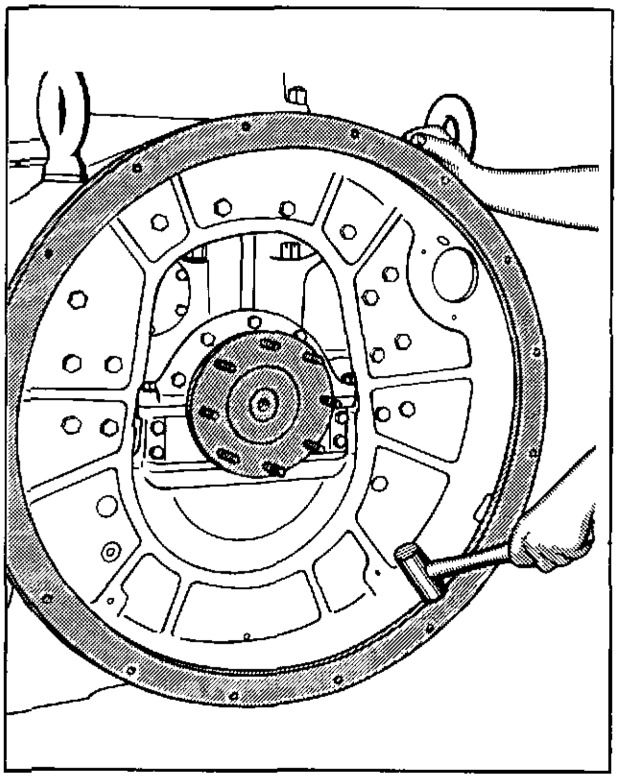
CHECKING HOUSING BORE RUN-OUT

2. Use a soft-face hammer as shown to correct misalignment until the run-out does not exceed .015" total indicator reading.

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

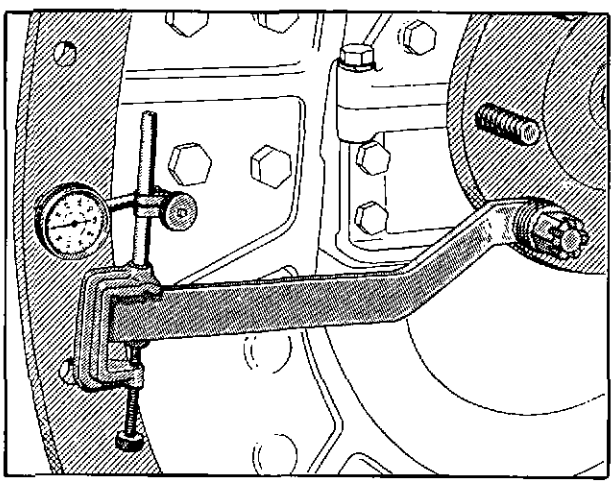
After tightening bolts to final tension, relocate the dial indicator as shown to indicate the flywheel housing face.

1. Housing face run-out should be confined to .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



FLYWHEEL HOUSING ALIGNMENT

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.



CHECKING HOUSING FACE RUN-OUT

2. When making the above inspection it is very important not to be mislead 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.

3. 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.

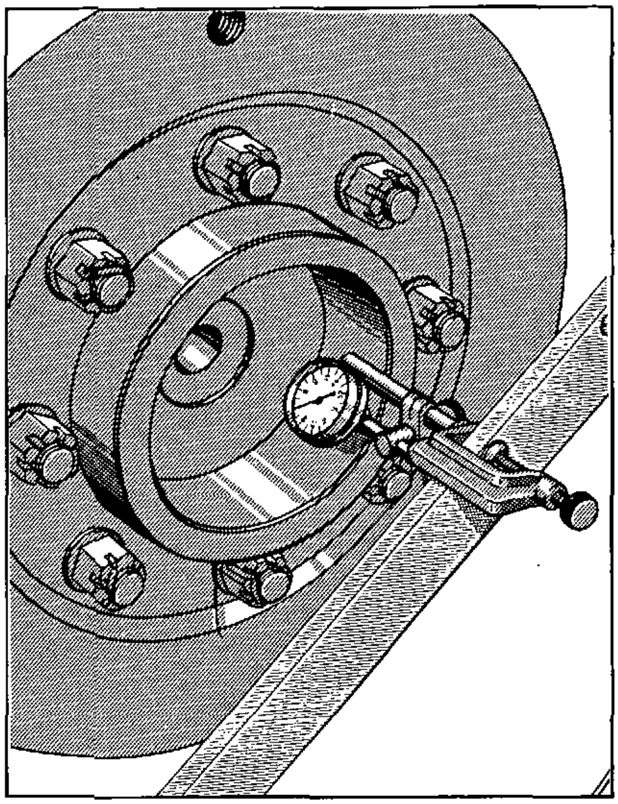
As with the flywheel housing, the mounting surface of the flywheel and the crankshaft flange must be free of burrs and conditions which would prevent accurate seating.

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 the wheel mounts on the flange.

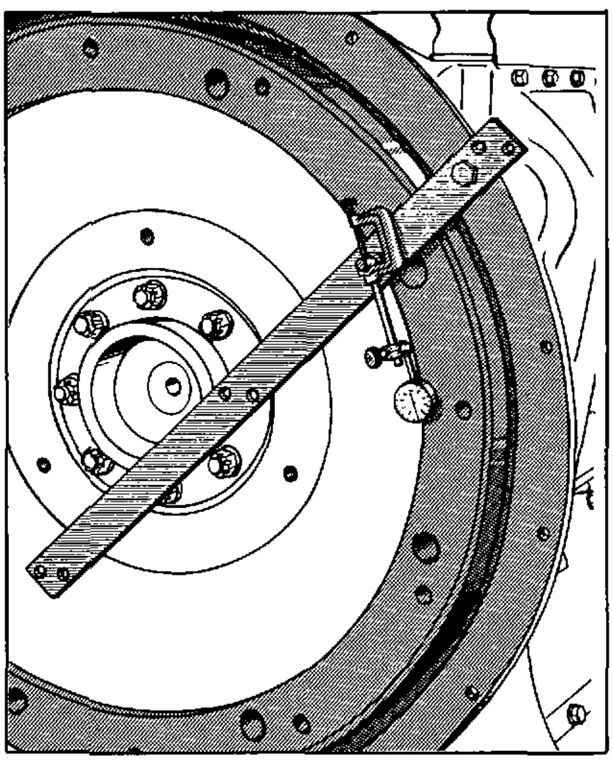
2. Use a torque wrench to apply the correct tightening value to all bolts evenly, working across the wheel from one to another in several stages. Refer to the table of tightening torque values in the back of this manual.

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

Remount the dial indicator as shown 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 .015".



CHECKING PILOT BEARING BORE



CHECKING FLYWHEEL FACE RUN-OUT

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.

## ENGINE STORAGE

Preservation of engines in storage involves several basic requirements. For a completely new engine, 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 against freezing, rusting or seizure of water pump seals.

5. Protection of a general nature against the elements, rain, snow, extremes of temperature, improper stacking and piling and objects that might scratch or batter the exterior, especially the radiator cores.

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

6. 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.

7. Protection of fuel system units against the effects of gas residues.

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

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

2. The severity of the weather and atmospheric conditions at the point of storage. The problems of storing an engine 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 engine for periodic inspection and attention. An engine on a show-room floor that may be turned over occasionally and given periodic oiling requires less extensive treatment than engines crated and stocked in a warehouse.

## NUCLE-OIL STORAGE
### (Recommended Procedure)

Although instructions will be found following these which describe more or less standard and traditional procedures for engine preservation, these NUCLE-OIL procedures based on volatile-corrosion-inhibiting chemicals are factory recommended for reasons of lower cost, convenience, and greater reliability. The primary advantages are avoidance of large and expensive quantities of special oil, freedom from the need to change the oil again when going back into service, and a simplified application technique without any requirement to actually coat the engine internal surfaces with oil.

Nucle-Oil, a recently developed storage oil that offers excellent engine protection over extended storage periods, plus ease of application with a minimum of quantity, is recommended by and available from the Waukesha Motor Company. This oil is similar in appearance to a conventional lubricating oil of about SAE No. 10 viscosity.

A unique feature of Nucle-Oil is its 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, for an almost indefinite duration as long as the engine is left sealed. Absolute sealing of an engine may not always be practical, but reasonable blockage of the escape paths for the vaporized chemicals is not difficult and ordinary storage procedures should present no problem.

Applied in the required amounts and in the proper way, Nucle-Oil will offer above average protection of engines stored for over one year, however, this oil cannot and will not protect engine surfaces in close contact with highly corrosive, used engine oil. In other words, Nucle-Oil will do an effective job if added to engine oil in normal clean condition. If high sulphur fuel or improper control of oil condition from whatever cause, 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.

The following procedure for preservation with Nucle-Oil is suggested:

1. Start with a cold engine containing fairly fresh clean oil and filter elements.

2. Add the required amount of Nucle-Oil to the crankcase.

3. Turn engine over 20 seconds.

4. Allow engine to cool, if necessary.

5. Add the required amount of Nucle-Oil to each cylinder through the plug openings and replace plugs. Apply to rocker arm area by light brushing or pouring. Replace the rocker covers.

6. Store engine up to one year.

NUCLE-OIL APPLICATION CHART

| Upper Cylinder | | Crankcase | | Total Ounces |
|---|---|---|---|---|
| Ozs. of Nucle-Oil Per Cyl. | Ozs. of Nucle-Oil All Cyls. | Oil Cap. Qts. | Ozs. Nucle-Oil | Nucle-Oil Required |
| 3 (3-1/2 FOR L-7042-G) | 36 | 140 | 89 | 125 |

## CONVENTIONAL STORAGE

Engines recently received from the factory and not intended to be used for an indefinite period may be stored successfully in the following manner. As mentioned above, circumstances may compel omitting some steps and, on the other hand, special conditions may point to greater emphasis on other steps.

### Gas or Gasoline Engines

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 thoroughly hot. Cooling water used in this run should have two to three per cent soluble oil added.

   B. Remove air cleaners. 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.

   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. Remove spark plugs and squirt or spray several teaspoons of preservative oil into each combustion chamber. Coat plug threads with oil and reinstall plugs.

   E. Remove water from butane vaporizer if freezing is likely.

   F. Remove magneto covers and apply small amount of petroleum jelly to polished surface of breaker cams. Where dampness in storage is expected, removal of magnetos may be worthwhile.

   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 fan belts. This is important because continual tension on these parts 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, clutch shafts and like areas.

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

2. When engine is not operable.

   A. Open drains in oil pan, radiator, carburetor, and butane vaporizer to remove oil, water and fuel.

   B. Remove 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 as many points as possible . . . oil pan plugs, valve rocker covers, push rod covers, front gear cover plates and so on, 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 "F" 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. Butane engines are probably less subject to this than others. Portions of these residues combine with atmospheric moisture to form corrosive compounds of a destructive nature. The following treatment will help reduce damage from this source.

1. Engine in operable condition.

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

   B. If practical, run engine with a good flushing oil in crankcase and drain while 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 "B" through "I" as the circumstances indicate.

2. When engine is not operable.

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

   B. If in the judgment of the operator, storage conditions and the time period likely warrant it, 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 contain considerable sulphur, 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 gun used ordinarily to lubricate inaccessible points on car and truck chassis. Another is a hand operated pump type sprayer with a pointed discharge nozzle commonly used with insecticides. If desired, small oil pumps may be rigged with a motor drive to make a convenient spray unit of the mechanical pressure type. In almost all cases, the air available from shop compressor lines carries too much moisture to be safe for this purpose. Do not use high-pressure air from this source.

### Heating Compounds

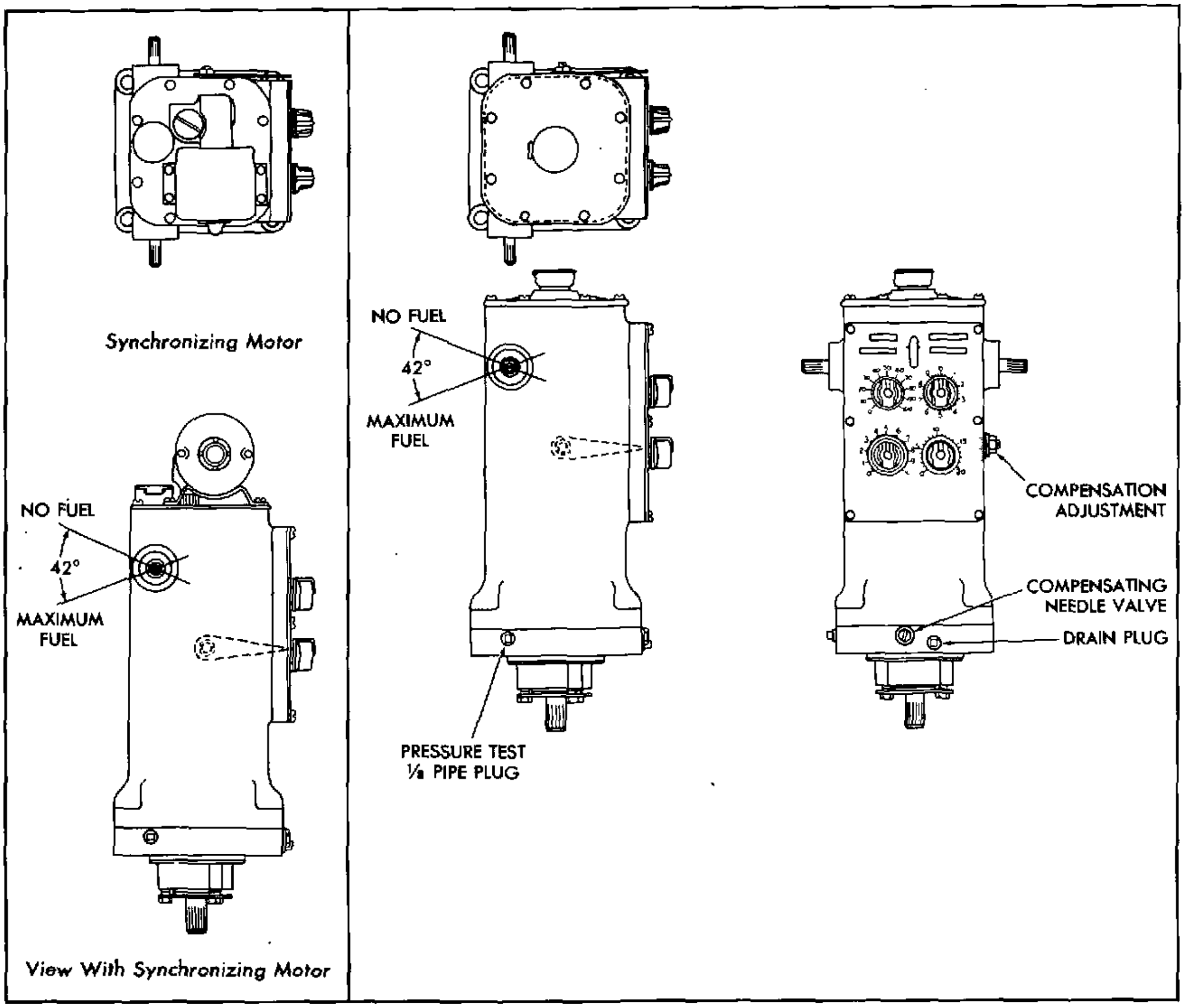
Many preservative compounds are most effective when heated before application. Heating reduces their viscosity so as to gain penetration into inaccessible areas. In addition, the hot compound reduces the moisture film at the metal surface and thus avoids trapping moisture under the preservative layer.

Generally speaking, such heating is confined to 200° F., 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

The steps needed to bring an engine in active service after storage in accordance with these instructions are about the same as those normally carried out on any new engine. These are inspection, checking for free rotation, adequate cooling water or anti-freeze, ample oil of the correct grade 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. Engines that have not been rotated for some time should be oiled through the spark plug openings and cranked by hand or with the starting engine 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.

| Specifications for Protective Materials | |
|---|---|
| **Internal Surfaces, Cyls., Etc.** | **External Surfaces** |
| U.S. Army Spec. 2-126 (Available as SAE 10 or SAE 30)<br><br>Nucle-Oil #120<br>Mil Spec. MIL-L-4600Z Grade 1 | U.S. Army Spec. 2-121 (Waxy Coating)<br>Army Ordnance Spec. AXS 673 (Harder black coating) |




SERVICE ADJUSTMENTS - UG-8 DIAL CONTROL GOVERNOR

## WOODWARD GOVERNOR, UG-8

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.

## OIL TROUBLE, GOVERNOR

A neutral (non-acid, non-alkali) petroleum oil is the most satisfactory for use in governors. Automobile lubricating oils of the correct viscosity are usually satisfactory.

Gasoline engine lubricating oils are satisfactory, but if they contain additives (inhibitors) which are used to free up rings, remove carbon, etc., a non-foaming additive must also be present.

The oil must not foam or sludge excessively when agitated, or form gummy deposits when heated to operating temperature and subjected to operating pressure changes.

Oil contaminated with water will cause foaming.

## DIRTY OIL CAUSES APPROXIMATELY 50% OF ALL TROUBLES

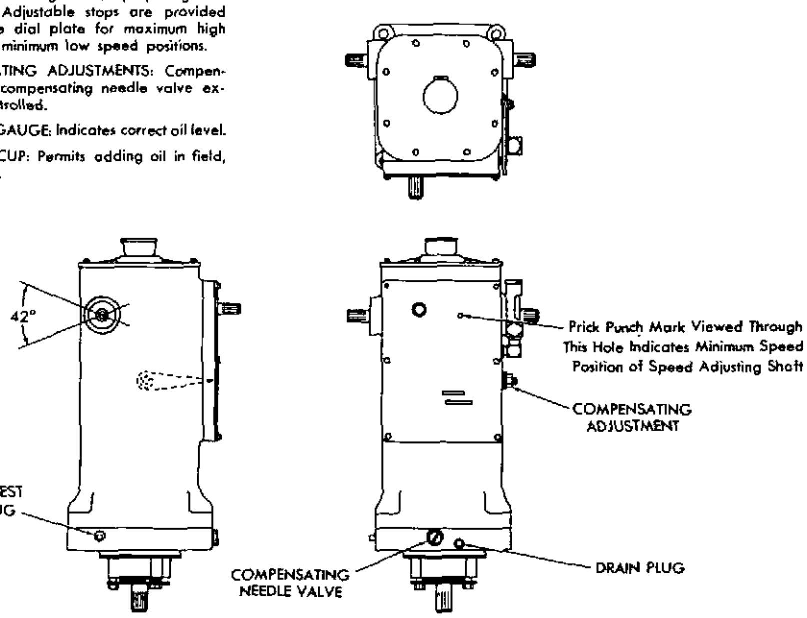
Use clean, new oil or filtered oil. All containers used to fill governors with oil should

SPEED ADJUSTMENT: Speed may be adjusted by positioning the shaft projecting from the panel. Adjustable stops are provided back of the dial plate for maximum high speed and minimum low speed positions.

COMPENSATING ADJUSTMENTS: Compensation and compensating needle valve externally controlled.

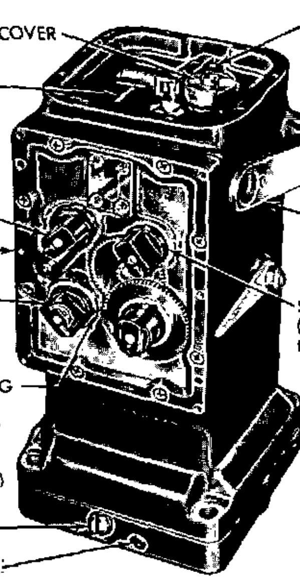
SIGHT OIL GAUGE: Indicates correct oil level.

OIL FILLER CUP: Permits adding oil in field, as required.

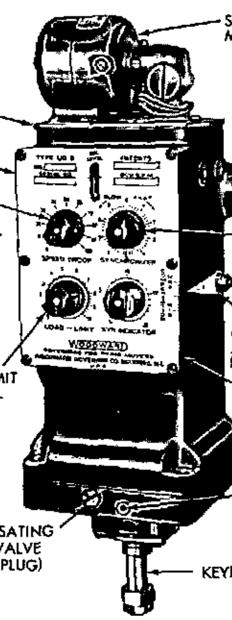



MAXIMUM GOVERNOR SPEED: 1500 RPM
MINIMUM GOVERNOR SPEED: 375 RPM

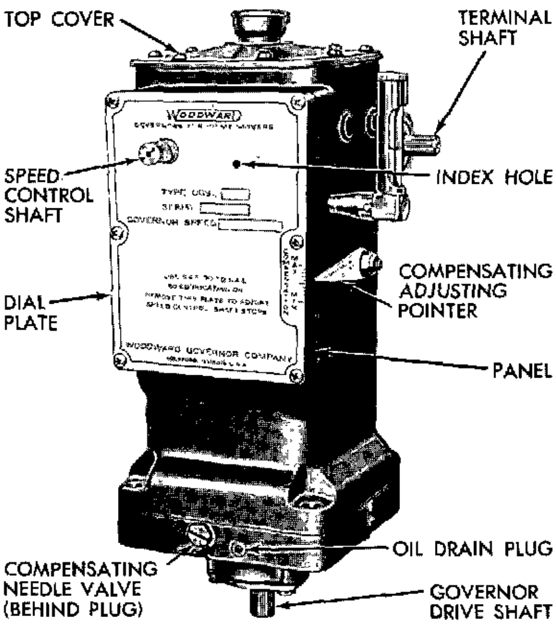
SERVICE ADJUSTMENTS - UG-8 LEVER CONTROL GOVERNOR




INTERNAL MECHANISM
UG-8 DIAL CONTROL GOVERNOR




EXTERNAL ADJUSTMENT POINTS
UG-8 DIAL CONTROL GOVERNOR




EXTERNAL ADJUSTMENT POINTS
UG-8 LEVER CONTROL GOVERNOR

be rinsed with clean kerosene or clean light grade fuel oil.

## GOVERNOR OIL LEVEL

Keep governor oil at correct level in oil gauge when the governor is running. The oil should be changed every 1,000 running hours if operating conditions are normal. If the governor is extremely active it may be necessary to change the oil every 500 hours. The oil should be changed at least every six months regardless of the hours of service.

## COMPENSATING ADJUSTMENT

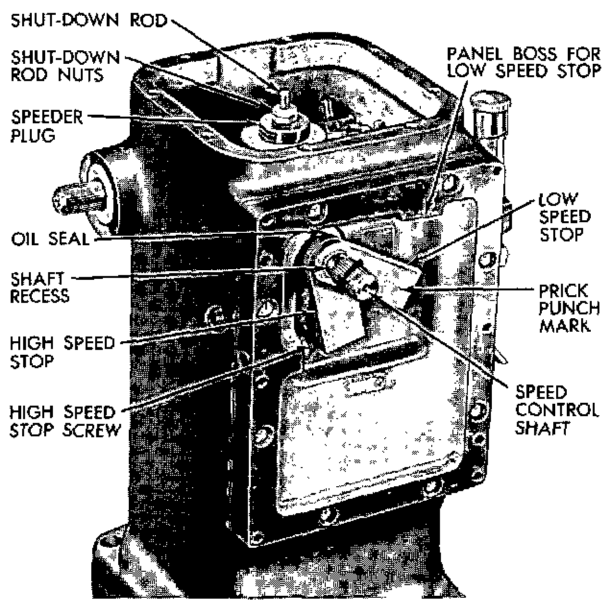
The compensating needle valve must be adjusted with the governor controlling the engine, although the compensation may have been previously adjusted at the factory or on governor test equipment.

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. The following governor linkage adjustments are necessary to provide mechanically desirable changes in the governor lever travel in response to changes in engine load.

1. Install the governor lever on the Woodward UG-8 governor terminal shaft in a nearly horizontal position (approximately 1 serration above horizontal), with the engine at rest and the governor set in "CLOSED" position. If the governor lever arm will not rotate to "CLOSED" position, trapped oil below the power piston in the governor must be relieved. If the governor is a UG-8 dial control type, turn the load limit knob towards 0 while rotating the lever arm to "CLOSED" position. If the governor is a UG-8 lever control type, lift the oil filler cap and with a long nosed pliers lift up on the shut-down rod while rotating the lever to "CLOSED" position.

2. Rotate the butterfly valve shaft lever on the butterfly valve shaft to closed position with the butterfly valve closed on its sharp edge.

3. Adjust the governor control rod to the approximate length between levers. The control rod connects to the second hole from the end in the governor lever. Now install the governor control rod, with the governor lever positioned on the governor terminal shaft, with the engine at rest and the governor set in "CLOSED" position. Make the necessary minor adjustment of the governor control rod length to just close the butterfly valve on its sharp edge.




INTERNAL MECHANISM
UG-8 LEVER CONTROL GOVERNOR

## ANALYSIS AND CORRECTION OF GOVERNING TROUBLE

The following chart may be used to determine the probable causes of faulty governor operation and to correct these troubles.

Definitions of a few common terms used in the chart are as follows:

1. Hunt: A rhythmic variation of speed which can be eliminated by blocking the energy medium supply manually or with load limit but which will reappear when returned to governor control.

2. Surge: A rhythmic variation of speed always of large magnitude which can be eliminated by blocking the energy medium supply manually or with load limit and which will not reappear when returned to governor control unless the speed adjustment or the load changes.

3. Jiggle: A high frequency vibration of the governor fuel rod end or engine linkage. Do not confuse with normal regulating action of the governor.

| TROUBLE | CAUSE | CORRECTION |
|---|---|---|
| I. Engine hunts or surges | A. Compensation adjustments incorrect. | 1. Adjust needle valve and compensating adjusting pointer. |
| | B. Dirty oil in governor. | 1. Drain oil, clean governor, and refill. |
| | C. Foamy oil in governor. | 1. Drain oil. Refill. |
| | D. Low oil level. | 1. Add oil to correct level on gauge glass. Check for leaks, especially at drive shaft. |
| | 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.<br>a. Check ballarms for sticking.<br>b. Inspect wear on ballarm toes.<br>c. Check speeder rod bearing.<br>d. Pilot valve or speeder rod may be sticking. See that floating lever is free.<br>e. Polish moving parts.<br>f. Inspect for lost motion of receiving compensating piston.<br>g. Inspect pilot valve adjustment.<br>h. Check for lost motion in governor internal linkage. |
| | H. Compensating spring incorrectly adjusted. | 1. Make adjustment. See governor instruction bulletin. |
| | J. Low oil pressure. Normal operating pressure 110 lbs. to 120 lbs. per square inch. | 1. Pump gear clearance incorrect. Use .005" gasket between controlet and base. No gasket used if controlet has oil groove.<br>2. Pump check valves not seating. |
| | K. Power piston sticking. | 1. Check alignment of piston, power link and power lever. Check for side play in terminal shaft. |
| | L. Engine misfiring. | 1. Check compression readings of each cylinder and make repairs or adjustments. |
| | M. Voltage regulator not operating properly. | 1. Adjust or repair voltage regulator. |

| TROUBLE | CAUSE | CORRECTION |
|---|---|---|
| II. Terminal shaft and engine linkage jiggles. | A. Rough engine drive. | 1. Check alignment of gears.<br>2. Inspect for rough gear teeth.<br>3. Inspect for eccentric gears.<br>4. Check backlash of gears.<br>5. Compensate for the roughness by changing the flexibility of the ballhead drive shaft. |
| | B. Compensating spring adjustment at critical setting. | 1. Change compensating spring pre-compression approximately .005" either way. |
| | C. Speed droop (if used) at critical setting. | 1. Reduce droop to eliminate critical setting. Load division will be affected if this is done. Readjust droop on units affected. |
| | D. Governor base not bolted down evenly. | 1. Loosen bolts, realign, and secure. |
| | E. Erratic action of flexible drive shaft. | 1. If governor has laminated spring drive inspect flexible drive parts for burrs, wear, or broken laminations. |
| III. Load does not divide properly in interconnected engines. | A. Speed droop adjustment incorrect. | 1. Readjust droop to divide load properly.<br>2. Increase droop to resist picking up (or dropping off) load.<br>3. Reduce droop to increase picking up (or dropping off) load. |
| | B. Speed droop shaft vibrating out of position.<br>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 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 speed droop adjustment are commonly used for D. C. service since the droop adjustment may be used to correct errors or inequalities of generator compounding. | 1. Increase tension of speed droop friction spring. |
| | C. Slippage in hydraulic or electric couplings if used. | 1. Adjust coupling. |
| IV. Engine is slow to respond to speed change or a load change. | A. Needle valve adjustment incorrect. | 1. 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. |

| TROUBLE | CAUSE | CORRECTION |
|---|---|---|
| IV. Engine is slow to respond to a speed change or a load change. (Cont.) | B. Governor is not sensitive in measuring speed change. | 1. See IG. |
| | C. Governor may be intentionally designed to protect engine from overloading during a load change. | 1. No field correction. |
| | D. Pilot valve not centered. It must open control ports equally in both directions. | 1. Make pilot valve adjustment. See governor instruction bulletin. |
| | E. Low oil pressure in governor. | 1. See IJ. |
| | F. Engine may be overloaded. | 1. Reduce load. |
| | G. Restricted fuel supply. | 1. Clean out fuel supply line and filters. |
| | H. Load limit knob set to restrict fuel. | 1. Open up on load limit. |
| V. Engine will not pick up full rated full load. | A. Butterfly valve will not open far enough. | 1. Adjust engine to governor fuel linkage.<br>2. Adjust load limiting device.<br>3. Check tension of load limit friction spring. Low tension may permit load limit cam to gradually work toward reduced load position. |
| | B. Restricted fuel supply. | 1. See IVG. |
| | C. Voltage regulator (if used) not functioning. | 1. Readjust or repair. |
| | D. Engine misfiring. | 1. Check compression readings 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.<br>2. See engine instruction manual. |
| | F. Speed adjustment of the governor is restricted. | 1. Check maximum speed limit adjustment on dial control governor.<br>2. Inspect speed adjusting linkage for interference on lever control governor. |

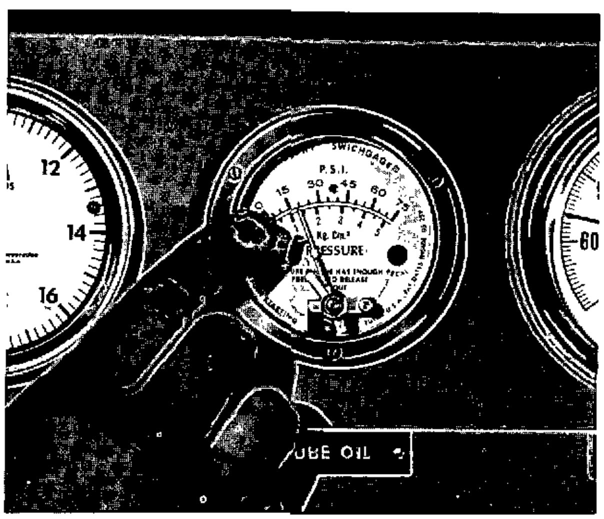
# OPERATION

## SAFETY CONTROLS

Current Waukesha Model L-5790-G series engines are factory equipped with Murphy fuel *shutoff valves to shut off the engine in the event* of lube oil pressure failure (below 10 psi), excessively high coolant temperature (above 210°F.), or engine overspeed (approximately 100 rpm above engine high idle speed). The Murphy valves are actuated electrically using power from the engine magnetos to shut off the fuel to the engine. In addition to the fuel shutoff, the magnetos are grounded when safety shutdown occurs.

In case of extreme conditions the oil pressure and water temperature Swichgages may have to be adjusted. The switch contacts are adjusted by means of an Allen head adjustment to obtain the desired settings. The settings mentioned above are the most desirable and normally should not be tampered with. The Waukesha Motor Company would be willing to assist in any special engineering problems and should always be consulted before making changes.

Since there is no oil pressure when starting the engine, the operator must re-set the oil pressure Murphy Swichgage by depressing its reset button until the lockout latches and must also re-set both Murphy fuel shutoff valves. These are reset by slowly depressing the large button on the valve approximately one inch, then depressing it firmly and briskly until it stops and holding it in this position for approximately five seconds. After the engine starts, its normal oil pressure should release the Swichgage lockout automatically. Be sure the engine de*velops sufficient oil pressure to release the* lockout as the Swichgage can not shut the engine down due to low oil pressure until the lockout has released. Whenever the engine is to be restarted after shutdown or after an attempted start which releases the Swichgage lockout, the Swichgage and both fuel shutoff valves must be re-set.



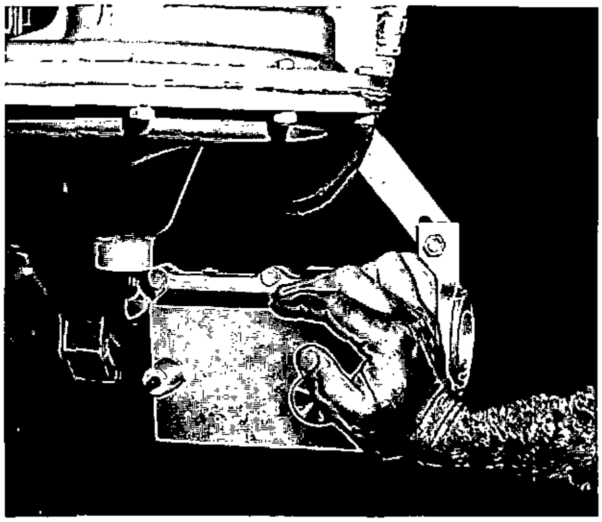
RE-SETTING OIL PRESSURE SWICHGAGE

Model L-5790-G series engines are also factory equipped with an overspeed governor, which when activated, allows engine oil pressure to actuate a trip plunger which flips a toggle switch to cause the fuel shutoff valves to stop the engine. *The toggle switch must be re-set before re-*starting only after an overspeed shutdown.

The Murphy fuel shutoff valves utilize a special coil and the junction box is also special for breakerless ignition systems. Therefore fuel shutoff valves and junction boxes are not interchangeable between engines with low tension ignition and those with breakerless ignition systems. Unless properly used with the ignition system they are intended for, they will be subject to damage and can not function properly.

The fuel shutoff valves are equipped with a small manual shutoff button which can be depressed to close the valve. Since there are two fuel shutoff valves used (one for each bank of the engine), both of them must be manually actuated if this shutdown method is applied.

Proper functioning of the low oil pressure Swichgage and the fuel shutoff valves can be determined each time the engine is shut down as the Swichgage should actuate the fuel shutoff valves when oil pressure drops to 10 psi. The high coolant temperature Swichgage can be checked by using a length of insulated wire or a screwdriver to "short it out" and actuate the fuel shutoff valves. Placing the overspeed toggle switch in "off" position will check its operation but the overspeed governor can only be checked by running the engine at approximately 100 rpm above engine high idle speed and adjusting the overspeed governor spring tension adjusting screw if necessary. Turning the adjusting screw in will raise the maximum rpm setting while



RE-SETTING FUEL SHUTOFF VALVE

backing the adjusting screw out will lower the maximum rpm setting.

The fuel shutoff valves are equipped with a "sensitivity" adjustment screw which in extreme circumstances may require readjustment from the factory setting.

Early Waukesha Model L-5790-G series engines were factory equipped with Sentinel safety valves which actuated to shut off fuel to the engine in the event of lube oil pressure failure or excessively high coolant temperature. The overspeed governor, when utilized on an engine with Sentinel safety valves, grounded the magnetos when it was activated. Engine oil pressure from the main oil header keeps the Sentinel safety valves open when the engine is operating. A heat sentinel valve used in conjunction with the oil pressure sentinel valves opens to relieve pressure from the oil sentinel valves if the engine overheats. Oil sentinel valves are reset before starting by rotating the reset lever completely clockwise. After the engine starts, its normal oil pressure should release the reset levers automatically. Be sure the engine develops sufficient oil pressure to release the reset levers as the oil sentinels are not in operation until they release. After every start or attempted start which releases the reset levers, the oil sentinels must be re-set in this manner.

The engine may be stopped by placing the ignition switch in "off" position which will ground the magnetos.

## PRE-STARTING CHECKS

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

1. Be sure the main clutch or other power-transmission device is disengaged.

2. Inspect the crankcase oil-level gauge on both the main engine and the starting engine, as well as the starting engine transmission. Make certain that the oil filter is full before starting the engine. Use the primer pump as required.

3. Trace through the external cooling system to make sure all control valves are properly opened and the drain cocks closed. Check the coolant level. If it is necessary to add a large quantity of coolant be sure to open the thermostat housing vent to allow any air trapped in the cooling system to escape.

4. Lubricate all electrical equipment, compressors, and other accessories in accordance with manufacturer's instructions. Turn down as required on grease cups or fill with the proper grease if empty. Lubricate pressure-gun fittings on power take-off a small amount.

5. If possible, particularly on a new installation, or on an engine long shut down, or in freezing weather, bar the engine over through several revolutions to be sure nothing will interfere with operation.

6. Be sure the fuel shut-off valve is opened prior to attempting to start the engine.

7. For engines with combination equipment for burning either natural or butane gas, be sure the main natural gas valve is closed and the butane gas shut-off valve and the liquid butane shut-off valve are both open when the engine is to be started on butane gas. Conversely, when the engine is to be started on natural gas, be sure the natural gas shut-off valve is open, and the butane gas shut-off valve and the liquid butane shut-off valve are both closed.

8. If a cooling fan is used, be sure that it is free to rotate, that the bearing is lubricated, and that the belt drive is snug and in good condition.

9. Relieve extra loads such as auxiliary air compressors or similar equipment.

## STARTING PROCEDURE

To start the FC engine:

1. Open fuel valve below the small tank. Drain water from glass bowl. Turn out float lock on carburetor.
2. Open FC throttle one-quarter way.
3. Close choke valve; turn engine over several times with crank. Choking is not always needed in warm weather or with warm engine. Never choke a hot engine.
4. Turn on FC ignition switch.
5. Pull up starting crank smartly.
6. Be sure to release the starting crank engagement lever when the FC engine starts.
7. FC oil pressure should be about 15 pounds after engine warms up.
8. When the FC engine is warm, engage the clutch and turn the main engine over several times (with fuel off) to be sure it is free. This is important in cool weather.

The main engine may now be started by following the procedure below:

1. Place the main engine throttle between one-quarter and one-half open.
2. Be sure to turn on the main engine ignition switch if it has not been left on.
3. Re-set the safety shut-down valves and the oil pressure Murphy Swichgage (if applicable). Do this after each attempted start. Prime the lubricating system before starting a cold engine.
4. Engage the starting engine Bendix gradually (with the FC at full throttle) and hold until the main engine starts. Release the *clutch immediately when the main engine* starts. Continued engagement will overspeed the Bendix and cause severe damage. If the engine is equipped with electric, pneumatic, or hydraulic starting, operate the starter to crank the engine. If the engine fails to start within 15 or 20 seconds, prime it for a second or two. If after priming, the engine still fails to start, then close the choke. If the choke is used for starting, be sure to release it as soon as the engine starts, thereby returning it to normal operating position. Priming and choking are with Ensign carburetor only.
5. Check the oil pressure and adjust the main engine speed to medium idle for warm up. IF OIL PRESSURE IS NOT INDICATED WITHIN 25 - 30 SECONDS, STOP THE ENGINE AT ONCE AND CORRECT THE CAUSE. DO NOT CONTINUE TO OPERATE WITHOUT OIL PRESSURE ON THE HOPE THAT A FAULTY GAUGE OR COLD OIL IS CAUSING THE TROUBLE. CHECK THAT THE FUEL SHUT-OFF VALVES OR THE OIL PRESSURE MURPHY SWICHGAGE RE-SET HAVE RELEASED OR ENGINE CAN CONTINUE TO RUN WITHOUT OIL PRESSURE.
6. Reduce the starting engine speed to idle; shut-off the ignition and gasoline, and lock the carburetor float.
7. Warm the main engine until the oil pressure stabilizes and the water temperature reaches at least 100° - 120°, F.
8. After the engine is warmed up the load may be applied. The engine speed for applying the load will vary depending upon the engine application. Generally, the load should be applied gradually with the engine speed set sufficient to carry the load.

## STARTING ENGINE CLUTCH ENGAGEMENT

Rapid jamming of the clutch should be avoided. The proper procedure is to momentarily engage the clutch, and in so doing the contact of the Bendix with the flywheel ring gear will be heard. Then the clutch should be engaged with sufficient pressure to crank the engine. Excessive pressure on the engaging lever will not help.

## LOW SPEED OPERATION

Some engines in the L-5790-G series are intended only for low speed operation and are modified to provide normal oil pressure at reduced operating speed.

CAUTION

Do not run low speed operation engines over 850 rpm, as they are equipped with large capacity oil pumps which will be damaged at higher speeds.

## STOPPING PROCEDURE

1. Release the load by disengaging the clutch control lever.

2. Place the throttle control lever in an idle speed position and allow the engine to idle for a few minutes to reduce and normalize the water temperature. It may be advisable after the engine has overheated due to excessive load or some fault of the cooling system, to run the engine at idle speed for ten minutes or longer before shutting it down. This is very important with a turbocharged engine.

3. When the engine has cooled sufficiently the operator should then close all the valves or shut-off cocks from the fuel supply to the carburetors to stop the engine. The Murphy fuel shutoff valves are equipped with manual shutoff buttons. If it is impracticable to shut off the fuel supply, stop the engine by shutting off the ignition. If the ignition shut-off system is used, be sure to run the engine at idle speed prior to stopping.

4. The exhaust pipe should be capped upon shutting down the engine for long periods of time to prevent condensation, rain, or snow from getting into the engine if it is exposed to the elements. A pail or bucket inverted over the exhaust pipe will be sufficient.

5. Test the coolant solution for adequate anti-freeze to protect the engine from freezing during shut-down. The immediate and anticipated air temperature will govern the amount of anti-freeze needed. If other than radiator means of cooling is employed, it will be necessary to drain the engine during shut-downs if the engine is operated in areas where the air temperature drops considerably below freezing, 32 degrees F. (0 degrees C.).

## INSPECTION

Thorough inspections at regular intervals will save money and prevent minor troubles from arising at inconvenient times.

ANY NEW or OVERHAULED ENGINE should always be checked over for unusual conditions at the end of the first week of operation. For example, cylinder head gaskets, base pan and gear-cover gaskets, and so on, should be examined for tightness. Re-torque replaced cylinder-heads after running the engine either idle or after load testing if possible.

The following table embraces a practical inspection routine that may be adapted as needed to individual variations in operating schedules. It is suggested that the operator consider the requirements of accessory maintenance and other features of the installation so as to fit these details into the regular engine inspection schedule.

### Daily Inspection

1. Water temperature and oil pressure — observe both before shutting down.

2. Oil level and quality — measure in both main and starting engine. If engine is operating for the first time, examine oil after 10 hours for signs of deterioration.

3. Coolant — examine condition and adequacy of supply. Rusty, scummy, or oily water may indicate the need for cleaning the cooling system or other servicing.

4. Fuel supply — measure in starting-engine fuel tank. Drain sump traps and strainers. Be sure main engine gas pressure is maintained at correct value.

5. Air-cleaners and breathers — inspect for cleanliness; under some operating conditions these units may require cleaning several times each day.

6. Water, fuel and lubricant lines — make a visual examination for indications of leaks, damaged tubing, or bad joints.

7. Back-fire valves — be sure they are in closed position. Check for condition and for evidence of damage.

8. Accessories — service in accordance with the manufacturer's recommendations.

9. Grease cups — turn down; replenish with proper grade of grease if necessary.

### Weekly Inspection

(Based upon approximately 50 hours)
Accomplish Items 1 - 9 in Daily Inspection.

1. Noises — any that may indicate need for repair or service should be traced to their source and corrected.

2. Engine exterior — clean thoroughly using a suitable solvent such as kerosene or mineral spirits; use care not to wash grit and dirt into inaccessible locations, around spark plugs, for example, where it might fall into the engine later on.

3. Starting engine clutch — adjust if needed. Grease Bendix bearings.

4. Mating surfaces — examine for indications of leaking gaskets; test for loose cap screws, nuts and engine hold-down bolts. Torque nuts, in areas where leaks are indicated, to specified values. Replace gaskets and re-torque evenly if leakage continues.

5. Clutch pilot bearing — grease this and other shaft bearings, with the proper grade of grease, but DO NOT OVERGREASE.

6. Fan belts — inspect this and other belt drives for proper tension, incipient breakage, fraying or other damage.

7. Water-pump — examine for evidence of leakage.

### Monthly Inspection

Accomplish Items 1 through 9 in Daily Inspection, and Items 1 through 7 in Weekly Inspection.

1. Top water manifold, thermostat housing — remove from both main engine and starting engine and clean away any scale or deposit in thermostat area.

2. Check and lubricate fan hub bearing, if fan is used.

### 100-Hour Inspection

Grease water pump idler pulley fitting and auxiliary water pump fittings (2) with ball bearing grease. Add water pump grease to the auxiliary water pump stuffing box fitting.

### 500-Hour Inspection

1. Spark plugs — remove and check the gap. Correct gap is .013"-.016" (.011" for platinum tip plugs).

2. Magneto — Check for correct breaker point clearance (.016" to .018") and condition.

3. Compression — check each cylinder. Be sure to close the gas shut-off valves, have the ignition switch in "off" position, and have the throttle wide open. Uneven compression or pressures lower than those in FITS AND CLEARANCES call for further investigation. When foregoing inspection has been completed, it may be necessary to decide on valve re-grinding, bearing adjustment or other overhaul.

4. Oil coolers — if increase in oil temperature is noticed, check operation of oil temperature control valve, and if necessary, remove and clean cooler unit(s).

5. Grease water pump fitting with ball bearing grease.

## TROUBLE SHOOTING

### Engine Fails to Start or Starts with Difficulty

The essence of successful trouble shooting is the location and isolation of an unsatisfactory condition without bringing several other equally bad troubles into existence by unsystematic "tinkering". When an engine is operating improperly, take time to define the difficulty clearly. Visualize the system involved and attempt to picture the most likely point where a condition might exist that would give the observed symptoms.

No Fuel to Carburetor

Lines plugged.

Tank empty.

Fuel regulator main diaphragm broken thereby preventing valve opening.

Fuel shut-off valve closed.

Too Much Fuel

Fuel regulator leaking.

Valve stuck open.

Starting adjustment set too rich.

Choke at fault causing wrong mixture.

Ignition Switch

Be sure ignition switch has been turned on and is not damaged.

Safety Controls

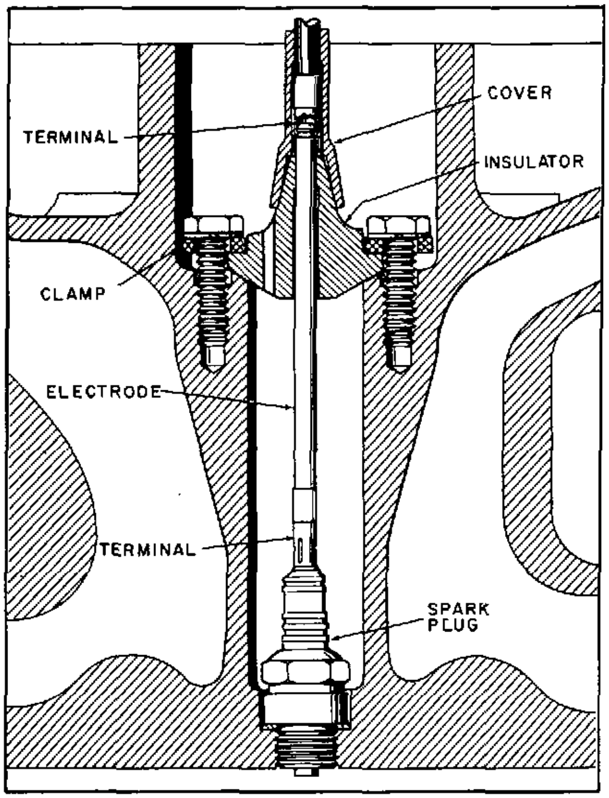
The safety shut-down valves and the oil pressure Murphy Swichgage (if applicable) must be re-set after every start or attempted start. Also the overspeed shut-down switch must be reset after an overspeed shutdown.

| | | |
|---|---|---|
| Engine Description | DAILY ENGINE INSPECTION REPORT | |
| #1 Engine Serial # #1 Drawworks Engine | | |
| #2 Engine Serial # #2 Drawworks Engine | | |
| #3 Engine Serial # #1 Pump Engine | COMPANY | LOCATION |
| #4 Engine Serial # #2 Pump Engine | DATE | DATE |
| #5 Engine Serial # #3 Pump Engine | ENGINE NUMBER | ENGINE NUMBER |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| MORNING TOUR | | | | | | | | | | |
| 1. Manifold Vacuum Reading | | | | | | | | | | |
| 2. Engine RPM | | | | | | | | | | |
| 3. Oil Pressure | | | | | | | | | | |
| 4. Oil Temperature | | | | | | | | | | |
| 5. Check Oil - Amt. Add Gal. - Change | | | | | | | | | | |
| 6. Check Oil Governor | | | | | | | | | | |
| 7. Check Oil Starting Engine | | | | | | | | | | |
| 8. Lubricate Gov. & Linkage | | | | | | | | | | |
| 9. Water Temp./Check Rad. Water | | | | | | | | | | |
| 10. Check Breathers & Oil Filters | | | | | | | | | | |
| 11. Check Fuel Filters & System | | | | | | | | | | |
| 12. Check Water Pump, Fan & Belts | | | | | | | | | | |
| 13. Oil Leaks - Water Leaks - Clean Eng. | | | | | | | | | | |
| 14. Operating Hours Per Tower | | | | | | | | | | |
| Motorman Signature | | | | | | | | | | |
| EVENING TOUR | | | | | | | | | | |
| 1. Manifold Vacuum Reading | | | | | | | | | | |
| 2. Engine RPM | | | | | | | | | | |
| 3. Oil Pressure | | | | | | | | | | |
| 4. Oil Temperature | | | | | | | | | | |
| 5. Check Oil - Amt. Add Gal. - Change | | | | | | | | | | |
| 6. Check Oil Governor | | | | | | | | | | |
| 7. Check Oil Starting Engine | | | | | | | | | | |
| 8. Lubricate Gov. & Linkage | | | | | | | | | | |
| 9. Water Temp./Check Rad. Water | | | | | | | | | | |
| 10. Check Breathers & Oil Filters | | | | | | | | | | |
| 11. Check Fuel Filters & System | | | | | | | | | | |
| 12. Check Water Pump, Fan & Belts | | | | | | | | | | |
| 13. Oil Leaks - Water Leaks - Clean Eng. | | | | | | | | | | |
| 14. Operating Hours Per Tower | | | | | | | | | | |
| Motorman Signature | | | | | | | | | | |

| | |
|---|---|
| Remarks: (Work Done, Needed Repairs) | Lube Oil Sample |
| | Total Hours on Lube Oil |
| | Total Hours on Engine |
| Mechanic Copy | Chief Mechanic |
| | Approved |

SUGGESTED DAILY ENGINE INSPECTION REPORT




SPARK PLUG CONNECTIONS

Improper Spark Plug Gap Adjustment

Remove the spark plugs and check the gap. Correct spark plug gap is .013"-.016" (.011" for platinum tip plugs).

Ignition Wiring

Inspect all wiring terminals. See that the metal tips are pinched onto the wire ends and are not pulled away from the ends of spark conducting wire. Ignition wires should be securely fastened to the magnetos and firmly attached to their respective plugs. Loose connections reduce the spark intensity or break the circuit completely. Wires on which the insulation has become cracked or frayed due to constant rubbing against some metallic part of the engine, will cause a short when the wire grounds against the engine. Wires saturated with oil or moisture can also cause shorting. Make sure all connections and terminals are clean and in good condition.

Magnetos

Check the magneto breaker points — dirty or maladjusted points will cause poor starting. Check the magnetos to be sure that current is being delivered to the No. 1 cylinder (right bank) spark plug when the flywheel timing pointer lines up with the correct degree mark on the flywheel timing tape, depending on the fuel and compression ratio. Be sure the magnetos are properly synchronized. Be sure the magneto impulse couplings are operative. The impulse coupling springs may be broken or other parts may be worn to such an extent that proper operation is impossible.

Throttle

Hand throttle should be set between one-quarter and one-half open for starting and immediately adjusted to give recommended idling speed of 450-500 R.P.M.

Air Intake

Clogged air cleaners, or protective covers accidentally drawn into the manifold, will cause starting difficulties.

Liquid Lock

It is possible for oil or water to form a *positive stop between the piston crown and* the cylinder head. This can occur if too much flushing oil has been poured into the cylinder for storage, or if cooling water has leaked past a head gasket. To detect this condition and thus prevent serious engine damage from this source, always try to bar the engine over if leakage is suspected — or after any lengthy period of storage. Do not force over center if resistance is felt. Remove spark plugs and locate source of trouble.

Compression

Other things being equal the easiest starting engine will ordinarily be the one with the best compression. When poor compression is indicated, check each cylinder for pressures within the range specified under FITS AND CLEARANCES. A good compression gauge should be used. The ignition switch should be in the "off" position, the fuel shut-off valves should be closed, and the throttle wide open.

Cranking Speeds

Low cranking speeds also contribute to hard starting. Poor starting engine condition, or *thick, cold oil will reduce speeds considerably.* Slow cranking may stem from too short a warm-up, a slipping clutch, or improper adjustment of the small engine governor. The starting engine, although used for comparatively short times, will perform better if given occasional valve overhauls. Once each year will ordinarily be adequate.

### Failure of Engine to Develop Power or Irregular Running

Governor

Lack of lubrication restricts free action — Control rods or cables bent, sticking, or creeping — Inspect entire system and correct to ensure free movement and secure, accurate settings. Check security of locking on adjustable control rods, eye bolts, and clevis assemblies. Governor improperly adjusted. Refer to Woodward Governor section.

Load

Slipping clutch or belt drives. Wide variations in loads or poor regulation on electrical equipment. Use vacuum gauges to avoid overloading from improper synchronization of multi-engine installation.

Air Intake

Examine manifolds and air cleaners for possibility of obstructions.

Compression

Low or uneven compression — Check hydraulic valve lifter settings and re-set if necessary. With properly set valves, continued indications of low compression signify the need for valve and seat overhaul, and possibly the replacement of piston rings or other parts. Always make visual inspection for possibility of a broken valve spring. Sticking valves may sometimes be freed with penetrating oil or similar gum-cutting lubricants. Occasionally, sticking cam followers may give the same symptoms.

Carburetion

Check the fuel pressure. Perhaps a volume tank should be installed to aid acceleration. The carburetors or the gas regulators, or both, may be improperly set and need adjustment.

Air Leaks

Air leaks to intake manifolds, manifold gaskets, and throttle shafts may cause irregular running. Test with a vacuum gauge. If the reading is low with a steady indicator, air leaks are indicated. Take corrective steps.

Exhaust

Exhaust back pressure is excessive. Check for bent, undersize, or clogged exhaust pipe. Clean out or replace as necessary.

### Engine Stops

Fuel

Fuel supply is exhausted or fuel supply lines clogged. Check the fuel supply, be sure all fuel line valves are open and clean fuel supply lines if clogged.

Ignition

Ignition system defective or grounded. Check wiring for bad or loose connections or for grounding due to wear or saturation. Check magnetos for proper operation.

Lubrication

Excessive loads, speeds, or temperatures may result in piston seizure. Neglect of the oil filter may cause plugged oil passages and lubrication failure. Low oil pressure, below 10 pounds per square inch, will automatically cause the safety shut-down to shut off the fuel and stop the engine.

Cooling

Excessive loads, speeds, frozen cooling system, or inadequate provision for reducing cooling water temperature may bring on overheating (over 210°F.) sufficient to cause safety shut-down to stop engine.

Overspeed

Engine overspeed will automatically cause the overspeed governor to stop the engine.

Load

Excessive overloads or improper governor adjustment for the loads involved may cause the engine to stall.

### Engine Misfires

Carburetion

One of the most common causes of misfiring is incorrect carburetor or regulator adjustment, particularly at idling speeds. Make adjustments as required. Remove and clean the carburetors, fuel regulators, or fuel supply lines if necessary. Check fuel pressure gauge readings. If supply pressure is too great, a secondary regulator should be installed in the line. Check fuel regulator diaphragms for dryness or stiffness which will prevent them from operating freely.

Ignition

A common cause of misfiring is dirty spark plugs. First check to see that current is flowing to each plug, then remove the plugs and inspect the electrodes. Clean the plugs and set the gaps. Replace plugs as necessary. Dirty plugs indicate faulty valve operation, or worn piston rings allowing oil to enter the combustion chamber. If the spark plugs are not the cause of misfiring, check the rest of the ignition system.

Sticking Valves

Remove a manifold plug and attach a manifold vacuum gauge to the intake manifolds. If the indicator drops several inches at regular intervals with the engine idling, the cause is generally a sticking valve or a defective spark plug. If the spark plugs are not defective it is assumed that the action of the vacuum gauge is a result of sticking valves. Sticking intake valves will result in a spitting or popping sound as the explosion in the cylinder backfires through the backfire valves. Check the hydraulic lifter setting. Valves holding open can be caused by weak or broken valve springs, however, use of poor fuel will cause valve stems to become gummed up so they do not work freely in guides. Inspect valves and springs and take corrective steps.

Leaking Intake Manifold (at low idle)

Inspect the intake manifolds for loose plugs, cracks or damaged manifold gaskets. Take steps to remedy the indicated condition. Replace intake manifolds if necessary.

Engine Not Warmed Up

Permit the engine to run at 450 - 500 R.P.M. until the water jacket temperature reaches 100 - 120 degrees F. before applying any load to the engine.

Compression

Test each cylinder to see if there is any loss of compression. Valves may need grinding or excessive blow-by may indicate need for replacement of rings.

## Knocking or Unusual Noises

Operation

The knocking sounds arising from unsatisfactory fuels, overloading, improper timing, and similar operational variables are usually easy to recognize and distinguish from genuine mechanical noises. Such conditions require some change in operating technique. Mechanical noises, however, may indicate the need for repairs or adjustments.

Installation

Engine loose on mounts, vibration disturbances of loose control rods, air cleaner, muffler, or similar parts. Do not fail to check accessories such as compressors, generators, fans, and so on. A notched-out Vee belt, for example, can sometimes produce a misleading knocking sound.

Mechanical

Loose bearings — connecting rods, piston pins, camshaft, or crankshaft. Loose flywheel or distorted housing. Damage, looseness or wear in water pump, oil pump, or magneto drives.

Excessive crankshaft end play.

Improperly adjusted valves, sticking valves, rocker arms, or hydraulic lifters.

Excessive time since overhaul — Worn pistons, stuck or broken rings, carbon or piston crown.

Bearing looseness — A loose connecting rod bearing may be located by running the engine briskly, and then closing the throttle. Rattling, as the engine slows down, is a good indication of one or more loose rod bearings. Main bearing knocks are harder to isolate and it is usually necessary to shut the engine down and test the bearings manually.

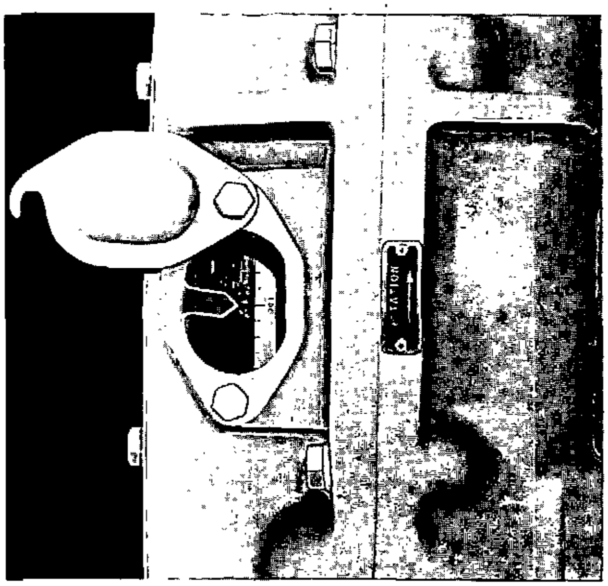
## Excessive Fuel Consumption

Carburetion

Carburetor adjusted too rich — Will produce a popping sound from the exhaust outlet. The engine will also "load up" and operate in a sluggish manner. Clogged air cleaners resulting in an improper mixture. Check for any leaks in fuel system.

Ignition

Improperly adjusted or dirty spark plugs — Remove and clean or replace. Be sure to use the correct type plugs. Loose wiring or broken connections — Make sure wires are firmly attached to magneto. Dirty, pitted, or improperly set magneto points — Service and adjust points as necessary. Damaged or carbon tracked rotor — A cracked rotor will cause shorting. Improper magneto timing. Loose or worn magneto couplings. Broken impulse coupling. Magneto timing is late.



LEFT BANK TDC MARK

Load

Excessive load — Poor synchronization in multi-engine installations. Poor regulation of electrical loads. Use vacuum gauges to balance loads. Improper matching of torque converter to engine and load. Failure to recognize normal loss through converter.

Mechanical

The engine that is in best mechanical condition is usually the most economical to operate. Poor compression from any cause, and general deterioration may indicate their presence and the need for a shop overhaul by high fuel consumption and smoking.

## Overheating

Cooling System

Insufficient coolant — Measure coolant level. Frozen coolant — Place hand on radiator and hoses to detect frozen areas. Partial freezing slush, and ice particles when present in only small amounts can cause severe overheating. Poor coolant circulation — Examine hoses inside and out for signs of collapse, rotting and air leaks; replace if not in good condition. Lime deposits must be removed. Thermostatic valve assembly not operating properly — Check settings and operation. Insufficient circulation of air — If the engine is in a small enclosure or engine room fresh air should be circulated around the radiator and engine proper by pusher type fans with ducts leading outside the building. Do not restrict the circulation by placing an obstruction near the radiator.

Water Pump

Cranking a frozen engine will sometimes cause water pump damage; likewise corrosive cooling water may have destructive effects. Remove outlet connections and examine impeller as first check. Fan belts slipping — Vee-type fan belts should be of proper width to seat on sides of Vee without bottoming in groove. Excessive tension is undesirable and not necessary if correct belts are used.

Timing

Late timing may cause overheating —Is normally detected by excessive exhaust temperatures.

Lubrication

Improper oil or excessive time between oil changes — Replace with fresh oil of type satisfactory for heavy duty lubrication; clean filter and replace elements. Oil too hot — Check oil temperature control valve and auxiliary water pump, clean oil cooler(s).

Load

Prolonged service at excessive loads will cause overheating. Improper synchronization so that one engine pulls more than another in an installation is a possible source of overloading. Use vacuum gauges to indicate the extent of load and to insure equal distribution of the load on each engine.

Installation

High exhaust back pressure due to improper piping or muffling may cause overheating and power loss.

**Low or Fluctuating Oil Pressure**

WARNING: STOP ENGINE AT ONCE.

Oil

Insufficient oil — Check and replenish oil regularly. Diluted or broken-down oil — Use better quality oil, change more frequently, clean filter, clean oil cooler, overhaul engine, clean sump screens. Wrong oil viscosity — change oil to viscosity recommended in Service section. Cold oil sludging — control oil temperature to hold 170° - 180°, F. Min.

Oil foaming — Change oil grade, check for water leaks.

Pressure Regulation

Relief Valve — Sticking, carboned, seat worn, out of adjustment or vibrating loose, vent behind relief valve plugged. Gauge operating inaccurately — Clean gauge line; replace gauge. Auxiliary relief valve improperly set — check adjustment sequence in Service section.

Pump

Inlet strainer screens clogged — Remove and clean in benzol or other solvent. Damaged or worn pump gears — Oil lines and passages clogged — clean thoroughly (this condition may result from using detergent oils in engines already very dirty).

Mechanical

Excessive bearing clearances on camshaft or crankshaft — Engine ready for shop overhaul. Cracked or broken oil line, leaking gasket on suction side.

# SERVICE MAINTENANCE

## FUEL SYSTEM

Waukesha Model L-5790-G engines are designed to burn several different types of fuel, depending primarily upon the engine application and location. Fuels most commonly used are natural gas, and propane/butane.

Operation of Waukesha spark ignition engines on gas type fuels requires that the fuel be delivered to the engine in adequate volume and pressure throughout the entire speed and load range of the engine. Reference to the illustrations will show that a gas fuel system consists basically of a primary or "field" regulator, a pressure reducing valve (when necessary) and a gas carburetor. A typical LPG system consists of a carburetor and a combination regulator and vaporizer unit. If the vaporizer does not contain any pressure regulating device, a field regulator must also be included in the system. The components of either system appear similar in most cases but it must be remembered that the internal parts such as orifices and diaphragm springs determine gas flow capacity. Only strict adherence to the recommendations given in this manual will result in optimum engine performance.

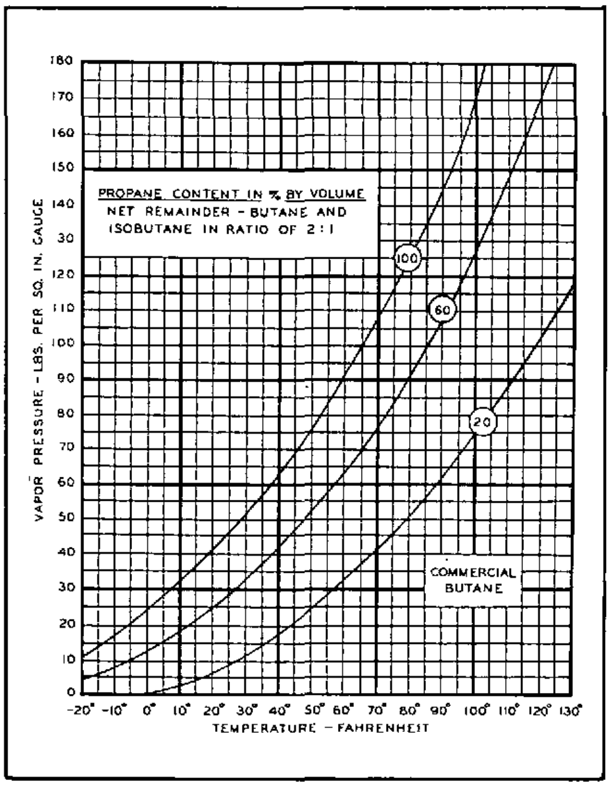
It is extremely important that gas engine users, especially those with high power output requirements, understand and appreciate the possible variations in the LPG fuel they purchase and the results of these variations in terms of engine service life and operating cost.

1. 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.

2. Substitution of liquified petroleum gas (LPG) for natural gas reduces the anti-knock margin of safety and often requires retarded ignition timing if the optimum natural gas timing was previously used. The detonation or knocking which can occur under certain load and operating conditions in combination with low octane fuel is dangerously destructive to the engine parts, frequently causing broken pistons, broken piston rings, bearing fatigue damage, heat gasket failures, and the associated troubles which follow the initial damage.

3. In addition to the higher octane rating of propane, it also has a higher vapor pressure. Unless the natural vaporizing tendency for the fuel is high enough to force the fuel from the tank to the regulator and carburetor in adequate volume, the engine will perform erratically and will be operating on a lean mixture. Since leanness is a condition often associated with detonation, the lower vapor pressure of butane may therefore contribute, with its lower octane value, to an even more dangerous combination.

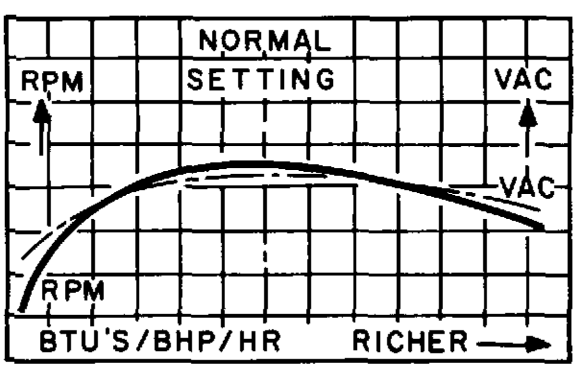
4. Examination of the accompanying chart will show that propane will maintain about 20# pressure even down to sub-zero temperatures. Butane, on the other hand becomes marginal as the temperature approaches freezing.




VAPOR PRESSURE OF BUTANE-PROPANE MIXTURE

The above facts should be taken into consideration when making the initial installation since the fuel tanks and associated fittings must be capable of handling the higher pressures of propane during warm weather. If such provisions are made, no problems will arise later when ordering fuel. The person charged with this responsibility should make certain that the supplier can and will supply a suitable propane specification. Ignition timing must always be adapted to the fuel in use. Never run on LPG with natural gas timing, and if frequent alternation between fuels is necessary, a compromise timing is suggested.

The variation in BTU content of gaseous fuels makes it quite important to re-adjust the carburetor when changing over from one to another. Failure to re-adjust may cause lean mixture, valve burning, back firing, and detonation, and in the case of some gaseous fuels, lacquering. Laboratory tests and field experience have shown the best and most practical guides for carburetor adjustment are manifold vacuum (naturally aspirated engines) and RPM. When adjusted for maximum vacuum and RPM the engine is operating efficiently and producing maximum power with the greatest margin of safety. In the case of engines where sudden acceleration loads are common or hard lugging at low RPM is anticipated, a slight over-adjustment towards the rich side is suggested to compensate for detonation tendencies and protect against minor variations in gas pressure. Other adjustment methods using exhaust temperature of field type gas analyzers are not regarded as accurate or safe by the Waukesha Motor Company and their use may prove to place the engine in a marginal range of operation.




NATURALLY ASPIRATED CARBURETOR ADJUSTMENT CHART

### Line Size

It is important that the line sizes of a natural gas fuel system be large enough to supply adequate gas volume. The line between the regulator and the carburetor must not be reduced in size from that provided for at the regulator inlet and outlet.

## LPG FUEL SYSTEMS

Operation of Waukesha engines on LPG (liquified petroleum gas) follows the same general recommendations as for Natural Gas engines. In both cases factory specifications in regard to regulator sizes, line sizes, and pressures must be followed. The basic difference between the two fuels is that LPG is initially a gas that has been compressed under extreme pressure to a liquid state. The liquid is then transported in a pressure vessel meeting rigid government construction specifications. The liquid must then be transformed into a gas at the engine for efficient mixing of fuel and air in the carburetor.

A complete LPG fuel system consists of a high pressure liquid regulator, a vaporizer, and a low pressure gas regulator. In those applications where the vaporizer is a separate component, the complete system must then include a field regulator as in the natural gas system.

### Vaporizer

The vaporizer utilizes the heat of engine coolant to provide sufficient temperature differential between the liquid fuel and the vaporizer body to aid in vaporization of the liquid and prevent icing of the regulator parts. Icing occurs when the expanding liquid absorbs heat with a resulting refrigeration effect.

## SYNCHRONIZATION PROCEDURE

The following procedure listed for applications where more than one engine is used in compound to overcome a load. In particular, this would be a drilling rig application where two or three engines are used to power the drawworks, rotary, and mud pump.

1. First adjust carburetors as outlined under Adjustment.

2. Put engines in compound and adjust low idle stop on carburetor until all engines have the same vacuum or manifold pres-

sure. (Since all engines are in compound all will be running the same speed.)

3. Disengage one engine clutch from compound and set throttle in wide open position to allow engine to run against governor. The desired governor speeds loaded are not to exceed the loaded speeds for continuous service. High idle speed will exceed loaded speed approximately 7 percent depending upon the governor used. Adjust governor to permit this speed on this engine.

4. Now put this engine in compound with the other engine (or engines) and place throttles of all engines in wide open position. Adjust the governor as necessary so that the performance reading or manifold pressure on the other engine or engines is the same as the one adjusted in Step #3, above.

5. The engines now should be in compound so that the performance readings on each will follow one another from idle to full governor speed and on load.

NOTE

If after the above adjustment, you cannot get the engines to run together, check the relative position of the governor butterfly valve of each engine (stopped). If you find a slight difference in the position of the governor butterfly this can be adjusted by changing the length of the governor rod at the rod ends.

6. Do not attempt to make adjustments on the carburetor to obtain equal performance on the engines in compound as this will offset the fuel mixture making the engines run too rich or too lean. Always adjust the carburetor for load before you try to synchronize engines in compound.

Balancing of the dual carburetor mixture ratio and throttle opening is necessary for normal engine operation. Before making the adjustments, the throttle cross shaft linkage must be connected when both carburetor throttle valves are fully closed.

Carburetor service consists largely of maintaining the fuel supply in a clean condition, checking proper adjustments at rare intervals, and leaving the carburetors alone when no specific attention is needed. More carburetors are ruined by tampering than by hard service.

When it becomes necessary to perform major cleaning and service operation, the carburetor manufacturer's special bulletin for the unit at hand should be followed without deviation.

## SCRUBBER TANKS

Natural gas powered engines frequently employ a scrubber tank. If the natural gas is high in sulphur content, a special scrubber is required. The scrubber tank filters the major impurities out of gas. Consequently, these impurities settle to the bottom of the tank and should be drained off. Periodically the operator should drain the oil from the tank and wash the tank with an accepted washing compound or solvent. Replenish the oil supply. Fill the scrubber tank slightly less than one-half full of motor oil.

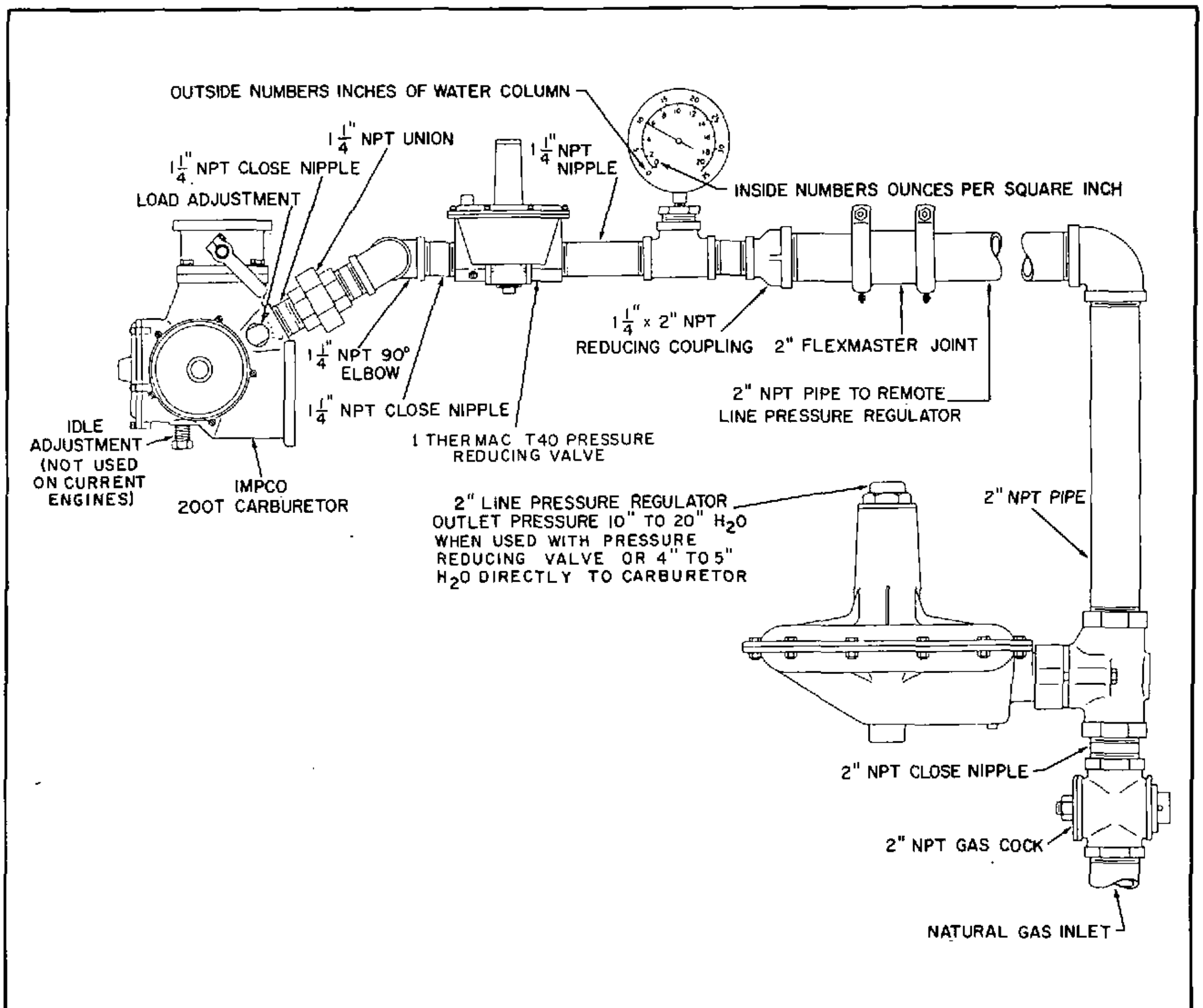
## IMPCO CARBURETORS

### Operation

The Impco carburetor may be arranged to operate on natural gas or a combination of natural gas and LPG with automatic changeover. These carburetors are of the air valve type, designed to operate directly from an "ounce" regulator. Normal pressure to the carburetor is 5" water column, with the engine stopped, (check at idle and readjust if necessary) for 1000 BTU natural gas. For natural gases of different heat values, slightly higher or lower pressures are required and adjustment is normally made in the field. LPG contains more heat units for a given volume than natural gas and for this reason the pressure at the carburetor inlet must be regulated at 1-1/2 inches water column negative. This pressure is non-adjustable and is controlled by the regulator.

The Impco Model 200T carburetor consists of a main body with a conventional butterfly valve and three diaphragm operated gas metering valves. The amount of air going to the engine is measured by three air-flow measuring valves which rise in direct proportion to the air volume passing through. The gas metering valves are mechanically fixed to the air measuring valves and rise with them, thus opening the gas passages an amount proportionate to the air entering the engine. This establishes and holds a definite fuel/air ratio throughout the operating range. The actual movement of the parts results from the negative pressure at the air measuring valves which is communicated to the back side of each diaphragm through four small holes. The Impco Model 600 carburetor has one large diaphragm operated gas metering valve.

On natural gas, the Impco carburetor is somewhat less sensitive than other types to the effects of moderate air cleaner restriction and a balance line may not be needed. When




TYPICAL NATURAL GAS PIPING LAYOUT

operating on LPG, however, the results of air cleaner restriction may be quite significant and a balance line is important.

NOTE

When used, mount Thermac reducing valve close to carburetor and place all other control valves, solenoids, etc. upstream of reducing valve.

### Installation

The illustration showing the natural gas installation of an Impco carburetor is largely self explanatory. The line pressure regulator must be large enough and of suitable pressure reducing capability to handle the fuel source involved and provide an adequate volume of natural gas. The Thermac reducing valve does not seal off with the engine at rest and pressure measurements to check pressure at the carburetor when a Thermac reducing valve is used must be made with the engine running at idle speed. Note that no mechanical choke is provided for starting and none is necessary with this type of carburetor.

## GENERAL IMPCO SERVICE INSTRUCTIONS

### Natural Gas

The normal arrangement for natural gas uses a field regulator to reduce pounds pressure to the final value of 5 inches water column (3 oz.) maximum. Excessive pressure will increase gas fuel consumption. This pressure will have its main effect on fuel economy.

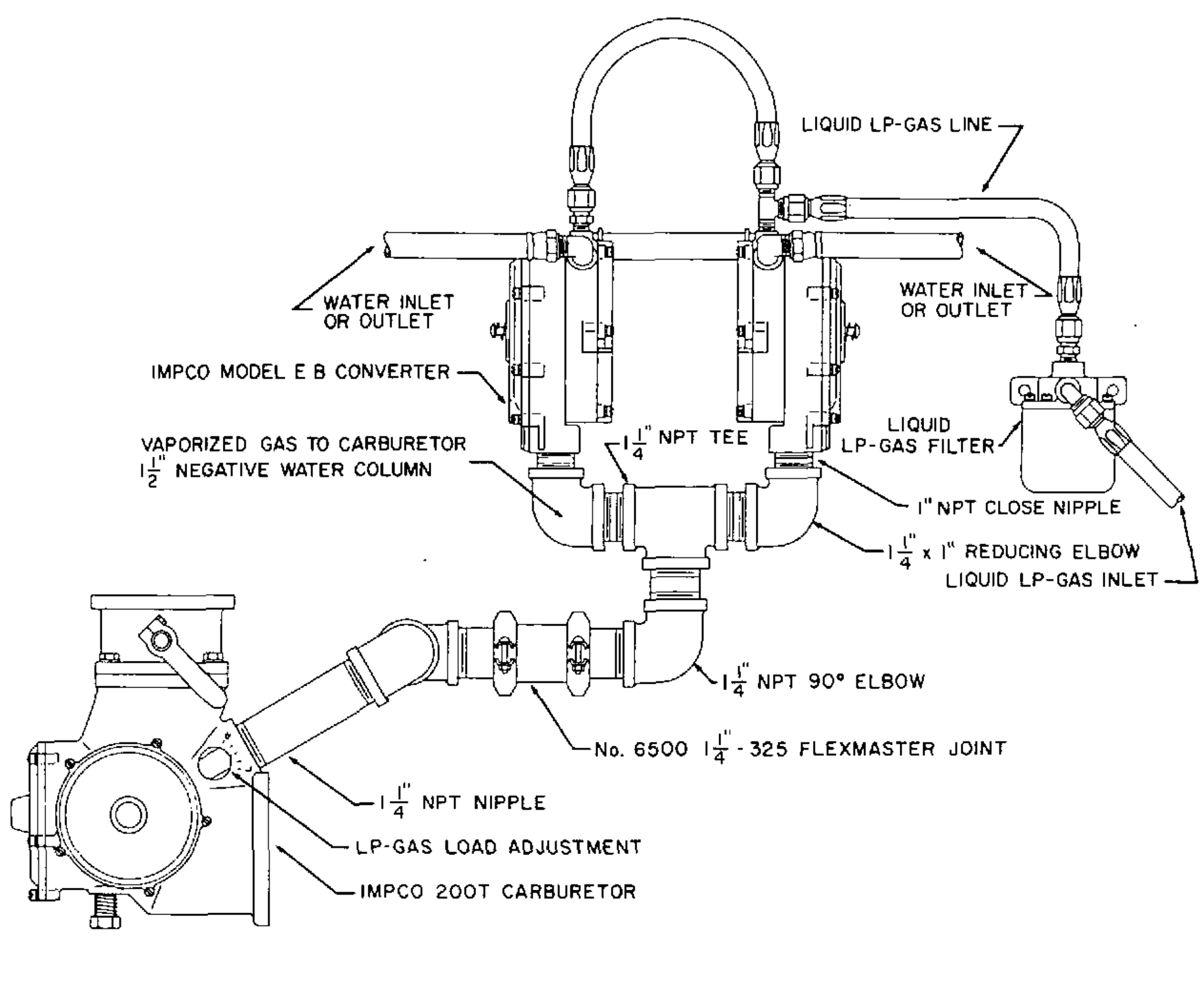
For reasons of safety. . .ALL GAS INSTALLATIONS IN CLOSED AREAS OR BUILDINGS SHOULD HAVE A POSITIVE SHUT OFF VALVE TO PREVENT GAS LEAKAGE WHEN THE ENGINE IS AT REST.

The LPG installation shows that liquid fuel should be filtered before entering the vaporizer or "EB" converter. The liquid fuel is converted to gas by addition of heat from the hot water from the engine jacket which is circulated through the water chambers of the vaporizer. The regulator section reduces the high pressure gas to the desired level for use. Because of the high BTU content of LPG, the gas volume required is smaller than needed for natural gas and the pressure at the carburetor is maintained at a negative value. A balance connection from the carburetor inlet to the regulator should be used in this installation although it is not shown in the illustration.

### Adjustment

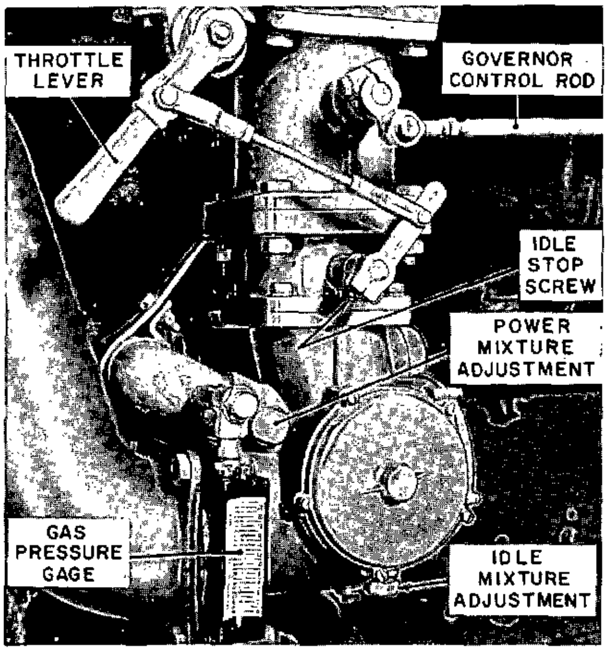
With the 2" line pressure regulator, the following orifice size and type of spring must be used to obtain required pressure to the carburetor.

| Inlet Line Pressure | Orifice Size | Spring Color | Outlet Pressure to Carburetor |
|---|---|---|---|
| 20 to 50 lbs. | 3/4 | Red | 5" water column |

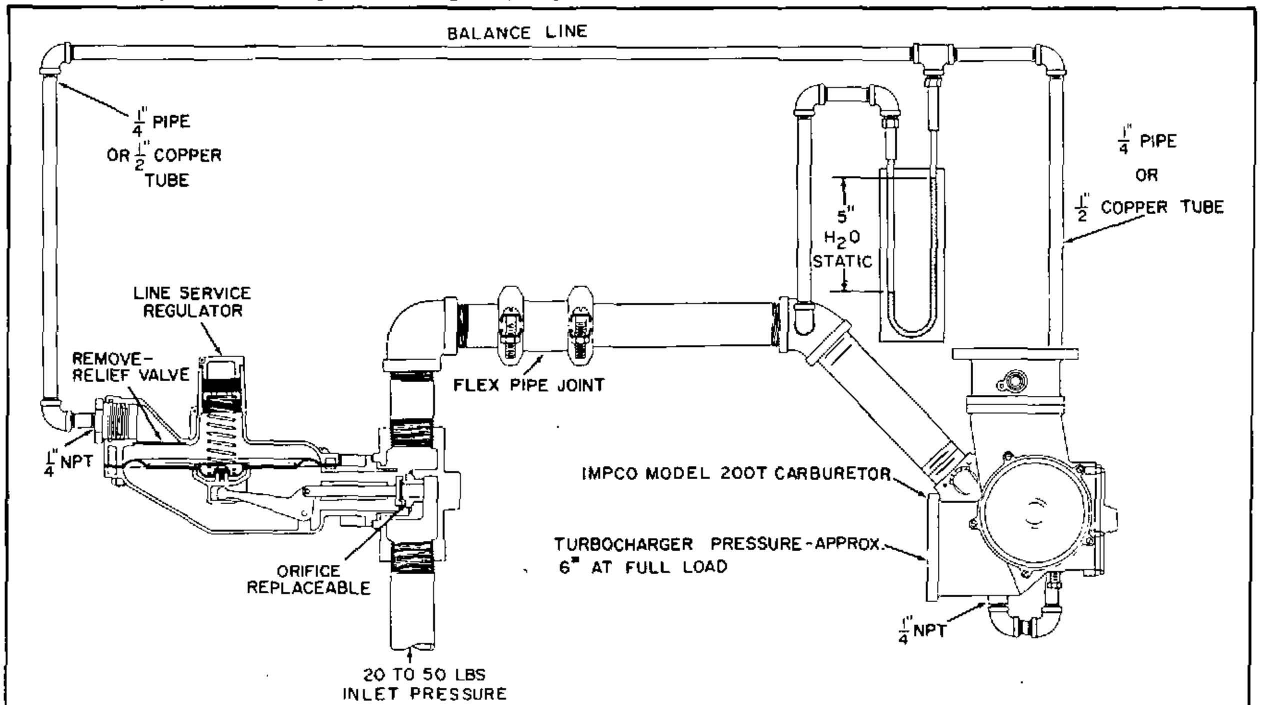



TYPICAL LP GAS PIPING LAYOUT

1. Set natural gas pressure at idle if Thermac reducing valve is used or with engine stopped (check at idle) if Thermac is not used, to 5" water column (3 oz.) for 1000 BTU gas with idle mixture screw backed out 2-1/2 turns (Impco Model 600 and current Model 200T carburetors do not utilize an idle mixture adjustment).
2. Full load gas pressure may drop as low as atmospheric (naturally aspirated) at the carburetor gas inlet. Exact pressure at full load is immaterial as long as power mixture adjustment is still effective.
3. For naturally aspirated engines, if intake manifold vacuum is below 8" mercury with the engine running loaded at governed speed, adjust the power fuel mixture from rich towards lean slowly to obtain maximum vacuum at a fixed speed or until the governor throttle begins to open further. The power adjustment of an Impco Model 200T carburetor is not effective at a fast idle or light load. If with full load, the manifold vacuum is above 8" mercury, adjust the field regulator (instead of the power fuel mixture) to lower or raise the gas pressure to the carburetor to obtain a leaner or richer fuel mixture for maximum vacuum. The power mixture screw of an Impco Model 600 carburetor turns in to lean and out to enrichen and is effective at a light load.
4. For turbocharged engines, with the engine running loaded at governed speed, adjust the power fuel mixture from rich towards lean slowly until engine speed increases or the governor throttle starts to open further. Gas supply pressure on both banks should maintain equal pressure, approximately 3" to 4" water column. Another adjustment method for turbocharged engines is to adjust the power fuel mixture for the lowest intake manifold pressure




CARBURETOR CONTROLS AND ADJUSTMENTS




TYPICAL TURBOCHARGED NATURAL GAS PIPING LAYOUT and then lean the mixture enough to raise the intake manifold pressure one-half inch of mercury above the lowest pressure to carry the load and speed.

### Thermac Pressure Reduction Valve

1. Natural gas pressure at carburetor should never exceed 5" water column (3 oz.) for 1000 BTU gas. When pressure cannot be reduced at the line regulator to 5" water column or more pressure must be used to overcome line loss of pressure due to small pipe or long line, use a Thermac secondary pressure reduction valve at the carburetor. The line (primary) regulator may then be set as high as 14 ounces (25" W/C).
2. A Thermac pressure reduction valve at each carburetor is desirable when several engines are using gas from a single line regulator.

### LP Gas

1. L.P. gas inlet pressure to the carburetor must be 1-1/2" (negative) water column as set by the IMPCO "EB" vaporizer regulator (blue spring).

### Balance Lines

1. Due to the insensitivity of the air valve carburetor to minor inlet air restrictions, most non-turbocharged installations do not require a balance line.
2. Series 200T carburetors use a 7/16" I.D. balance line.

### Turbocharged Engines

1. A balance line must be used on all turbocharged engines from the pressurized air at the carburetor air horn to the atmospheric vent in the regulator. This will raise gas pressure equal to air pressure rise.
2. Use carburetor with internal seals for turbocharged engines.

## TURBOCHARGING AND INTERCOOLING

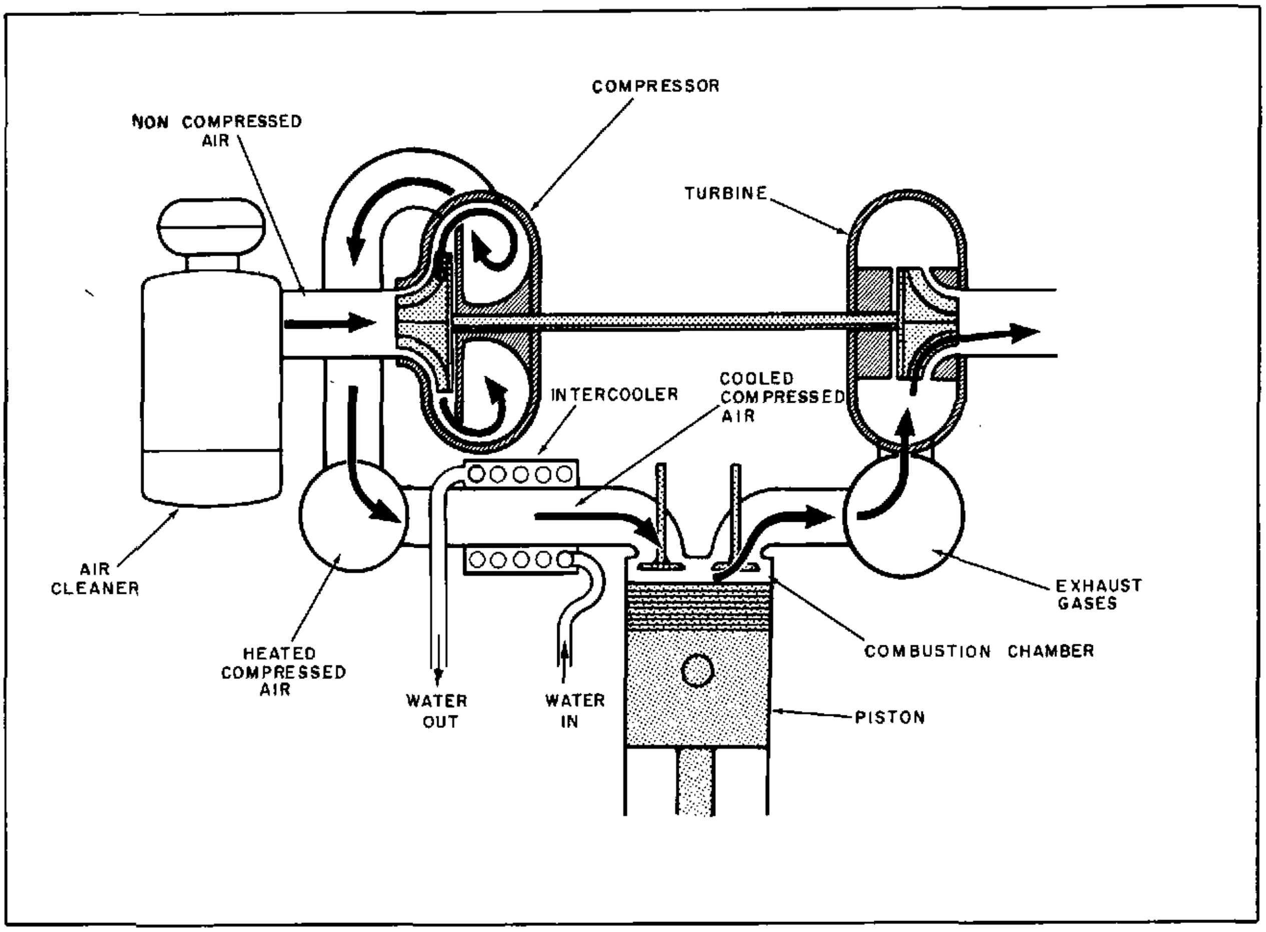
### Turbocharging

The following information is supplied as a general guide to the better understanding of the principles surrounding the operation of turbo-supercharged models, and is not to be construed as complete engineering or service data. It is recognized that in some instances special circumstances may be encountered in the operation of high-output turbocharged engines where specialized operation and maintenance techniques will be required. Under such circumstances, it is recommended that the Service Division of the Waukesha Motor Company be consulted.

As shown in the accompanying very simple schematic diagram, the exhaust driven turbine and its impeller are not connected to the working parts of the engine in any physical manner with the exception of the exhaust and air manifolding and the oil lines. Hence, the turbocharger will not be troubled by gear train, belt, or other mechanical drive troubles. Moreover, since the supply of hot gases under high velocity supplied to the exhaust turbine is a reflection of the engine speed and load, the supercharger output is closely matched to the engine air requirements. Without enlarging beyond the scope of this discussion, examination of the schematic diagram will make it apparent how the high speed impeller driven by the exhaust turbine provides additional air for the combustion process and thus materially boosts the power output of the engine. In this connection, since the question is often asked, it should be pointed out that the increase in exhaust back pressure which might at first be anticipated because of the turbine is actually very slight since it is the velocity of the gas and its unused energy which is put to work.

The turbine or driving member of the unit is made of a special heat resisting alloy and is surrounded by a nozzle ring which directs the flow of exhaust gases onto the turbine blades. On the opposite end of the same shaft which supports the turbine, the precision-made aluminum alloy impeller operates within a surrounding diffuser housing. Both turbine and impeller turn at the same speed. The full load speed of the two units together with their shaft is approximately 30,000 (thirty thousand) RPM. For this reason, these parts must be in as close to perfect balance as it is humanly possible to make them. Therefore, not even the slightest filing, scraping, sandblasting, drilling, or other cleaning or repair procedure which could conceivably remove or add metal can be permitted in the field. A very small amount of unbalance can cause severe damage at the speeds involved.

The physical construction of the engine proper remains the same for both the supercharged and the non-supercharged models and all major components such as the crankshaft, camshaft, and cylinder heads are identical. The fuel system, however, differs in that the supercharged model is adjusted to provide the additional fuel needed for the higher power output and the gas pressure must relate to the manifold air pressure rather than ambient air pressure.




SCHEMATIC OF TURBOCHARGER - INTERCOOLER PRINCIPLE

## Air Leaks

Since the turbocharger is basically a centrifugal air pump driven by a gas turbine, anything which causes leakage or impedes the gas 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 and capable as possible in order to prevent substantial amounts of dirt from reaching the impeller. Proper and regular air cleaner maintenance helps greatly.

## Turbo Cleaning

Since even the most efficient air cleaner is certain to pass a slight amount of fine dirt, it is possible for some of this material to collect on the impeller if sufficient oil or other binder material is present. This can cause impeller unbalance and will definitely reduce efficiency. Depending on conditions, a periodic program should be established for removal of the air inlet connection at the impeller to inspect for dirt accumulation on the impeller surfaces. When and if dirt is found, caution anyone entrusted with the cleaning against using the common methods of scraping away such material with a screwdriver, dirty rag, sandpaper, or emery or steel wool. Such techniques are certain to damage the impeller. Cleaning may usually be accomplished with a clean, soft brush and solvent such as carbon tetrachloride, tri-chlorethylene, lacquer thinner or benzol. Carbon tetrachloride has the advantage of being non-inflammable 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.

## Mufflers

The possiblity 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.

#### 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.

#### General Maintenance Comments

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 PREPARING ENGINE FOR STORAGE may provide adequate protection; or, removal of the turbocharger to a clean, dry place may be best.

The turbocharger is designed and constructed to eliminate 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.

#### Summary

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 shut-down if it is hot from heavy loads.
4. Be sure oil line to turbo and its return is 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 cleaners well serviced and of proper capacity.
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.

#### Installation

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. If an inlet strainer is found on a service unit, remove it at once or after approximately 8 hours on an overhauled engine.

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.

#### Lubrication Requirements

The oil supply should be engine oil which has been filtered by a full-flow engine oil filter or an auxiliary by-pass oil filter of 20 micron filtration. Oil pressure at the turbocharger must be a minimum of 10 psig.

Oil must drain from the turbocharger by gravity under all operating conditions. Minimum I.D. of oil supply line should be 0.250 inch, and minimum I.D. of the oil discharge line should be 3 times larger.

Immediately prior to installation, prime the turbocharger per instructions in Mounting Paragraph below.

### Air Duct Requirements

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

### Mounting

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. The oil inlet lines have check valves installed 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 turbo before loading the engine.

CAUTION

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

### Initial Run-in

If the turbocharger is 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.

CAUTION

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

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 for 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.

### Daily Service and Maintenance Inspection

a. Inspect mounting and connections of turbocharger for security, lubricant leakage, or air leakage.

b. Check engine crankcase breather for restrictions to air flow.

c. 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.

d. Check turbocharger for unusual vibrations while operating engine at rated output. If excessive vibration is evident remove turbocharger, disassemble, and inspect.

e. 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.

f. Inspect and service the engine air cleaner per manufacturer's instructions.

### Periodic 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. Refer to air cleaner condition indicator instructions for information on that component.

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.

### Trouble Shooting

Refer to Table I for aid in determining the cause of turbocharger malfunction.

### Bearing Inspection

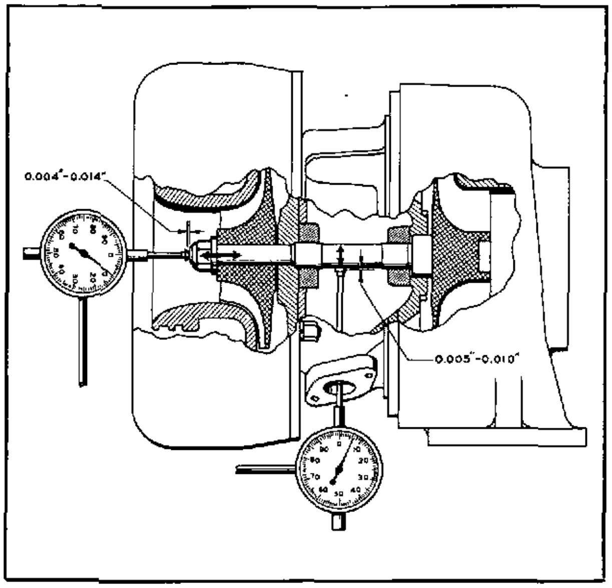
The purpose of this procedure is to determine whether it is necessary to replace or repair the turbocharger. In most cases this bearing check can be made while the turbocharger is still mounted.

### Radial Bearing Check

After securing a dial indicator properly, move the rotating shaft forward and away from the indicator. Use care to move the shaft in the same direction as the dial indicator travels. Equal pressures should be applied to the shaft at both ends simultaneously. The total dial indicator displacement should be less than 0.010 inch; if the measured movement is 0.010 inch or

TABLE I - TROUBLE SHOOTING

| TROUBLE | CAUSE | REMEDY |
|---|---|---|
| Excessive noise or vibration. | Improper bearing lubrication. Loading engine before warm oil is supplied to turbo. | Supply required oil pressure. Clean or replace oil line; clean oil strainer. 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 manifold system. | Clear all ducting. |
| | Foreign material lodged in compressor impeller or turbine. | Disassemble and clean. |
| | 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. |




TURBOCHARGER BEARING CHECK

more, the turbocharger must be repaired or replaced. The minimum should be no less than 0.005 inch.

### Axial Bearing Check

Fasten a dial indicator to the center housing so that the indicator tip rests on the end of the rotating shaft on the compressor side. Move the shaft axially back and forth by hand; the total indicator reading should be between 0.004 and 0.014 inch. If the total indicator reading exceeds 0.014 inch, the turbocharger must be repaired or replaced.

### Intercooler

The turbo-intercooled engines are equipped with a fin and tube type intercooler which is installed between the turbocharger air outlet and the manifold inlet. The purpose of the intercooler is to reduce the temperature of air which has been heated by compression in the turbocharging process. Since a greater mass of air can be contained in a given area when cool than when hot, intercooling further increases the amount of air available to the engine.

Generally speaking, the intercooler as supplied on engines of this series is rated to cool the compressed air expelled from the turbocharger from approximately 225° to about 125° Fahrenheit. To accomplish this, fifteen to twenty gallons per minute of water at an approximate temperature of 85 degrees must flow through the intercooler at all times. These figures are for general information only. Consult the Waukesha Motor Company for the exact data for each particular engine application.

The intercooler is installed with air from the turbocharger entering the fin side and raw water entering the tube side inlet. For peak efficiency, air and water must be in counterflow within the intercooler. If freezing temperatures are anticipated during an engine shutdown period, be sure the intercooler is completely drained or sufficient anti-freeze is added. When placing the engine in operation, be sure that the intercooler is properly vented and that inlet and outlet connections are secure. If possible, check fluid inlet temperatures to see that they are within the desired range for efficient cooling.

### Maintenance

Usually the raw water flowage rate is sufficient in providing a turbulent action which will keep mineral or salt accumulation at a minimum for long periods of time. It is however recommended that the intercooler be removed from the engine periodically for complete disassembly and thorough cleaning. This is accomplished by "rodding-out" the tubes with a soft wire brush or by circulating a commercially available solvent such as Oakite through the tubes. Precautions must be taken when employing a chemical cleaner to make sure that the solution used does not corrode the tubes or aluminum fins. If an acid solution is used, the residue in the intercooler must be neutralized. Normally the air or fin side of the intercooler can be cleaned by blowing steam over the fins. A zinc anode is pressed into the pipe plug which is located midway between the intercooler water inlet and outlet. This is provided to minimize galvanic corrosion caused by the salt content in some water supplies. If salt content is high, this anode may be replaced occasionally.

### Impco Carburetor - Adjustment

As in all Impco carburetion systems, an initial pressure of 5 inches water column is required to the carburetor gas inlet with the engine stopped.

Using the same pipe and fitting sizes indicated for the naturally aspirated engine, add a balance line from the carburetor air horn to the vent hole of the regulator.

The gas pressure will then rise with the air pressure as the engine accelerates. The difference in the gas and air pressure will remain the same as in naturally aspirated carburetion systems.

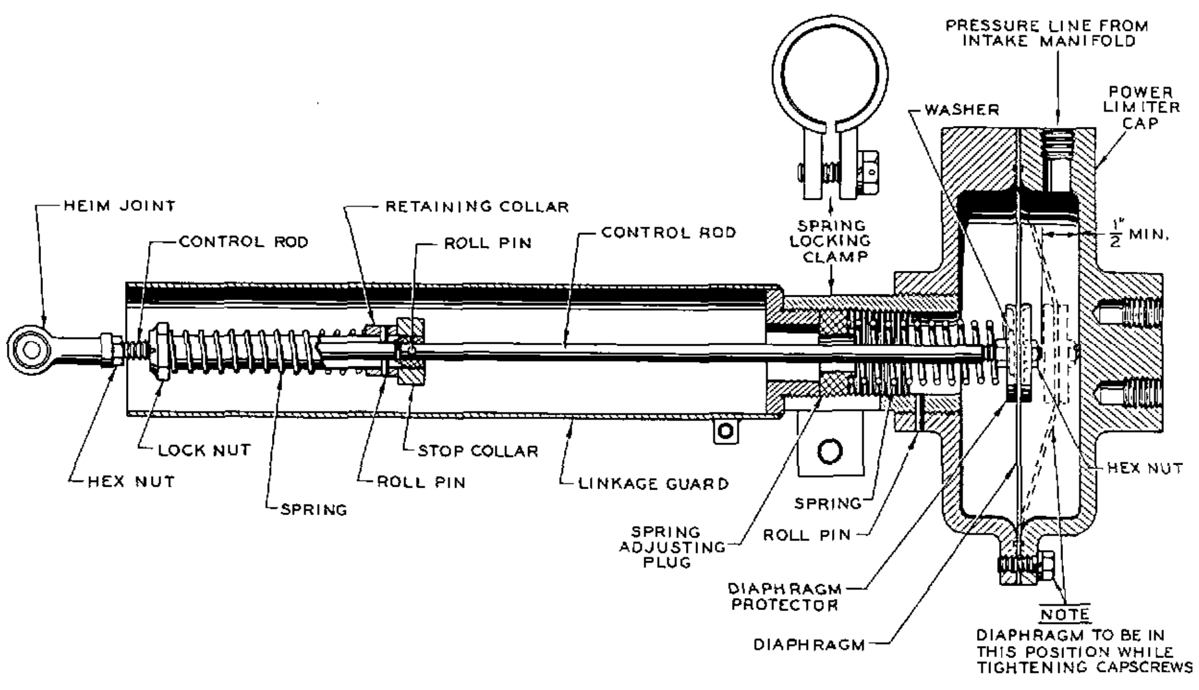
## POWER LIMITER

The power limiter is a Waukesha patented device to control the permissible power developed by a turbocharged gas engine. To inspect and adjust this device it is helpful to understand the reason for its use and its basic principles.

To a normally aspirated gas engine running at full load and governed speed with the carburetor butterfly full open, any increase in load will simply cause the engine to slow down. The governor will attempt to maintain speed, but the ultimate result of overload will be lugging down in a manner very evident to the operator who will then ease off on the load or take other corrective action. The turbocharger, however, can permit the engine to assume heavy and dangerous overloads before the operator could be made aware of it, because the turbocharger immediately responds to the increased heat energy in the exhaust caused by load increase and governor opening. Raising the turbocharger speed automatically raises the intake manifold pressure and forces more air into the engine. This cycle of increased turbo output and subsequent increased engine loading can pyramid until either turbo or engine damage occur. To prevent this, the power limiter can be applied to the carburetor butterfly of Waukesha turbocharged gas engines. It will react by limiting the air passing through the carburetor, thereby holding the engine to safe loading limits even though the governor butterfly opens fully. In some cases, the separate governor butterfly will not be used and the governor will connect to the carburetor butterfly cross shaft by a spring loaded connection which will permit the limiter to function regardless of governor action.

The essential components of the power limiter are a diaphragm, control rod assembly, adjustable spring, and the power limiter caps which secure the edges of the diaphragm. One side of the diaphragm is exposed to atmospheric pressure and the other side is exposed to manifold vacuum or pressure through a suitable line to the intake manifold. In actual operation, the vacuum becomes pressure as the engine is loaded and the turbocharger output increases the manifold pressure above atmospheric (0 inches vacuum). The diaphragm moves in response to this manifold pressure.

The spring bears against the atmospheric side of the diaphragm which connects to the




WAUKESHA POWER LIMITER

control rod. Thus, spring pressure opposes manifold pressure. In operation, the increased engine load will increase manifold pressure and cause the diaphragm to move against spring pressure. This moves the control rod and linkage and swings the butterfly control arm to close the carburetor butterfly. Obviously, the manifold pressure at which this action will start will depend on the pressure on the spring. Adjustment consists of establishing the correct spring pressure and making sure the linkage is free and traveling the proper distance to obtain the desired power limiting action for a given engine installation.

Before installing the limiter and before attempting to adjust it, the following details should be checked . . .

1. 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.

2. Be sure no control rods or other linkages are connected to the carburetor butterfly cross shaft. If a control rod has been installed to move the throttle for low idle operation, it will interfere with the limiter action and must be removed.

3. Be sure the pressure chamber is air tight. Check this by bench testing the unit. Light air pressure of 4 to 6 inches of mercury (HG) may be applied from a small pump or suitable shop pressure reducer. Use a mercury manometer teed into the pressure line. Do not use conventional automotive oil pressure gauges or such equipment. They are not accurate or reliable enough for such use.

4. The exact pressure at which the limiter starts to act will depend on the engine model and power required. Normally, however, 1/16 to 3/32 inch of movement indicating the start of action will be seen at 4 to 6 inches HG. If the spring pressure is not correct, remove linkage guard, loosen the spring locking clamp and adjust it at this time by turning the spring adjusting plug. Be sure that the spring locking clamp is tightened before testing further.

After bench test and adjustment, the limiter may be installed. No binding or friction can be permitted in the limiter action or linkage. The butterfly shaft action must also be smooth and free of sticking. Be sure the manifold pressure line is air and vacuum tight. To adjust the limiter . . .

1. Warm up and load the engine to the correct speed and intake manifold pressure with the limiter lever loose on the carburetor cross shaft. The limiter is usually set for 5% over the rated horsepower.

2. Close the butterfly manually until the slightest reduction in load and speed can just be detected.

3. Lock the limiter to the cross shaft so that limiter action will just come into play at this manifold pressure.

4. The procedure is essentially the same even though the governor and the limiter are both connected to the carburetor butterfly.

NOTE

Before initial start-up, the cap screw joining the power limiter arm to the carburetor should be removed and the carburetor butterfly wired in the full open position. This is done so that movement of the power limiter before it is properly adjusted will not affect the other engine adjustments.

## SERVICING HYDRAULIC PUSH RODS

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

I. Complete failure (all or most of the push rods are noisy).
II. Single push rod failure.
III. Intermittent failure.
IV. Starting noise.

### I. 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 anti-freeze 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 excess loss of oil due to worn parts. As can be seen, generally these failures are due to some unfavorable condition in oiling system.

II. 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. A leak-down comparison can be made by holding the valves slightly open so that the hydraulic unit overfills, while upsetting the idle of the engine. The time required for the engine to recover should be noted, indicating the relative leak-down rate of the hydraulic components. A fast recovery indicates rapid leak-down due to non-sealing hydraulic parts, therefore push rod replacement would be desired.

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. Locate the defective push rod as described in the fast leak-down comparison (recovery of engine idle should be immediate).

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 use.

F. Any condition preventing oil delivery to a single push rod will cause noise. Check each part removed to determine that all ports are not restricted.

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. Compare the lift to other valves or to the height given in the Fits & Clearances.

III. 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 I. 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.

IV. 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 anti-freeze leaking into the oil. Starting noise due to anti-freeze 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 can not 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.

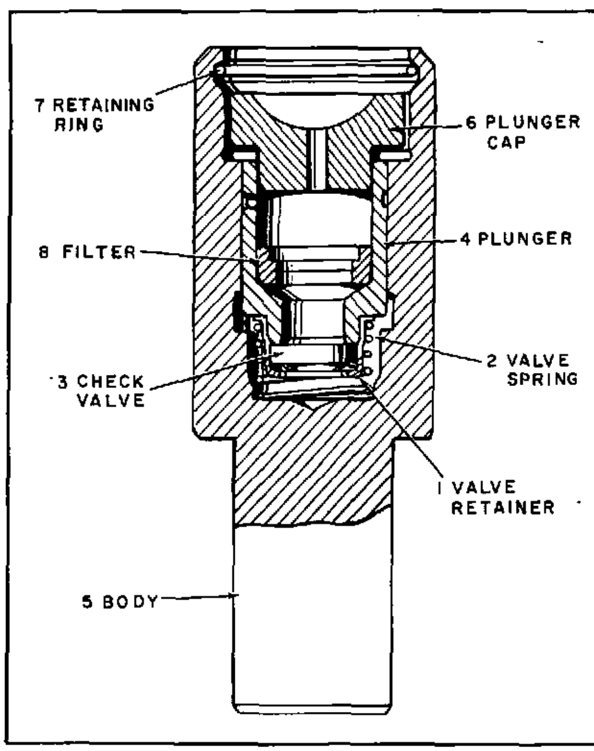
### Assembly

Seat the valve retainer (1) firmly into the valve spring (2). Position the check valve (3) into the retainer (1) and place on flat surface.

NOTE

Be sure that the check valve (3) convex side lies down so that it fits into the hole in the retainer (1). The concave (recessed) side should then lie up. The filter (8) must be cleaned or replaced as required.

Press the plunger (4) smaller O.D. into the retainer (1). Carefully turn the assembled parts over and insert them into the unit body (5) without disturbing the check valve position as stated in the note above.




PUSH ROD TYPE HYDRAULIC VALVE LIFTER

### Testing

To fill the unit for testing, brace it upright, submerged in clean kerosene. With a thin tool, push the check valve down only enough to allow air bubbles to escape. When air bubbles cease completely and all air is out of the unit, replace the plunger cap (6) and the retaining ring (7). Be careful not to mishandle because if tipped over or dropped, the plunger may move outward allowing the check valve to turn over in which case it is necessary to take it apart and start over. If preferred, use a small arbor press or drill press, then submerge the unit without previous filling, but with the cap (6) and the ring (7) inserted, and pump until all air is bled out of the unit. After filling, determine whether the unit is holding properly, by comparing with another unit. Although the unit may be pushed all the way down, it will resist being compressed rather than collapsing quickly. After this test, prime the unit for installation with clean recommended oil in the prescribed filling manner. Removal of the kerosene is not necessary, as the small amount left after filling with the clean oil will do no harm. After installing and operating, the push rod should quiet in a few minutes. If noise persists after longer running, and the set was previously satisfactory, something in the assembly of the parts, or the check valve position, may be wrong.

CAUTION

In handling the hydraulic units, cleanliness and good inspection procedures must be practiced. Care must be exercised to reassemble the parts properly. There is no interchangeability of parts.

## CRANKCASE VENTILATION SYSTEM

The crankcase ventilation system consists of a breather, an oil separator mounted on the crankcase (turbocharged engines only), piping, retaining hardware, a regulating unit (turbocharged engines only), and a venturi in the exhaust outlet (turbocharged engines only--naturally aspirated engines have the breather system vented to the air intake).

The breather and the oil separator filter oil mist from the vented crankcase air by means of a metal nozzle element, condense it and let the drops drain back to the crankcase.

Exhaust flowing through the venturi of turbocharged engines creates a pressure drop drawing the filtered air from the breather. In order to keep the system from pulling excess vapor into the exhaust, the regulator admits outside air to the system to keep the flow from the breather when the limits of 0 to 1/2 inch negative pressure are reached.

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

Maintenance of the breather system consists of cleaning of the breather and the oil separator at monthly intervals or more often on engines operated under unusual conditions. To service the breather, it must be disconnected at both the crankcase and at the tubing connection and removed from the engine. Remove the lid and lift out the removable top element. Wash both the top element and the body which includes the permanent filter in kerosene or some other nonvolatile cleaning solution. After washing, dry these parts thoroughly with low pressure compressed air. High-pressure air could damage the easily crushed light metal filter maze and eventually cause breather system restriction and the resultant excessive crankcase pressure condition.

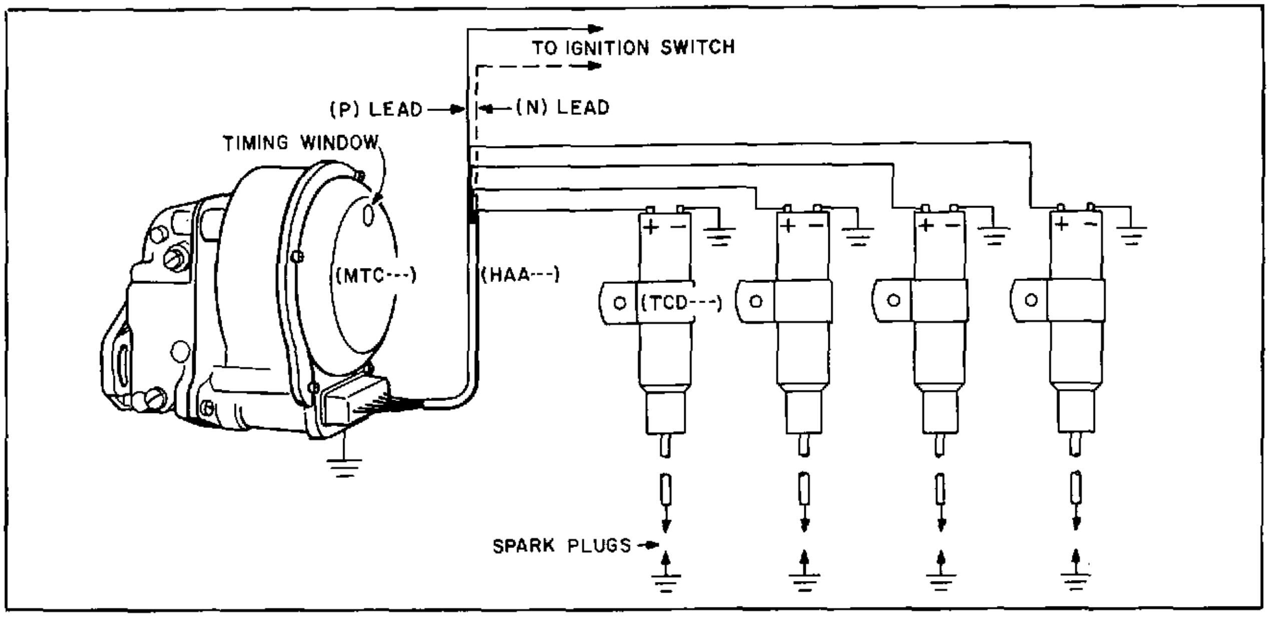
After the Ejector breather system and related components are properly serviced and the engine is again placed in operation, re-check crankcase pressures to make sure that the system is functioning properly.

## IGNITION SYSTEMS

Waukesha Model L-5790-G engines are equipped with dual low tension or breakerless ignition systems. For top engine performance, each unit of the ignition system must be in good condition and properly adjusted. Normal maintenance consists of replacing defective units at periods determined by experience with the type of service involved. Adjustment several times during the service life of the ignition system will extend its usefulness and help to prolong engine life.

## MAG-TRONIC IGNITION SYSTEM

The American Bosch Mag-Tronic ignition system can be used for these engines. This system is both "breakerless" and self-powered, so it is useful in unattended or remote applications where prolonged, reliable operation is vital. The absence of both breaker points and high tension distributor contacts prevents internal arcing



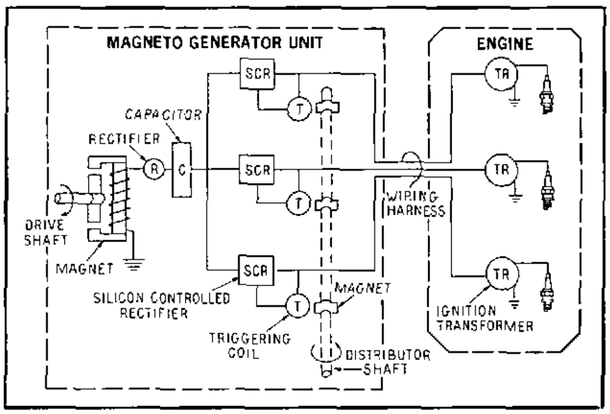

MAG-TRONIC IGNITION SYSTEM

making for a "low-fire-hazard" ignition device. The inductor rotor and electronic distributor shaft (mounted in ball bearings) are the only moving parts.

The system consists of three main elements; an ignition generator (MTC), a wiring harness (HAA), and an ignition transformer (TCD). The ignition generator delivers six pulses for every 360° of the inductor rotor and can fire a maximum of 12 spark plugs. Each pulse is rectified by a diode circuit and stored in a capacitor or capacitors until triggered to fire. The electronic timer-distributor shaft is driven through timed internal gears from the inductor rotor shaft at one-half engine speed. A distributor magnet rotor phased to the engine timing requirements, in conjunction with a series of silicon controlled rectifiers, performs the distribution and timing function. These are essentially electronic switches with triggering coils, one for each cylinder. A low tension wiring harness with connectors and high frequency ignition transformer, for each spark plug, complete the Mag-tronic ignition system. The Mag-tronic transformers have cores of ceramic magnetic material which responds faster than conventional iron core material. Relatively small in size, the high frequency transformers can be mounted either in contact with the spark plugs or near the spark plugs.

Mag-tronic transformers have a low energy factor which minimizes spark plug electrode erosion. The rapid voltage rise time, inherent in this system, often permits the transformers to fire partially fouled spark plugs. The solid impregnation resists stress and vibration and, when mounted correctly, there is a minimum of flash-over from the spark plug terminals to ground.

The wiring harness consists of an appropriate number of #14 A.W.G. stranded copper wires insulated with a heat resistant material, and fitted with a molded terminal plug that mates with the receptacle in the ignition generator. Each lead in each harness is identified by a letter stamped into the insulation at the plug and which corresponds with a similarly identified terminal in the harness receptacle. Regardless of the direction of rotation or number of cylinders served, the firing order of the ignition generator at the receptacle terminals is always in alpha-




MAG-TRONIC CURRENT FLOW

betical sequence, beginning with the letter "A". All of the harness leads, excepting harness leads "N" and "P", are connected to the spark plugs in accordance with the engine firing order.

CAUTION

Under no condition should leads "N" and "P" ever be connected to a single pole ignition switch. The result would be the same as grounding the primary of a magneto.

### Installation

Mount each transformer as close as possible to each spark plug, using the mounting bracket and primary terminal hardware furnished. Ground the negative terminal to the engine with a short length of #14 insulated wire. The high tension lead from the transformer to the spark plug must not exceed two (2) feet. Inverted transformer mounting is recommended if practical. With upright mounting, a sealant such as American Bosch TSE 52115 is suggested to exclude moisture from the terminal well.

When installing the generator, set the engine on number 1 right cylinder compression stroke, and align the correct timing mark on the flywheel. Then rotate the drive shaft coupling on the generator, in the direction of rotation, until the leading edge of the longest finger of the distributor rotor is approximately in the center of the timing window in the cover. Now assemble the drive disc to the drive plate and then connect the unit to the engine drive. It is very important to establish 1/32-inch axial float in the drive disc. Check to be certain that the internal timing has not been disturbed. The ignition generator should now be secured in place with the mounting bolts.

Connect the harness terminal plug to the receptacle on the ignition generator. Remember that the firing order of the generator is in alphabetical order, beginning with the "A" terminal. Also, harness leads "N" and "P" require a double pole switch. A single pole switch is used with the "P" harness leads. Never connect "N" and "P" leads to a single pole switch. Doing so will ground the system.

### Final Timing

Connect the lead of a stroboscopic type timing light to the spark plug lead of No. 1 right cylinder. Run engine at governed rpm and observe timing marks on engine flywheel. If timing is not correct, shut down engine and adjust by removing coupling screws and rotating magneto drive hub in applicable direction. Replace coupling screws and recheck timing. Repeat procedure as necessary. Be sure to lockwire coupling screws when timing is correct.

CAUTION

No attempt should be made to obtain final engine timing by rotating the ignition generator within the base adapter. When an ignition generator is rotated more than two degrees, a "camming" action occurs that disturbs the 45 mm. shaft vs. base height. This misalignment results in early failure of the drive disc and possible damage to the inductor rotor shaft and drive plate. All final timing adjustments should be made with the engine's vernier coupling adjustment.

### Periodic Inspection

The generator and ignition transformers will benefit from periodic cleaning with a cloth dampened with solvent. Inspect the primary terminals and harness plug for security and make certain that the ignition cable is inserted all the way into the high tension well. If corona appears to have affected the high tension terminals, they may be cleaned with a fine, brass wire brush. Periodic inspection of the mounting bolts is also recommended.

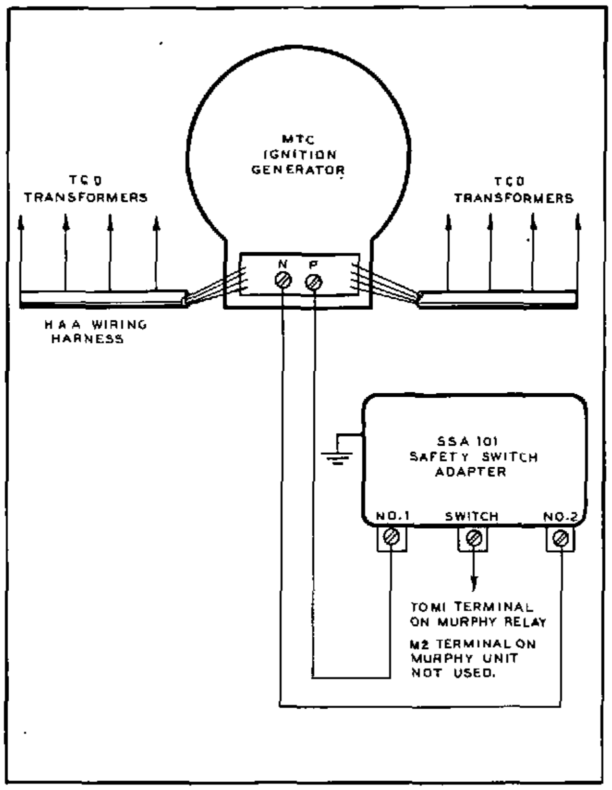
Since there are only two moving parts within this unit, and no breakers, it is not necessary to open the unit for periodic inspection. Opening of the unit will only permit dirt to enter.

### Safety Shut Downs

Many engines are equipped with automatic shut-off devices to shut the engine down by grounding the magneto or Mag-Tronic when temperature limits, oil pressure, engine speed, etc., exceeded normal operating range.

Such an automatic shut-off device will keep the ignition system grounded only as long as the particular malfunction is beyond its normal range.

To prevent the engine from cycling, safety switches of relay type (Murphy type and others) are used in conjunction with the shut-off devices. The relay type switches keep the engine permanently shut down until it is reset. A relay type safety control system usually operates on the primary current of a magneto, usually in the order of 3 amperes.




MAG-TRONIC SAFETY SYSTEM - SCHEMATIC

The Mag-Tronic is a capacitor discharge system which uses a high voltage and low current generator and the current is not sufficient to operate the relay type grounding switch. An SSA-101 adapter has been designed to operate the grounding relays when used with the Mag-Tronic ignition system.

The SSA-101 takes power from the Mag-Tronic during the first few revolutions and stores this power in such form that it can be delivered at the required current level to operate the safety control system. During normal operation of the Mag-Tronic and the control system, no power is drawn from the system after the first few revolutions. The required power for SSA is generated and stored below starting speeds so there is no effect on the operation of the ignition timer.

The SSA-101, provides for two inputs from the Mag-Tronic and a single line out-put to the safety controls. This makes possible the use of one SSA 101 for control of one Mag-Tronic of seven to twelve cylinders.

The output of two or more SSA adapters may be paralleled when dual Mag-Tronics are used in a single application. Isolation is provided within the adapter such that there is no interaction between MTC inputs when the outputs of the SSA adapters are placed in parallel. This still retains the single line shut-off control system for multi-timer applications.

Only one SSA-101 is required with each Mag-Tronic regardless of the number of relay type safety switches used.

Murphy type relays #101-D101PH and 101-D-PH require the use of the American Bosch SSA-101 adapter. There possibly are other Murphy applications that will require the safety switch adapter, however, these are all that can be confirmed as of this time.

The Murphy master units which as the 202, 404 and 606 types are replaced in their entirety by one or more SSA-101 units operating in conjunction with the Murphy #101 series of relays.

The safety switch adapter is available from the factory under Part Number 69579.

The nature of the electrical discharge make shielding of the spark plug leads unnecessary and undesirable.

## LOW TENSION IGNITION

The Fairbanks Morse FM-LTR low tension magnetos used generate and distribute low voltage current through low tension cables to individual coils, one located adjacent to each spark plug. The current is stepped up to high voltage by the individual coils and is then conducted to the spark plug by a short length of high tension cable at the proper firing interval of the cylinder.

This low tension ignition system differs from high tension ignition in several ways. Primarily, the low tension system confines the high voltage electricity necessary to fire the spark plugs to a relatively small part of the entire system. Thus, possible deterioration of longer wires and loss of current is minimized.

### Timing

1. Rotate the engine flywheel until the No. 1 right cylinder is in running or advanced spark position on the compression stroke. Refer to table of "Fits and Clearances".

2. Remove the timing bolt from the top of the right bank magneto end cap. Turn the magnetic 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 the No. 1 right cylinder. The point opening can easily be determined by inserting a thin piece of cellophane between the contact points, by using a timing light or by the use of a sounding device.

3. Align the painted groove on the impulse coupling shell with the painted groove on top of the coupling outer shell. When these two marks are properly aligned and the yellow mark on the edge of the distributor disc is centered in the timing window, the magneto is timed to fire the No. 1 right cylinder.

Since all base mounting 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 member.

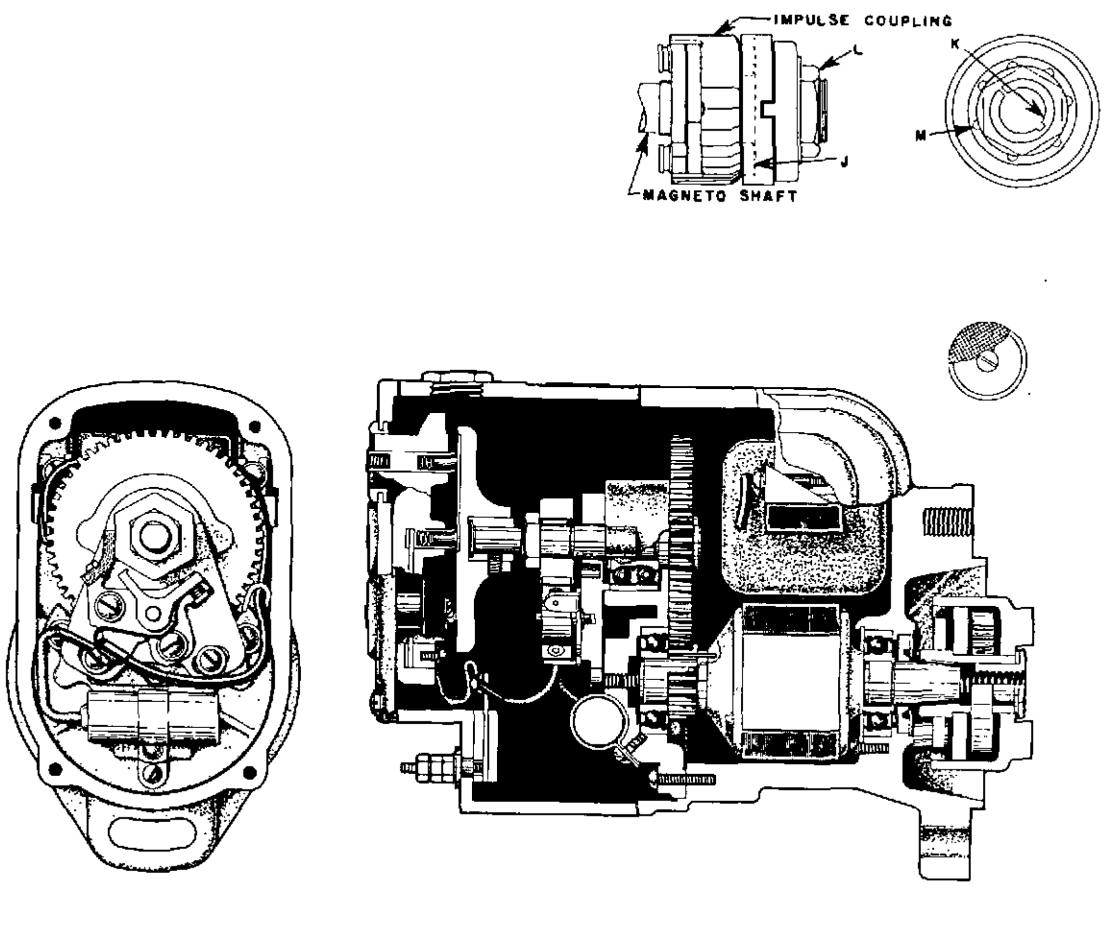
4. After the magneto is installed on the engine, connect the transformer lead wires on the end cap terminals. Starting with the No. 1 terminals, connect the wires to agree with the engine firing order. When facing the end cap cover, the No. 1 terminal is at the upper left. Connect the wires in clockwise rotation.

5. Repeat timing procedure for left bank, timing on No. 6 left cylinder.

6. After the engine is running, the timing should be checked with a timing light. Be sure to lockwire coupling screws when timing is correct.

### Adjustable Drive Members

Ordinarily, the position of the drive member is not altered when removing the magneto but, when necessary, the drive collar nut can be loosened to permit relative movement of the engine drive shaft. The drive member slots J can then be turned for alignment with the impulse coupling




TYPICAL LOW TENSION FM-LTR MAGNETO

lugs, after which the nut L should be tightened. Turn locking washer lugs M up around the nut to prevent it from loosening.

### Installation Instructions

Use the following procedure to obtain peak performance of Fairbanks-Morse heavy duty Type FM-LTR low tension magnetos.

Install the magnetos on the engine as described. When this is completed, the engine No. 1 *right cylinder will be on the compression stroke* ready to fire. The magneto timing mark on the edge of the distributor disc will be visible through the timing window and the No. 1 magneto terminal will be ready to fire. The No. 1 magneto terminal is in the upper left hand corner of the magneto end cap cover when facing the cam end of the magneto.

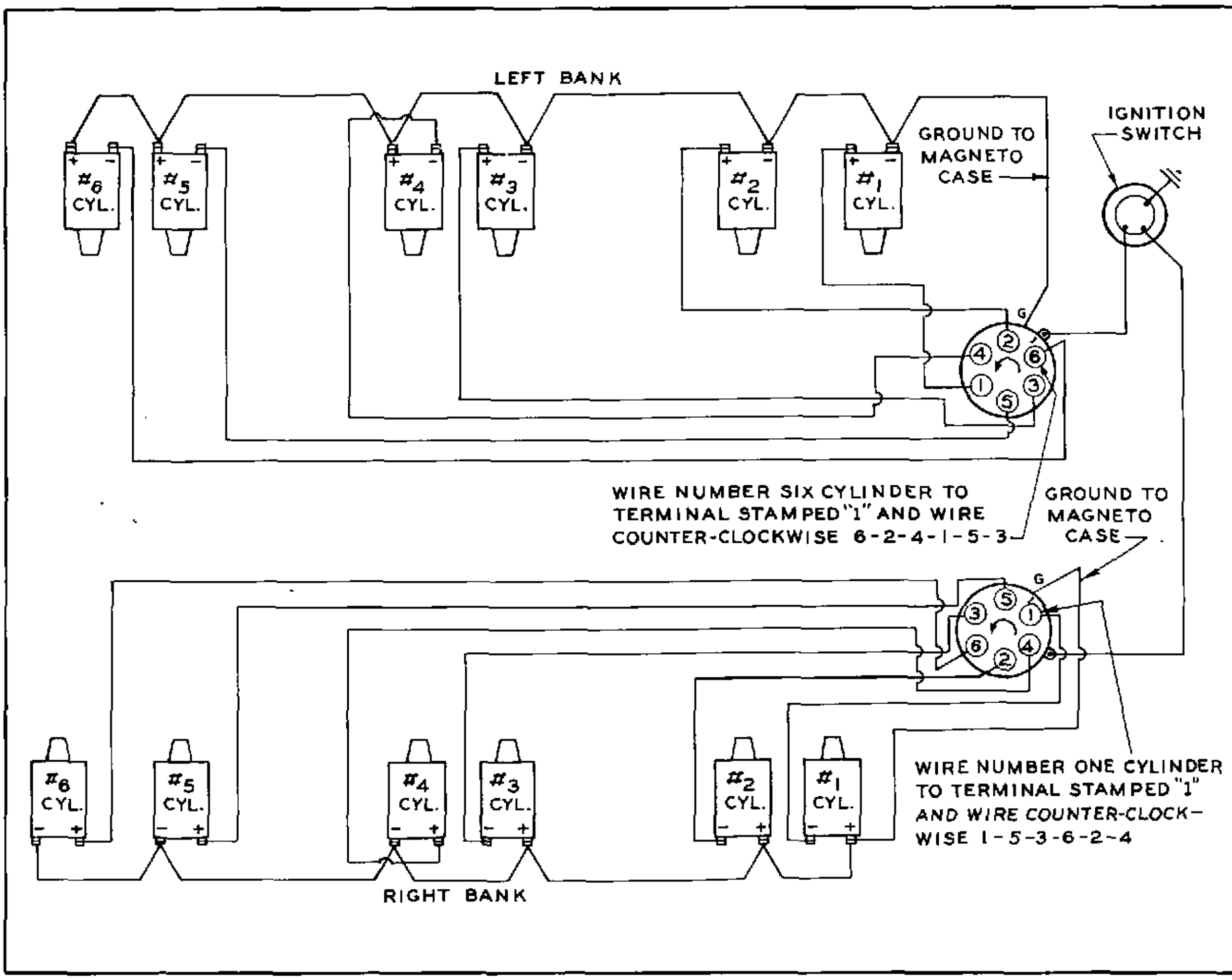
Using No. 14 stranded automotive lighting wire, connect the No. 1 magneto terminal to the negative (-) terminal of the transformer *at the No. 1 right engine cylinder.*

After noting the engine firing order, connect the No. 2 magneto terminal to the positive (+) terminal of the transformer at the cylinder which is second in the engine firing sequence.

Connect the No. 3 magneto terminal to the negative (-) terminal of the transformer which is third in the engine firing sequence.

*Complete the wiring of the magneto terminals* to the transformers in accordance with the engine firing order with transformers being connected in alternate negative (-), positive (+) sequence.

By means of a jumper wire, interconnect the remaining primary transformer terminals. From the transformer nearest the magneto, connect the jumper wire or the common ground wire of the transformers to the magneto end cap screw.




LOW TENSION MAGNETO WIRING DIAGRAM

Connect a ground wire from the primary terminal, on the magneto housing, to the engine panel switch or relay.

Recheck the hookup to be sure all screws are tight and that the magneto and transformers are connected in the correct engine firing order.

Repeat this procedure for the left bank magneto, which is timed to No. 6 left cylinder.

Start the engine and check the magneto-to-engine timing with a timing light. Be sure to lockwire coupling screws when timing is correct.

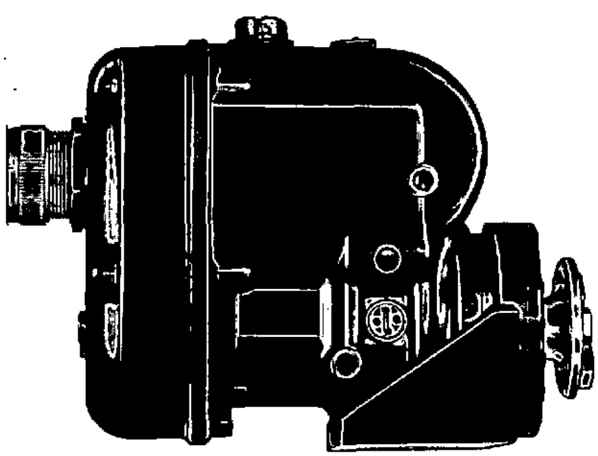
## BENDIX BREAKERLESS IGNITION

### Description

The Bendix S-1700 low tension ignition system incorporates a generator-distributor, a control unit, and transformer coils.

Operating on the capacitor discharge principle, a uniformly controlled amount of energy is provided for each spark at the igniter plug. The generator charges a capacitor which, at the proper time, is discharged through the primary of a transformer coil inducing high voltage in the secondary of the coil which is connected to the spark plug. Voltage and energy of the resulting spark across the plug gap are ample for reliable ignition requirements.

There are no breaker assemblies or contacts in the Bendix S-1700 system. The distributor includes a trigger wheel with metal vanes and a magnetic pickup unit. As a vane approaches the tip of this unit an electrical pulse is generated in the pickup. This pulse passes through a lead to the control unit and switches an SCR (silicon controlled rectifier) which closes the circuit from a charged capacitor through the distributor and the primary of the transformer coil for the plug that is to fire. The capacitor discharges through the coil primary. The resulting high voltage induced in the secondary winding produces a spark across the plug gap. Unlike breaker assemblies, SCR units have no moving parts to wear and require adjustment. Spark timing remains constant throughout the life of the ignition system.



BENDIX S1700 GENERATOR-DISTRIBUTOR

The control unit contains an energy storage circuit and a control circuit. Capacitors in this unit are charged by the generator. A large capacitor provides the energy required to fire the plug. A smaller capacitor provides the energy to switch the silicon controlled rectifier which is also in the control unit.

Interconnecting leads between the coils, the control unit, and the generator-distributor are connected to the control unit and the generator-distributor with electrical connectors. The connectors are keyed for proper connection and can only be connected to the correct unit.

### Preliminary Timing and Installation

When timing the ignition unit to the engine, proceed as follows:

1. Bar the engine to number one right cylinder firing position on the compression stroke.

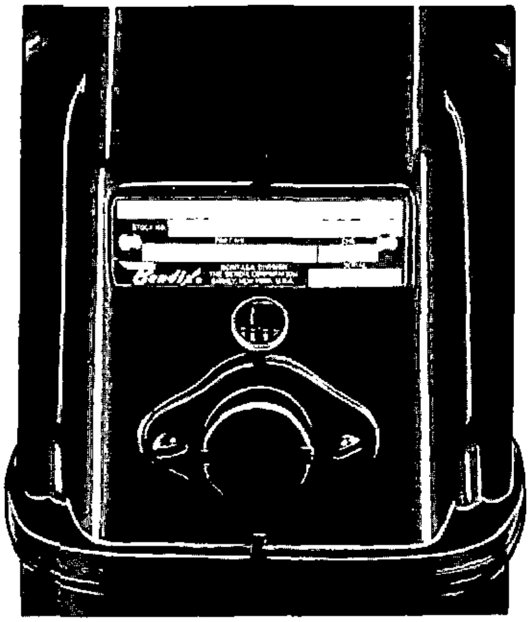
CAUTION

Place shutdown switch in off position or disconnect cable from S-1700 unit before barring engine over.

2. Check magneto for proper rotation, remove plug from timing window in top of magneto and turn drive shaft of unit in direction of rotation until timing pointer on large distributor gear is centered in timing window. This indicates unit is in position to energize the number one segment of the distribution block.

3. Remove all backlash from engine drive train by turning the engine drive shaft for the magneto as far as possible against rotation.

4. Install intermediate drive disc on engine drive hub.



BENDIX S1700 INTERNAL TIMING

5. Keeping timing pointer in center of timing window, install magneto on engine. Install coupling screws.

6. Secure magneto to engine bracket with mounting hardware. Check that drive coupling members have a total end clearance of 1/64 inch.

NOTE

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

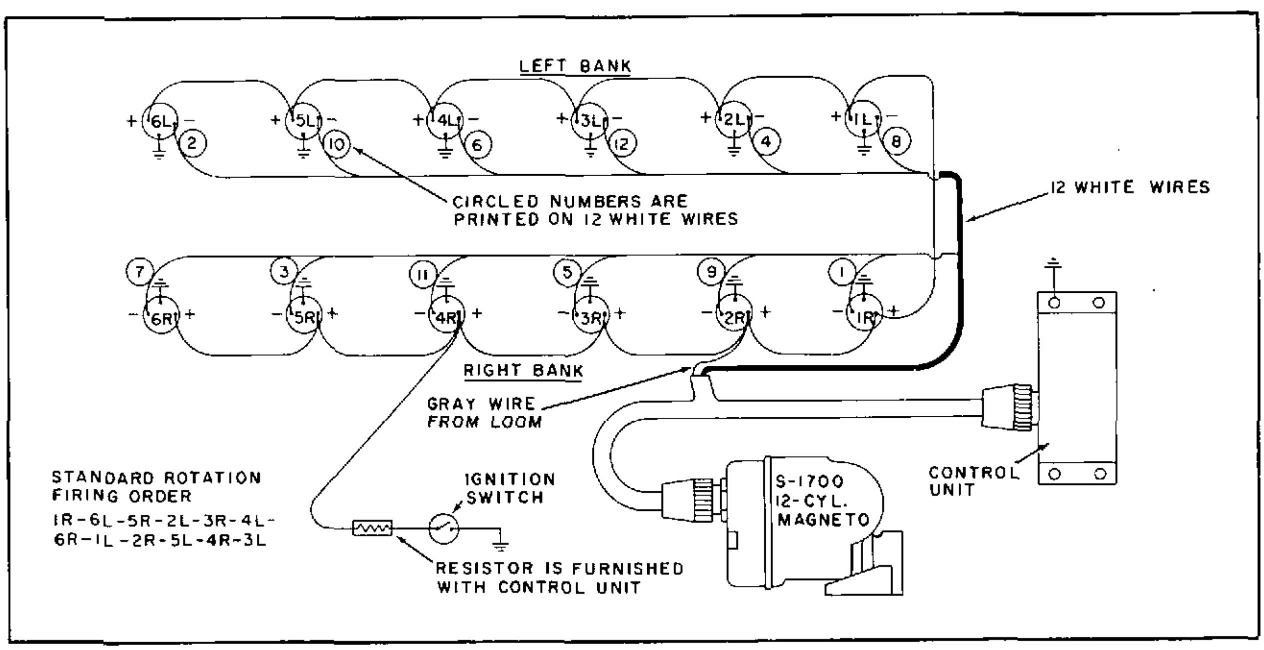
To either connect or check wiring refer to the wiring diagram. Leads are connected to the magneto and the control unit with electrical connectors. The twelve white wires of the wiring harness are identified as 1 through 12 and are connected to the negative terminals of the transformer coils in engine firing order. That is, no. 1 to no. 1 right cylinder, no. 2 to no. 6 left cylinder, no. 3 to no. 5 right cylinder, and so on. The gray wire of the wiring harness is the common ground wire which connects through jumpers to the positive terminals of all the transformer coils. The lead through the resistor to the ignition switch may be connected to the positive terminal of any one of the transformer coils.

NOTE

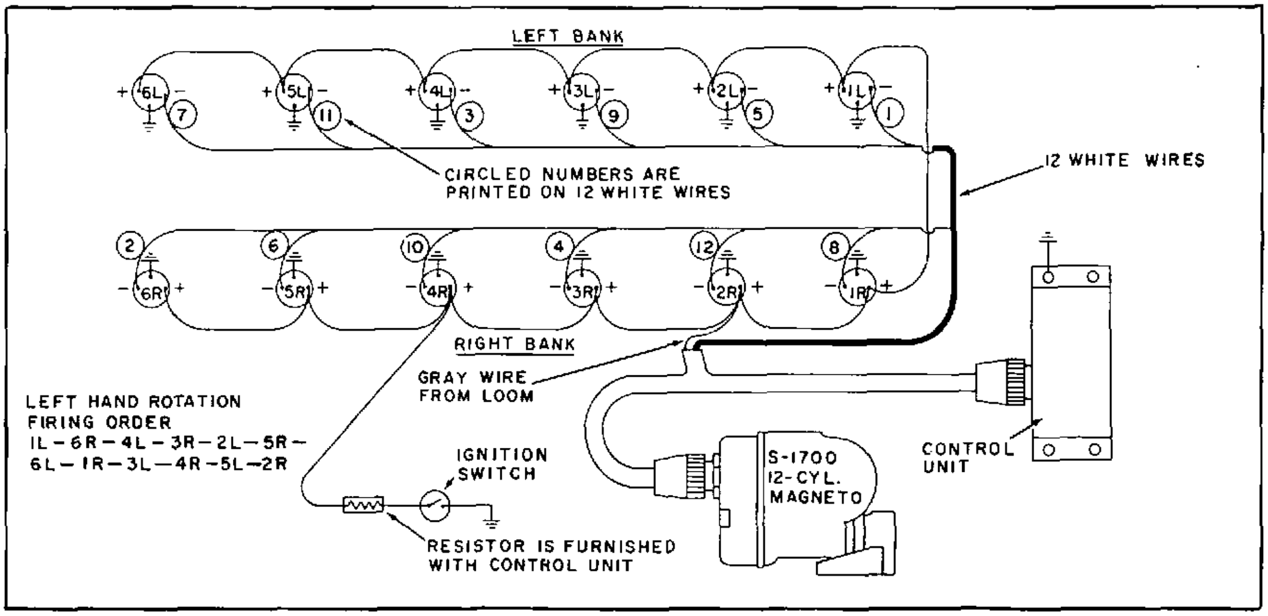
Be sure the control unit is well grounded to the engine. Poor electrical connections can cause erratic ignition.

### Final Timing

Connect the lead of a stroboscopic type timing light to the spark plug lead of No. 1 right cylinder. Run engine at governed rpm and observe timing marks on engine flywheel. If timing




BENDIX S-1700 WIRING DIAGRAM — STANDARD ROTATION




BENDIX S-1700 WIRING DIAGRAM — LEFT HAND ROTATION

is not correct, shut down engine and adjust by removing coupling screws and rotating magneto drive hub in applicable direction. Replace coupling screws and recheck timing. Repeat procedure as necessary. Be sure to lockwire coupling screws when timing is correct.

After the ignition system is installed and properly timed, re-check all mounting bolts, electrical connections, etc. be sure they are securely tightened. Also recheck position of leads and cables to be sure they are not exposed to excessive heat or sharp metal edges.

CAUTION

When using the Bendix S-1700 low tension ignition system with a Murphy electrically operated gas shut-off valve, the valve must be Model M-50-67CD (special coil) instead of the commonly used Model M-50-67.

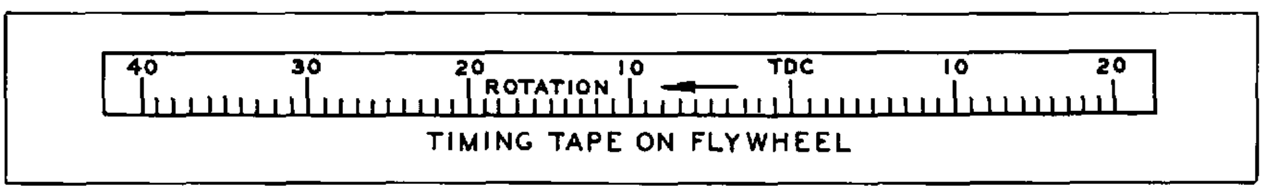
### Maintenance

The Bendix S-1700 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 magneto or control unit, remove control unit from engine and replace with a unit known to be good. It is suggested that a spare control unit and magneto be kept on hand at the facility for these emergency situations. If system fails to operate with the replacement control unit installed, remove magneto and replace with one known to be good. The defective control unit or magneto shall be sent to a qualified service station for overhaul.

### TIMING TAPES AND CHARTS

The Waukesha Motor Company has eliminated the stamped timing marks, except for TDC, from all flywheels. Instead, industrial type ad-




TIMING TAPE ON FLYWHEELS

hesive-backed timing tapes with degree markings are affixed.

The tapes with special adhesive backing are a readily visible silver color with black markings and will 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 actual engine timing procedure is still basically the same. The positioning of the correct flywheel degree mark under the housing pointer differs somewhat, however, in that the serviceman must now refer to a timing data chart mounted on the engine crankcase or valve cover. This mounted chart displays all of the necessary timing information. The timing charts for spark ignition engines are stamped according to engine fuel, type of ignition system (magneto or distributor), compression ratio, and engine operating speed.

## CROSS-BOLTED BEARINGS

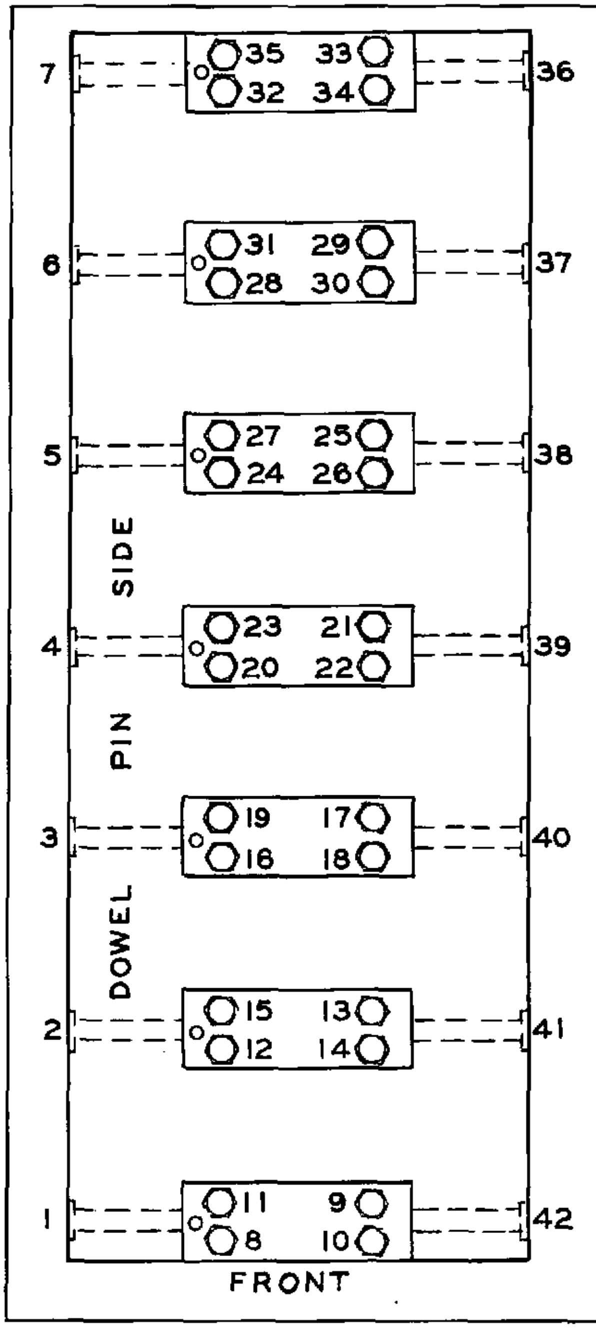
Model L-5790-G crankcases utilize special self-locking bolts which pass inward through the crankcase side wall and enter the main bearing caps from each side for additional rigidity. The use of 3M sealer on both surfaces of the cross-bolt head washers is recommended. The correct tightening sequence for these bolts and the main bearing cap nuts is . . .

1. Tighten 28 cap nuts to snug fit, working from front to rear of engine, in criss-cross sequence starting with dowel pin side of each cap (numerical sequence 8 through 35 in illustration).

2. Tighten 7 cross-tie bolts to snug fit, working from front to rear of engine, on dowel pin side of each cap (numerical sequence 1 through 7 in illustration).

3. Tighten 7 cross-tie bolts to snug fit, working from rear to front of engine, on opposite side of each cap (numerical sequence 36 through 42 in illustration).

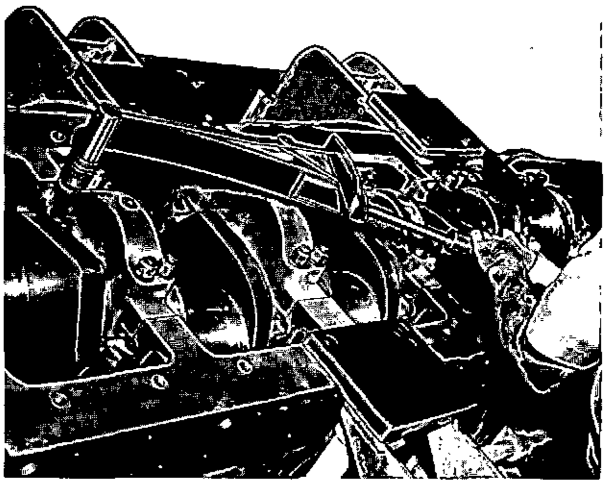
4. Torque 7 cross-tie bolts to 3000-3100 in. lbs., working from front to rear of engine, on dowel pin side of each cap (numerical sequence 1 through 7 in illustration).



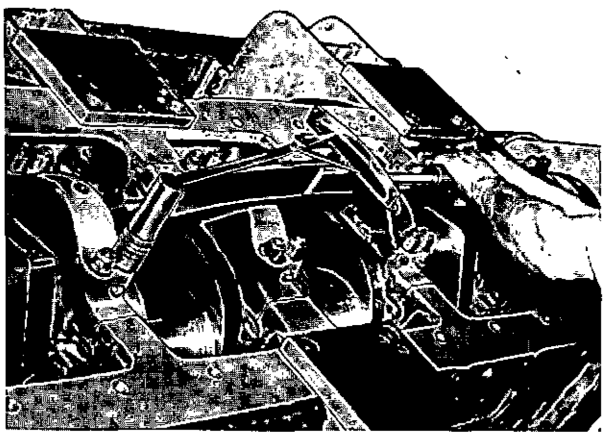

MAIN BEARING CAP TORQUING SEQUENCE

5. Torque 28 cap nuts to 3500-3600 in.lbs., working from front to rear of engine, in criss-cross sequence starting with dowel pin side of each cap (numerical sequence 8 through 35 in illustration).

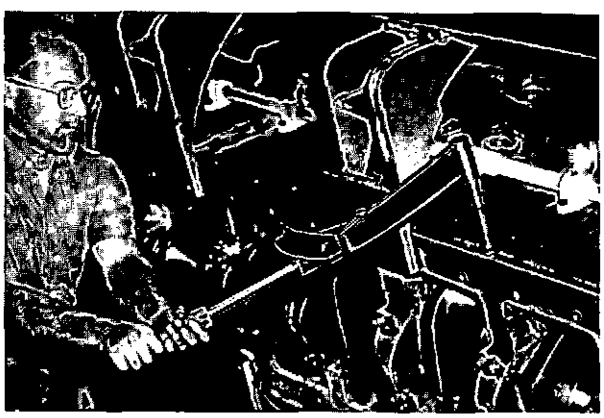
6. Torque 7 cross-tie bolts to 3000-3100 in. lbs., working from rear to front of engine, on opposite side of each cap (numerical sequence 36 through 42 in illustration).



TORQUING DOWEL PIN SIDE
MAIN BEARING CAP NUT



TORQUING OPPOSITE SIDE MAIN
BEARING CAP NUT



TORQUING MAIN BEARING CAP CROSS BOLT

WARNING

To prevent possible injury or damage when removing bearing caps, leave one cap nut partly on its stud until the cap is loosened. When installing bearing caps, be careful not to wedge fingers between crank cheeks and bearing cap.

## CRANKSHAFT GEAR REMOVAL

The crankshaft gear has two 3/8-16 N.C. puller holes and a tapped port in the front face of the gear opposite the keyway to accommodate a 1/4-28NF hydraulic fitting. This hole is connected by a drilled passage to a groove on the inner diameter of the gear.

When used in conjunction with a heavy-duty puller, a hydraulic pump or grease gun forces fluid or grease into the gear and around the groove creating a high hydraulic pressure between the gear and the crankshaft. This pressure will overcome and relieve the shrink fit of the gear just enough to allow removal of the gear (and consequent re-use) without damage to it or any other parts.

## CAMSHAFT GEAR REMOVAL

The camshaft gear has two 1/2-13 N.C. puller holes in the web of the gear and a tapped port which is angled into the hub of the gear to accommodate a 1/8-27 NPSI hydraulic fitting. This hole is connected by a drilled passage to a groove on the inner diameter of the gear.

When used in conjunction with a heavy-duty puller, a hydraulic pump or grease gun forces fluid or grease into the gear and around the groove creating a high hydraulic pressure between the gear and the camshaft. This pressure will overcome and relieve the shrink fit of the gear just enough to allow removal of the gear (and consequent re-use) without damage to it or any other parts.

## SERVICING ROLLER TYPE VALVE TAPPET ASSEMBLIES

Waukesha has revised assembly methods for roller type valve tappets used in Waukesha Model L-5790-G series engines. As we do not believe that these methods can be duplicated effectively in field shops, only complete assemblies can be used for service replacement purposes.

## LEFT HAND ROTATION ENGINE DATA

GENERAL: This information applies only to engines having left hand or counterclockwise rotation as viewed facing the front or gear cover end of the engine. Due to this direction of rotation, which is reverse of the common right hand rotation engines, such things as valve timing, ignition wiring and firing order are different. Firing order of the left hand rotation engine is: 1L-6R-4L-3R-2L-5R-6L-1R-3L-4R-5L-2R.

The following listed parts are not to be interchanged with right hand engine parts.

CAMSHAFT, Cam lobe configuration.

CRANKSHAFT, Rear oil grooves reversed.

OIL PUMP, Body inlet & outlet reversed.

WATER PUMP, Impeller vanes, Body configuration.

GEARS, Flywheel ring gear, engine drive gears, accessory gears may have different P.D., helix angle.

MAGNETOS, Clockwise Rotation (Facing coupling end).

STARTING UNITS, Reverse starting.

To avoid any confustion resulting from the different direction of rotation it may be a good idea to specify Left Hand Rotation in any correspondence or parts orders for these engines.

## INSTALLATION OF SPRING-LOADED TEFLON SLEEVE SEAL RINGS

A significant advance in sleeve sealing technique for special cooling applications is now being incorporated in Waukesha Model L-5790-G series engines. The new seal consists of a machined Teflon ring with a flat-wound stainless steel inner spring. The materials used make this seal extremely resistant to temperature variables and attack by crankcase or cooling water chemicals. The Teflon seal is employed in the lower groove only and the standard sealing rings are used in the upper (water side) grooves.

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

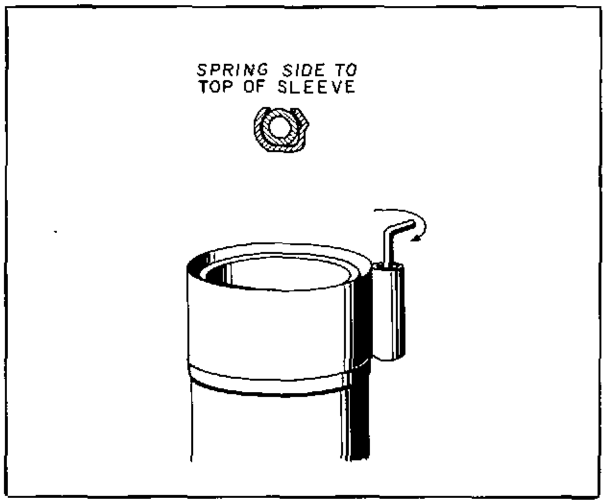
1. All seating surfaces and all surfaces over which the seal must pass on the sleeve and within the crankcase must be absolutely free of burrs and nicks. The crankcase bore must be smooth and the upper edge entering portion must be blended so the seal can slip into it freely without catching.

2. The seal ring should not be stretched by hand to slip over the lower end of the sleeve. After aligning and starting the ring on the taper it should be thrust down to the groove smartly with hand pressure.

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 resize 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.

4. 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.

5. Lubricate the seal with liquid soap or other lubricant in the conventional manner and install and inspect as usual. Check for leakage and cylinder bore roundness.




TEFLON SLEEVE SEAL INSTALLATION

# FITS AND CLEARANCES
# L-5108-G, L-5790-G, AND L-7042-G SERIES ENGINES

(INFORMATION APPLICABLE TO ALL MODELS, EXCEPT AS NOTED)

NOTE: Illustrations found in this section are for locating purposes only - they are therefore not intended as accurate representations of the parts involved.

## GENERAL

Cylinder number and arrangement . . . 12-V

Bore and stroke
- L-5108-G . . . . . . . . . 8-1/2 x 7-1/2"
- L-5790-G . . . . . . . . . 8-1/2 x 8-1/2"
- L-7042-G . . . . . . . . . 9-3/8 x 8-1/2"

Displacement (cubic inches)
- L-5108-G . . . . . . . . . . . . . . . 5100
- L-5790-G . . . . . . . . . . . . . . . 5788
- L-7042-G . . . . . . . . . . . . . . . 7040

Compression ratio
- Standard piston . . . . . . . 8.0:1 or 8.25:1
- High compression pistons . . . . . . . 10.0:1

Valve arrangement . . . Overhead (two intake, two exhaust per cylinder)

Firing order . . 1R-6L-5R-2L-3R-4L-6R-1L-2R-5L-4R-3L

Flywheel housing size . . . . . . . SAE No. 00

## TORQUE VALUE RECOMMENDATIONS

*Cylinder head . . . . . . . . . 4750-4800

**Main bearing
- Elastic stop nuts . . . . . . . 3500-3600
- Cross-tie bolts . . . . . . . 3000-3100

Connecting rods . . . . . . . . . 2100-2200

Camshaft gear nut . . . . . . . . . . . 5400

Idler stud nut (in crankcase) . . . . . . . 8200

Idler stud nut (in bearing cap) . . . . . . 2100

Vibration damper . . . . . . . . . . . . 1050

Flywheel . . . . . . . . . . . . . . 1450-1500

Oil pan . . . . . . . . . . . . . . . . . . 2500

(Above values stated in pounds inch. Divide by 12 for pounds-foot values.)
(Values stated are for oiled threads.)

*Note: Consult the Valve Location and Cylinder Head Bolt Tightening Diagram in this section for the proper head bolt tightening sequence.

**Note: Consult the Service Maintenance Section for the proper main bearing cap nut and bolt tightening sequence.

## GENERAL TORQUE VALUE RECOMMENDATIONS

The values specified below are to be used only in the absence of previously specified torquing instructions and are not to be construed as authority to change existing torque values. A tolerance of ±5% is permissible on these values.

Heat treated material may be identified by the following markings on the bolt or cap screw head:

| | |
|---|---|
| Grade 5 | 3 radial dashes, 120° apart |
| Grade 6 | 4 radial dashes, 90° apart |
| Grade 7 | 5 radial dashes, 72° apart |
| Grade 8 | 6 radial dashes, 60° apart |

If there is no marking, torque readings must be reduced 50% unless the hardness is checked and found to be in range of 19 Rc to 38 Rc scale readings.

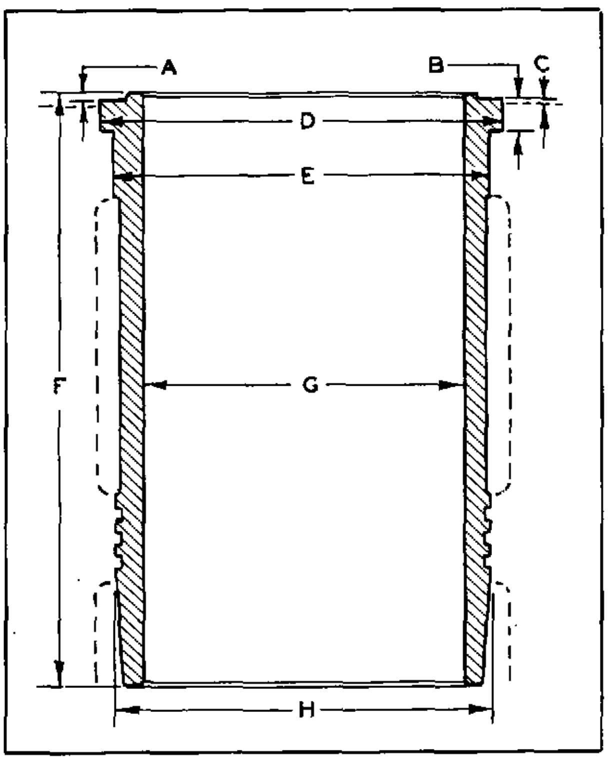
RECOMMENDED TORQUE
HEAT TREATED MATERIAL SAE GRADE 5, 6, 7, and 8
(62000 PSI BOLT STRESS)

| THREAD SIZE | OILED THREADS | | | | DRY THREADS | | | |
|---|---|---|---|---|---|---|---|---|
| 1/4 - 20 | 95 LB-INCH | or | 8. | LB-FT. | 105 LB-INCH | or | 8.8 | LB-FT. |
| 1/4 - 28 | 101 " | or | 8.4 | " | 112 " | or | 9.4 | " |
| 5/16 - 18 | 195 " | or | 16.2 | " | 206 " | or | 17.2 | " |
| 5/16 - 24 | 207 " | or | 17.3 | " | 230 " | or | 19.2 | " |

| THREAD SIZE | OILED THREADS | | | | | DRY THREADS | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 3/8 - 16 | 320 | LB-INCH | or | 26.5 | LB-FT. | 356 | LB-INCH | or | 29.7 | LB-FT. |
| 3/8 - 24 | 351 | " | or | 28. | " | 390 | " | or | 32.6 | " |
| 7/16 - 14 | 528 | " | or | 44. | " | 565 | " | or | 47. | " |
| 7/16 - 24 | 558 | " | or | 46. | " | 612 | " | or | 51. | " |
| 1/2 - 13 | 788 | " | or | 65. | " | 876 | " | or | 73. | " |
| 1/2 - 20 | 855 | " | or | 71. | " | 950 | " | or | 79. | " |
| 9/16 - 12 | 1098 | " | or | 91. | " | 1220 | " | or | 102. | " |
| 9/16 - 18 | 1211 | " | or | 101. | " | 1345 | " | or | 112. | " |
| 5/8 - 11 | 1539 | " | or | 128. | " | 1710 | " | or | 142. | " |
| 5/8 - 18 | 1697 | " | or | 141. | " | 1885 | " | or | 157. | " |
| 3/4 - 10 | 2700 | " | or | 224. | " | 3000 | " | or | 250. | " |
| 3/4 - 16 | 2961 | " | or | 246. | " | 3290 | " | or | 274. | " |
| 7/8 - 9 | 4397 | " | or | 366. | " | 4885 | " | or | 403. | " |
| 7/8 - 14 | 4956 | " | or | 410. | " | 5440 | " | or | 445. | " |
| 1 - 8 | 6480 | " | or | 530. | " | 7200 | " | or | 600. | " |
| 1 - 14 | 7137 | " | or | 595. | " | 7930 | " | or | 660. | " |
| 1-1/8 - 7 | | | | 770. | " | | | | 855. | " |
| 1-1/8 - 12 | | | | 842. | " | | | | 935. | " |
| 1-1/4 - 7 | | | | 1080. | " | | | | 1200. | " |
| 1-1/4 - 12 | | | | 1170. | " | | | | 1300. | " |
| 1-3/8 - 6 | | | | 1413. | " | | | | 1570. | " |
| 1-3/8 - 12 | | | | 1566. | " | | | | 1740. | " |

## CYLINDER SLEEVES

Type . . . . . . . . . Wet type, replaceable
(A) Heat dam projection . . . . .045"-.049"
(B) *Flange height* . . . . . . .5345"-.5365"



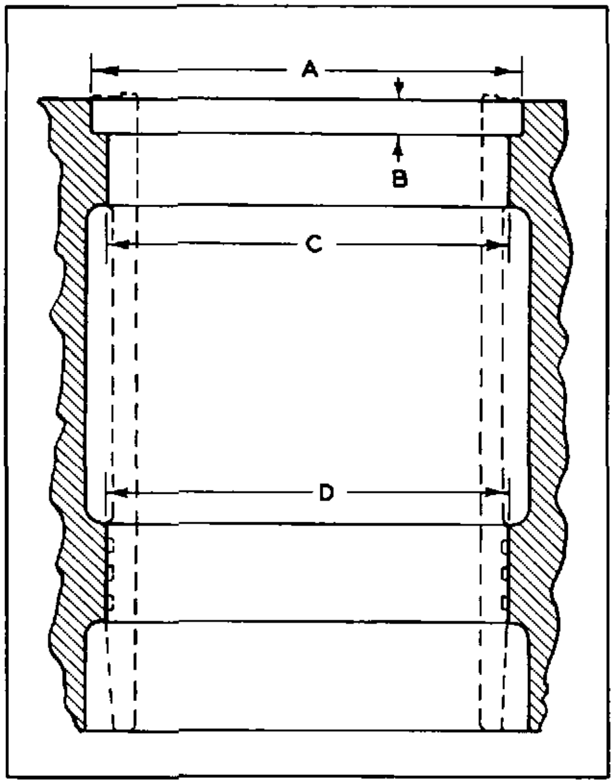

TYPICAL CYLINDER SLEEVE

(C) Sleeve projection above crankcase (with .0285 - .0305" flange sealing ring) . . . . . . . . . . . .001"-.005"
(D) Flange diameter
    L-5108-G and L-5790-G . 9.866"-9.868"
    L-7042-G . . . . . . 10.616"-10.618"
(E) Sleeve diameter (below flange)
    L-5108-G and L-5790-G . . . 9-7/16"
    L-7042-G . . . . . . . . . 10-1/4"
(F) Sleeve length . . . . . . . . . 18-5/8"
(G) Sleeve bore diameter
    L-5108-G and L-5790-G 8.5003"-8.5008"
    L-7042-G. . . . . . . 9.3753"-9.3758"
(H) Sleeve diameter lower seal area
    L-5108-G and L-5790-G 9.4345"-9.4360"
    L-7042-G. . . . . . 10.2425"-10.2440"
Sleeve out of round limits . . . . . . . .001"
Sleeve seal area to crankcase clearance . . . . . . . . . .002" to .0055"

## CRANKCASE

Main bearing number and type . . . . Seven-precision
Camshaft bearing number and type . . . . . . . . . Seven-precision
(A) Sleeve counterbore dia.
    L-5108-G and L-5790-G . 9.875"-9.877"
    L-7042-G . . . . . . 10.625"-10.627"
(B) Sleeve counterbore depth . .5605"-.5625"
(C) Crankcase upper bore
    L-5108-G and L-5790-G . 9.500"-9.510"
    L-7042-G . . . . . . 10.312"-10.322"
(D) Crankcase lower bore
    L-5108-G and L-5790-G . 9.438"-9.440"

| | |
|---|---|
| L-7042-G | 10.246"-10.248" |
| Crankcase main bearing journal bore | 6.663"-6.662" |
| Crankcase camshaft bearing bore | 3.752"-3.753" |



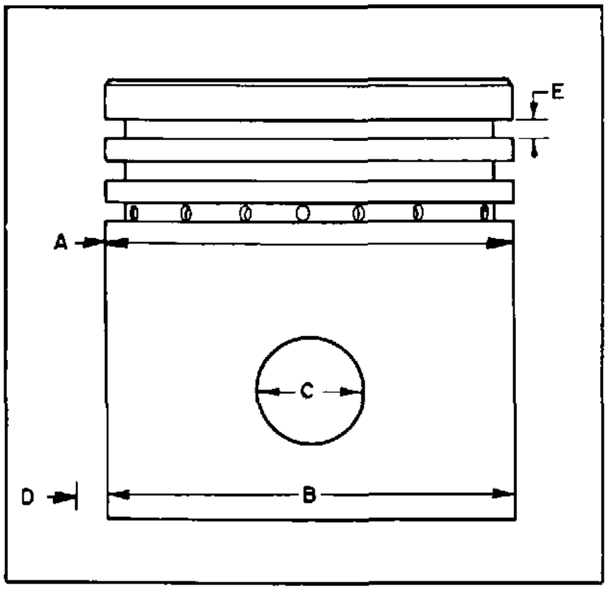

TYPICAL SECTION THROUGH CRANKCASE

## PISTON PIN

| | |
|---|---|
| Piston pin diameter | |
| Red | 2.9991"-2.9994" |
| Blue | 2.9994+"-2.9997" |
| Piston pin length | |
| L-5108-G and L-5790-G | 7.33375"-7.34375" |
| L-7042-G | 8.33375"-8.34375" |
| Piston pin fit: Pin selected (color) to provide a loose hand push fit at normal room temperature | .0010"-.0014" |

## PISTON

| | |
|---|---|
| Piston material | Tin plated aluminum alloy |
| Piston type | Cam ground |
| Pistons are removed from | Top of crankcase |
| Permissible weight variation per set | 8 ounces |
| Piston hole center to piston crown | |
| Standard compression ratio | |
| L-5108-G (8.25 to 1) | 6.245"-6.255" |
| L-5790-G (8.25 to 1) | 5.620"-5.630" |
| L-7042-G (8.0 to 1) | 5.465"-5.475" |
| 10.0:1 Compression ratio | |
| L-5108-G | 6.587"-6.597" |
| L-5790-G and L-7042-G | 6.087"-6.097" |
| (A) Piston skirt diameter (top) | |
| In line with pin hole | |
| L-5108-G and L-5790-G | 8.461"-8.462" |
| L-7042-G | 9.336"-9.337" |
| 90° from pin hole | |
| L-5108-G and L-5790-G | 8.477"-8.478" |
| L-7042-G | 9.352"-9.353" |
| (B) Piston skirt diameter (bottom) | |
| In line with pin hole | |
| L-5108-G and L-5790-G | 8.480"-8.481" |
| L-7042-G | 9.354"-9.355" |
| 90° from pin hole | |
| L-5108-G and L-5790-G | 8.488"-8.489" |
| L-7042-G | 9.362"-9.363" |
| (C) Piston pin hole bore | |
| Red | 3.0004"-3.0006+" |
| Blue | 3.0007"-3.0009" |
| (D) Piston skirt to sleeve clearance (Thrust area) | |
| L-5108-G and L-5790-G | .0113"-.0128" |
| L-7042-G | .0123"-.0138" |
| (E) Groove width | |
| Top, 2nd and 3rd | |
| L-5108-G and L-5790-G | .189"-.190" |
| Top | |
| L-7042-G | .1915"-.1925" |
| 2nd and 3rd | |
| L-7042-G | .190"-.191" |
| 4th and 5th | |
| L-5108-G and L-5790-G | .313"-.314" |
| L-7042-G | .376"-.377" |

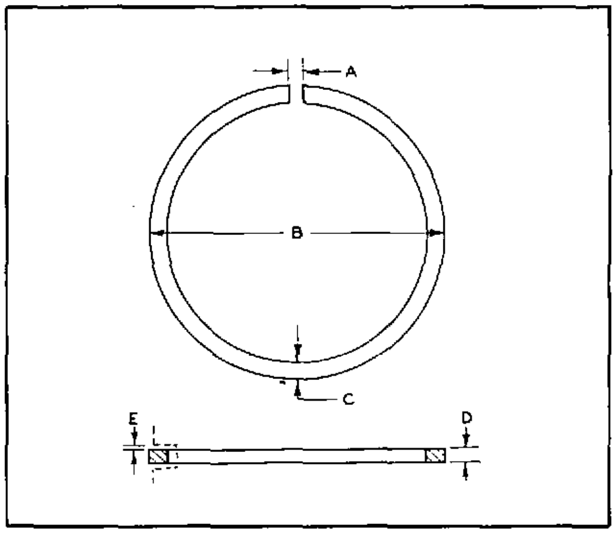



TYPICAL PISTON

## PISTON RINGS

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")

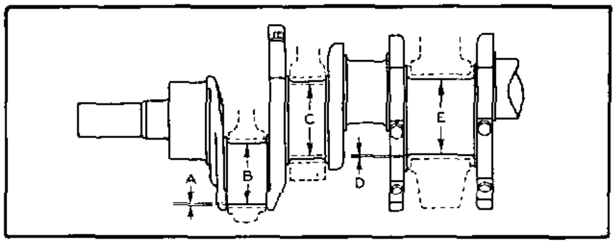
| | Top | 2nd and 3rd | 4th | 5th (when used) |
|---|---|---|---|---|
| (A) Ring gap | | | | |
| L-5108-G and L-5790-G | .025"-.035" | .025"-.040" | .015"-.035" | .025"-.040" |
| L-7042-G | .030"-.045" | .030"-.045" | .015"-.035" | .015"-.035" |
| (B) Ring Diameter | | | | |
| L-5108-G and L-5790-G | 8.500"@30# Min. | 8.500"@15# Min. | 8.500"@28.5 Min. | 8.500"@17# Min. |
| L-7042-G | 9.375"@22# Min. | 9.375"@15# Min. | 9.375"@24# Min. | 9.375"@25# Min. |
| (C) Ring wall | | | | |
| L-5108-G and L-5790-G | .305"-.315" | .305"-.315" | .225"-.240" | .304"-.319" |
| L-7042-G | .302"-.317" | .302"-.317" | .290"-.310" | .327"-.342" |
| (D) Ring width | | | | |
| L-5108-G and L-5790-G | .185"-.1865" | .1835"-.185" | .3085"-.310" | .3095"-.3110" |
| L-7042-G | .185"-.1865" | .185"-.1865" | .372"-.3735" | .372"-.3735" |
| (E) Side clearance | | | | |
| L-5108-G and L-5790-G | .0025"-.005" | .004"-.0065" | .003"-.0055" | .002"-.0045" |
| L-7042-G | .005"-.0075" | .0035"-.006" | .0025"-.005" | .0025"-.005" |




TYPICAL PISTON RING

## CRANKSHAFT

Crankshaft end play. . . . . . . . .008"-.016"
End play adjustment . .010" oversize thrust rings
Thrust ring thickness (standard) . .216"-.218"
(A) Connecting rod bearing running clearance (theoretical) . . .0026"-.006"
(B) Connecting rod bearing journal diameter
Early Model L-5108-G . . 5.749"-5.750"
All Current Models . . . 6.249"-6.250"
Connecting rod bearing journal maximum undersize . . . . . . . . . . .040"
(C) Main bearing journal maximum undersize. . . . . . . . . . . . . .040"
(D) Main bearing running clearance (theoretical) . . . .004"-.0074"
(E) Main bearing journal diameter . . . . . . . . 6.249"-6.250"




TYPICAL CRANKSHAFT

## CAMSHAFT

Camshaft journal diameter . . 3.498"-3.499"
Camshaft journal running clearance (theoretical) . . . .003"-.0056"
Thrust ring thickness . . . . . .154"-.156"

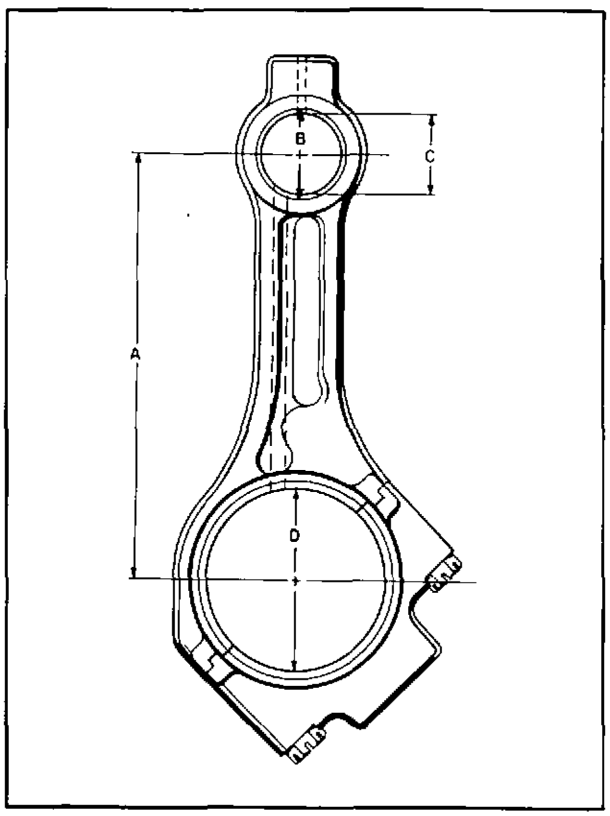
Camshaft end play . . . . . . . .005"-.008"
End play adjustment . . . . . . .002" shims
Cam lift (Intake and Exhaust) . . . . . .670"
Rocker arm ratio. . . . . . . . . . .1.0926 to 1
Camshaft coupling fit should never be loose.

## FLYWHEEL AND HOUSING

Pilot bearing run-out . . . . . . . . . . .005"
Total indicator reading
Face run-out on wheel
24" to 30" wheels . . . . . . . . . . . .012"
30" and oversize . . . . . . . . . . . .015"
Total indicator reading
Housing bore run-out . . . . . . . . . .015"
Total indicator reading
Housing face run-out . . . . . . . . . .010"
Total indicator reading

## CONNECTING ROD, BUSHING AND BEARING

Rod material. . . .Heat treated - steel forging
Permissible weight variation
per set. . . . . . . . . . . . . . 6 ounces
(A) Rod length, center to
center . . . . . . . . . 18.001"-18.002"
(B) Rod small end finish
size . . . . . . . . . . . 3.250"-3.251"

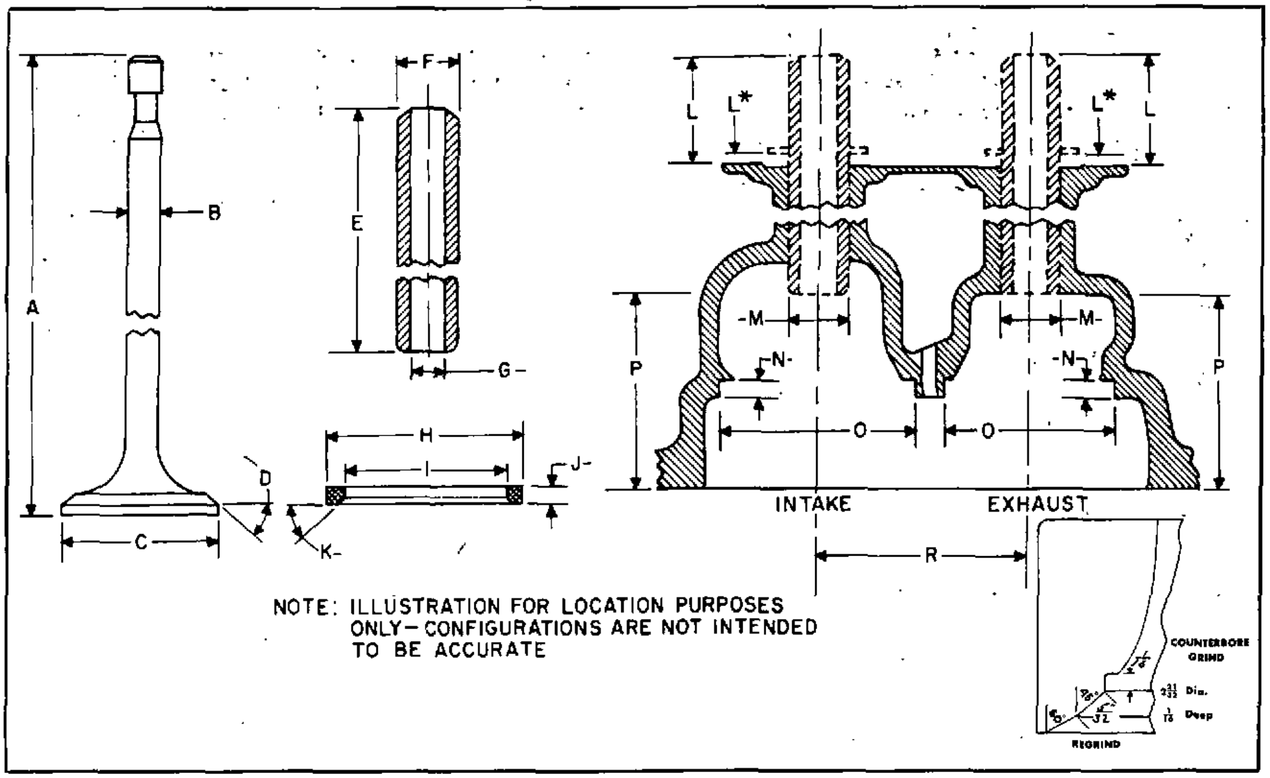



TYPICAL CONNECTING ROD, BUSHING

(C) Bushing bore diameter (diamond bored)
(Assemble 2 bushings with open ends
of grooves toward inside) 3.0015"-3.002"
Pin clearance in bushing . .0018"-.0029"
Bushing press in rod. . . .0035"-.0065"
(D) Rod large end finish size
Early Model L-5108-G . . 6.125"-6.126"
All Current Models . . . 6.625"-6.626"
Rod large end width
Early Model L-5108-G . . 3.049"-3.052"
All Current Models . . . 2.799"-2.802"
Rod bearing width
Early Model L-5108-G . . 2.740"-2.750"
All Current Models . . . 2.490"-2.500"
Bearing running clearance
(theoretical) . . . . . . . . .0026"-.006"
Rod large end width . . . . . 2.799"-2.802"
Rod bearing width . . . . . . 2.490"-2.500"
Rod side clearance
Early Model L-5108-G . . . . .021"-.037"
All Current Models . . . . . . .021"-.033"

## VALVE TRAIN, VALVE PORT CLEARANCES

Intake and Exhaust
(A) Valve length . . . . . . . . . . 10-57/64"
(B) Valve stem diameter (intake) .557"-.558"
(exhaust-nat. aspir.) .555"-.556"
(exhaust-turbo) .5593"-.5598"
taper to .5575"-.558"
(C) Valve head diameter. . . . 2.825"-2.835"
(D) Valve seat angle (intake). . 44° 30' ± 15'
(exhaust). . 45° 30' ± 15'
(E) Guide length . . . . . . . . . . . 5-3/16"
(F) Guide outside diameter . 1.0015"-1.0025"
(G) Guide inside diameter .5615"-.5608"
Guide I. D. to stem
O. D. clearance (intake) . .0028"-.0045"
(exhaust-nat. aspir.) . .0048"-.0065"
(exhaust-turbo) . . .001"-.004"
(taper)
(H) Insert outside diameter . . 3.128"-3.129"
(I) Insert inside diameter . . 2.640"-2.650"
(J) Insert depth . . . . . . . . .605"-.610"
(K) Insert seat angle . . . . . 45° 30' ± 15'
(L) Guide extends above head . . . . 1-3/4"
(M) Guide bore in head . . . . 1.000"-1.001"
(N) Insert counterbore depth . . .825"-.830"
(O) Insert counterbore diameter 3.124"-3.125"
(P) Valve port depth (nominal) . . . 3-1/16"
(R) Valve - centerline to centerline
Intake to intake and exhaust
to exhaust . . . . . . . . 3.676"-3.696"
Intake to exhaust . . . . 3.990"-4.010"
Valve insert seat width . . .151"-.164"
Valve face width. . . . . . . .157"-.172"
Valve spring free length
204035 (inner) . . . . 3-25/32" ± 1/16"
204135 (outer) . . . . 4-9/32" ± 1/16"




VALVE TRAIN, VALVE PORT CLEARANCES

Valve closed spring length
204035 (inner) . . . . 3" @ 56.7# ± 3#
204135 (outer) . . 3-27/64" @ 111# ± 5#
Valve open spring length
204035 (inner) . . 2-17/64" @ 110# ± 5#
204135 (outer) . 2-11/16" @ 205# ± 10#

* Rocker arm bushing I.D. . . . 1.375"-1.376" (press fit in arm and diamond bored)

Rocker arm shaft O.D. . . . 1.3735"-1.3745"

Running clearance, bushing to shaft . . . . . . . . . . . . .0005"-.0025"

*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. Also with the hydraulic 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") 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") oil hole to the lifter adjusting screw which is plugged with a rivet and this hole and the 1/8" 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. The intake rocker arm lever bushings do not require any oiling holes to be drilled before the bushings are diamond bored.

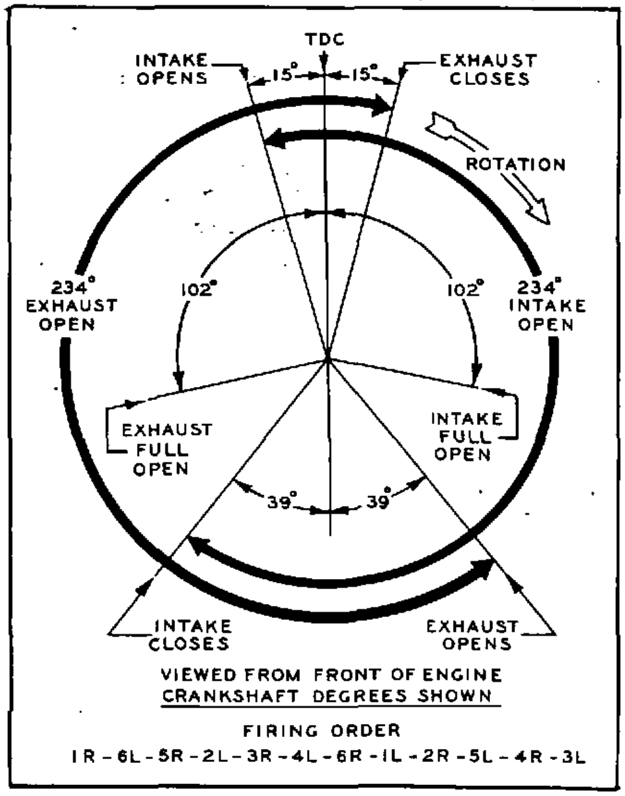
## VALVE CLEARANCE

Valve clearance . . . . . . Hydraulic lifters

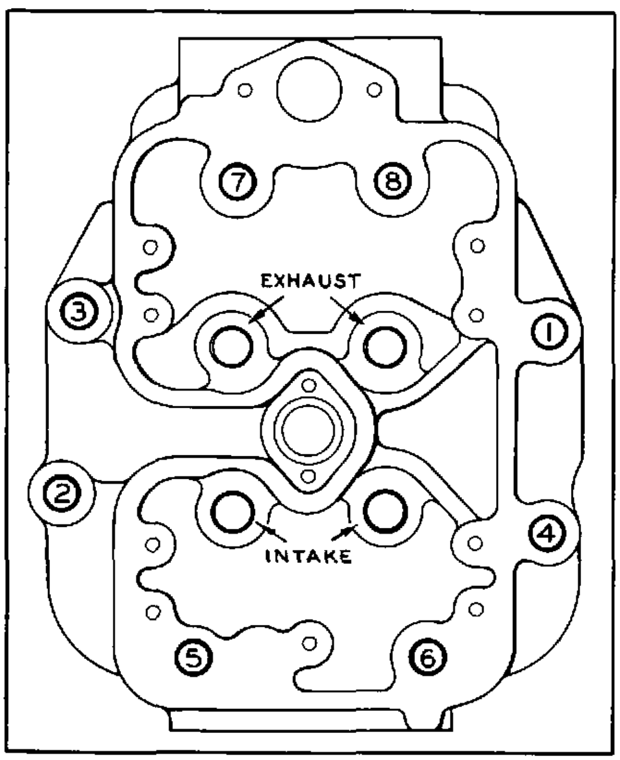
Cam lift (measured at push rod) . . . . . . . . . . . . . .670"

## VALVE LIFTERS

Valve lifter body to valve lifter guide clearance . . . . . . . . . .002"-.004"
Valve lifter body O.D. . . . 1.4965"-1.4975"
Valve lifter guide I.D. . . . 1.5005"-1.4995"




VALVE SEQUENCE




Re-torque replaced cylinder heads after running the engine either idle or after load testing.

VALVE LOCATION AND CYLINDER HEAD BOLT TIGHTENING DIAGRAM

## OIL PUMP

Backlash oil pump pressure gears .012"-.015"
Pressure gear(s) to cover endplay. .005"-.011"
Drive shaft bushing I.D. (ream)
In cover . . . . . . . . . 1.2505"-1.2515"
In body . . . . . . . . . . 1.375"-1.3755"
Drive shaft running surface O.D.
In cover. . . . . . . . . . 1.248"-1.2485"
In body . . . . . . . . . . 1.372"-1.3725"
Drive shaft running clearance
In cover bushing . . . . . . .002"-.0035"
In body bushing . . . . . . .0025"-.0035"
Idler gear bushing I.D. . . . 1.0005"-1.0015"
Idler shaft O.D. . . . . . . . .998"-.9985"
Idler gear running clearance
on shaft. . . . . . . . . . .002"-.0035"
Radial clearance between pumping gear teeth and pump chamber wall . . . . . . . . . . . .002"-.003"
Space drive gear at assembly 1/32" from body. Drill through 1/4"
Press driven gear on shaft 1-1/2" from end. Drill and ream 1/4" 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 I.D. . . . . . . . . 1.4995"-1.5005"
Idler gear stud O.D. (running surface) . . . . . . . . 1.4975"-1.498"
Crankshaft to oil pump drive idler gear running clearance . . . . . .0015"-.003"
Crankshaft to oil pump drive idler gear end play . . . . . . . . .010"-.016"

## TIMING GEAR BACKLASH

Between oil pump drive idler gear and oil pump drive gear . . . .015"-.020"
Between all other timing gears . . .008"-.012"

## 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 dipstick) . . . . 35 gals.
Oil pan (high level dipstick) . . . . 43 gals.
Filter . . . . . . . . . . . . . 30 gals.
Oil cooler 8 inch - . . . . 8 gals.
Oil cooler 6 inch - . . 5 gals.

**COOLING SYSTEM** (engine only) . . . 90 gals.

## IGNITION DATA

ELECTRICAL SYSTEM . . . . Either two six cylinder low tension magnetos with individual coils for each cylinder, or Bendix or American Bosch Magtronic single twelve cylinder ignition timer with individual cylinder ignition transformers.

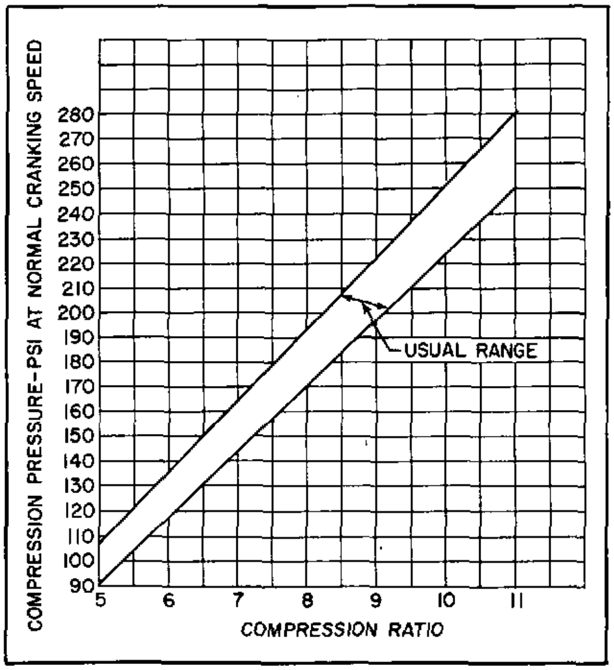
Spark plug size . . . . 18 mm with 1/2" reach
Torque to 32 to 38 lbs. ft.
Use steel gasket Champion A-678
Spark plug type (standard) Champion RM-77N
(platinum tip) Champion RM78P
(shielded) Champion REM-84P
Spark plug gap . . . . . . . . . . .013"-.016"
(platinum tip) .011"
Magneto point clearance . . . . .016"-.018"

## TIMING

Note: Time low tension magnetos with engine stopped. Time Bendix and Magtronic units with timing light at operating rpm.

| Compression Ratio | RPM | Natural Gas | LPG |
|---|---|---|---|
| 7.0:1 | 600-800 | 24° BTC | 24° BTC |
| 7.0:1 | 900-1200 | 28° BTC | 28° BTC |
| 8.0:1 | 600-800 | 20° BTC | |
| 8.0:1 | 900-1200 | 24° BTC | |
| 8.25:1 | 600-800 | 21° BTC | |
| 8.25:1 | 900-1200 | 24° BTC | |
| 10.0:1 | 600-800 | 20° BTC | |
| 10.0:1 | 900-1000 | 22° BTC | |
| 10.0:1 | 1100-1200 | 24° BTC | |

## COMPRESSION PRESSURE




COMPRESSION PRESSURE VS RATIO

# DISTRIBUTORS AND SERVICE

The Waukesha Motor Company has established a system of distributors of unquestioned reputation with trained mechanics and full facilities for maintenance, rebuilding, and consultation, and to carry adequate parts stock in nearly every state of the Union and Canada as well as most Latin American and overseas contries. In addition, the Waukesha Motor Company owns and operates branch warehouses and servicing facilities in the Carlstadt, New Jersey; Tulsa, Oklahoma; Los Angeles, California; and Anchorage, Alaska areas, so that owners and operators are thus always within easy reach of a "Waukesha man." See the title page for correct addresses.

Your service needs will be greatly facilitated whenever you have occasion to call upon either an Authorized distributor, a Factory Branch, or the Factory Service Department if the following procedure is observed:

Give Engine Model Number — Always specify size, model, and number of the engine, which is stamped on the nameplate attached to the crankcase. The engine number may also be stamped on the crankcase at either the gear cover or flywheel housing end, and sometimes on the front end of the crankcase. Be sure to give the number stamped after "SPEC" as "G20000", or whatever the number may be on the particular engine.

When ordering parts — Always furnish complete description and number, where known, of the part or parts wanted. Do not use the word "complete", state exactly each item that is wanted and do not designate the quantity by "sets"; mention how many parts are required.

Tell How to Ship and Where — State whether to ship by freight, express or parcel post; furnish shipping point and post office address. Without specific shipping instructions the shipper will use his own discretion, and will not be responsible for any charges by so doing.

Mail Shipments — Goods shipped by mail are entirely at customer's risk, unless cash or postage for insurance accompanies the order.

When Shipped to Us — Shipments to us should be accompanied by the bill of lading or express receipt with a letter of advice. Do not enclose shipping papers with the shipment.

How to Mark Shipment to Us — It is very important to have all shipments properly marked with the sender's name and address, to insure prompt identification upon receipt. Always prepay the charges.

Terms on Repairs — To avoid delay, all repairs will be sent C.O.D. unless cash accompanies the order. All prices quoted are f.o.b. Waukesha, Wisconsin.

How to Return Parts for Credit — When returning parts for inspection and credit, (see Warranty, on page 94 of this book), the engine number from which the parts were taken must be given and all transportation charges must be prepaid. Our receiving department is not authorized to accept "Collect" shipments.

# WAUKESHA MOTOR COMPANY

## *STANDARD WARRANTY*

(Effective March 15, 1958)

The Waukesha Motor Company warrants each new Waukesha, Climax or Roiline engine or power unit manufactured and sold by them to be free from defects in material and workmanship for eighteen (18) months from date of shipment, but not to exceed one (1) year of service, including rental or demonstration service or the first 100,000 miles of operation, whichever shall first occur.

The obligation under this Warranty, statutory or otherwise, may be limited to the replacement or repair at the Waukesha factories of such part or parts as shall be determined by the Waukesha Motor Company, upon inspection at such point, to have been defective in material or workmanship.

This Warranty does not obligate the Waukesha Motor Company to bear the cost of labor or transportation charges in connection with the replacement or repair of defective parts, unless the Waukesha Motor Company or an Authorized Waukesha or Roiline Distributor assumes such obligation, prior to the time repairs are made. In no event will the Waukesha Motor Company assume or require its Distributors to bear the cost of labor in connection with the replacement or repair of defective parts, when the engine or power unit has been in the possession of a using owner or rental operator for a period of six (6) months or longer or has operated more than 50,000 miles.

The Waukesha Motor Company makes no Warranty in respect to trade accessories, such being subject to the Warranties of their respective manufacturers.

This Warranty shall not apply to engines or power units, which in the opinion of the Waukesha Motor Company or an Authorized Waukesha or Roiline Distributor have been damaged as a result of overloading, overspeeding, overheating, inadequate maintenance, accident or improper installation or storage.

The Waukesha Motor Company shall in no event be liable for consequential damages or contingent liabilities arising out of the failure of any engine or power unit or parts to operate properly.

This Warranty does not obligate the Waukesha Motor Company to provide "tune up service".

Waukesha Motor Company

WAUKESHA

MOTOR COMPANY