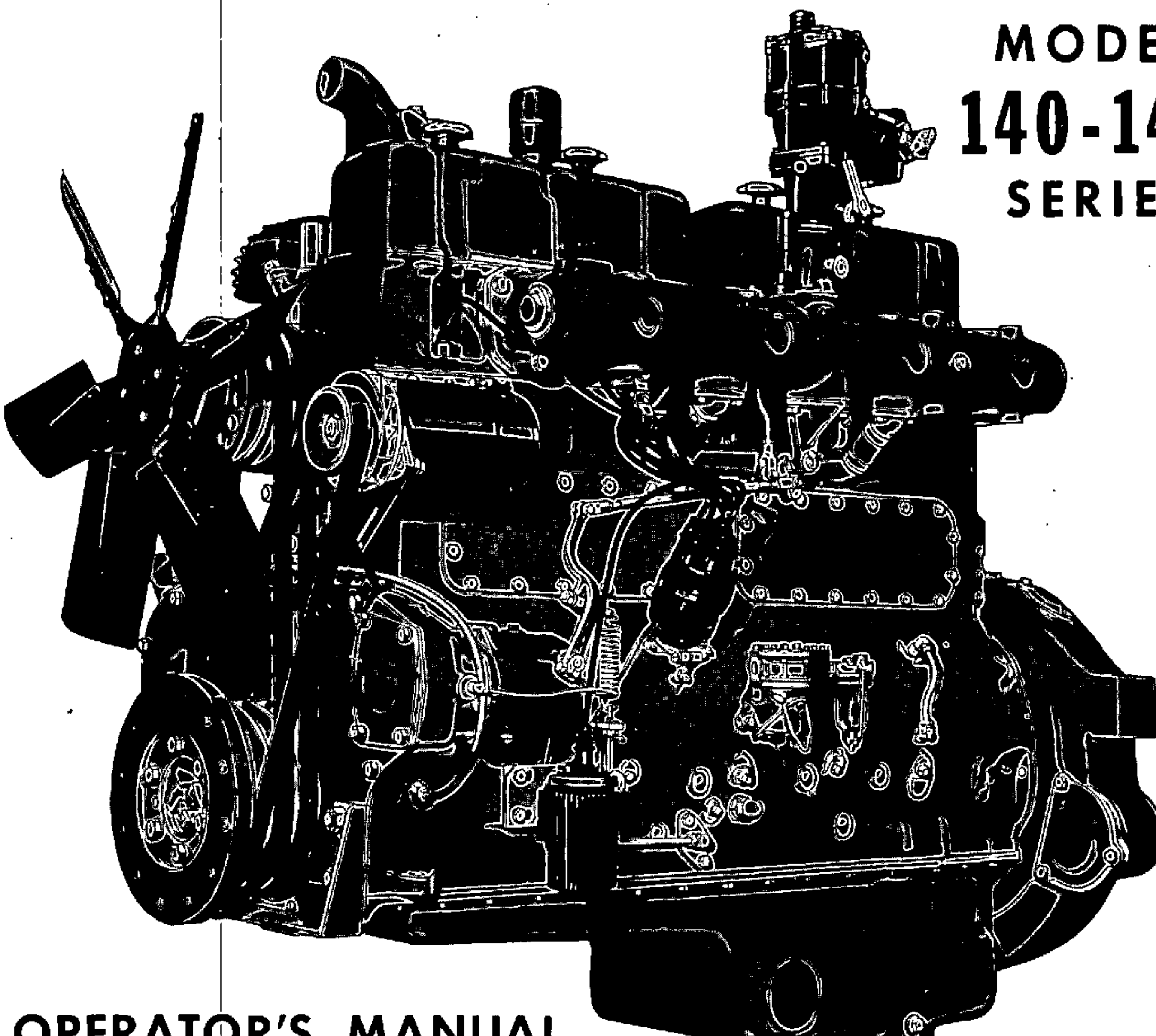
WAUKESHA ENGINES

MODEL
140-145
SERIES



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SERVICE MANUAL WAUKESHA 140-145 SERIES ENGINES

WAUKESHA
MOTOR CO

REG. U.S. PAT. OFF.

EDITION SIXTEEN

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INTRODUCTION

THIS manual is intended as a source of information on the specialized features of the Waukesha 140 and 145 series gas-gasoline engines. For the practicality and convenience of the user, discussions of standard or well-established maintenance practices have been limited or omitted. Where tabulated data is provided, the user should realize that the clearances, part numbers, and so on, are likely to change over a period of time. Hence, it will be necessary to consult the manufacturer or his authorized representative if any doubt arises as to the suitability of a given part or clearance.

When requesting information from the manufacturer, address the Service Department, Waukesha Motor Company, Waukesha, Wisconsin, and 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.

It is the sincere desire of the Waukesha Motor Company that every engine gives the service and performance for which it is built. We are always receptive to suggestions for improvements in our products or our service and will give all suggestions the most careful consideration.

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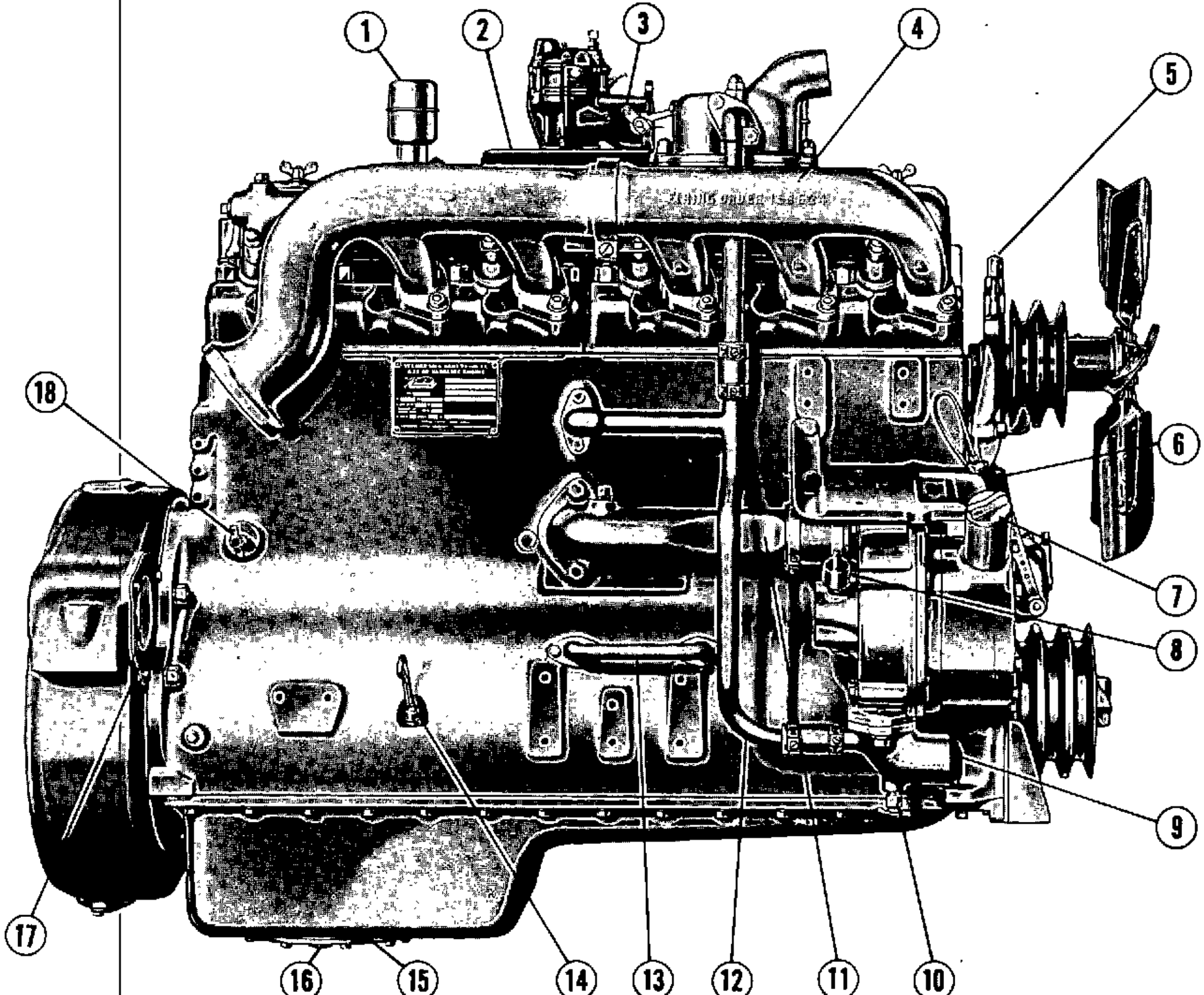
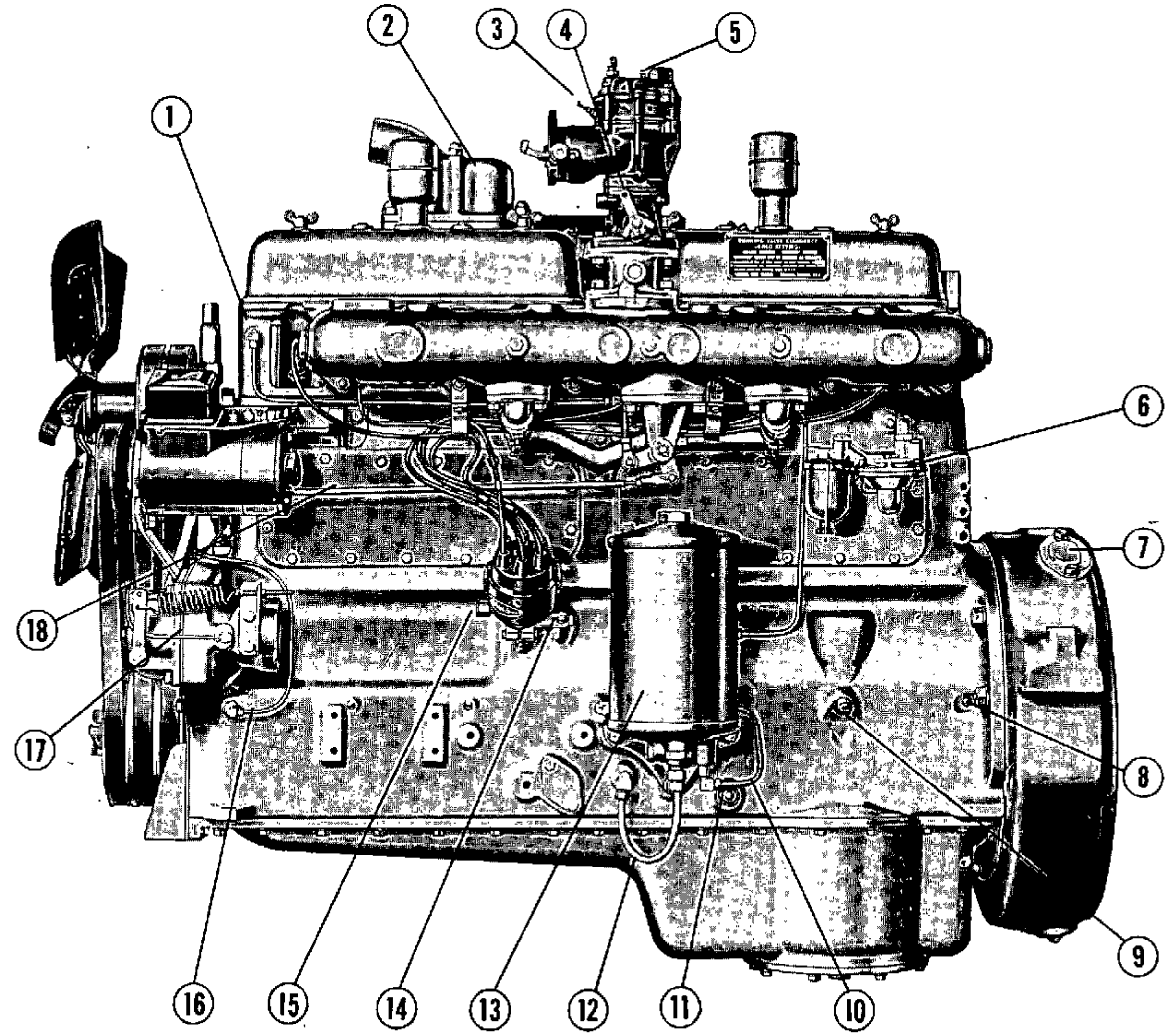


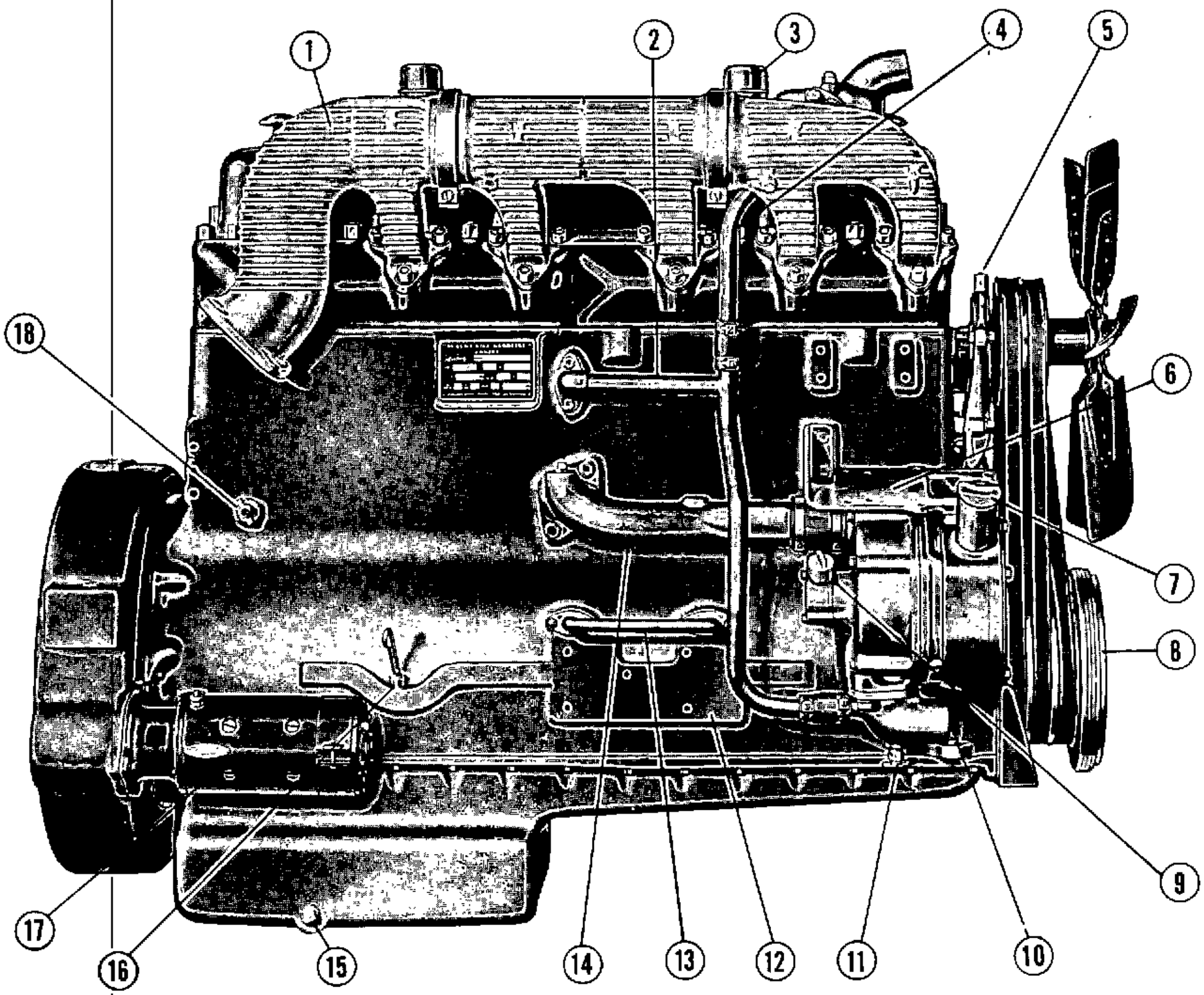
WAUKESHA MODEL 140-GZ, Right Side View

1. Rocker Arm Cover Breather
2. Heat Shield
3. Carburetor Choke Lever
4. "Rear Down" Exhaust Manifold
5. Fan Belt Tension Adjustment
6. Compressor Mounting (Optional)
7. Oil Filler Cap
8. Water Pump Grease Cup
9. Water Pump Inlet
10. Water Pump Drain
11. Water Pump Outlet - To Crankcase
12. Cooling System By-Pass
13. Lubrication System Jumper Line
14. Oil Level Gauge
15. Oil Pan Access Plate
16. Oil Pan Drain
17. Starter Mounting Pad
18. Crankcase Water Drain



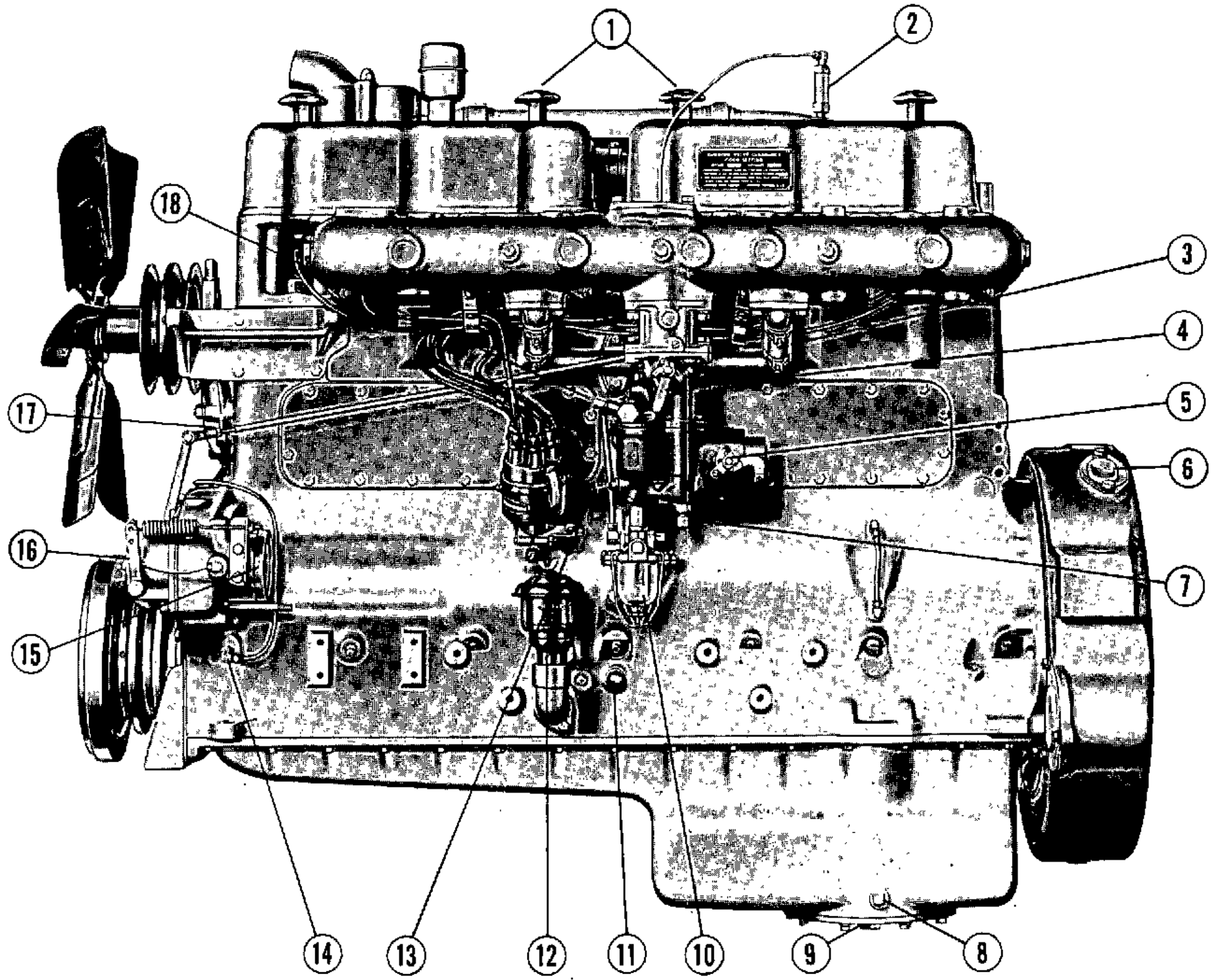
WAUKESHA MODEL 140-GZ, Left Side View

1. Rocker Arm Lubrication Line
2. Thermostat Housing
3. Carburetor Main Jet Adjustment
4. Throttle Stop Lever
5. Idle Mixture Adjustment
6. Fuel Pump
7. Flywheel Timing Access Door
8. Oil Pressure Gauge Fitting
9. Main Oil Header Drain
10. Oil Filter Inlet - From Engine
11. Oil Pressure Adjustment
12. Oil Filter Outlet - To Engine
13. Oil Filter - Shunt Type
14. Distributor Timing Adjustment
15. Ignition Distributor Grease Cup
16. Compressor Lube Line
17. Governor Lube Line
18. Governor Linkage to Butterfly



WAUKESHA MODEL 145-GZ, Right Side View

1. "Rear Down" Exhaust Manifold
2. Intake Manifold Coolant Line
3. Rocker Arm Cover Breather
4. Cooling System By-Pass Line
5. Fan Belt Tension Adjustment
6. Compressor Mounting Pad
7. Oil Filler Cap
8. Vibration Dampner (High Output Engine)
9. Water Pump Grease Cup
10. Coolant Inlet To Water Pump
11. Coolant Drain
12. Oil Filter Mounting Pad
13. Lubrication System Jumper Line
14. Water Pump Outlet To Crankcase
15. Oil Pan Drain
16. Oil Level Gauge
17. Electrical Starter
18. Crankcase Water Drain



WAUKESHA MODEL 145-GZ, Left Side View

1. Rocker Cover Hold-Down Nuts
2. Crankcase Ventilation Regulator
3. Intake Manifold Coolant Line
4. Throttle Stop Lever
5. Updraft Carburetor Choke
6. Flywheel Timing Access
7. Updraft Carburetor - Zenith 63 Series
8. Oil Pan Drain
9. Oil Pan Access Plate
10. Fuel Pump Sediment Bowl
11. Oil Pressure Adjustment
12. Crankcase Breather
13. Carburetor Main Jet Adjustment
14. Compressor Oil Supply Line
15. Magneto Mounting Pad
16. Governor Lever
17. Governor Linkage Adjustment
18. Carburetor Fuel Inlet

WAUKESHA MODEL 140-145 SERIES
PRINCIPAL ENGINE DIMENSIONS

ENGINE MODEL	140-GK	140-GZ	145-GK	145-GZ
Bore	4-1/2	4-5/8	5-1/4	5-3/8
Stroke	5-1/2	5-1/2	6	6
Displacement (Cubic Inches)	525	554	779	817
Intake Valve Diameter, Clear	1-7/8	1-7/8	2-1/8	2-5/16
Exhaust Valve Diameter, Clear	1-3/8	1-3/8	1-5/8	1-13/16
Connecting Rod Bearings, Dia. x Lgth.	2-5/8 x 1-23/32	2-5/8 x 1-23/32	3 x 2-1/4	3 x 2-1/4
Connecting Rod Length	10-1/4	10-1/4	11-3/4	11-3/4
Front Main Bearing, Dia. x Lgth.	3-1/4 x 1-19/32	3-1/4 x 1-19/32	3-1/2 x 2	3-1/2 x 2
Center Main Bearing, Dia. x Lgth.	3-1/4 x 2-15/16	3-1/4 x 2-15/16	3-1/2 x 3-3/4	3-1/2 x 3-3/4
Intermediate Main Brgs., Dia. x Lgth.	3-1/4 x 1-19/32	3-1/4 x 1-19/32	3-1/2 x 2-1/8	3-1/2 x 2-1/8
Rear Main Bearings, Dia. x Lgth.	3-1/4 x 3	3-1/4 x 3	3-1/2 x 3-1/2	3-1/2 x 3-1/2
Piston Pin, Floating, Dia. x Lgth.	1-3/8 x 3-7/8	1-3/8 x 3-7/8	1-5/8 x 4-1/2	1-5/8 x 4-1/2
Piston Rings, Compression (3) Width	1/8	3/16	1/8	1/8
Piston Rings, Oil Control (2) Width	3/16	1/4	1/4	1/4
Timing Gears, Face Width	1-1/2	1-1/2	1-1/4	1-1/4
Carburetor, SAE Size (Standard)	1-3/4	1-3/4	2	2
Carburetor, SAE Size (Fire Engines)	2	2	2	2
Spark Plugs, SAE Size	14mm	14mm	14mm	14mm
Flywheel Housing, SAE Size (Standard)	3	3	2	2
Flywheel Housing, SAE Size (Unit)	1	1	0	0
Fan Diameter (Six Blade)	20	20	24 & 28	24
Cooling System Capacity (Units)	15	15	18	18
Weight-Engine, Approximate (lb.)	1390	1390	1810	1810
Weight-Unit, Approximate (lb.)	2750	2750	3700	3700
Lubrication System Capacity * (Engine Only) Standard Pan	10 quarts	10 quarts	18 quarts	18 quarts
Lubrication System Capacity * (Engine Only) Box Base	19 quarts	19 quarts	26 quarts	26 quarts

*Allow approx. 4 qts. additional for filter.

(All dimensions in inches unless otherwise stated.)

NOTE: Do not use the above for service adjustment. This information is for general purposes only. Consult the Clearance Section of this manual for specific information.

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.

DESCRIPTION

GENERAL

Since this manual covers both the 140 and 145 models, the following method has been used to avoid confusion, and at the same time to prevent repetition when discussing parts that are essentially alike except for size. In all descriptions the 145 series will be considered the basic model. Minor differences between a 145 and 140 part will be mentioned where necessary. If no differences are mentioned, it is because the parts differ, for the most part, in size only. Where major differences exist for a given part between the two series, separate paragraphs will be used to describe each part. Where variations exist among engines in a given series, for example piston variations, mention will usually be made in the text, and detailed information may be obtained by writing the Service Department, WAUKESHA MOTOR CO. Always include the engine serial number when writing. In most cases no attempt has been made to retrace the variations in design over years past.

Both the 140 and 145 models are produced in a commercial and industrial version. The main differences involve operational speeds and the crankshaft vibration dampner. Also, there are a number of variations in ignition, manifolding, flywheels, fans, and so on, possible within the framework of a given series and type. For this reason, the description of the parts in both series must be somewhat generalized. All models may be converted to operate on either gasoline or gaseous fuels. They are not available for kerosene operation. Engines with the GZ designation have 1/8-inch larger bore than the earlier GK models.

When rebuilding or servicing an engine, it is suggested that the latest changes and clearances be incorporated. Tabular data printed here represents the latest recommendations at time of printing. Separate Parts Manuals, which facilitate ordering of replacement parts and repair kits, are also available for the 140 and 145 series.

For purposes of discussion, or correspondence, the following reference points have been established.

CYLINDER NUMBERING - Cylinders are numbered consecutively from one to six, starting from the gear cover end of the engine.

FRONT and REAR - Reference to such locations on the engine shall be interpreted as meaning from the gearcover (front) and flywheel (rear) ends.

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

Since many of the parts described contain complex oil or water passages, no mention has been made of these openings in most cases. Lubrication and cooling are discussed under separate headings later in the Description Section.

CRANKCASE

The crankcases of both the model 140 and 145 are single high-grade iron castings incorporating seven heavily ribbed main bearing supports and locations for the six wet-type cylinder sleeves. Cooling water passages are formed between the side walls of the crankcase and the cylinder sleeves. Thus, the sleeves are always in direct contact with the coolant for their full length.

Since the cylinder sleeves are of the removable type, it is necessary to provide a seal at both ends. At the upper end this is done by the head gasket which seals the accurately finished mating surfaces at the joint between the sleeve flange and the crankcase deck recess. Two rubber seal rings are used at the lower end of the sleeve.

The crankcases have four accurately aligned locations for the camshaft bushings. These bushings, located on the left side of the engine, support the camshaft at the front and rear, and at two intermediate points, all of which are line bored* and supplied with oil under pressure. Immediately above the camshaft are 12 cam-follower guides cast as integral parts of the crankcase. These guides may be

*Precision sized service bushings available.

rebushed as a service measure, providing machine shop facilities are available. Drilled holes from the tappet compartment meter oil to each tappet and cam lobe.

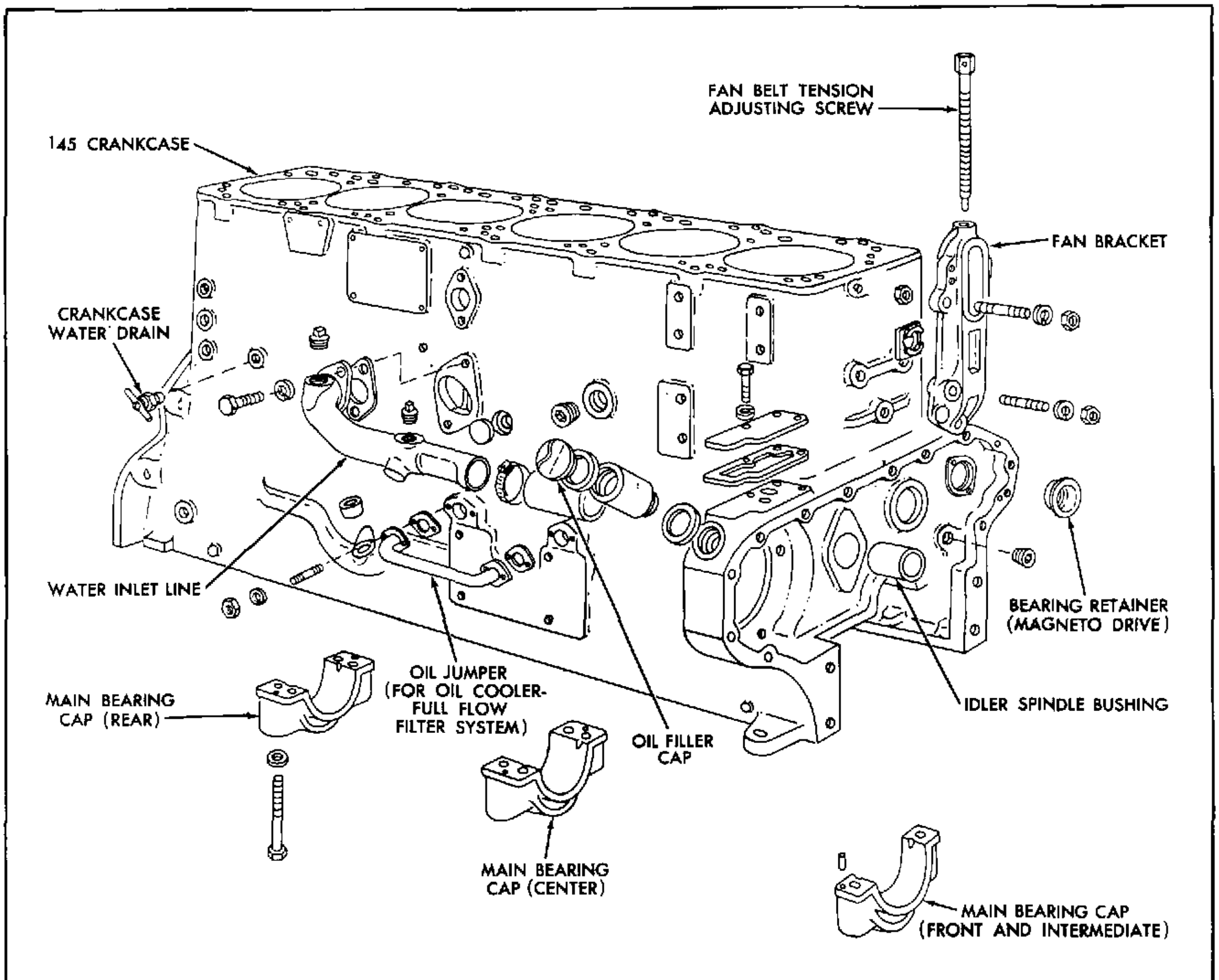
The forward end of the crankcase provides a housing for the crankshaft-drive gear, and the cam gear, magneto-drive gear, water-pump drive gear, and idler gear. The front end of this housing is closed by a gear cover supporting the crankshaft oil retainer and camshaft and idler thrust-button plates. A line-bored idler bushing is pressed into the front of the case. A pre-fitted, precision-type replacement is available for service use.

At the rear end of the crankcase is a mounting surface for a flywheel housing of a specified size and a spring-loaded oil retainer. To ensure accurate mounting of the clutch or other drive unit on the flywheel housing, the rear surface of the engine is held to very close tolerances and the housing itself is machined true after the engine has been assembled.

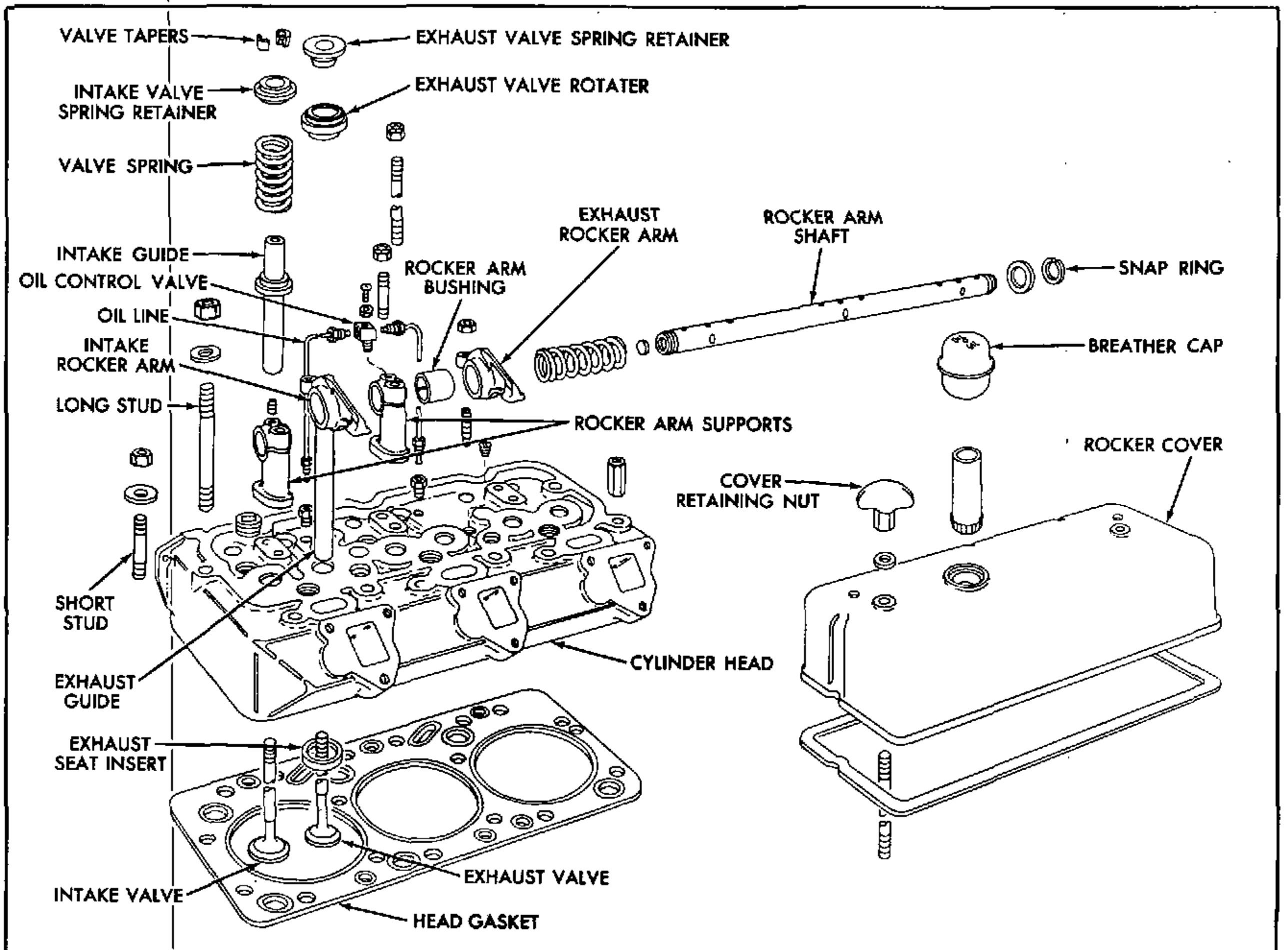
Inspection panels, located on the left side of the crankcase, permit cleaning if required.

A longitudinal rifle-drilled passage extending along the left side of the crankcase forms the main pressure-oil header. Threaded plugs spaced along this rib indicate the intersection points of oil leads to the main bearings. Removal of these plugs permits cleaning of the oil passages after crankshaft and main bearings have been removed for major inspection or repair.

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



CRANKCASE - RIGHT SIDE 145 SERIES



CYLINDER HEAD (145 COMMERCIAL)

CYLINDER HEADS

The cast-iron cylinder heads used on both engine series are available in a number of variants depending upon the purpose and fuel for which the particular engine is designed. It is usually necessary to change both heads on a given engine when an older head is replaced by a new one of superseding part number.

Also, promiscuous interchange of heads with conflicting part numbers between engines of different variants can seriously impair performance and result in costly damage.

Do not attempt to judge two heads as being alike merely because they appear to be so. Differences in valve insert and guide metals, port ratios, cooling passages invisible to the eye, valve spacings, and so on are not readily apparent. Heads of different part number should be used only after consulting the Service Department, WAUKESHA MOTOR CO.

In those heads incorporating valve seat inserts, the inserts are retained by a combination pressing and shrinking method. The inserts are both shrunk and pressed in place. On earlier models pressure on the cylinder head material around the edge of the inserts was applied in such a manner as to form a flange-like collar. This is no longer done. Heads used on late model engines are equipped with separate studs for retaining the rocker arm covers and the rocker arm shaft support studs are no longer used for this purpose. To avoid replacement of the rocker covers when using a new type head for service the long studs may be re-installed as in the original design.

On new or recently overhauled engines the cylinder head hold down stud nuts should be retightened to the proper torque values after first warm-up and after approximately fifty engine hours. It is equally important that the stud nuts be tightened in the proper sequence as illustrated in the clearance sections at the rear of this manual.

CYLINDER SLEEVES

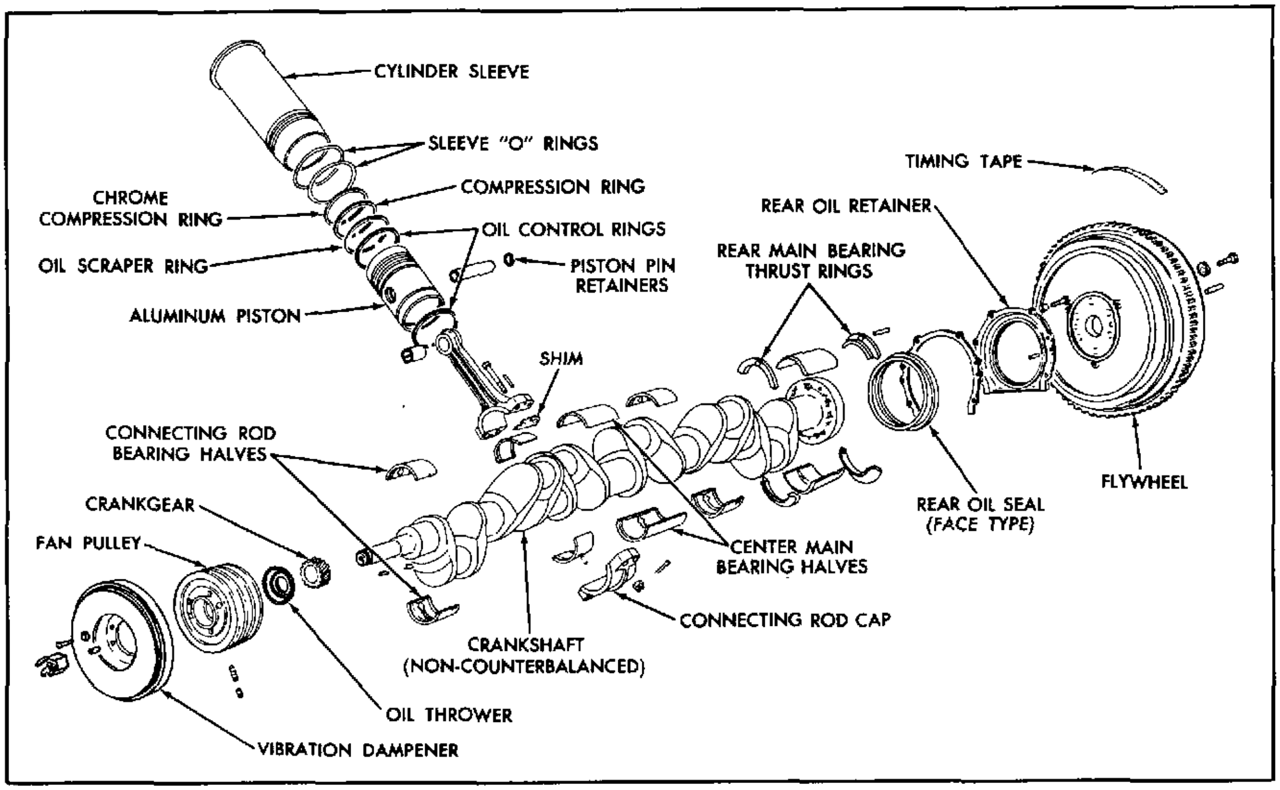
The wet-type cylinder sleeves are cast from high-grade iron especially selected for long wearing qualities and resistance to distortion. Each sleeve has a shoulder and flange at the upper end to locate it in the crankcase upper deck and prevent shifting and leakage when the cylinder head and gasket are above it. Both this flange, and the crankcase deck recess into which it fits, have precision-finished mating surfaces to form a water seal in this area. The lower end of the sleeve is tapered, and immediately above the taper are two grooves for the rubber seal rings.

CRANKSHAFT

The 140-145 crankshafts are precision ground from heat-treated steel forgings. Operating smoothness in high-output engines is gained from the torsional vibration dampner at the forward end. Crankshafts are of massive design to provide ruggedness for hard, continuous service and have seven locally-hardened main-bearing journals. Older model engines used precision-type, steel-backed, tin-base babbitt alloy bearing shells. Connecting rod bearings were of similar construction. Present engine bearings are similar, but of copper-lead material. Drilled passages, running diagonally from the main-bearing journals through the crank-cheeks, carry pressure oil to the connecting-rod bearing areas. The rear extremity of the shaft has an integral flange for the flywheel. This flange is drilled and tapped for six flywheel mounting bolts. One bolt hole is offset in order to ensure the installation of the flywheel in the proper relationship with the crankshaft. The rear journal blends into a finished shoulder surface designed to absorb thrust loads at the crankcheek. This shoulder bears against the inner of the two rear main bearing flanges on the 140 engines and earlier model 145 engines. Current 145 engines utilize thrust rings and flangeless rear main bearing inserts in place of the thrust or flange type bearings. The proper crankshaft end thrust must be maintained at all times within the allowable limits as stated for each engine series in the respective clearance section in this manual.

The front extension of the crankshaft provides two keyed mounting surfaces to support the crankshaft drive gear and fan pulley.

In high-output engines, a torsional vibration dampner is bolted to the outer face of the fan pulley.



CRANKSHAFT, PISTON, SLEEVE, AND FLYWHEEL (145 ENGINE SHOWN)

CONNECTING RODS

Six forged and heat-treated I-section connecting rods are used in both the 140 and 145 engines. In the 145-type rod, four heat-treated bolts and slotted nuts retain the rod cap. The 140-type connecting rod cap is retained by two heat-treated bolts and slotted nuts. The rods and caps are forged, heat-treated, and machined in one piece, then separated, spaced with .006 shims, and bored to accommodate steel-backed, precision bearing shells. The shells are positively located in the rod and cap by small offsets that engage reliefs in the cap and rod at the joint. Also, the 145 cap has a locating dowel that engages a hole in the bearing shell.

Hard bronze bushings are pressed into the piston pin end of the rods, broached to expand the metal into the rod, and diamond bored for precise alignment. These bushings are used as a master reference for boring the large end bearing shell seats. For this reason, 140 or 145 connecting rods are never bent for alignment purposes, at the factory or in the field.

A rifle-drilled passage running upwards through the connecting rod center conducts oil from the crankpin bearing to the piston pin bushing and piston pin bosses.

Recent engines have a 1/8"-wide oil slot in each big-end outer face. These slots direct positive oil sprays to the cam-tappet area.

The crankpin bearing shell seats are precision bored, as mentioned above, with .006 spacer shims between the cap and rod on each side. On assembly, three .002 shims are laminated to a total of .006 and installed between the cap and rod on each side. These shims may be peeled apart for adjustment, but if such a procedure is undertaken, it will also be necessary to remove equal amounts from the bearing shell crush ends by careful filing, or lapping on a surface plate. This should never be attempted except as an emergency temporary repair. For this reason, current production engines will discontinue usage of the shims.

PISTONS

Pistons of several different designs, types, and materials have been employed in both the 140 and 145 engines depending upon the engine application. A continuing program of research has led to the development and release of a new piston design for Waukesha model 145-GZ engines which will provide improved oil control. This piston is now being used for new engine production and will be supplied for parts replacements. The new piston which incorporates a ni-resist insert is not interchangeable with the previous design because of the narrow type compression rings that are required. Replacement in complete sets is recommended. When ordering rings or replacement pistons, the operator should carefully check the exact part number of the piston and its ring installation. In those cases where pistons have been reworked locally, it may be impossible to fit the proper rings.

The piston pins are of full-floating, tubular design, lapped and hardened. They should be a light push fit at normal temperatures. Retainers in the piston-pin bosses limit pin end travel but enough freedom should be apparent here to be sure the pin is not binding. Considerable care should be used in service operations to ensure proper piston pin fitting. Carelessness may result in over-tight fits that encourage scoring, or loose fits that make for a noisy engine.

VALVES AND MECHANISM

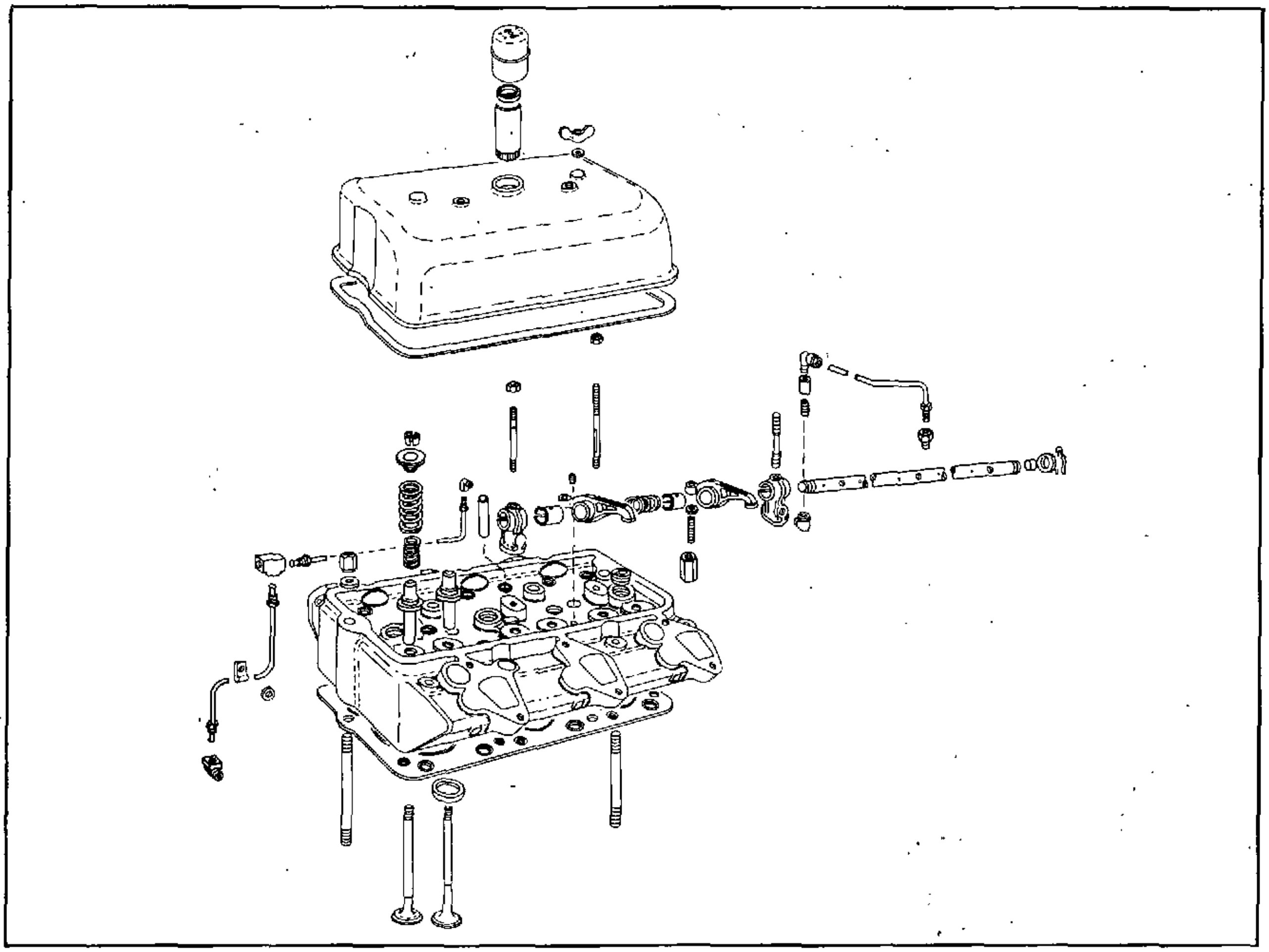
Intake and exhaust valves are of the poppet type with hardened tips and annular recesses for split-taper locks. A considerable variation in valves and guides exists among the different engine models and also among superceding heads used on the same model. In some cases, the differences are entirely a matter of the metal employed. When replacing valves, valve guides, or valve seat inserts, exercise caution to use service parts of the correct material.

Stellite seat facings are employed on the exhaust valves of some models and these valves seat on stellite faced inserts. In all cases, hardened exhaust inserts are used and are retained by shrinking and pressing in the cylinder head.

Intake and exhaust guides are pressed into the cylinder head but may be pulled and replaced if necessary.

Valves and springs are retained by hardened washers stepped to center the springs and seating on split-taper locks. Dampner coils (close wound) on the valve springs should always be installed downward; towards the head. Again, care must be exercised to use the proper springs for a given engine.

Valve actuation is obtained through chilled and polished alloy cam followers operating directly on the camshaft. This motion is transmitted to the rocker arms through steel push rods hardened at each end.



TYPICAL VALVE ARRANGEMENT (140 INDUSTRIAL ENGINE SHOWN)

The forged steel rocker arms pivot on graphite-bronze bushings riding on a hardened hollow steel shaft. The bushings are pressed into place, then reamed. The rocker arms are offset to align with their respective exhaust and intake valves, and to ensure long wear and accurate adjustment are hardened in the valve tip contact area. Since valve and guide lubrication are controlled by the width of the ridge leading from the oil hole to the tip, intake and exhaust rocker arms must not be interchanged at assembly.

The rocker arm shafts are plugged at each end and drilled outlets along the shafts mate with passages in the rocker arm bushings to permit lubrication. An adjustable oil control valve is used on recent 145 model engines.

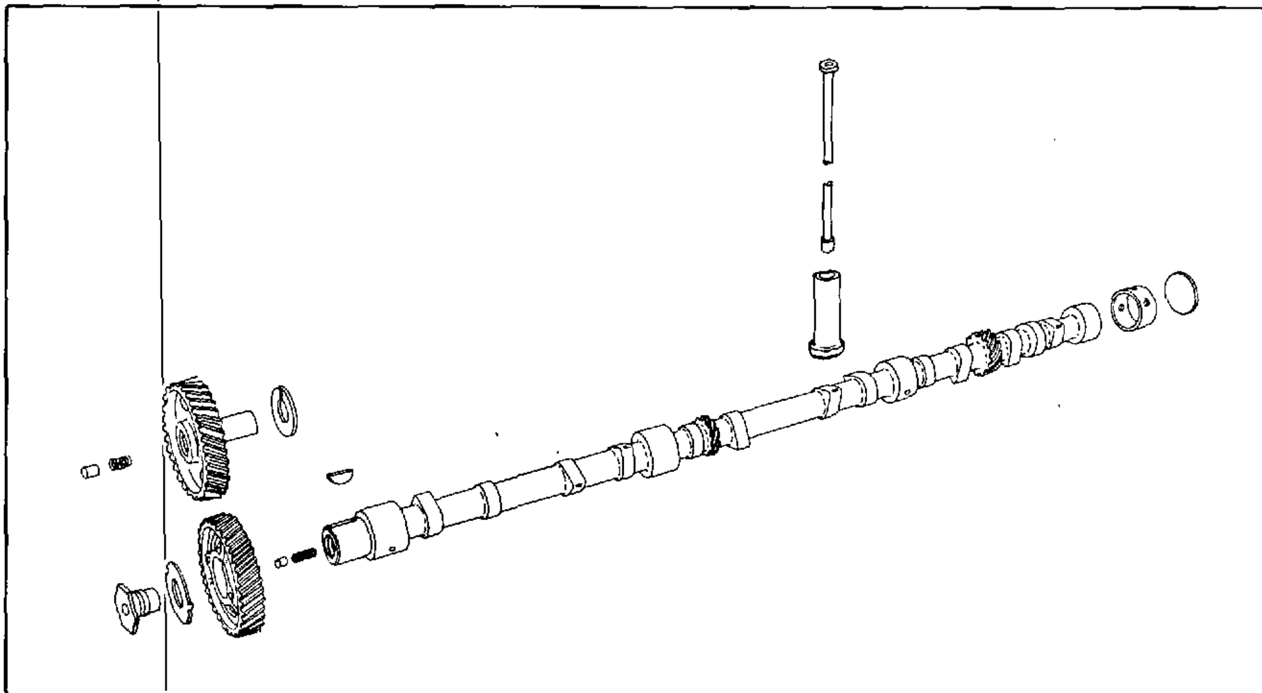
CAMSHAFT

Both the 140 and 145 camshafts are single forgings with ground and hardened cam lobes and journals.

An integral spiral gear is located between the rear intermediate and rear journals for the oil pump drive. Another spiral gear located midway on the camshaft drives the distributor. The forward end of the camshaft is keyed for the pressed-on cam drive gear and is drilled to provide a location for the spring-loaded thrust button.

Rotation of the camshaft provides a regulating action, in proportion to engine speed, for the rocker arm lubrication. In the 140 camshafts, this is achieved by one hole drilled diametrically through number three camshaft journal. The same intermittent oiling effect is gained in the 145 series by one hole drilled through each of the intermediate camshaft journals.

Intermittent oiling of the camshaft drive gear is obtained from two intersecting drilled passages in the front camshaft journal. All camshaft journals run in pressure lubricated steel-backed babbitt bushings.



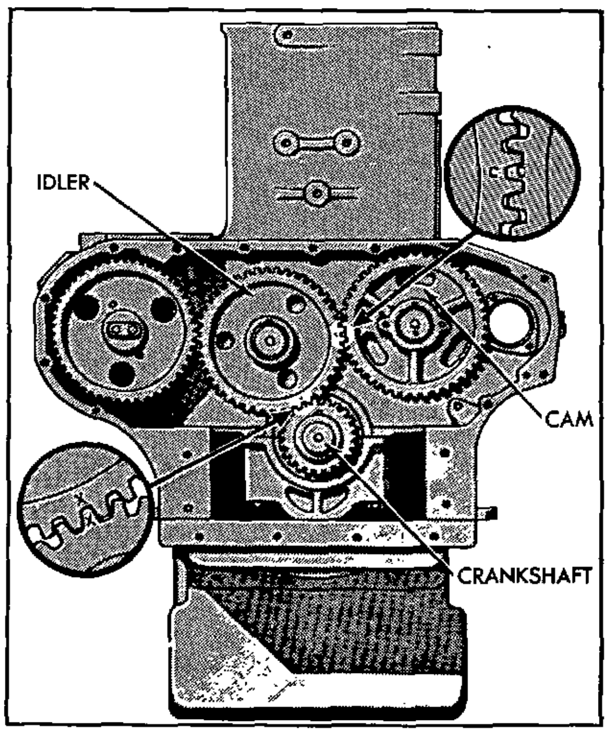
CAMSHAFT, GEAR, FOLLOWER

In addition, an eccentric lobe, located properly with respect to the crankcase mounting pad of the engine model involved, is used to drive the fuel pump.

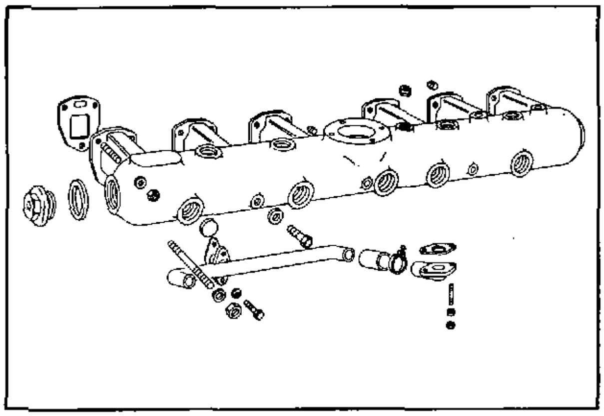
Recent cam designs in the 140-145 series have developed a (harmonic contour) cam superceding the previous designs. When checking the timing on a cam of this type, a distinctly different procedure must be followed than is customary with the earlier (constant-radius contour) cams. This is explained in the section of this manual dealing with valve timing and the reader is cautioned that camshafts with different part numbers must be checked with clearance limits specifically established for the contours used. The camshaft part number is located on either front or rear end of the shaft, and the timing checking clearance is noted on a plate attached to the rocker arm cover. Other methods or clearances will give misleading and erroneous results. Special camshafts are available for extended low speed operation. Refer to service bulletin Nos. 1681 and 1681-A.

To re-time the engine, adjust the gears so as to place the timing marks in the relationship shown in the accompanying diagram.

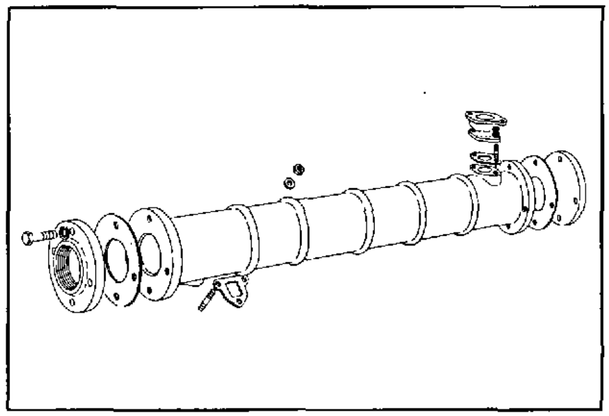
Both gear fitting and re-timing will be necessary if a service bushing is used to replace the original idler spindle bushing. Here, the original bushing is jig bored within certain center limits from the camshaft and the crankshaft bearing centers. A replacement bushing, concentric in itself might cause the idler shaft to locate on slightly different centers. Hence, larger or smaller gears, as the case might be, will sometimes be needed to obtain proper fits. Special gears with slightly larger or smaller pitch diameters may be ordered if needed.



DRIVE GEAR MARKINGS



WATER-HEATED INTAKE, 145



WATER-COOLED EXHAUST, 145

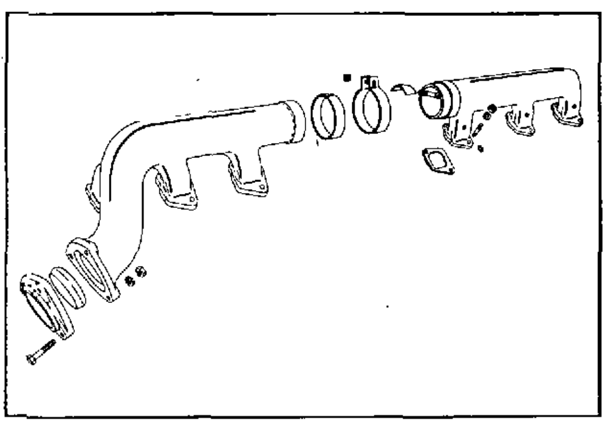
INTAKE MANIFOLDS

The intake manifolds used on the 140-145 series are selected according to the engine application. They may be of the water-heated type for gasoline or the conventional cold type for gaseous fuels; in either case updraft or downdraft types are available.

EXHAUST MANIFOLDS

As with the intake manifolds, exhaust manifolds are suited to the engine installation. Provisions are made for various combinations to permit exhaust gas to exit at center or rear of the manifold; and in some cases in an upward or downward direction. Installations where high exhaust manifold temperatures might create a fire hazard or cause operator discomfort may be equipped with water-cooled manifolds.

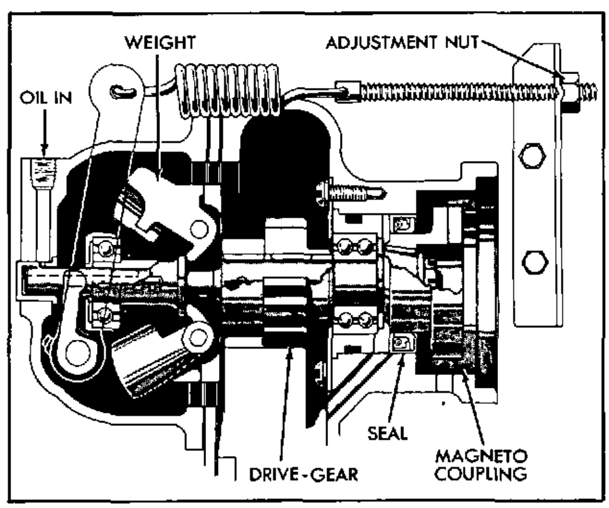
When designing systems to conduct exhaust gases from the engine, restrictions to flow should be minimized and back pressure held to one-half pound per square inch maximum. For high speed operation with a muffler, one pound per square inch is permissible.



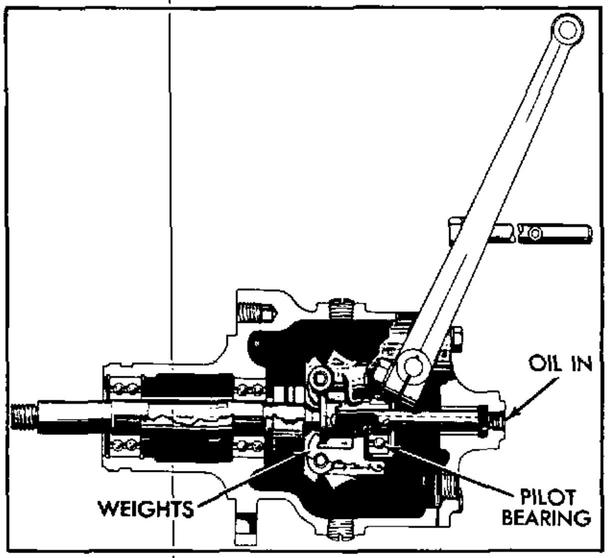
REAR-DOWN EXHAUST MANIFOLD, 140

MECHANICAL GOVERNORS

The mechanical governors used on the 140-145 series engines are of the familiar centrifugal type. Two weights, driven directly from the engine gear train, respond to variations in engine speed by moving inward or outward from the governor shaft. This movement is transmitted to the governor weight shifter lever through a pilot bearing sliding on the governor shaft. From the shifter lever the movement is carried to the butterfly valve between the intake manifold and the carburetor by a series of linkages. For example, as the engine tends to slow down under an applied load, the weights move inward due to the reduced centrifugal force. Through the linkage system, this weight movement causes the butterfly valve to open and admit more fuel and air to the engine, thus restoring normal loaded speed.



FRONT MOUNTED GOVERNOR



REAR-MOUNTED GOVERNOR

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

From the preceding paragraph, it can be seen that the maximum speed of the engine is regulated by the tension of the spring. An increase in spring tension increases the maximum governed speed; a decrease in spring tension decreases the maximum governed speed.

Because overspeeding is apt to have such serious effects upon engine life, it is strongly recommended that the rated speed for any particular engine not be exceeded. In cases where some advantage seems possible through increased speed, the Engineering Department of the WAUKESHA MOTOR COMPANY should be consulted before changes are made.

For installations requiring speed variations with the top speed definitely limited, the main governor spring is attached to a movable pivot linked to a hand or foot throttle.

Also, since the speed of response to load, the desired speed drop under load, and so on, will differ depending on the engine application and circumstances, it is recommended that unusual governing requirements be worked out with the assistance of the Engineering Department of the WAUKESHA MOTOR COMPANY. Ordinarily, certain minor changes are all that is required to adapt this type of governor to its job.

For use with the high-output versions of these engines, a governor type especially adapted for higher rotational speeds has been designed. This type of governor mounts on the pad used to support the magneto in other types of engines and is readily identifiable both from its location and its appearance. Also, the dome-shaped housing at the front of the gear cover is not used with this unit. In principle and general construction, however, the rear-mounted governor does not differ from the others. Therefore, it requires no unusual adjustment techniques or service attention.

As an aid to quick stabilization at maximum speed, a small surge spring is incorporated in most governors.

ZENITH MECHANOVAC GOVERNOR

The Zenith mechanovac speed governor is a mechanical type governor which uses the engine manifold vacuum to actuate the throttle controls. As the name "Mechanovac" implies, it combines the use of mechanical force and vacuum to regulate the speed of the engine. It consists of a conventional flyweight type speed unit and a vacuum-powered slave unit with a control cable assembly connecting the two units.

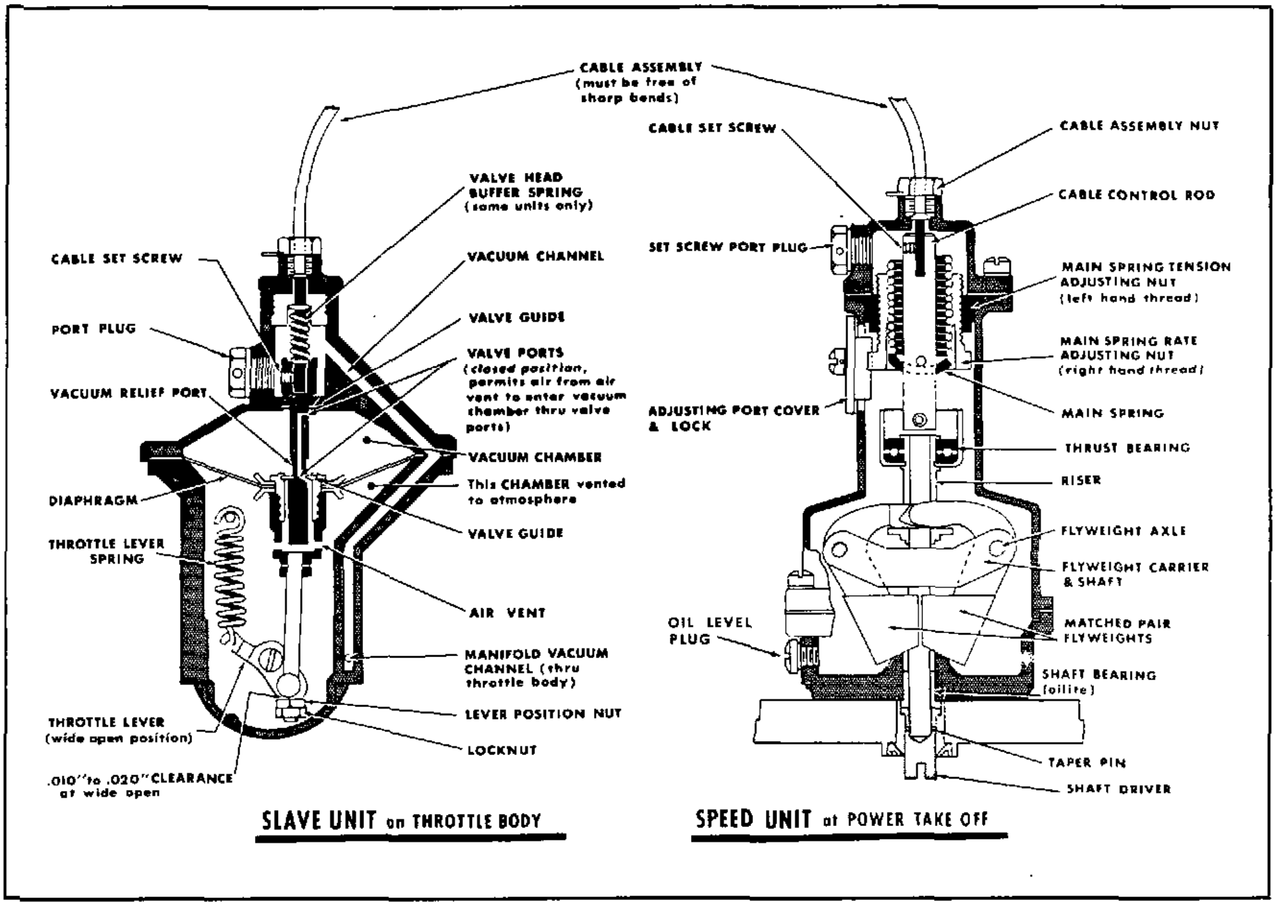
The distance between the speed and slave units is not a matter of importance. The control cable and housing assembly is "tailored" to fit with as few bends as possible; and with no sharp bends which would interfere with the free travel of the cable inside the housing. The total travel of the cable is less than 1/2".

The design of the valve includes a vacuum safety device. If for some reason the diaphragm in the slave unit becomes inoperative, the mechanical force alone is sufficient to prevent a runaway engine speed.

OPERATION

The speed of the engine causes the flyweights in the speed unit to swing out. This motion is transmitted by the flyweight levers to the control valve in the slave unit by means of the cable that connects the two units.

The governor spring in the speed unit and, in some installations, a buffer spring in the slave



ZENITH MECHANICAL GOVERNOR, CROSS SECTION

unit resist the free movement of the cable and, therefore, of the control valve. The governor spring rate and the tension are adjustable. The "pull" of the spinning flyweights increases with the speed of the engine. At a pre-determined speed the spinning flyweights have sufficient force to overcome the spring-tension and pull the cable to open the control valve in the slave unit. This permits manifold vacuum to evacuate the chamber back of the diaphragm. The evacuation of the space back of diaphragm causes the throttle to be moved towards the closed position against the tension of the throttle lever spring.

This movement of the diaphragm (and throttle) will continue to follow the movement of the valve until the bearing over-reaches the orifice in the control valve to permit orifice to function as an air bleed to bring the evacuated chamber into balance with the tension of lever return spring.

The head of the valve is so designed that, in the event of a diaphragm or vacuum failure, it will press against the bearing to close the throttle mechanically and prevent a runaway engine speed.

Any change in road or load conditions is reflected immediately in the engine speed and manifold vacuum which causes the governor to respond automatically to the new demands.

VACUUM COMPENSATOR

The vacuum compensator which is used on certain applications and is located on the governor housing, is a tempering device which works in combination with the engine governor to provide closer speed regulation than is possible with the governor alone. Its operation is a function of the intake manifold vacuum which reflects the load on the engine. (At full load, vacuum is low; at no load, vacuum is high.) Thus the governor's action is controlled not only by speed, as in ordinary operation, but by load as well. This close regulation is necessary in generator operation to permit proper control of generator frequency and voltage. Adjustment of vacuum compensator equipped governors is discussed in the Service Section.

HYDRAULIC GOVERNOR

In engine applications requiring extremely close governor regulation the Woodward Model PSG Hydraulic Governor is frequently used. This governor is mounted vertically on a right angle drive housing and is driven by the governor-magneto drive gear in the engine's gear train.

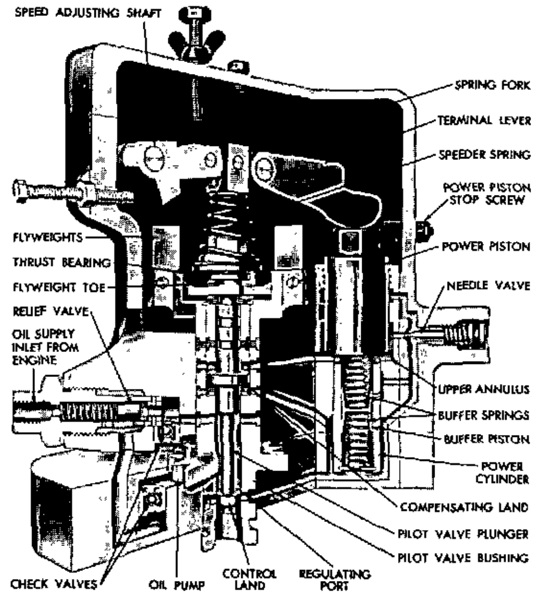
The PSG governor is a hydraulic speed governor with buffer type compensation. It is normally isochronous, that is, if the engine is not overloaded it maintains the same speed regardless of load, except momentarily at the time load change occurs.

It is desirable that the engine be equipped with a separate overspeed device to prevent runaway in the event of any failure which may render the governor inoperative. A distributor drive featuring a tachometer or overspeed adapter can be provided to mount and drive a device of this type.

The governor uses engine lubricating oil. Oil is supplied to the governor oil pump where its pressure is boosted to 175 psi above inlet pressure. Four check valves two of which are shown are used to permit rotation of the governor in either direction. Relief valve discharge is back to supply, so unused oil is recirculated within the governor.

The governor oil under pressure is carried through ducts to the pilot valve, which is a three-way spool valve arranged to connect the area below the governor power piston to the pressure oil supply upon an underspeed signal or to discharge upon overspeed. The governor flyweights are carried on pivot pins in the rotating bushing which forms both the outer member of the valve and the drive shaft. The flyweights act upon a thrust bearing attached to the pilot valve plunger and their centrifugal force is translated to axial force at the flyweight toes and opposed by the speeder spring. Speeder spring compression, and therefore the speed at which the governor must run in order that the flyweight force will balance that of the spring, is adjusted by the position of the speed adjusting lever.

The isochronous feature of this governor is provided through the use of a compensating system which establishes temporary speed droop stability and then dissipates this droop so that engine speed is constant under steady state conditions regardless of load. This compensating system consists of a buffer piston floating between two springs to establish a pressure differential as oil flows to or from a section of the power cylinder together with a compensating land on the pilot valve plunger across which this differential pressure is applied, and a needle valve through which the pressure difference is dissipated.



WOODWARD PSG HYDRAULIC GOVERNOR

Upon a reduction in engine speed from its set value, the speeder spring force overcomes the reduced centrifugal force of the flyweights and the pilot valve plunger moves downward in its bore. This movement uncovers the port at the lower end of the plunger, permitting oil under pressure to enter the passage leading to the power cylinder. The power piston has two concentric areas, both of which are exposed to the control oil metered by the pilot valve, the lower smaller diameter being acted upon directly, and the upper annulus being connected through the bore in the power piston in which the buffer piston is carried. Flow of the oil into the power cylinder forces the power piston up against the return spring and some of the oil displaces the buffer piston to force oil into the upper annulus. This flow into the upper annulus establishes a pressure differential across the buffer piston, which is transmitted to the spaces above and below the compensating land on the pilot valve plunger. The higher pressure on the lower side of this land acts in the direction to supplement the flyweight force, causing the closure of the pilot valve before the original speed has been regained. As oil leaks across the needle valve this false speed signal is dissipated and the buffer piston recenters in its bore with engine speed returning to normal.

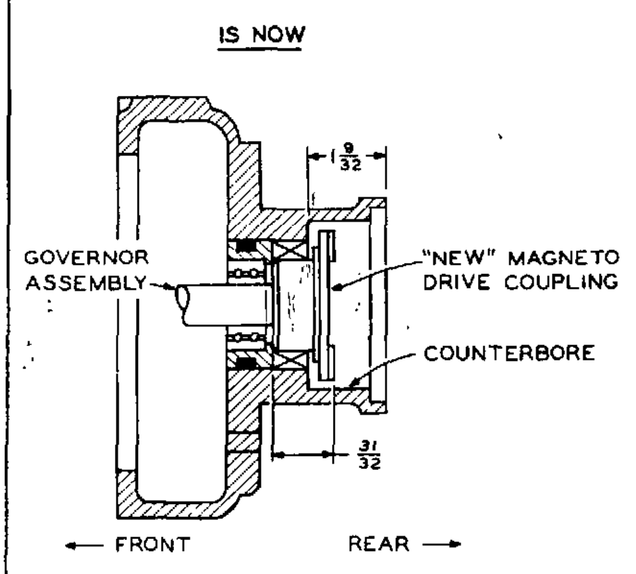
Action under the influence of an overspeed is similar but in the reverse direction. The increased centrifugal force of the flyweights, due to the increased speed, overcomes the speeder spring force and lifts the pilot valve plunger. Upward movement of the pilot valve plunger opens the regulating port to drain and permits the power piston to be forced in the reduced fuel direction by the return spring. At the same time, flow of oil out of the annular space between the two diameters of the power piston, uncenters the buffer piston in the downward direction. The pressure difference thus created across the buffer piston, acting on the compensating land, recenters the pilot valve plunger. As oil leaks across the needle valve this pressure difference is dissipated and the return of speed to normal brings the flyweight force back to normal.

MAGNETO DRIVE

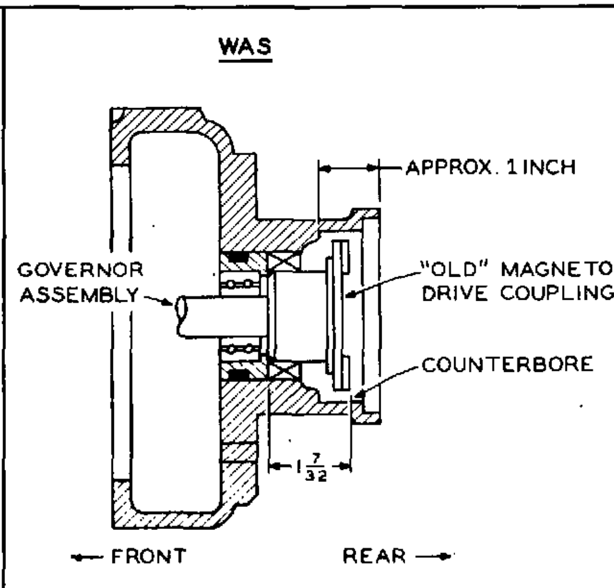
In addition to driving the governor system, the gear and shaft of some 140-145 governors may be used for a magneto drive when magneto ignition is employed. For this purpose a standard key and slot magneto coupling is located at the back end of the governor shaft. It should be noted that the practice of marking one tooth on the magneto-drive gear has been discontinued although the letter "M" may still be found on the cam gear. This was done because the large number of magneto variations, timing differences, and so on, required for different services made the setting of the magneto coupling in any fixed place impractical.

The magneto coupling discs on late engines are marked on the face with an "X" and have two keyways, one of which is displaced 10° from being diametrically opposite the other. This permits a variation of about the width of one gear tooth when timing the magneto. That is, if the magneto coupling slot and keyway cannot be engaged without tilting the magneto beyond the limit of the adjustment slot for the mounting stud, it is possible to pull the coupling from the governor shaft, and shift it around to the other keyway. If the 10° gained in this manner is not enough to locate the magneto in the desired position, it will be necessary to remove the governor and magneto drive and re-mesh the gear as needed. Generally, the magneto position will be about right if the key on the governor shaft is located as shown in the illustration accompanying the Magneto Timing instructions in the Service Section of this manual.

The present magneto drive coupling is shorter by 1/4" to provide clearance for a fiber drive disc, between the drive coupling and the magneto. The fiber disc, along with other design changes, has lengthened the magneto coupling life greatly, and should be used whenever pos-



PRESENT CRANKCASE



PREVIOUS CRANKCASE

sible. The shorter coupling, however, requires that the crankcase counterbore be deeper to provide the proper clearance. The former coupling, since it was longer, accommodated a shallower counterbore. Examination of the accompanying illustrations should clarify this point.

Emergency field problems can be solved by using the "old" coupling, Part No. 80269, which has been reinstated for service only. However, it is highly recommended that, whenever possible, the crankcase be counterbored to a total depth of 1-9/32" to accept the present coupling and fiber disc.

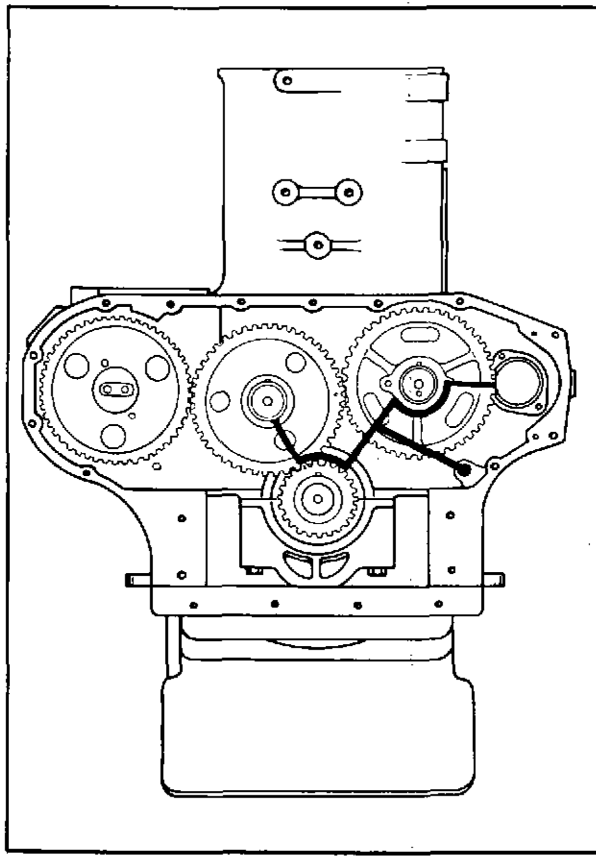
LUBRICATION SYSTEM

The 140 and 145 Engine Series lubrication systems are very similar and will therefore be discussed jointly with the exception of differences which will be noted in the text. Two types of lubrication systems have been used. Earlier the lubrication system was intended for shunt type oil filtering only. Current engines, although still supplied with the shunt type oil filter as standard equipment, feature a modified lubrication system which was designed for easy conversion to full flow oil filtering and oil cooling or both. Engines having this latest system are identified by the external oil cross tube which is located on the right side of the crankcase just below the water pump outlet to crankcase connection. Internal and external differences between the early shunt type and the current lubrication systems will be noted in this section. Conversion of the current system to full flow oil filtering will be discussed further in the Service Section.

Both engines use a wet-sump, full pressure system. The capacity of the 140 with the commercial/oil pan and less accessories and filter is 10 qts.; for the 145 the capacity is 18 qts. With the exception of the incidental oil ordinarily left in the lines, filters, and passages, the entire oil supply of the engine is contained in the sump.

The oil pump inlet is submerged within the oil screen and the equalizer cup. Therefore, the pump is self-priming under all normal conditions. When the engine starts and the oil pump gears rotate, the oil is picked up between the pump gear teeth and the pump walls and carried around to the outlet side of the pump.

The major difference between the old and new lubrication systems occurs at this point.



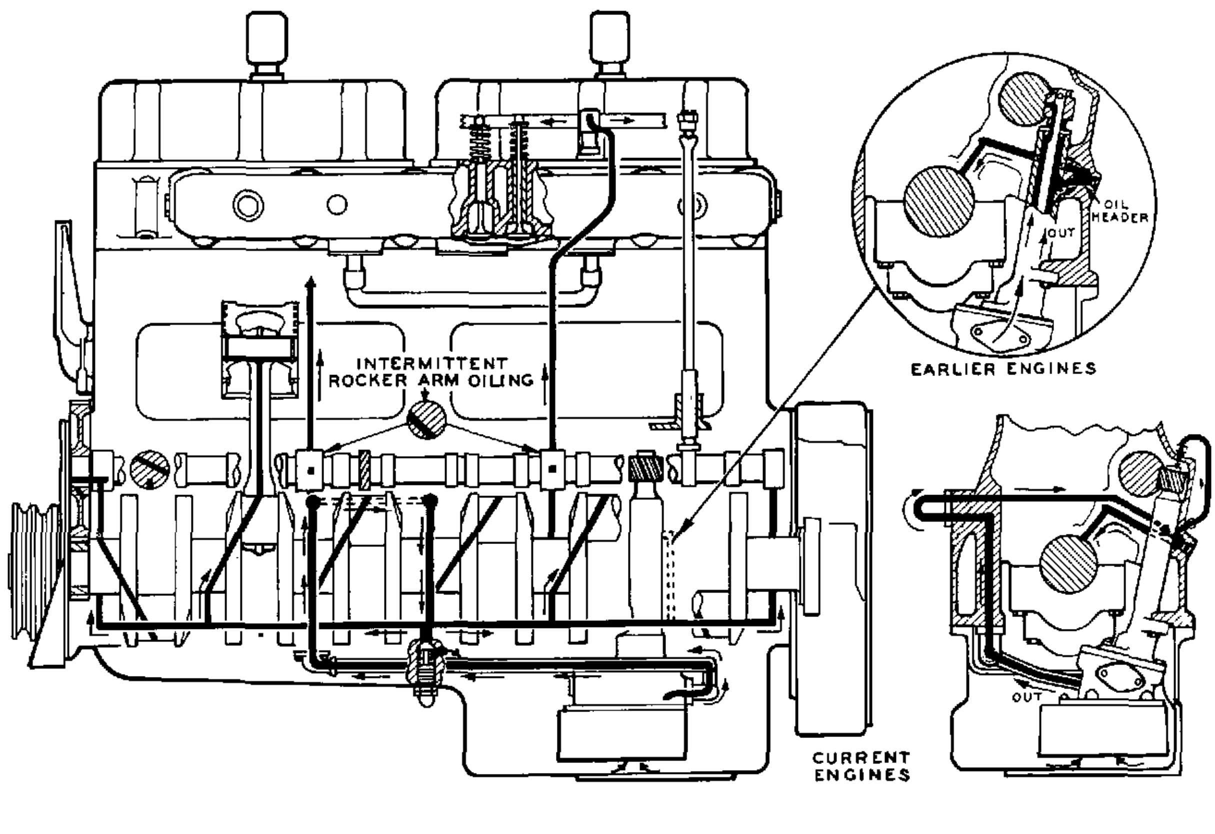
GEAR LUBRICATION SYSTEM

In the early system, oil is directed up into the hollow pump shaft support housing. This housing has, on the earlier oil pumps, an oil hole which aligns with a crankcase oil passage which in turn leads directly to the main oil gallery running lengthwise along the left side of the crankcase. Oil would therefore flow under pressure out of the hollow pump housing directly to the main oil gallery on the early system. On the oil pumps used in both the old and new systems a portion of the oil entering the housing is metered through small holes in the shaft and pump drive gear to lubricate this gear meshing with the spiral gear on the camshaft. On current lubrication systems, oil leaving the oil pump outlet is carried through internal tubing to an oil passage located on the right side of the crankcase. Pumps used in the new system do not have the oil hole in the drive shaft support housing so oil cannot flow directly to the main gallery as in the earlier system. Entering the passage on the right side of the crankcase, oil is directed out of the case into either a full flow type filter or an oil cooler. If the full flow filter or cooler are not used an external connection is used to direct oil back into the case where it passes through a transverse passage which connects to the main oil gallery on the opposite or left side of the engine. From the main oil gallery oil flow remains the same in both the early and the current systems with a few minor exceptions as noted further in the text.

The pressure relief valve, controlling oil pressure, opens off the main oil gallery. A spring-loaded piston of conventional design moves outward to relieve oil pressure through a spillback 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 should not require attention for a long period of service unless disturbed.

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 seven drilled passages through the crankcase webs to each main bearing. Each crankshaft main-bearing journal is drilled diagonally to provide a passage leading through the crankcheek and emerging at the crankpin to lubricate a connecting rod bearing. 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 piston rings for correct piston lubrication.

On recent engines a slot in the upper bearing shell running surface is provided in a location 30° off center on the tab side. This slot conducts oil to mating slots on each face of the connecting rod. Oil leaving these openings impinges directly on the cam contact area of the tappets, thus providing positive lubrication at this point.



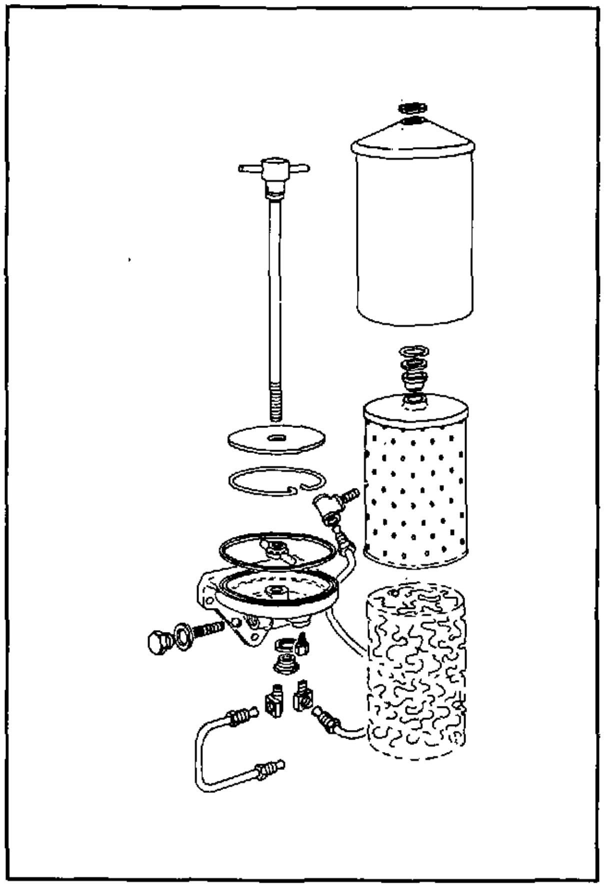
LUBRICATION SYSTEM SCHEMATIC

Four drilled passages from the front, rear, and two intermediate main bearings lead to the camshaft journals. Oil delivered to these journals serves the primary function of lubricating the cam bearings and in addition accomplishes several auxilliary oiling functions. At the gear end of the camshaft, drilled holes in the journal intersect a passage leading outwards for a short distance into the cam drive gear hub. Drilled holes allow oil under pressure and centrifugal force to escape towards the gear interior rim where part of it is trapped in a shallow groove. Short drilled holes leading from this rim through the gear teeth allow the oil to pass outward and lubricate the gear train.

In the 140 series engines, the rear intermediate cam journal is provided with two flats and a connecting drilled passage to allow oil to pass through the journal each time the journal indexes with the oil passage in the cam bushing. This intermittent oil supply, metered in accordance with engine speed is conducted to an external fitting on the crankcase. From this fitting an external line carries the oil to a "Tee" fitting at the upper center part of the crankcase. A line leaves each of the two branches of the "Tee" and conducts oil to an angle fitting in the side of each cylinder head. From here, the oil is picked up through a similar fitting on the head within the rocker arm cover and led to the rocker arm support brackets. In later construction engines small cup-shaped standpipe units reduce the oil pressure to that resulting from the very slight "standpipe" level of the cup lip. Consequently, the oil bled out to the individual rocker arms and valve guides is held to a quantity consistent with good lubrication and minimum oil consumption.

In the 145 series engines, both intermediate cam journals meter rocker arm oil, and instead of being carried in external tubing, the oil passes through drilled holes in a pillar-like strut running vertically across each tappet compartment. To provide for interchangeability of heads, the mating oil hole in the cylinder head is duplicated by another hole that seats blind upon the upper deck of the crankcase. Both of these holes are equipped with fittings and tubes leading to the rocker arm lubricating system. Here, the oil pressure is relieved by metering orifices that serve to prevent over-lubrication of the valve guides. Late 145 engines have adjustable metering as described in the Service Section of this manual.

Scavenger oil drains back through the tappet compartments via the space around the push rods. A drilled passage leading from the tappet compartment at each tappet returns the oil to the crankcase and lubricates the cam lobes individually.



OIL FILTER, SHUNT TYPE

The front end of the crankcase contains two other drilled passages not yet mentioned. One leads from the front crankshaft bearing to the idler gear shaft bushing. The other leads from a small groove behind the front cam bushing to the governor and magneto drive support pad. In the standard governors, this oil is forced through the governor drive shaft and released between the sliding pilot and the outside surface of the shaft. The rear-mounted high-output governors are lubricated by oil led through a separate line from a case outlet at the left of the mount pad. A lower line leading from the rear of the governor to the oil filler elbow fitting is for drain purposes.

In those operations where unusual angles may prevent oil from reaching the pressure pump gears at all times, scavenger pump units and pickups for various points in the oil pan are available. Fore and aft angles in excess of those stated in the Clearance Section require investigation by the Engineering Department, WAUKESHA MOTOR CO., to determine exact scavenging requirements.

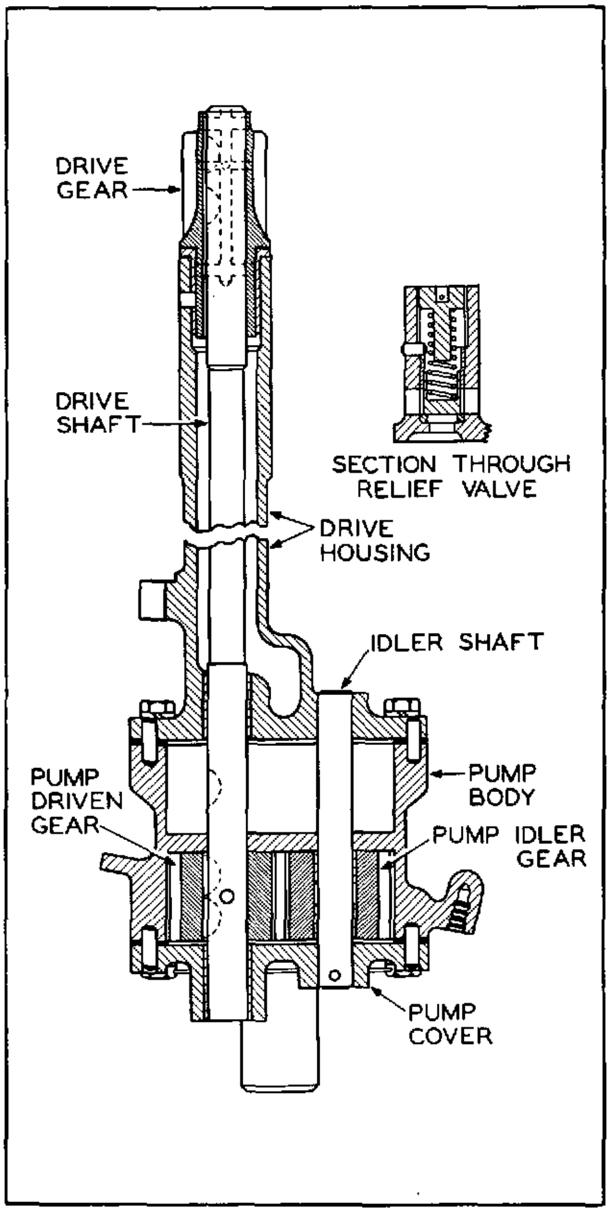
OIL PUMPS

The lubricating oil pumps used on 140-145 engines are all of the spur gear type. The exact size, drive method, and design of a given pump depends upon the engine application and the oil pan design and type of lubrication system. As discussed previously under Lubrication, a different pump must be used for each system. Particular care should be exercised to make sure that a pump designed for the new system is not used on an engine having the earlier type lubrication system. Although the pump would fit correctly, the new pump does not have the necessary oil hole in the upper pump shaft support housing to deliver oil directly to the main gallery. Ordinarily, only a pressure pump is used, but where the engine may be subjected to angular operation a scavenger pump is available.

In all cases, the pumping action is obtained from a pair of precision gears running together within a closely fitted housing. Since the oil is carried from the inlet side to the pressure side of the pump in the pockets formed between the pump walls and the gear teeth, it is plain that clearances must be correct in this area. Hence, the use of gaskets of incorrect thickness when inspecting or repairing the pump may lead to trouble. Also, foreign material such as hard carbon, bits of broken cotter pins, lock wire, and so on will ruin the pump if allowed to run through the gears.

For the above reasons, as well as for the sake of the engine in general, the pumps are all provided with a so-called "diving bell" oil level equalizer and a screen. The level equalizer helps maintain an air-free supply of oil at the pump inlet regardless of engine movement. Together with the screen, this unit protects the engine against poor lubrication. Removal of the screen followed by a thorough cleaning and replacement is recommended at intervals determined by experience with the service and oil involved.

Oil pump drives of the spiral gear type actuate the pumps from the camshaft through a shaft running in bronze bushings at each end of the pump casting. The pump drive gear in turn rotates the mating driven gear which runs on an idler shaft supported at each end by bronze bushings. Oil pressure control is maintained by a conventional piston-type, spring-loaded, pressure relief valve located in the main oil header and adjustable from the outside of the engine. A second pressure relief valve integral with the oil pump is set at a pressure higher than the external valve and is not intended for service adjustment.



OIL PUMP - PRESSURE TYPE
(145 SERIES SHOWN)

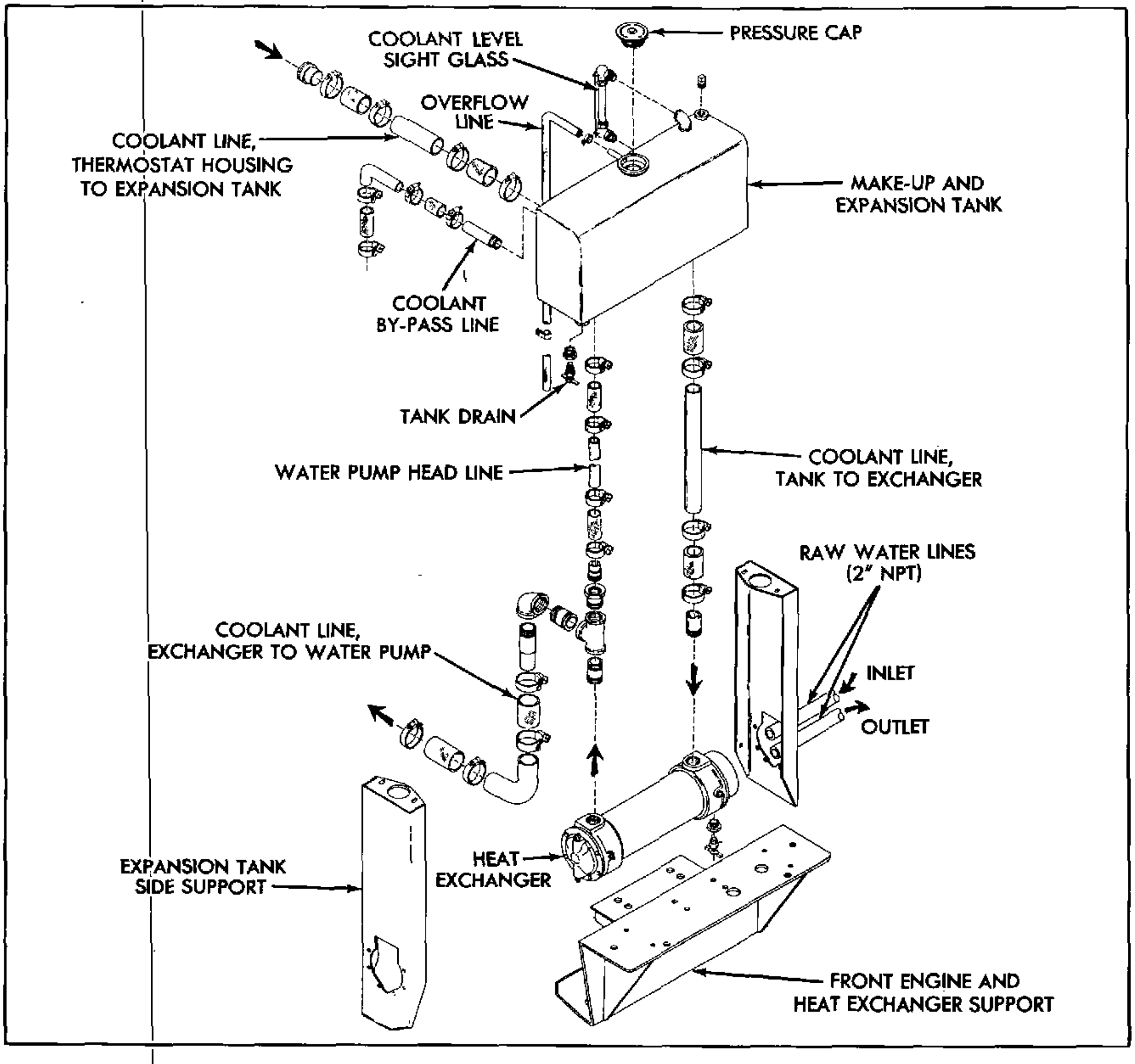
OIL FILTERING

Oil filtering is usually accomplished by the shunt method in which a portion of the oil is bled from the main oil header, passed through the filter, and returned to the sump. With this system a severely clogged filter will not shut off oil pressure to the engine. On the other hand, a filter in a clogged condition permits rapid accumulation of foreign material in the lubricant and contributes greatly to engine wear. Current engines featuring the new lubrication system can be easily converted to the full-flow system if desired.

Pressure lubrication for air compressors mounted on the accessory pad above the gear housing on the right side of the engine is provided by a line leading from the main oil header on the left side of the engine. Scavenge oil from the compressor drains back through a passage in the mount pad into the gear housing.

OIL COOLER INSTALLATION

Special circumstances may make it necessary to provide oil cooling. Such an installation might be an irrigation pump operating in high ambient temperatures at relatively heavy load, and without the benefit of cooling fan blast. Such a combination of conditions may cause localized heating of accessories, primarily the magneto, and the use of an oil cooler will often ease the heat concentration in a practical manner.



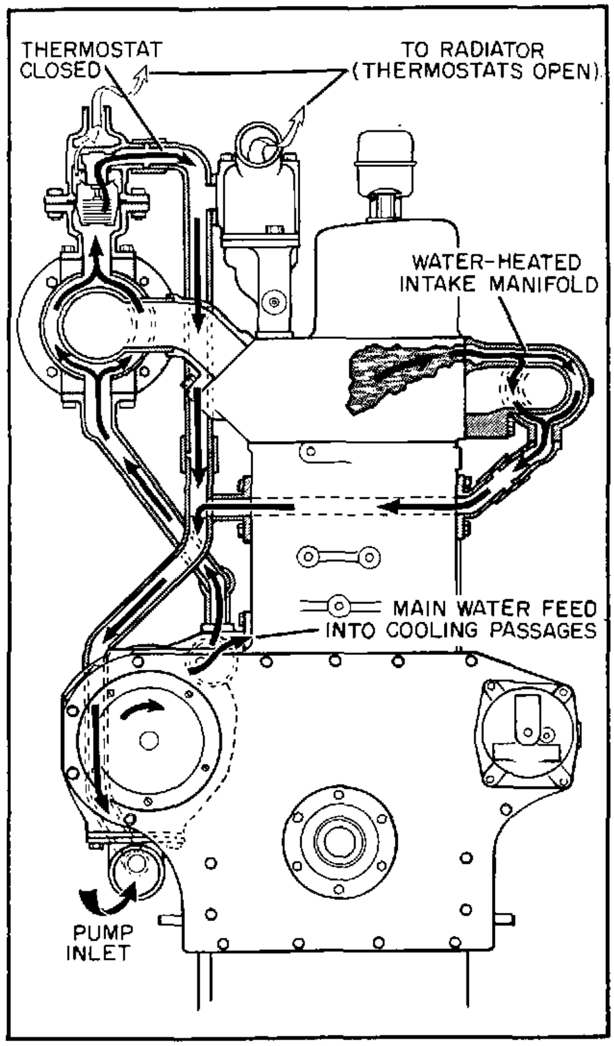
TYPICAL HEAT EXCHANGER COOLING SYSTEM

The Waukesha Motor Company has recommended an external oil cooler which may be connected into the engine oil system. Oil cooler installation and maintenance is discussed further in the Service Section of this manual.

COOLING SYSTEM

The cooling systems used on the 140 and 145 engine are of the pressure circulating type and may employ a variety of external cooling devices such as radiators, cooling towers, heat exchangers, and so on. Maximum back pressures, feeding into cooling devices, should not exceed 1 lb. per square inch at 900 RPM, and 2 lbs. per square inch at higher speeds. In all cases, the water enters the water pump inlet on the lower right side of the engine. The centrifugal pump causes this supply of cool water to pass into a fitting that leads directly into the engine cylinder jacket. The water enters the engine in the area of the cylinder sleeve lower ends. From here the water flow is directed about the cylinder sleeves in an even manner until it passes upward from the crankcase and into the cored passages in the cylinder heads. These passages are carefully designed to allow cooling water access to all areas around the valves. A water manifold collects the water from the cylinder heads at several points on the right side of the engine and directs it to the radiator or other cooling device. Thermostats at the forward end of the water manifold control the exit temperature of the water. A bypass line from the thermostats leads vertically down the right side of the engine and returns the water to the pump inlet for recirculation under cold water conditions. 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 bypassing will occur.

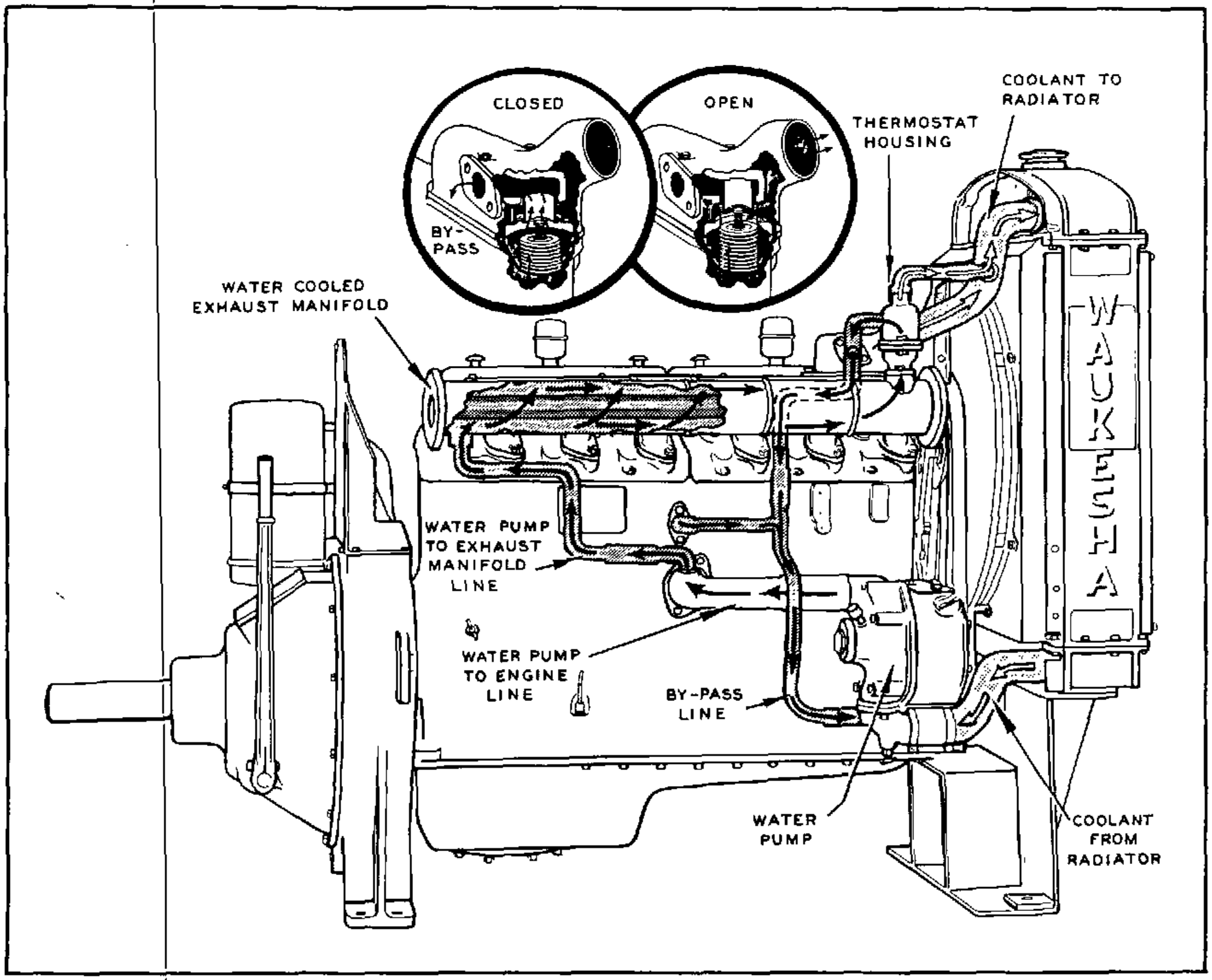
When the water heated intake manifold is used, the water for this purpose is picked up from the cylinder heads at the intake manifold attachment pads. After passing through the double walled intake manifold, the water is discharged through two external lines and directed to a fitting on the side of the crankcase. From here, the water passes across the case, emerges on the opposite side and is carried by a short line to join the by-pass line that runs vertically from the thermostat housing to the water pump inlet. This circuit is used in order to give a quick warm up. In operation, the water near the cylinder heads heats quickest and is therefore the most desirable for application of manifold heat. The connection through the by-pass line takes advantage of the water pump



TYPICAL COOLING SYSTEM SCHEMATIC
FRONT VIEW

suction action while the main circulating pattern through the radiator is still closed off by the thermostat.

When a water-cooled exhaust is used, the water supply is taken from the main circulating stream at the elbow where the water enters the cylinder block after leaving the water pump. An external line conveys the water into the exhaust manifold jacket. At the exit point on the forward end of the manifold, a thermostat acts to direct the water to the by-pass line until it has warmed to approximately 165 degrees. A short line leads directly to the junction of the by-pass line and the main engine thermostat housing. On reaching normal operating temperatures, the water in the exhaust jacket opens the outlet thermostat and then follows a line leading from the top of the exhaust manifold thermostat housing to an elbow connection in the main water outlet hose fitting.



TYPICAL COOLING SYSTEM SCHEMATIC, SIDE VIEW

WATER PUMPS

All water pumps used on the 140-145 engine series are of the centrifugal, high-capacity type. Although in many cases they may show no external differences, a number of variations have occurred in the designs of these pumps. When contemplating repair or overhaul operations, the assembly number of the specific pump involved should be checked carefully before ordering service parts.

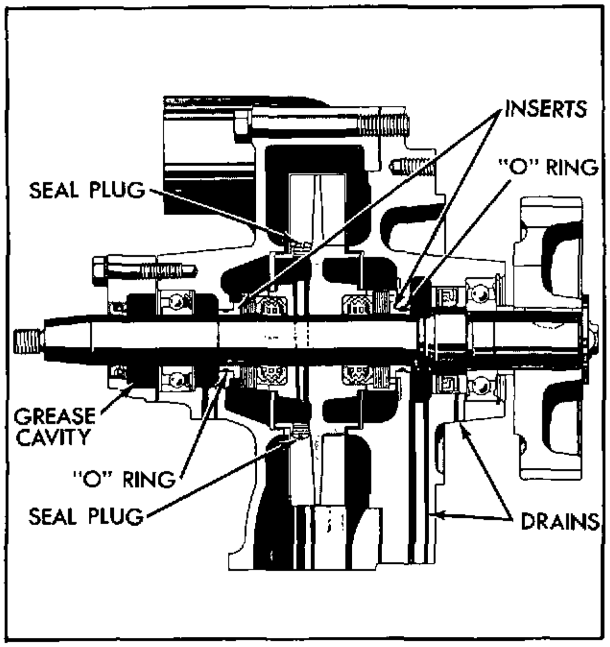
Be sure to order by the pump assembly number stamped on the two halves of the pump housing at the joint. In many cases the same basic castings are used but machined differently. Hence, the raised numbers on the castings may be misleading with respect to service parts.

Generally speaking, overhaul operations on these pumps are not recommended for field practice. This is partly due to the specialized techniques and equipment needed for assembly and disassembly, and partly due to the fact that the cost involved in salvaging rusted and corroded parts is seldom economical. When suitable shop facilities are available, refer to the rebuilding instructions in the overhaul section.

When making inquiries about, or servicing the 140-145 pumps, the following points should be considered.

Through Shaft or Blind Shaft

The extension end of a through-shaft pump is usually fitted with a sheath-like cover or a collar-type grease retainer member. Blind-end pumps have either a screw cap or an expansion plug to control grease and water in the rear bushing area.



WATER PUMP - 140 SERIES
BALL BEARING TYPE

Impeller Seals

Blind-end pumps are usually equipped with a single spring-loaded water seal on the gear side of the impeller. Through-shaft pumps usually have a spring-loaded water seal on each side of the impeller. This is because the through-shaft rear bearing is of the anti-friction type to carry loads external to the water pump.

The spring-loaded seals may be found to be of either the internal spring or external spring type. In the former, the rubber-like seal member contains the spring expansion member. With the external spring, the expansion or pressure member slips over the seal material. These two types of seals are not interchangeable and replacements should always be made with the seal specified for the model pump involved. If the pump has been serviced previously, make sure that interchanges or reworks have not been undertaken that will prevent satisfactory service in the future. Current pumps have stainless steel inserts with external "O" rings.

Oil Seals

Oil seals retaining the engine oil in the gear-end bearing area may be either an individual, spring-loaded, rawhide type, or integral with the ball bearing and supplemented by an external slinger ring located behind the drive gear.

Rear Bearings

The rear bearings in some blind-end pumps are of the *sleeve*, or *bushing* type. These sleeves differ in respect to the grease grooves provided and also as to the metal used. Later models use a bronze of higher lead content. The ball bearings used with the through shaft and also with the *all-ball-bearing* pump are equipped with a felt seal which should be installed towards the impeller.

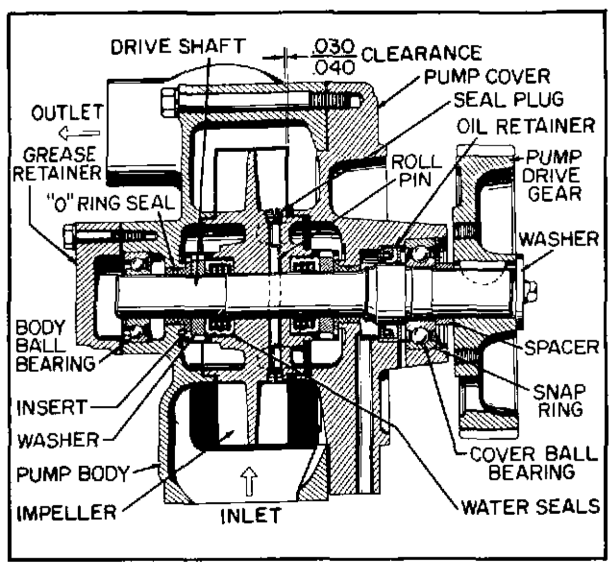
Housing and Covers

The housings and covers used on these pumps appear similar in many cases and may be impossible to identify unless disassembled. Variations here will include the contours in the *seal areas, drain passages, differences* in counterbores, and so on. Because of the relatively complex nature of these parts, reworks or conversions cannot be recommended.

Lubrication

Some of the ball bearings used in these pumps have been of the sealed, self-lubricating type. Others depend upon engine oil from the gear case for lubrication. When the latter type are used, it will be noted that a rawhide oil seal is located on the shaft a short distance behind the bearings. The space between the seal and the bearing is drained by a drilled passage into the gear case.

When ball bearings are used on the outboard end, as in the case with the through shaft, they are packed with grease at assembly.



WATER PUMP - 145 SERIES
BALL BEARING TYPE

The lubrication for the bushings used at the outboard end of the blind-end shaft is water-pump grease, packed into the cavity at the end of the shaft during assembly and supplied by a grease cup during operation. Ball-bearing pumps require grease intended for ball-bearing use.

Shaft Design

Pump shafts have been improved from time to time both in design and material. Because of the anti-corrosion and hardening treatments employed, grinding shafts to adapt them to new seals or bearings is almost impossible. Many pumps have hardened stainless steel shafts.

Interchangeability

Pumps of later design may be installed as complete units in place of earlier models when service replacement is required.

GASOLINE CARBURETION

The standard carburetors used on gasoline fuel engines in this series are of Zenith manufacture. The Zenith updraft 63 Series or the downdraft model IN67SJ or downdraft 29 Series carburetors are employed depending on the particular engine application. These carburetors feature a double venturi design which aids in more complete fuel vaporization.

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

Idling performance is obtained through a special fuel jet and air bleed past the throttle valve supplying fuel independently of the normally loaded system of the carburetor. When the engine is working under part load, economical use of fuel is desirable and is obtained by a mixture leaning out provision that supplies only enough fuel to carry the load at the most economical fuel and air mixture. With the throttle wide open and maximum power is the major concern, the leaning out system becomes, ineffective so that the fuel and air mixture becomes rich enough for maximum power.

The extra amount of fuel needed for quick acceleration necessary when load is suddenly applied to the engine is provided by an accelerating pump and special accelerating jet system. Without this provision the engine would operate momentarily after the throttles opened with too lean a mixture to 'pick up' the load rapidly.

GAS CARBURETION

On those engines intended for gaseous fuel operation only, the Ensign Model KG1 carburetor is usually supplied. The Ensign Model KGN1 "Combination" Carburetor is normally furnished in applications requiring alternate usage of gasoline and gaseous fuels.

Operation of an engine on gaseous fuels requires the use of a gas carburetor, fuel line regulators, and fuel filter.

The gas mixer, or carburetor, consists of a simple jet, a throttle valve and special idling system passages and venturi to operate in conjunction with the carburetor regulator. Some models of gas carburetors with air shutter type choke are provided with an economizer action that permit part load operation with economical mixtures and enrich the mixture for maximum power when necessary.

When liquified petroleum gases (LPG) such as butane or propane are used, the fuel system will include a butane filter, butane regulating unit, either a gas or gas-gasoline carburetor and a heat exchanger to vaporize the fuel.

The butane regulating unit reduces the higher incoming fuel pressure to that required by the carburetor and converts LPG fuel from a liquid state under tank pressure into a dry gaseous fuel slightly below atmospheric pressure. This is achieved by heating the fuel with hot water drawn from the engine cooling system.

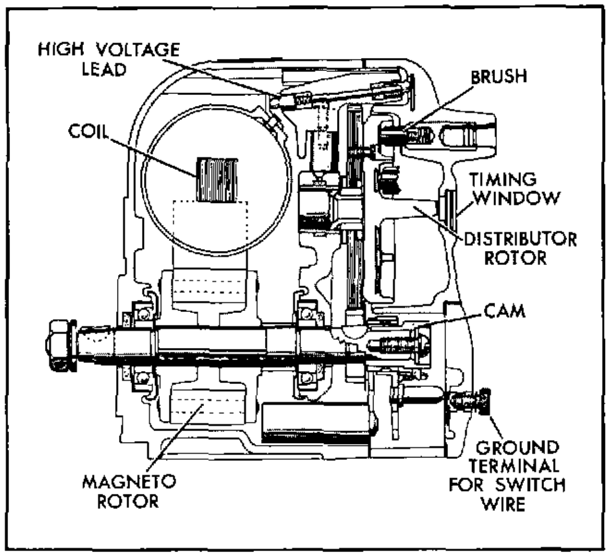
IGNITION SYSTEMS

Smooth combustion requires positive ignition in the cylinders at finely defined intervals. This function is performed on the engine by a magneto or distributor. Magneto equipped engines employ either a high-tension, low-tension, or semi low-tension magneto system depending upon the engine service involved. The magneto is mounted to the rear of gear housing and driven by governor drive gear. The distributor is usually mounted on the left front side of the crankcase and is driven by a spiral gear mating with a similar distributor drive gear on the camshaft.

Dual ignition engines are quite common in this series. A magneto is often used along with a distributor or two distributors are sometimes used. On the dual distributor applications, the second distributor is mounted on and driven *through a right angle drive to the governor.*

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

A new breakerless distributor ignition system is receiving some usage in certain engine applications requiring long periods of unattended service. The distributor used in this system does not have contact breaker points or automatic advance device. Since the only moving part in this system is the distributor rotor trigger wheel shaft assembly, longer periods of operation are possible. The system currently in use employs an external electrical power source of 100 to 125 volts AC at 50-60 cycles.



TYPICAL HIGH-TENSION MAGNETO

High-Tension Magneto Ignition

Magneto equipped engines in this series employ a high-tension magneto in the variant required for the service involved. Here, the variable factors include the speed at which the engine is expected to operate continuously, the possibility of fire hazard from combustible vapors, installation factors requiring wire exit positions on vertical or horizontal lines, spark advance and impulse coupling angles, radio shielding and so on. These points should be considered when ordering replacement units or parts.

An impulse coupling is built into the magneto to produce a spark at cranking speed to assure easy starting. When the magneto attains a speed of approximately 180 RPM, the coupling will automatically disengage and act as a positive drive timing the ignition to the normal spark advance.

Low-Tension Magneto Ignition

The low-tension magneto available as optional equipment 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 the high-tension ignition system 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.

The low-tension system is less affected by moisture, since only the short high-tension lead is directly vulnerable. The stationary coil used in this magneto has only a single primary winding. The pivotless contact breaker is connected in series with the coil in the primary circuit. The condenser is connected across the breaker points.

The small magneto distributor gear, located on the rotating magnet shaft, drives the large distributor gear and distributor cam. The ratio between these gears is such that the low-tension current is distributed by a group of contacts, one pair for each cylinder, arranged about the *magneto distributor camshaft. The individual* high-tension coils, one for each spark plug, are enclosed in housings protecting them from moisture and vibration. The cartridge type condenser is located inside the magneto housing.

Semi Low-Tension Magneto Ignition

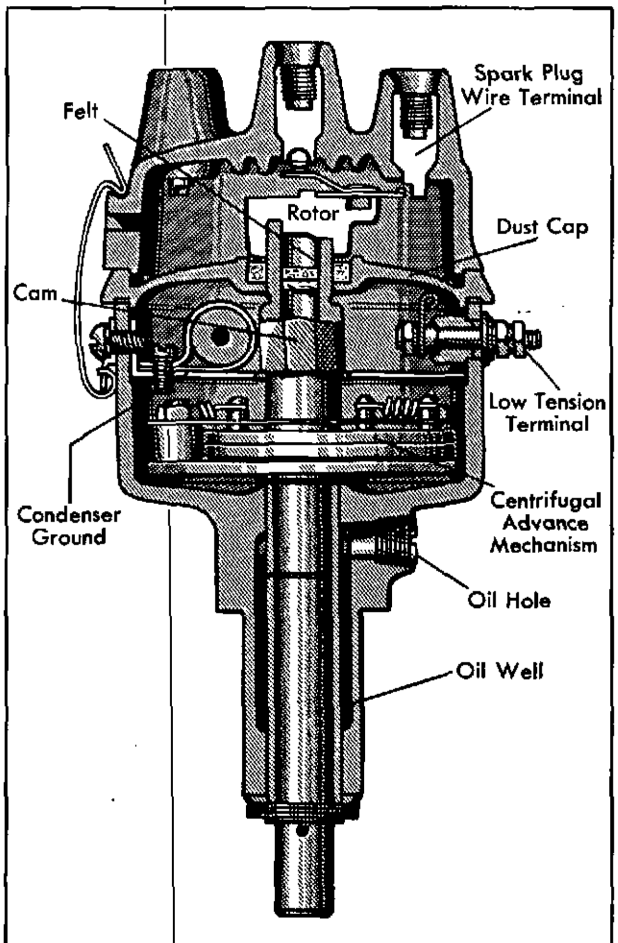
Semi low-tension ignition differs from low-tension ignition in that a single transformer or high-tension coil is used in place of the separate coil for each cylinder used in the low-tension system. In the semi low-tension system, current generated in the magneto is supplied through the center terminal to the single coil which is usually mounted very near to the magneto. Here the low voltage is stepped up to spark voltage and returned to the magneto for distribution to the spark plug electrodes in the proper firing order.

Distributor Ignition

Utilizing battery current and an ignition coil, the distributor functions in much the same way as the magneto. The retarded spark for starting is usually obtained by the centrifugal spark advance mechanism that automatically advances the spark as engine speed increases. The centrifugal advance feature is used on all but a few engine applications.

Breakerless Distributor Ignition

The Bendix breakerless ignition system currently used consists of three parts, (1) a distributor with a magnetic triggering device, a distributor rotor, and a standard distributor cap; (2) a control unit which provides an energy storing circuit, a control circuit, and a transformer coil; (3) a lead assembly to connect the distributor and control unit. Metal vanes mounted on the distributor shaft move past the end of a magnet in the triggering coil in the distributor, and, in passing, upset the magnetic flux through the coil. This change in flux produces an electrical pulse in the coil which is transmitted through the lead to the control unit, releasing the energy previously stored there. The output of the control unit discharges through the primary of the ignition coil, which is a part of the control unit assembly. This discharge of current through the coil primary induces a high voltage current in the secondary and produces a spark across the spark plug gap. The trigger circuits immediately become nonconductive and the whole cycle repeats at as fast a rate as required for engine operation.



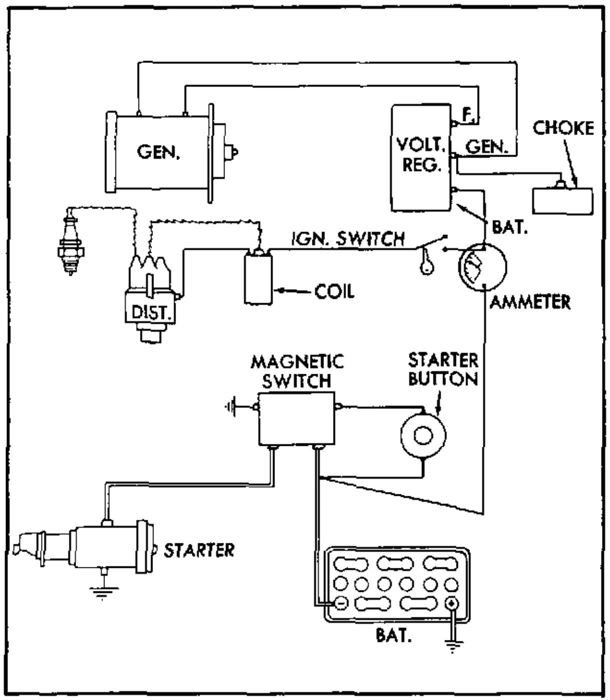
TYPICAL IGNITION DISTRIBUTOR

ELECTRICAL SYSTEM POLARITY

The Waukesha Motor Company has for some time now, supplied new engines with negatively-grounded electrical equipment only. This standardization of electrical system polarity is standard practice for most equipment manufacturers and thus increases compatibility between Waukesha supplied electrical equipment and that supplied by the equipment builder. There are instances, however, when it will be necessary to supply positive-ground electrical equipment to adapt to other equipment related to the engine.

Therefore, servicemen engaged in the installation and trouble shooting of electrical equipment must be aware of the importance of correct polarity to avoid damage to the system. In most cases damage to the voltage regulator and rapid battery discharge will result from incorrect polarity. Voltage regulators are marked to indicate their installation with a negative or positive ground battery. A typical Delco-Remy polarity marking is 24VP which indicates 24 volts and a positive ground, while 6VN would indicate 6 volts and a negative ground. The regulator polarity is indicated either on the regulator base along with the Delco-Remy part number, or on a tape which has been affixed at the Waukesha Motor Company.

Since it is the voltage regulator, for the most part, that dictates the polarity of an electrical system it is possible to change the polarity of a system by replacing the regulator and rewiring the other components. In most cases the engine electrical equipment will include only a starter, generator, voltage regulator, ignition coil, distributor, and possibly an electric over-



TYPICAL ELECTRICAL SYSTEM WITH AUTOMATIC CHOKE & VOLTAGE REGULATOR

speed shutdown, fuel shutoff, and a choke. If a replacement regulator of the correct polarity is not available it is possible to change the polarity of the system by reversing the leads at the battery and coil, substituting a regulator with one of the opposite polarity and repolarizing the generator. Remember that the ignition coil lead wire to the distributor must correspond to the ground polarity of the battery. For a negative ground battery connect the distributor wire to the negative terminal of the coil.

When engines are equipped with the Waukesha Engomatic Control System, however, it is imperative to follow the polarity of the unit as marked on the panel. When a polarity change is required on an Engomatic Control System consult the Waukesha Motor Company.

STARTING SYSTEM

Several starting methods are utilized, depending upon the particular application, on the 140-145 engine series. All starters are geared to a Bendix device which is in turn, engaged to the main engine flywheel ring gear during start up. An electric starting system similar to the typical automotive arrangement is frequently used. In certain applications the Waukesha Model ICK starting engine or an air driven starting motor is employed.

Electric Starting

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

Starting Engine

A Waukesha Model ICK gasoline starting engine may be provided for units requiring heavy-duty starting equipment that operates through a starter drive mechanism. The starter engine is easily started by a rope starter on the gear end. By furnishing adequate power for full cranking speeds even when the oil is heavy, dependable starts for the main engine are insured.

The starting engine is built up of a four-cylinder block containing the valves and tappets; a cast head; a crankcase which supports the crankshaft and camshaft; and miscellaneous oil pan and cover parts. The crankshaft is supported by two single-row, annular, ball-bearings, one at each end. Remaining elements of design are entirely conventional with the exception that the cooling-water system is a branch of the main engine cooling supply. Those points involving the starting engine that are of importance to the operator are treated in their respective locations.

Air Starting Motor

Engines located near a convenient source of compressed air or near a gas supply of sufficient pressure may utilize the Ingersol-Rand Air Driven Starting Motors. The velocity of gas or air entering the motor strikes the vanes causing a rotor shaft to revolve. The rotor shaft rides in two ball bearings and is geared to a Bendix starter device which is manually engaged when rotation is sufficient to crank the engine.

When natural gas is used for engine starting through the air motor, the exhaust and breather openings should be connected and piped to a safe distance from the engine. The motor should also be checked periodically for gas leakage at all points where gaskets and seals are used.

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 quantity and quality.
3. Clean, correct fuel-air mixture.
4. Valve clearances within limits.
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

Because Waukesha engines are in service all over the world, this company does not attempt to recommend either by name or brand all the lubricating oils which are suitable for use. The viscosity, or "body" of the oil is the only property specified in the lubrication recommendations. Quality, including such things as life, heat resistance, detergency, and other commonly specified physical properties--should be the supplier's responsibility. 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.

Special Industrial Service

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

Fire Engine Equipment

This type of engine requires special care to avoid serious damage when it is new. Until the engine has been thoroughly run in, lubricating oil must be added to the fuel--one pint of oil to each five gallons of gasoline. If the equipment is kept in a station where the temperature is below 50°F., unless in frequent use, use a lighter oil than the standard recommendations in the following paragraphs. Besides using a lighter oil, the oil supply should be checked frequently, and maintained at top level.

Additive Oils

Practically all oil companies are marketing additive type oils to meet service requirements common to industrial engine operation. The performance level of these oils under engine operating conditions are defined by the following three military specifications:

MIL-L-2104A Run with 0.35% sulphur fuel
SUPPLEMENT 1 (S-1) Run with 1% sulphur fuel
SERIES 3 "Superior Lubricants"

The Internal Combustion Engine Institute, 201 North Wells Street, Chicago 6, Illinois, has published a list of oil brand names represented by their suppliers as meeting the above service requirements. This list indicates the three military specifications.

The Waukesha Motor Company recommends the use of MIL-L-2104A oils for carburetor type engines in average heavy-duty industrial service engines.

SUPPLEMENT 1 (S-1) oils are recommended by Waukesha Motor Company for carburetor type engines in severe service resulting from extremely high or low operating temperatures or for operating conditions giving excessive piston ring coking.

For light and medium duty carburetted engine service, oils that do not meet the minimum requirements of MIL-L-2104A oils, may be entirely satisfactory.

OIL CHANGES

The oil capacities of the 140-145 engines are listed here for oil pans only. When filters, oil coolers, and other accessories that require engine oil are installed, an extra quantity of oil is required. When the proper quantity has been established it may all be put in at one time. On the first run of a new installation, however, put in the listed quantity, run the engine 10-15 minutes, and then check the dipstick for the oil needed to bring the level up to "Full". The proper quantity will then be known for subsequent fillings.

Engine Model	Hot Oil Pressure, Governed Speed	Oil Capacity, Quarts St'd Pan	Oil Capacity, Quarts Box Base
140	40	10	19
145	40	18	26

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. A good rule is to change it every 50 hours until experience shows that the particular oil in use will remain serviceable for a longer time. Whenever oil is changed, the filters must be serviced. If it is desired to use oil longer than 100 hours of active duty, it is suggested that the lubrication engineer of the supplier be consulted. Not all oils in every type of engine will give maximum service, therefore be careful to examine the oil after the first draining to determine whether it is standing up in service. Trial periods of 10 hours are suggested and at the end of such periods make careful inspections for sludging, frothing, and emulsification. Such conditions call for more frequent changes or a different oil. In winter operation, low oil temperatures (below 160 degrees F) are particularly likely to cause sludge formation. Temperature-control devices--curtains, shutters, or other means--should be used if needed in order to hold the oil temperature around 180 degrees, Fahrenheit. Butane, natural gas, and other fuels not tending to dilute oil may contribute materially to greater oil life if operating conditions are suitable.

In winter operation the condition may arise where low temperatures congeal oil and make starting difficult. At the same time the oil temperatures reached once the engine is started prevent the use of extremely 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 re-filling the crankcase.

Very important to maintaining proper lubrication, is the removal and cleaning of the screen mesh strainer below the oil-level equalizer in the oil sump. This screen strainer is readily removed through the handhole in the bottom of the oil sump. To remove the 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 of the deposit permits easy removal without damage to the screen.

OIL VISCOSITY RECOMMENDATION

Heavy Duty Service

Heavy duty service is considered to be an average load exceeding one-half maximum engine power. To determine the correct SAE grade of oil select the correct SAE oil number from the table after measuring the crankcase oil temperature.

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

2. Find the temperature noted in the above test in the tabulation range 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.

OIL OPERATING TEMPERATURES	SAE VISCOSITY NUMBERS
200-230° F.	40
150-190° F.	30
130-150° F.	30
---	10

Where oils are required for starting at low temperature, multi-viscosity oils can be used which will give low enough viscosity for starting and still provide the proper SAE grade indicated in the above table for the operating temperature. Use such oil only when absolutely necessary for cold starting. Be sure the oil supplier accepts full responsibility for the oil's performance in your application.

Estimated Oil Temperature

When the actual operating oil temperature is not known, an estimate of the SAE oil grade to use can be made by assuming the oil temperature will be 130 degrees above the air temperature in heavy duty service. For example: At an air temperature of 70°F, estimated oil temperature would be 200°F. Use SAE 40 as indicated in the above table. Note: This is only an estimate, since the type of installation determines the amount of air circulation for cooling around the oil pan. Actual crankcase operating oil temperatures should be measured whenever possible.

Operating Temperatures

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

Minimum Viscosity

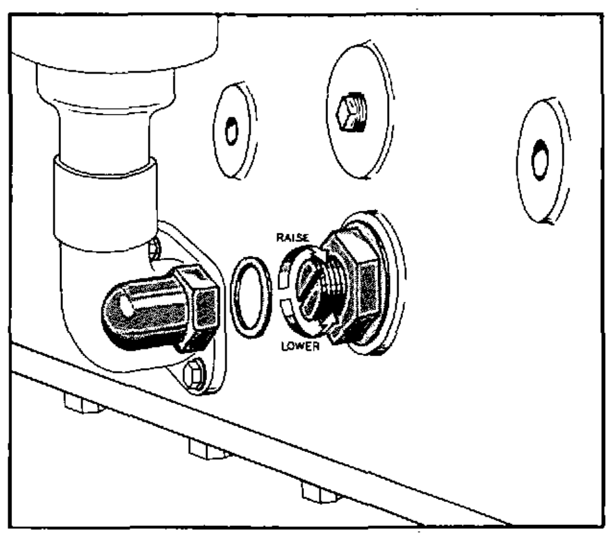
The oil temperature chart is arranged on the basis of providing a minimum viscosity for each class of engine throughout the operating temperature range.

OIL PRESSURE CONTROL

Under all normal operating conditions, the high-capacity pump used on the Model 140-145 will maintain the oil pressure within the specified limits of 40 lbs. 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. Moreover, the oil pressure gauge of an engine started under cold conditions may fail to register pressure immediately because of congealed oil in the gauge line. If pressure still fails to register after the engine has run for 25 to 30 seconds, the engine should be shut down and the cause of the lack of pressure determined and corrected.

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. Tightening the pressure relief valve is not proper compensation for diluted or broken-down lubricating oil. When adjustment is necessary, the steps involved should be carried out as shown in the accompanying illustration.

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

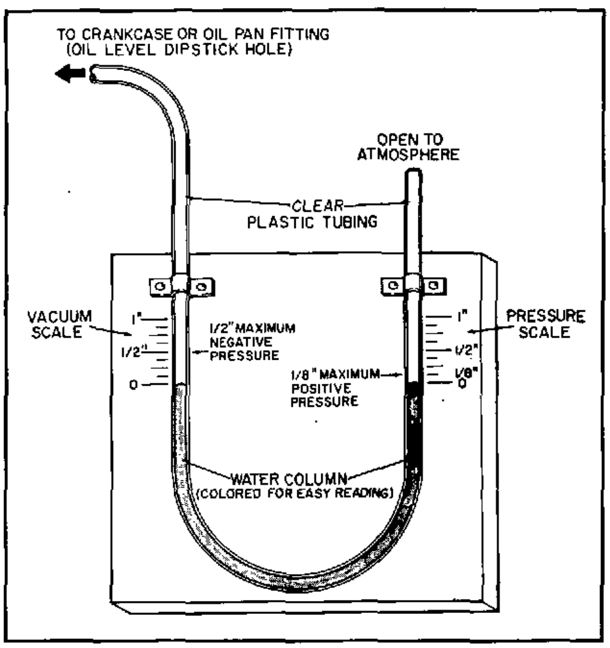


OIL PRESSURE ADJUSTMENT

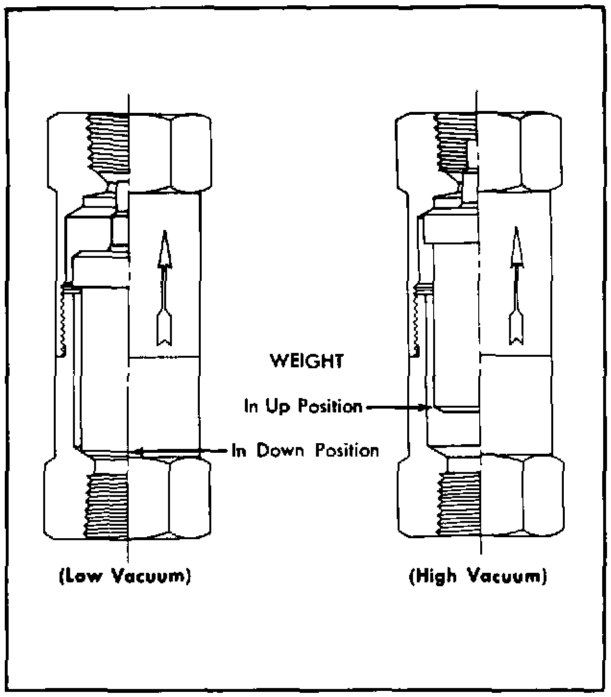
and the spring be removed. It is then possible to check the pressure relief valve itself for freedom of movement. Small particles of carbon or other material may have jammed the valve or clogged the vent passage behind the valve. In both cases, the valve and the control valve body passages should be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

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 removing the oil level dipstick, and tapping the dipstick hole to receive a brass elbow fitting to which a length of clear plastic tubing can be connected. 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 accompanying 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.



MANOMETER USED TO CHECK CRANKCASE PRESSURE



CRANKCASE VENTILATION REGULATOR

Components of the ventilation system should be serviced on a monthly basis or more often if unusual conditions are encountered. A typical system consists of a breather for each of the rocker arm covers. Service of the breathers consists of removing them from the engine and washing them in solvent. If sludge accumulation or rust formation is too great replace the breather.

Regulated System

In some commercial applications, crankcase ventilation is accomplished through a check valve ventilation regulator and breather line, continuously circulating fresh air through the crankcase. Fresh air is admitted at the breather caps located on the cylinder head covers, displacing harmful blow-by gases which are exhausted at the ventilation regulator into the intake manifold.

At high manifold vacuum, the weight assembly in the check valve ventilation regulator is lifted into the "up position" so that the weight pin restricts the flow of gases passing from the crankcase to the intake manifold.

At low manifold vacuum, the weight assembly drops to the "down position", to allow the passage of increased blow-by gases.

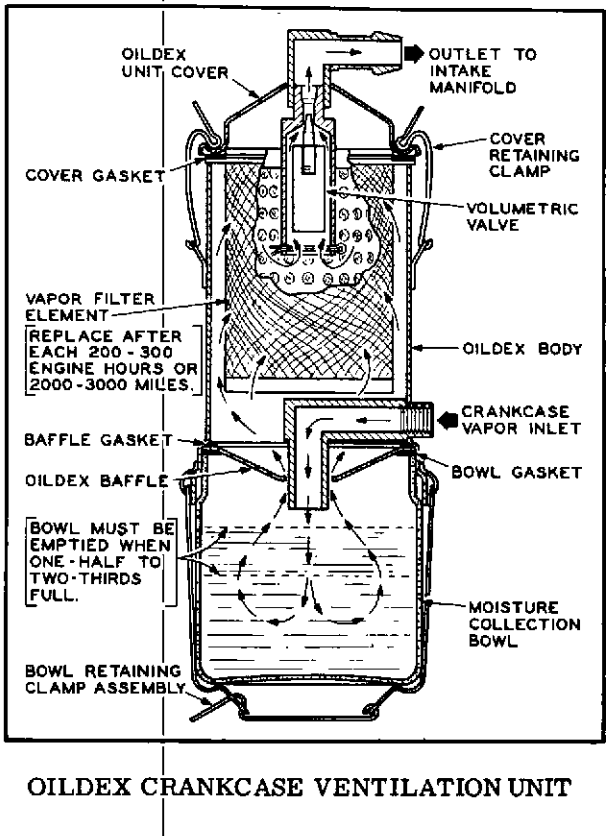
The crankcase ventilation regulator should be washed in solvent when the discharge of oil vapors from the engine indicates increased pressure within the crankcase. Oil leaks may occur due to increased crankcase pressure, when the regulator is clogged.

In this system, the breather-filler unit and the single rocker cover breather must also be serviced at frequent intervals.

Oildex Ventilation System

In certain applications, particularly crane operation, the usage of an Oildex unit has become common practice due to the units ability to prevent premature spark plug fouling resulting from crankcase oil contamination. This may be especially prevalent on engines subject to this type of alternating idle to full load operation. The Oildex unit removes diluent crankcase vapors, extracts and filters these vapors and returns the remaining fumes containing unburned fuel and light oil vapor to the intake manifold.

Although the Oildex does an effective job of removing water, acid, unburned gasoline, varnish and other impurities from the crankcase it must be serviced frequently to prevent these contaminants from being introduced into the intake manifold.



OILDEX CRANKCASE VENTILATION UNIT

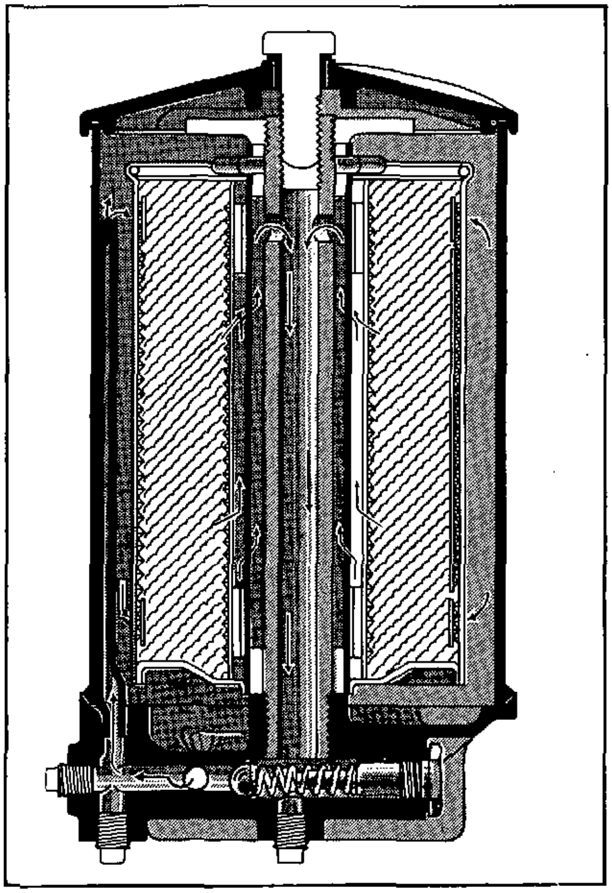
In addition to the recommended service points as found on the accompanying Oildex illustration the unit should be completely disassembled and cleaned at least once a year. Particular attention should be given to cleaning of the volumetric valve, the vapor inlet passage and the area around the Oildex baffle as these, if clogged, will seriously affect operation of the unit and cause excessive crankcase pressures.

OIL COOLER

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

OIL FILTERS

Although some variations may appear in the oil-filter installations used on the Model 140-145 engines the same general principles of maintenance apply to most of them. In all cases the manufacturer's recommendations accompanying the filter, or the instruction label applied to the side of the filter should be followed carefully. The filters supplied with the engine as it leaves the factory are intended for the so-called shunt-type connection. Here, at all times when the engine is operating, a portion of the oil passes from the pressure lubricating system, through the filters, and back into the engine sump as cleaned oil. In those cases where neglect of the filters or an unusually rapid accumulation of sludge tends to bring about filter clogging, a built in by-pass valve



SHUNT TYPE OIL FILTER

of the differential type opens to allow the oil a direct return to the engine without passing through the clogged filter elements. When this happens, the engine will not be starved of oil because of the filter condition, but it is very important to remember that the dirty oil that brought about the filter clogging is now passing through the engine itself and may reduce engine life materially.

Because of the above possibility, the recommendations made for filter change periods coincide with the recommendations for oil change. If the oil shows evidence of sludge formation or improper filter operation it should be changed and the filter element as well. Also, a check should be made to see that the oil and water temperatures are within the desired range of 160° to 180°, Fahrenheit.

If experience indicates the practicality of running the lubricating oil for maximum periods between changes, then the filters 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.

The filtering units sometimes supplied with this engine require no special elements for replacement since the filtering material is clean, white, long-fibre cotton, mechanic's waste; 2-1/4 pounds for each element. WOOL WASTE IS NOT SATISFACTORY AND MUST NOT BE USED. Use care to pack the element evenly, otherwise channeling may occur and result in an inoperative filter.

A throw-away cartridge element is also available for this filter. (Waukesha part No. 101606-A). Many engines are equipped with this type filter element.

No particular difficulties are involved in replacing the waste or the cartridge, although for the sake of cleanliness it is suggested that the filter be drained of the accumulation of sludge and oil before removing the element. About once a year it is good practice to remove the slotted-head screw plugs at the ends of the drilled passages through the filter base and flush out the entire unit with mineral spirits, kerosene, benzol, or similar solvent. At the same time, the by-pass valves should be examined for freedom and proper operation. To ensure a clean job without leaks, it is important that the filter seal gasket be handled carefully and renewed at the same time as the element.

ACCESSORY LUBRICATION

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

Lubricate power take-off units according to the instructions of their manufacturers. Apply a 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.

LUBRICATION AND SERVICE GUIDE

ENGINE SERVICE	VALVES - Check clearance and readjust each 200 hours of operation. CYLINDER HEADS - Tighten to specified sequence and torque values at first warm up and after 50 hours on new or rebuilt engine.
LUBRICATING OIL	Check oil level and observe condition daily, adding oil as required to maintain FULL mark on the dipstick. Oil should be changed at 50-100 hour intervals or as chemical analysis of the oil indicates the necessity of changing.
OIL PAN	Clean out oil pan and oil pump pick-up screen at each opportunity. Low or fluctuating pressure is often caused by sludge accumulations in these areas.
OIL FILTER	Oil filter elements must be changed at each oil change period. Clean the interior of the shunt type filters before installing new element.
FUEL PUMP	Observe fuel sediment bowl daily and remove and clean the bowl whenever an accumulation of foreign material appears.
AIR CLEANERS	Service cleaners according to the attached instruction decal at least once daily and more often under severe operating conditions.
COOLING SYSTEM	COOLANT - Check level daily, adding clean coolant as needed to maintain level. Soluble oil should be added to the coolant frequently to prevent rust formation. Clean and flush cooling system at least once yearly. Maintain sufficient anti-freeze protection. WATER PUMP - 1/4 turn on grease cup daily. Use grease as noted on instruction tag attached to fitting. THERMOSTATS - Test periodically to see that opening and closing temperatures will maintain the desired 160° - 180° system temperature range. FAN BELTS - Check weekly for correct tension, replace belts (in sets) showing signs of cracks or unusual wear.
ELECTRICAL SYSTEM	BATTERY - Check electrolyte level weekly and maintain proper level. STARTER - Lubricate bearings with about five drops of light engine oil at every 300 engine hours. Avoid over lubrication! GENERATOR - Same instructions as given for starter.
IGNITION SYSTEM	SPARK PLUG - Remove, clean and re-gap plugs at 200 hour intervals. Replace plugs showing any signs of damage or unusual wear. Replace entire set at 500 hours. Long life plugs should be replaced after 1000 hours. DISTRIBUTOR - Apply three or four drops of light engine oil to the breaker cam wick every 200 engine hours. Lubricate distributor shaft at oil plug every 200 hours. Fill with SAE 20 engine oil. MAGNETO - Keep magneto external surfaces in clean condition at all times. Lubricate cam wick with SAE 50 oil every 500 engine hours.

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 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 3 quarts of SAE 10 oil.

Check the oil level, air starting motor, by opening the oil level cock in the motor case. The motor case holds approximately 1-1/2 quarts of oil. Air motors are equipped with two grease fittings to which a good #2 cup grease should be applied monthly. On systems equipped with line lubricators, maintain the proper oil level as marked on the "Lubricator" bowl with SAE 20 oil. On systems not having the "Lubricators" the air motor oil chamber must be filled with SAE 20 at monthly intervals.

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

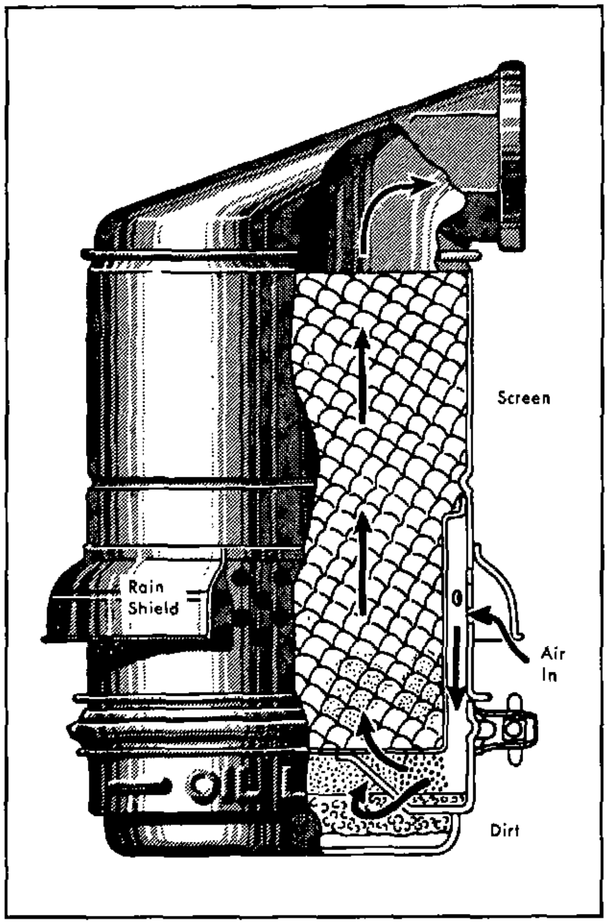
The air motor breather cap should be inspected frequently to make sure it is not plugged with dirt. Excessive use of oil may be due to a dirt clogged breather cap.

Increasing amounts of oil vapor escaping through the breather cap indicates wear of the internal parts of the air motor. When this occurs, the air motor should be removed and overhauled.

AIR-CLEANERS

Servicing

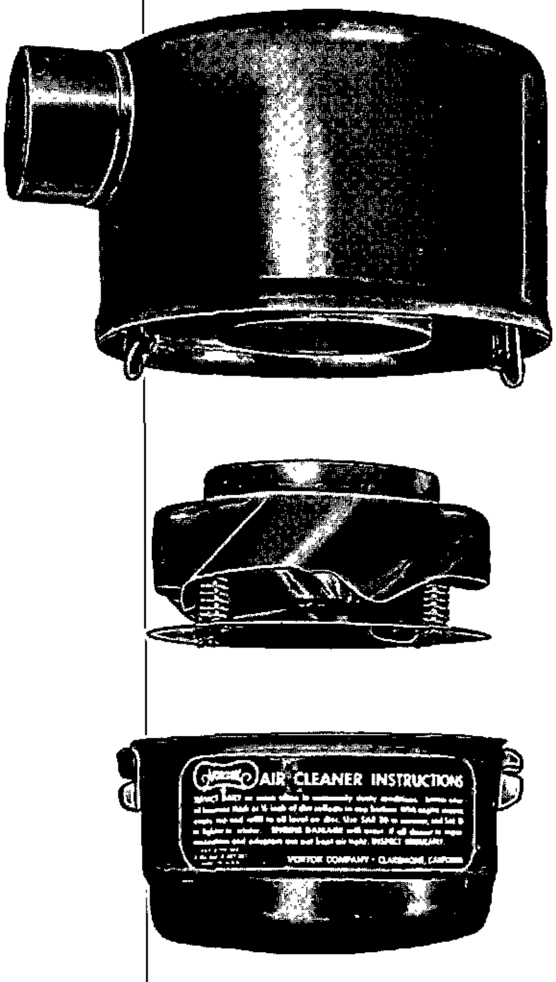
Although various types of engine installations will have differences in air-cleaner types and arrangements it is important for the operator to appreciate that the common purpose of all air-cleaners is to collect dirt and grit and so keep it out of the engine working parts. As a result, the cleaner units must themselves be cleaned, sometimes several times each day if operating conditions are particularly bad. Glass jars, on those cleaners employing glass-jar pre-filters, should be emptied whenever they approach half-full. Do not oil the jar interiors. Most modern cleaners are of the so-called oil-bath type. In principle, the intake air passes over a pool of oil located at the bottom of the filter shell. Some of the dust particles are simply caught by the oil and settle at the bottom of the pool; other particles adhere to the oil vapor and droplets that leave the surface of the oil pool. The latter are prevented from entering the engine by a wire-screen element.



OIL BATH AIR CLEANER (140 ENGINE)

To clean filters of the type described above, flush out the oil in the lower part whenever an obvious accumulation of sediment, or thickening of the oil, makes itself apparent. Scrape away any accumulation, then refill the unit with fresh, clean engine oil. A bead pressed in the metal or an oil level stamping in some types indicates the proper oil level. The screen filter is easily washed out in gasoline or a similar solvent.

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



OIL BATH AIR CLEANER (145 ENGINE)

COOLING SYSTEM MAINTENANCE

The cooling system of the bare Model 140 engine holds 6 3/8 gallons of water without provision for radiators or other equipment. For the 145 engines this figure is 9 3/4 gallons. When adding anti-freeze compounds on a percentage basis therefore, remember to include the coolant volume of the radiator and other external parts of the cooling system. The following table may be used as a guide.

Pure Methyl Wood Alcohol	Denatured Wood Alcohol	Ethylene Glycol "Prestone"	Radiator Glycerine (G.P.A.)	Freezing Points °F.	Freezing Points °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, and 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 overheating can occur. This last method requires, of course, that the water be drained immediately when the engine is shut down.

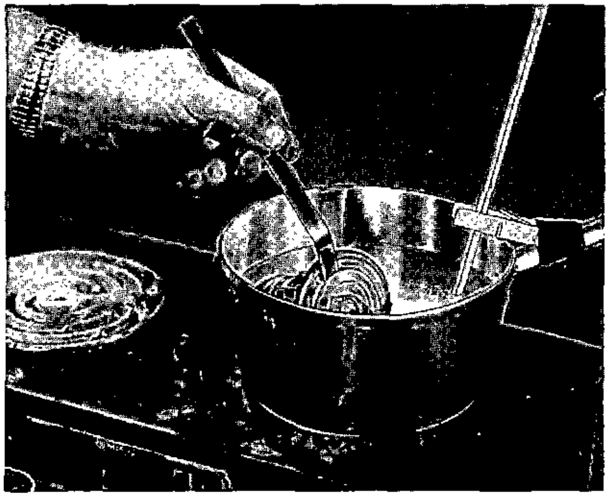
Periodic additions of anti-freeze will be required to compensate for evaporation. Use a hydrometer type test gauge to ensure that the anti-freeze solution is maintained at its proper strength.

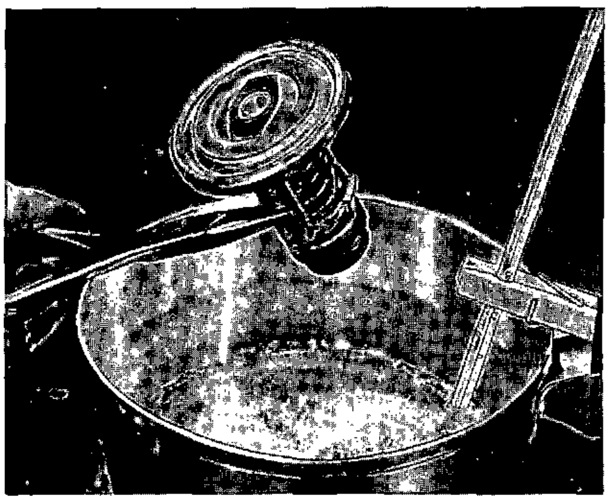
Under normal conditions, the two heat-sensitive thermostats in the outlet of the water manifold will maintain temperatures within the desired limits of 160° to 180° F.

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

Thermostat Removal

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





THERMOSTAT TESTING

Thermostat Testing

Thermostats should be tested in hot water for proper opening. A bucket or other container should be filled with sufficient water to cover the thermostats and fitted with a good quality thermometer suspended in the water so that the sensitive bulb portion does not rest directly on the bucket bottom or side. A stove or torch is used to bring the water to a heat range of 160°, F. while the thermostat is submerged in the water. Stir the water for even heating. As the temperature passes the 160°-165° range, the thermostat should start to open and should be completely open when the temperature has risen to 185°-190°, F. Lifting the thermostat into the colder temperature of the surrounding air should cause a pronounced closing action and the unit should close entirely within a short time. Both thermostats must be tested in this way. Two thermostats are used in order to ensure adequate reserve circulation for heavy operation and to pass large volumes of cooling water. Use care to seat the thermostat squarely and concentrically to avoid interference with the thermostatic action.

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 accomulations will not be excessive. About 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 . . .

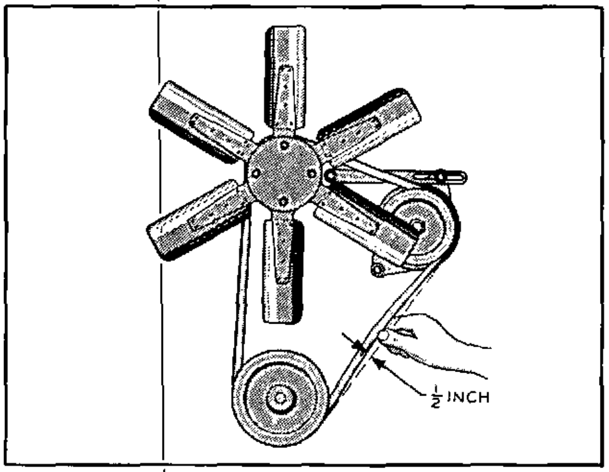
1. Drain system and measure water volume.
2. Replace half of measured volume with fresh water.
3. Boil other half of volume and add washing soda until no more will dissolve.
4. Add hot soda solution to cooling system (fill up).
5. Operate engine normally for 24 hours.
6. Drain, flush, refill with clean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

Cooling Fans

About the only maintenance work encountered in connection with cooling fans will be 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.



CHECKING FAN BELT TENSION

Fan Belts

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

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

1. Loosen the fan-hub nut located behind the fan-support bracket.

2. Loosen the fan adjustment nut on top of the fan-support bracket and lower the fan hub and pulley until the belt tension is completely relieved and the old belts can be slipped free.

3. Slip the new belts over the pulley and take up on the adjusting nut until the belts show some tension but are not so tight as to prevent movement with the thumb and forefinger for about one-half an inch to either side.

4. Retighten the fan-hub retaining nut.

Compressor Drives

Many installations will use a three-point belt drive to drive an air compressor. This arrangement is detailed on the installation drawings obtainable from the WAUKESHA MOTOR COMPANY.

Greasing Fan Hub

On those installations with a fan, it will be necessary to remove the screw plug from the fan hub about once a month, install a grease fitting temprorarily, and apply a good quality grease selected for ball-bearing applications.

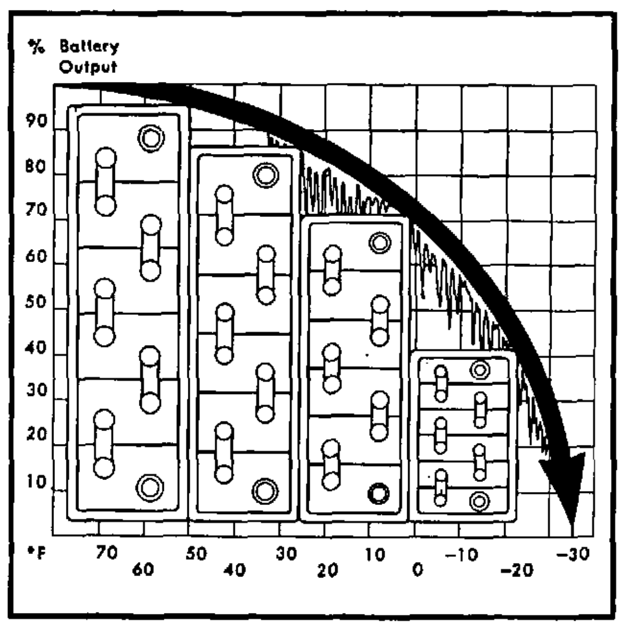
IGNITION ELECTRICAL SYSTEM MAINTENANCE

The 140-145 series engines may be equipped with either battery or magneto ignition. In some applications both battery and magneto are used and dual spark plugs are employed with special cylinder heads. For top engine performance, each unit of the ignition system must be in good condition and properly adjusted. Normal maintenance consists of replacing defective units at periods determined by experience with the type of service involved. Adjustment several times during the service life will extend the usefulness and help benefit engine life.

The battery is often subjected to abuse and insufficient maintenance in a distributor ignition system. Occasionally the starting motor and generator brushes and commutator require reconditioning. For other repairs and adjustments, these units should be referred to a qualified service man with the necessary tools and instruments.

Battery

Check the electrolyte level weekly and maintain it 3/8" above to even with the lead plates. If possible check the specific gravity at this time



COLD REDUCES BATTERY POWER

since that information is valuable in detecting trouble before damage occurs. A specific gravity of between 1.250 and 1.285, all cells reading within 0.010 and 0.015 of each other, indicates a well charged battery. Readings below 1.250 indicate the necessity for commercial charging while repeated specific gravities below 1.250 call for thorough inspection of the electrical system. Deposits that appear on the battery cables may be removed by washing with a weak baking soda and water solution or household ammonia. A vasoline coating on the exposed parts will prevent the formation of more deposits.

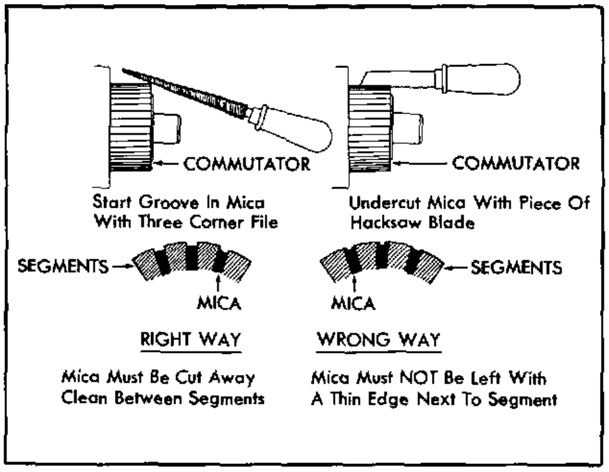
Starter and Generator

The starter and generator bearings must be lubricated with about five drops of light engine oil every 300 hours, oftener for the starter if it is used frequently. Do not over lubricate because excess oil may reach the commutator, brushes, or insulation and seriously impair the unit's operation.

Also after 300 hours of operation inspect the commutator and brushes for indications of excessive wear. A slightly tan commutator that is smooth and shiny is in good condition and will not require attention. If it is rough and dirty, place a strip of 00 or 000 sandpaper, not emery cloth or paper, over a block of wood and hold it against the commutator while the motor is turning over. Continue this operation until the commutator is free from dirt and rough spots but do not remove any more stock than is necessary. Then blow any sandpaper dust out of the motor.

The mica insulating strips between copper segments should be about 1/32" below the commutator surface. If through wear or several dressings of the commutator the mica is flush with the copper, remove the unit and refer it to a service shop for undercutting. Any visible out of round must be corrected by turning the commutator then undercutting the mica.

During each 300 hour inspection check to see that the brushes are loose in the holder, remove them, clean in gasoline or solvent until they fit freely. Replace the brushes when worn down to one half their original length. New brushes should be fitted to the commutator by placing a strip of 00 or 000 sandpaper, abrasive side facing upward, under the brush and sanding until about 3/4 of the brush end makes contact with the commutator.



UNDERCUTTING MICA

Regulator and Solenoid Switch

Do not attempt repairs or adjustments of the regulator or solenoid switch without the aid of a competent service man and special instruments. Generator manufacturers report that almost every case of early failure of the generator is due to tampering with the charging rate or voltage adjustment by inexperienced personnel.

Spark Plugs

Misfiring or ragged operation may be due to faulty spark plugs caused by carbon accumulations and burning of the electrodes. They should be cleaned, inspected, and the gaps checked approximately every 200 hours of operation, or oftener if the engine idles for prolonged periods. After 300-400 hours, it is advisable to replace the entire set when any spark plug is defective.

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

After the spark plug has been cleaned, adjust the gap with a round wire gauging tool to .018 - .020" by bending the outer electrode. As the spark plugs will have a tendency to burn the electrodes and widen the gap, it is important that gap be checked whenever the plugs are removed from the engine. Missing at low speeds is very often due to a wide spark plug gap.

Also inspect the plug for cracked or porous insulator and check condition of the ignition cable.

When replacing spark plugs, use new gaskets. Proper seating of the gasket is necessary for sealing the combustion chamber and transferring heat from the plug.

IGNITION SYSTEM CHECKLIST

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

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

PLUG GAP

Gasoline	.025
Gas, New	.025
Gas, Re-set	.018-.020

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

DISTRIBUTOR CAP Check for secure seating, clean exterior, and interior free from oil, grime, powdered metal, paint, or hairline cracks. Clean corrosion from terminal sockets.

DISTRIBUTOR ROTOR Check for cleanliness, firm seating, shiny center contact, arm contact not eroded short, nor striking cap contact lugs.

BREAKER POINTS Check for wear on fiber cam follower; secure mounting; tight, clean, well-insulated low-tension wire; correct spring breaker tension (19-23 ounces); point contacts meeting squarely and not excessively pitted; point movement (gap) .018-.020.

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

BREAKER HOUSING Check for interior cleanliness, freedom from oil and grease, free movement of centrifugal advance system without looseness or slack in parts.

DISTRIBUTOR SHAFT Provide periodic lubrication at grease plug; test manually at breaker cam for wobble from excessive bushing clearance.

TIMING Use simple light circuit across points to establish correct point opening with flywheel marks. Centrifugal advance compensates for higher speed timing. Time for the correct degree of advance on the engine instruction plate or in the clearance table in this book.

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

TIMING TAPES

The Waukesha Motor Company has recently eliminated the stamped timing marks, except for TDC, from all flywheels in current production. Instead, industrial type adhesive-backed timing tapes with degree markings will be affixed.

The new 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. Straight or curved tapes, shaped to fit the flywheel rim or face, are used depending upon the location of the flywheel housing timing opening.

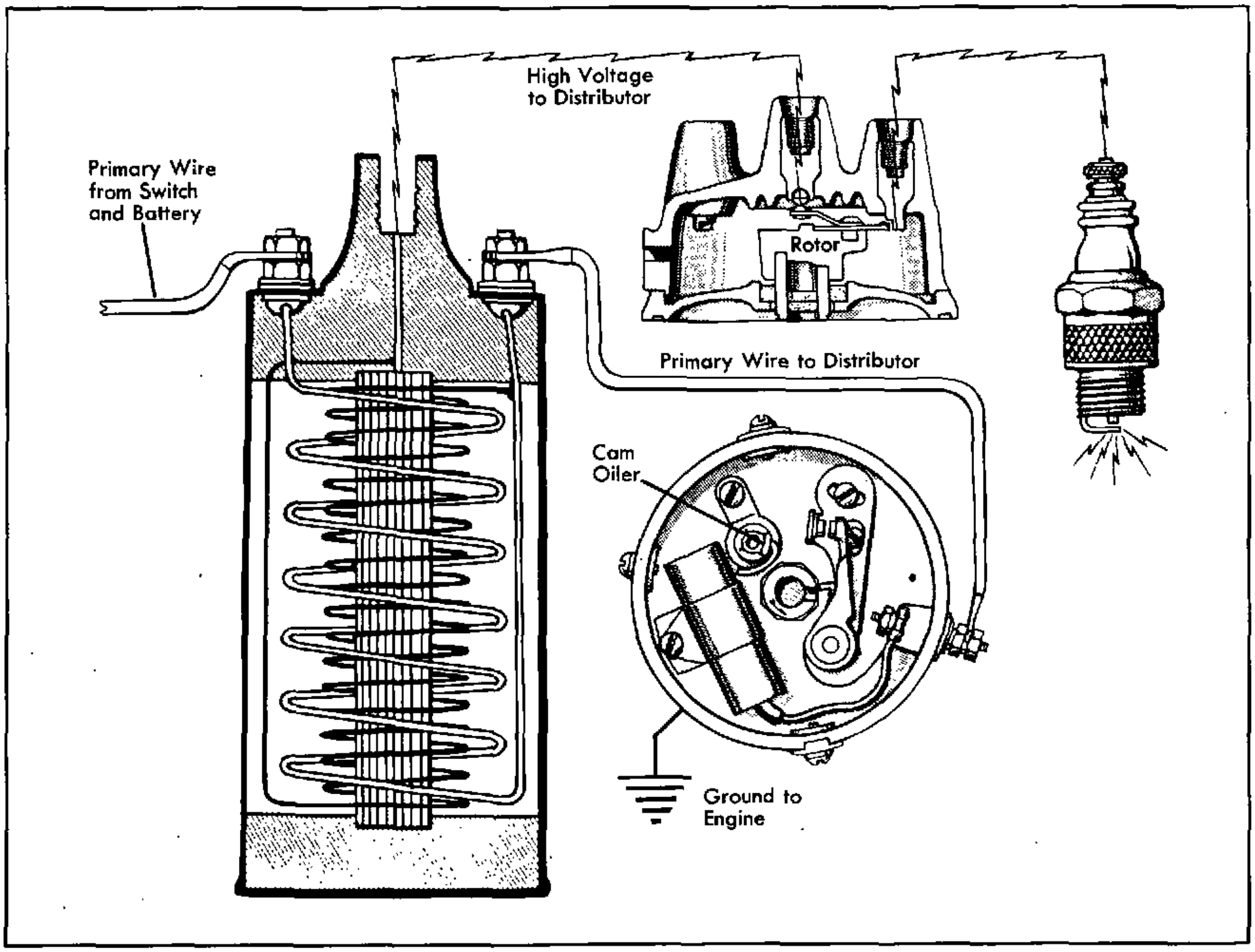
The actual engine timing procedure is still basically the same. The positioning of the correct flywheel degree mark under the housing pointer differs somewhat, however, in that the serviceman must now refer to a timing data chart mounted on the engine crankcase or valve cover. This timing chart displays 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), and engine operating speed. Timing data is also listed in the Clearance Section of this manual.

IGNITION DISTRIBUTOR

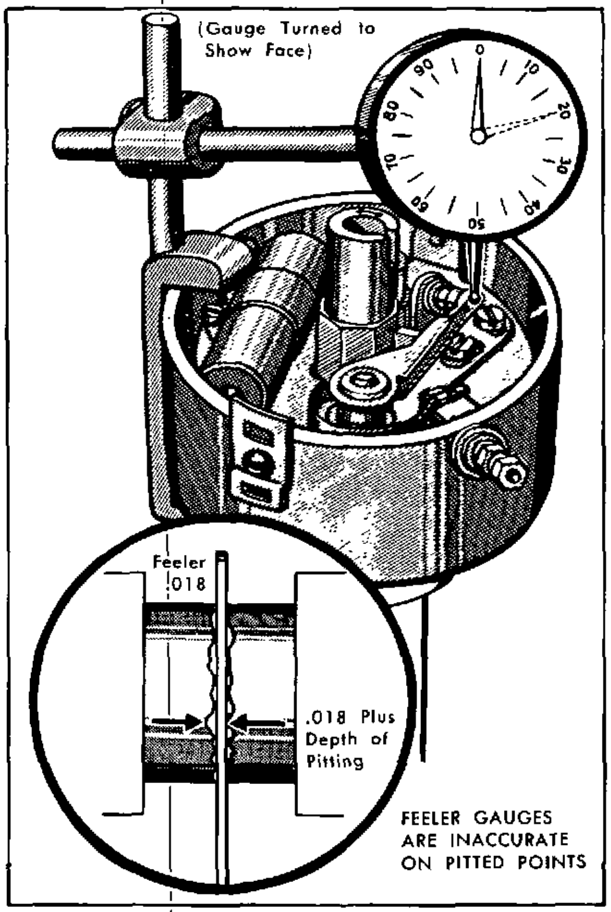
The primary or low-tension circuit of an ignition distributor passes directly from the primary wire connection, through the breaker points, to the grounded body of the distributor. The condenser is connected across the breaker points. One side of the condenser is connected to the insulated primary wire connection; the other side is grounded to the distributor body. Each time the rotating cam in the center of the distributor permits the breaker points to close the primary circuit is complete. Hence, the cam and breaker assembly is nothing more than a switch timed to pass primary current through the ignition coil six times for every two revolutions of the engine crankshaft.

When the cam forces the breaker points apart, the primary current flow through the coil is interrupted. It is this abrupt interruption in primary current that induces the secondary current in the separate secondary winding of the coil. An explanation of the induction principle will be found in the publications of electrical equipment manufacturers. From the standpoint of engine maintenance, it is only necessary to be able to recognize when ignition units are in good condition, working properly, and accurately adjusted.

The high-voltage secondary current induced in the coil passes through another circuit of the distributor. Entering the distributor cap at the center lead, the current passes through the carbon button at the center of the cap interior and into the rotating distributor rotor. The distributor rotor moving contact is held against the carbon button by spring pressure. The distributor rotor passes in turn each of the six electrodes leading to the spark plugs. The positioning of the rotor tip opposite an electrode occurs at the same time the breaker points separate to cause a high voltage discharge through the secondary system. Consequently, this high-voltage current jumps from the rotor tip to the opposite electrode and into the lead going to the spark plug.



TYPICAL BATTERY IGNITION SYSTEM SCHEMATIC



DISTRIBUTOR POINT ADJUSTMENT

Since the mechanical arrangement of the engine requires a certain firing order, the wires leading to the spark plugs must be crossed to lead the successive sparks to the proper cylinder. Thus, the proper method is to start with number one spark plug wire in the terminal of the distributor cap to which the rotor points when number one cylinder is approaching TDC on compression stroke. The next wire would go to number five cylinder, the next to number three cylinder, and so on in firing order 1-5-3-6-2-4. Since both the 140 and 145 have clockwise distributor rotation (viewed from above the cap) the wires are installed clockwise around the cap.

Timing-Distributor Ignition

The steps in timing the ignition system are shown in the accompanying illustration. This cannot be accomplished until the breaker points are accurately adjusted for clearance. Point clearances may be adjusted with the distributor installed in the engine. In some cases, however, it will be found much more convenient to remove the capscrew holding the adjustment collar and carefully lift the entire distributor from the engine for inspection and adjustment. This avoids working in cramped quarters and difficulties in trying to crank the engine over to bring the cam peak under the fibre bumper block.

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

A feeler gauge is not an accurate method of setting points, particularly when there are some inequalities in the contact surfaces.

The simplest method, and the most accurate, is the use of a dial indicator. Here, the gauge is solidly clamped to the distributor body in whatever manner is convenient. The gauge tip is brought to bear against the movable breaker point just behind the contact surface and the gauge is set to read zero with the fibre bumper on the flat of the cam and the points closed. Thus, by rotating the distributor cam, with the starter if the distributor is installed, or with the fingers if being bench adjusted, the exact point opening in thousandths is read on the dial indicator. This method will also reveal worn cams and distributor shafts that are loose in the bushings because the opening readings will be erratic. Clearances are adjusted in the conventional manner by turning the eccentric screw holding the fixed point. Do not forget to re-tighten the fixed point clamp screw after adjustment.

When the breaker point clearance is accurately adjusted, the engine should be turned to firing position on the compression stroke for #1 cylinder. This may be determined by bringing the degree mark on the flywheel to the center of the timing hole in the flywheel housing or aligning the timing pointer on the gear cover with the notch on the crankshaft pulley. At the same time make sure that both valves on number one cylinder are closed, or remove number one spark plug and feel the compression with the thumb.

Instances have been reported where the valve timing mark INO1 (intake opens #1) has been mistaken for the ignition timing mark when the position of the flywheel opening made it necessary to view the letters in an inverted *position. The letters IGN1 do not appear on* these flywheels. The DIST mark is the correct point for timing the ignition of older 140-145 series engines without timing tapes on the flywheel.

If the distributor assembly was removed from the engine, *turn the rotor to the same position* it was in when removed. Insert the drive shaft carefully in the opening with the distributor body held approximately the same as it was when removed. For example, if the primary wire terminal and the grease plug were to the right originally, reinstall them that way' if possible.

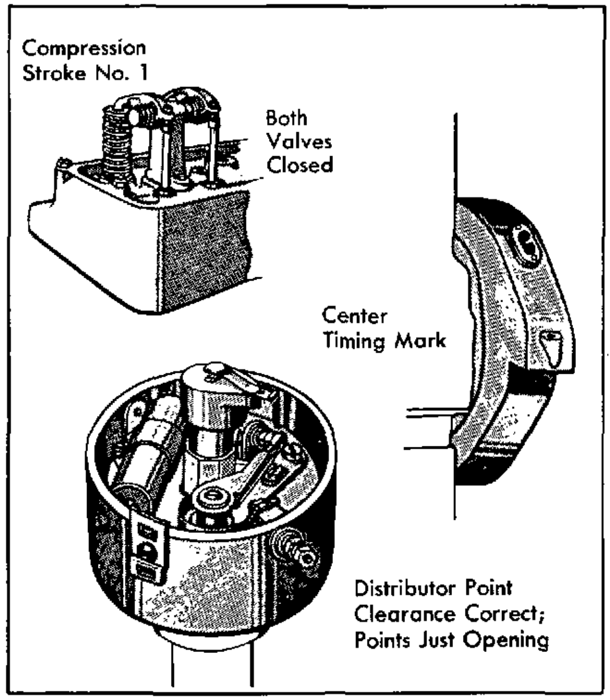
When the distributor drive strikes its mating member in the crankcase, it may be necessary to rotate the shaft slightly by turning the rotor back and forth until the proper alignment is felt and the distributor drops into position. Install and tighten the cap screw holding the slotted adjustment arm to the boss on the crankcase with the cap screw in the approximate center of the slot. The screw and nut holding the split clamp collar on the distributor body may now be loosened just enough to permit slight rotation of the distributor body for final adjustment.

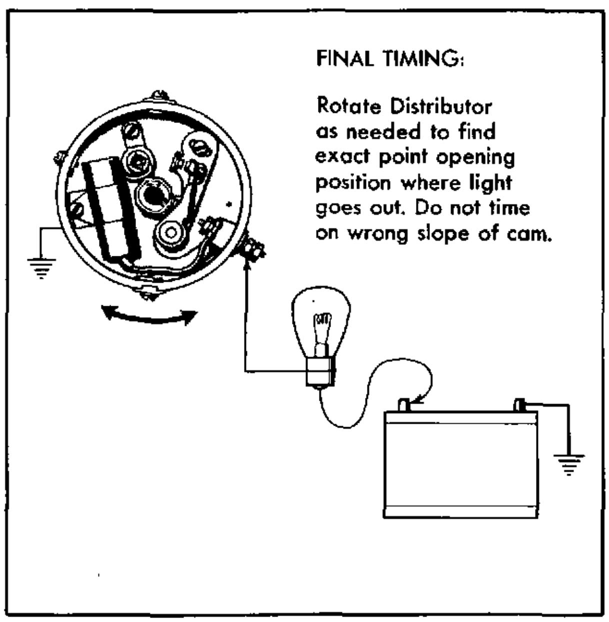
The exact timing of the spark depends on the actual breaking of electrical contact across the points. Hence, checking for the apparent mechanical separation with feeler stock, cellophane, and so on is apt to be misleading depending on the condition of the points and the skill of the operator. To assure accurate timing, make up a simple light circuit consisting of an automotive light bulb with soldered on leads or a socket with lead wires attached. Clip or wedge one lead to the ungrounded side of the starting battery, and attach the other lead to the primary wire connection at the side of the distributor. Note: If using a 6-volt bulb and a 12-volt starting battery, use only half of the battery voltage by clipping the wire to one of the inter-cell straps midway on the battery.

With the above installation, if the bulb is lit the points are closed and the distributor should be shifted slightly to determine the point of opening where the light just goes out. The distributor clamp may now be tightened *and the flywheel turned backwards* about a quarter of a revolution and then brought forward towards the timing mark on the flywheel as before. The light should just go out as the proper mark on the flywheel centers in the flywheel housing opening.

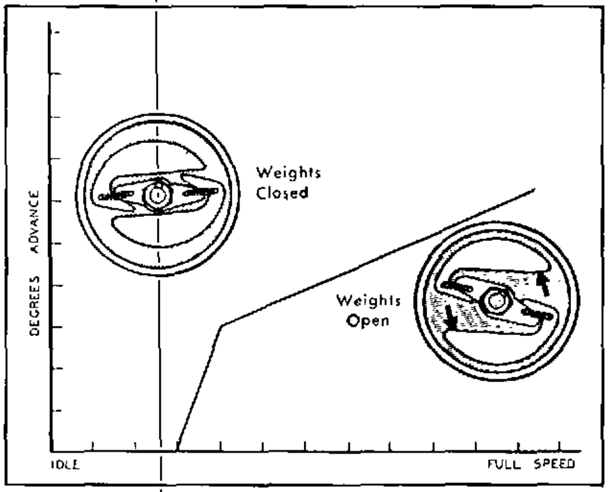
Since the engine is set for number one cylinder firing, install the distributor cap and start installing the spark plug wires with number one in the hole to which the rotor points and working clockwise around the cap.

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





STEPS IN TIMING DISTRIBUTOR IGNITION



CENTRIFUGAL ADVANCE CURVE

Once the timing is properly set for the idle (no-speed) position, the centrifugal weight system of the distributor will automatically advance the spark as required by changes in engine speed. The mechanism involved is matched to each engine application by laboratory tests determining the best spark advance point over the entire speed range. Therefore, substitution of unmatched parts from other equipment will impair timing and engine performance. The advance curve for the distributor used on the 140-145 series engines is shown in the accompanying graph.

The distributor requires lubrication of the shaft, advance mechanism, breaker cam, and breaker lever pivot. For shaft lubrication, a supply of oil is placed in the oil reservoir at the time of assembly sufficient to last 1000 hours under normal operating conditions. Thus, the oil plug need not be removed oftener than this period (or at overhaul) except when unusual heat or other operating conditions are experienced. Add grade 20W oil when the plug is removed. Avoid over-filling; there should be a small air space above the plug hole when the plug is replaced. Seal the plug with a sealing compound that will retain oil.

For cam lubrication, add a drop or two of light engine oil to the center hole of the lubricator if the cam wick appears to be dried out. Inadequate lubrication here is shown by excessive wear of the breaker bumper fibre and traces of the fibre material on the cam surface. Excess oil is indicated by fouling of the points, carbon streaks under the points, and a generally dirty appearance of these parts. Every 200 hours put one drop of light engine oil on the breaker lever pivot, and a few drops on the felt wick under the rotor.

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

BREAKERLESS DISTRIBUTOR IGNITION

The Bendix system consists of the following three parts: (1) a control unit which provides an energy storage circuit, a control circuit, and a transformer coil; (2) a distributor which includes a magnetic triggering device, a distributor rotor, and a standard distributor cap; and (3) a lead assembly which electrically connects the control unit and the distributor.

The engines for which this system is designed usually operate on Natural or LP gas and are used to run commercial and residential air conditioners, referigeration units, and heat pumps. The Bendix Breakerless Ignition System operates from an external electrical power supply of 100-125 volts ac at 50-60 cps.

The input is fed into the control unit by means of a three-wire lead. The green wire is grounded inside the control unit. The black wire goes to a 1/4 amp, 3 AG type 250 volt fuse and then to the filter unit. The white wire connects directly to the filter unit. The filtered input current goes to an electronic module which converts it to dc. The direct current is then used to charge a capacitor in the energy storage circuit. This capacitor is connected to the high-voltage transformer coil through a trigger circuit containing a switching device which is normally non-conductive or "open."

The distributor includes a trigger wheel with four vanes and a magnetic pickup unit. When one of the vanes approaches the tip of the pickup with sufficient speed, an electrical pulse is generated in the pickup. This pulse goes thru the lead from the distributor to the control unit and is used to turn on the switching device in the trigger circuit. This permits the electrical energy in the storage capacitor to discharge thru the primary winding of the high voltage transformer coil. The resulting high voltage from the secondary winding of this coil is conducted to the distributor and then to the spark plugs. The trigger circuit quickly recovers its non-conductive state and the whole cycle of events is repeated at the rate required by the engine rpm.

Installation Timing

Before installing the distributor on engine, rotate engine to its No. 1 firing position as specified. Hold the distributor so the connector points in the direction most convenient for installation of the lead between the distributor and control unit. Lower the distributor into position so the drive member mates with the engine drive. Remove distributor cap and note the two timing bosses on the inside wall of the distributor housing. Each boss is identified by an arrow above it. Rotate the distributor until one of the trigger wheel vanes is in line with the proper timing boss as indicated in the timing illustration. Arrow adjacent to each timing boss indicates direction of distributor shaft rotation.

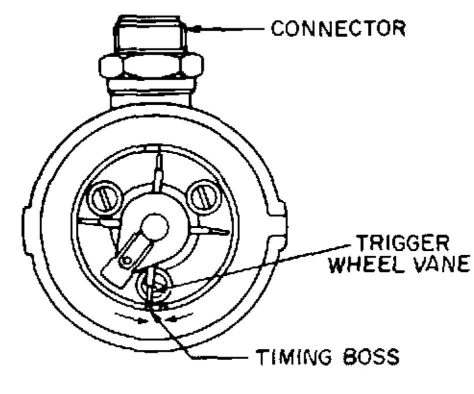
Install the distributor cap after noting with which electrode and cable well the rotor electrode is aligned. Install high tension cable between this cable well and the spark plug in the No. 1 cylinder. Install the other three cables relative to distributor rotation and engine firing order. With engine turning, adjust final timing in accordance with engine instructions. Secure distributor to the engine. Make sure that the mounting surface of the control unit is grounded to the engine to complete the high voltage circuit to the spark plugs.

> CAUTION: It is recommended that the control unit be mounted so its coil outlet is at the top and the mounting flange in full contact with a horizontal metal surface to provide a good heat sink for the unit.

Install the end of the power input cable in an electrical junction box which provides 100-125 volt ac 50-60 cps power. Connect the green wire to a good earth ground. Make sure that the correct fuse (1/4 amp, 3 AG type 250 volt) is in the fuse post on the side of control unit.

Connect the control unit to the distributor using the Bendix lead assembly and tighten retaining nuts.

Install one end of a high tension cable in the coil outlet at top of control unit and the other end in the center cable well of the distributor cap. No terminal is required on the end which is installed in the coil. To assist in weatherproofing the system, it is recommended that a light film of Scintilla #47 Compound or equivalent non-hardening sealing compound be applied to the first 1/4 inch of the cable outside diameter before insertion into the coil. Insert the lead into coil a minimum of 5/8 inch.



TIMING BREAKERLESS IGNITION SYSTEM

Maintenance

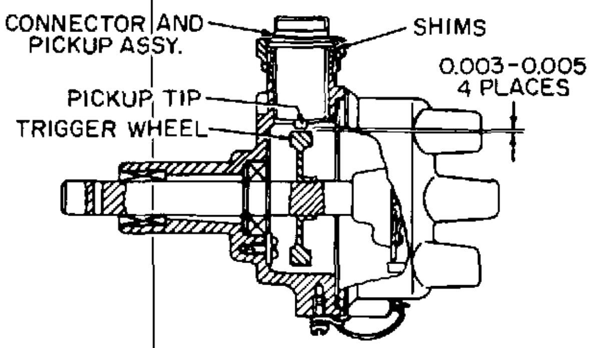
The Bendix Breakerless Ignition System is designed to give thousands of hours of maintenance-free service. However, the following preventive maintenance procedures, if followed at each engine inspection period, will greatly prolong its trouble-free service life.

Remove the distributor cap by unhooking the two clips which secure it. In confined areas, be sure the cap is lifted enough to clear the spring terminal on distributor rotor before moving it to the side.

Wipe cap with a clean, dry cloth if cleaning is necessary. Check all cable wells and electrodes to insure that they are clean and free of corrosion. If necessary, carefully clean the inside of distributor housing with a dry cloth.

> CAUTION: The vanes of the trigger wheel are of necessity made of a relatively soft metal. Use extreme care that they do not get bent at any time. Their location controls the timing accuracy and proper functioning of the ignition system. Therefore, any change in their position relative to the shaft will adversely affect engine operation.

Inspect all wiring insulation for fraying, scuffing, cracking, or other conditions that could cause malfunction. Replace any defective wiring and locate it so the above conditions will be avoided.



BREAKERLESS IGNITION DISTRIBUTOR (TRIGGER WHEEL TO PICKUP CLEARANCE)

> CAUTION: The clearance dimension between trigger wheel and pickup tip is critical. If the connector and pickup assembly on side of distributor is removed for any reason, this dimension shall be checked during reassembly. Adjust the clearance to 0.003 to 0.005 inch between each vane and the pickup tip by adding or removing Bendix shims where indicated in the accompanying illustration. Nonconformance with this requirement will cause malfunction of the system.

MAGNETO IGNITION SYSTEM VARIATIONS

Three different types of magneto ignition systems are employed on engines in this series. They are the high tension, low tension and semi-low tension systems. Usage of each particular system is dependent on the engine application.

In the high tension system, the magneto produces and distributes high voltage current directly through insulated high tension leads to the engine spark plugs. The conventional or high tension magneto contains a single internal coil which has both primary and secondary windings. The low tension and semi-low tension magnetos differ from this in that they generate only low tension or primary current. In the low tension system the magneto distributes this primary current to individual coils, one for each cylinder, where energy is transformed into high voltage current and delivered to the spark plug through a short high tension lead. The semi-low tension system employs a single external coil. In this system the low tension current generated in the magneto passes out of the magneto center terminal to the external coil where it is transformed into high voltage energy. From the coil the current flows back into the magneto where it is distributed in the proper firing order through high tension leads to the spark plugs.

MAGNETO-GENERAL

Minor servicing of the magneto is confined to cleaning, replacement, and adjustment of the breaker points. More extensive repair and overhaul operations require specialized training and equipment and should be made only at authorized service agencies.

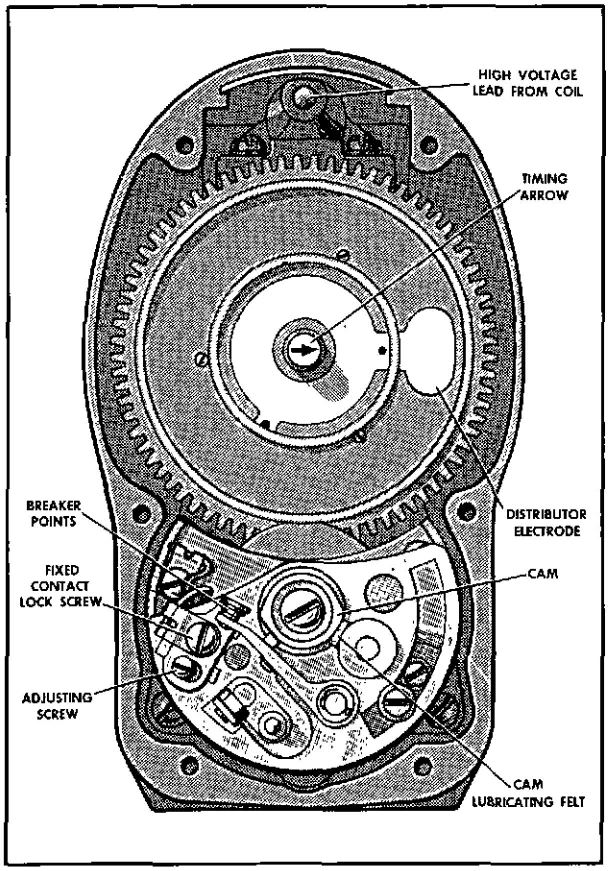
In both theory and service practice there is little difference between a magneto and a distributor. Whereas a distributor depends upon a generator and storage battery for its primary current, the magneto uses a primary current generated within itself by rotation of permanent magnets between the pole shoes. Because of the movement of the permanent magnets and the periodic reversals of magnetic flux a magneto must be timed internally as well as with relation to the engine. To accomplish this internal timing requires an edge distance gage of a size specified for the magneto involved and for this reason a magneto that is properly adjusted at the factory or a service agency should not be upset by tampering with the breaker plate adjustment.

HIGH TENSION MAGNETO

Timing Instructions

The magneto timing procedure follows very closely the steps given for timing the distributor. The engine must be turned over until the proper mark on the flywheel is centered in the timing opening and number one piston is coming up on compression stroke. This is the point at which firing occurs when the engine is running and the impulse coupling has disengaged. Hence, this is also the point at which the breaker contacts must just begin to separate when the magneto is rotated in the direction indicated by the arrow on the name plate.

When the impulse coupling is engaged, as it is when starting to time the magneto, it must be released or "snapped" in order not to incorporate its lag angle in the timing procedure. The easiest way to do this is to turn the magneto impulse coupling backwards (against the arrow on the name plate) as many turns as needed



HIGH TENSION MAGNETO, COVER REMOVED

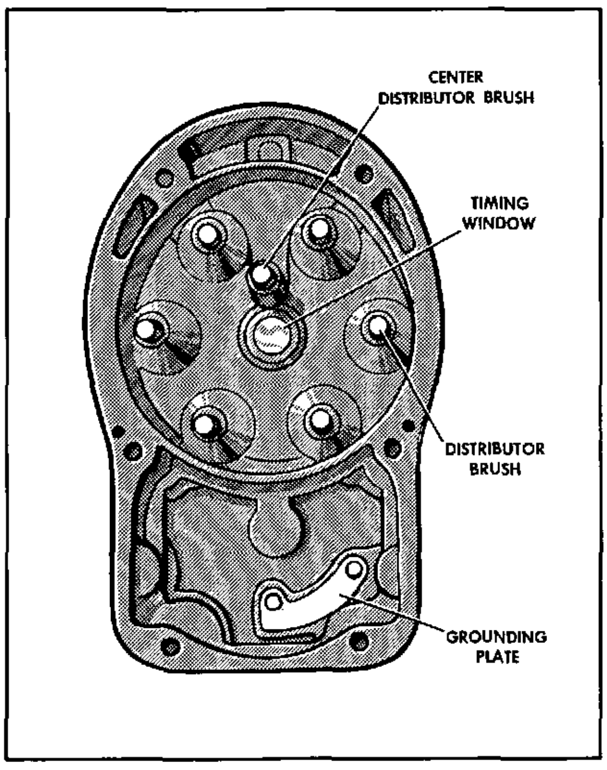
to align the arrow in the inspection window with the terminal connecting to number one spark plug. Reverse rotation automatically disengages the impulse unit. With the breaker point cover open, it will be seen that the points just close as the arrow lines up with the terminal. Rotate the impulse coupling very slightly in the opposite (normal) direction enough to just open the points, hold the rotor from further turning, and connect the magneto drive to the engine. This same procedure applies to low tension ignition except that a marked gear tooth under a removable plug designates #1.

In some cases, it may be found impossible to engage the slot and tongue magneto drive without tilting the magneto so far that it either strikes against the crankcase or leans outward from the engine more than desired. Also, a situation of this kind may require the magneto to be tilted beyond the range of the slot for the mounting stud.

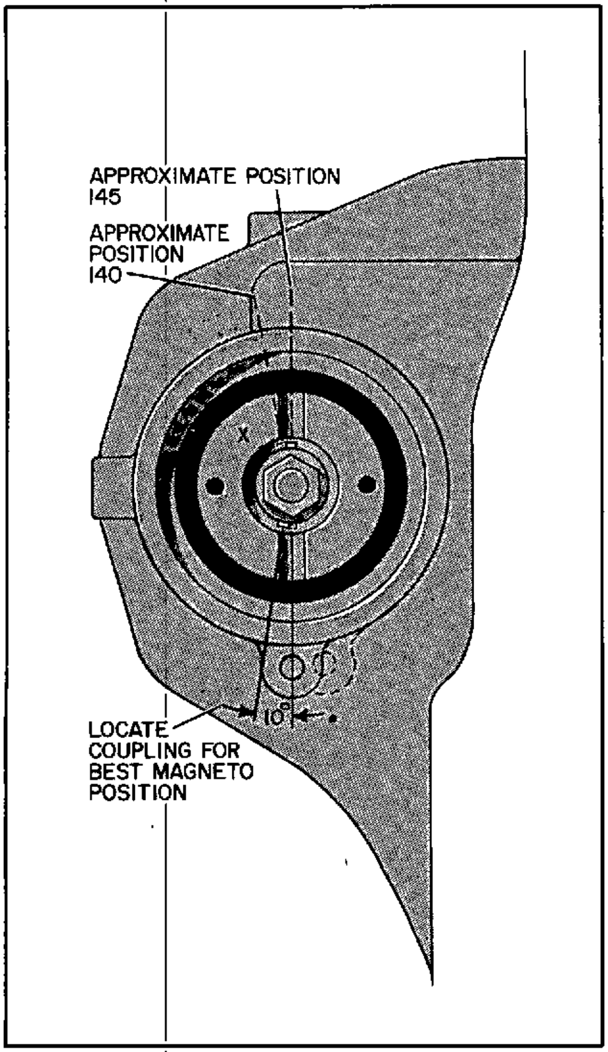
There are two possible methods of correcting the above condition. The first, when the magneto tends to lean in too close to the engine, consists of removing the coupling nut, pulling the slotted coupling from the governor shaft, and relocating the coupling so the other keyway slot engages the key in the governor shaft. This provides 10 degrees variation, or the equivalent of one gear tooth. Only late model engines are equipped with couplings incorporating two keyways. These couplings have an "X" stamped on the face. The second method consists of removing the governor and magneto drive as a unit from the gear cover, rotating the shaft until the coupling will permit magneto installation, and re-meshing the governor and magneto drive gear.

When building up an engine after overhaul, the above difficulties will ordinarily be avoided if care is used to install the governor and magneto drive gear so that the key securing the magneto coupling to the shaft points vertically on the 145 series, and slightly left of vertical on the 140 series.

Final timing is done after the flange coupling screws are almost tight. Here, either a timing light or cellophane may be used to determine the exact location where the points open. If cellophane is used, be extremely careful that a tiny fragment does not tear away and remain between the points. If a timing light is used, ample current will be available from a few flashlight cells. Clip one side of the circuit



HIGH TENSION MAGNETO COVER



MAGNETO COUPLING POSITION

to the breaker points and the other side to the magneto housing for a ground. If excessive current is used for such a timing light, two things may happen. First, by grounding back through the primary coil, which has too much resistance to permit passage of a small current, erroneous results will be obtained. Secondly, passage of current through the primary wires may cause weakening of the magnets.

Whichever method is used to determine point opening, the remaining steps are the same. With the engine in firing position, tap the magneto with the hand enough to rotate it on the mounting flange. With careful tapping, one direction or the other as needed, the exact point opening position is readily determined and the mounting screws may be given their final tension. Replace the breaker cover.

LOW TENSION MAGNETO

Installation Instructions

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

Install the magneto on the engine as described for the high tension magneto. When this is completed, the engine No. 1 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.

Timing Instructions

1. Rotate the engine flywheel until the No. 1 cylinder is in running or advanced spark position on the compression stroke.

2. Remove the timing bolt from the top of the magneto end cap. Turn the magnetic rotor shaft 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 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 cylinder.

4. After the magneto is installed on the engine, connect the transformer lead wires on the end cap terminals. Starting with the No. 1 terminal, 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 counterclockwise rotation as viewed from the terminal end of the magneto.

5. After the engine is running, the timing should be checked with a timing light.

SEMI LOW TENSION MAGNETO

Installation Instructions

The following installation procedure should be used to obtain peak performance of Fairbanks-Morse Type FM-LX semi low tension magnetos.

Rotate the engine crankshaft until the No. 1 engine cylinder is in the advance firing position on the compression stroke. Turn the magneto distributor rotor until the timing mark on the rotor is centered in the timing window which is located on the side of the end cap. The terminal in line with the timing window is designated as No. 1 terminal.

Install the magneto in place on the engine. Timing of the magneto to the engine can be done at this time or after the installation is completed.

Mount the transformer on the engine close to the magneto in any position to fit the installation.

Using No. 14 stranded automotive lighting wire, connect the primary terminal on top of the magneto housing to the positive (+) transformer primary terminal. If desired, a wire may be connected from the magneto housing terminal to a switch or relay to ground the installation. Refer to the semi-low tension wiring schematic.

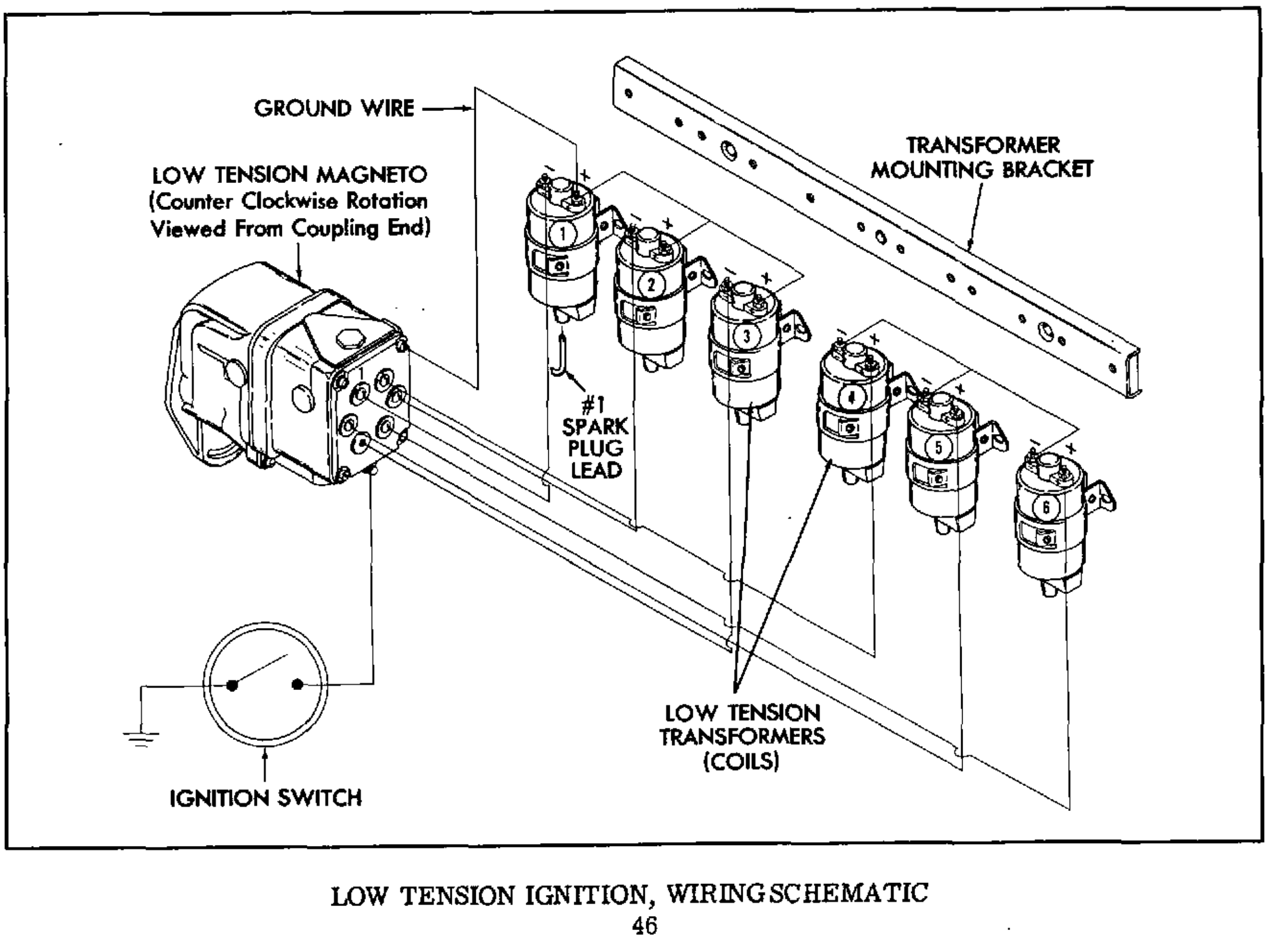
Connect the remaining transformer primary terminal to the magneto end cap screw.

Using 7 mm ignition wire and clips, connect the transformer high voltage tower to the magneto end cap cover center tower.

Beginning with the No. 1 magneto tower, connect the high tension towers to the engine spark plugs in the correct engine firing order in a counterclockwise direction.

Timing Instructions

With the magneto circuit complete between the magneto and the transformer, set the magneto for spark discharge to the No. 1 terminal. This may be checked by removing the cable from the No. 1 magneto tower and inserting a short piece of stiff wire in its place. Be sure the wire is far enough in the terminal



LOW TENSION IGNITION, WIRING SCHEMATIC

to make good contact. Bend the wire to within 1/8 in. of the magneto housing. Turn the magnetic rotor from the impulse coupling end in the direction of normal rotation until a spark occurs between the wire and the housing.

Hold the coupling in the position in which the trip occurred.

Remove the spark plug, or otherwise determine top dead center for the piston in the No. 1 cylinder. Then turn the engine over until this position is reached, being certain that the piston is just at the end of its compression stroke.

Without disturbing the setting of either magneto or engine as determined by the methods above, couple the magneto to the engine in the following manner:

Engage the drive lugs of the impulse coupling with the driving slots of the engine drive member. A slight movement of the engine flywheel may be necessary to secure accurate alignment. Tighten capscrews and nuts securely.

After starting the engine check the timing with a timing light.

MAGNETO MAINTENANCE

High-Tension Magneto

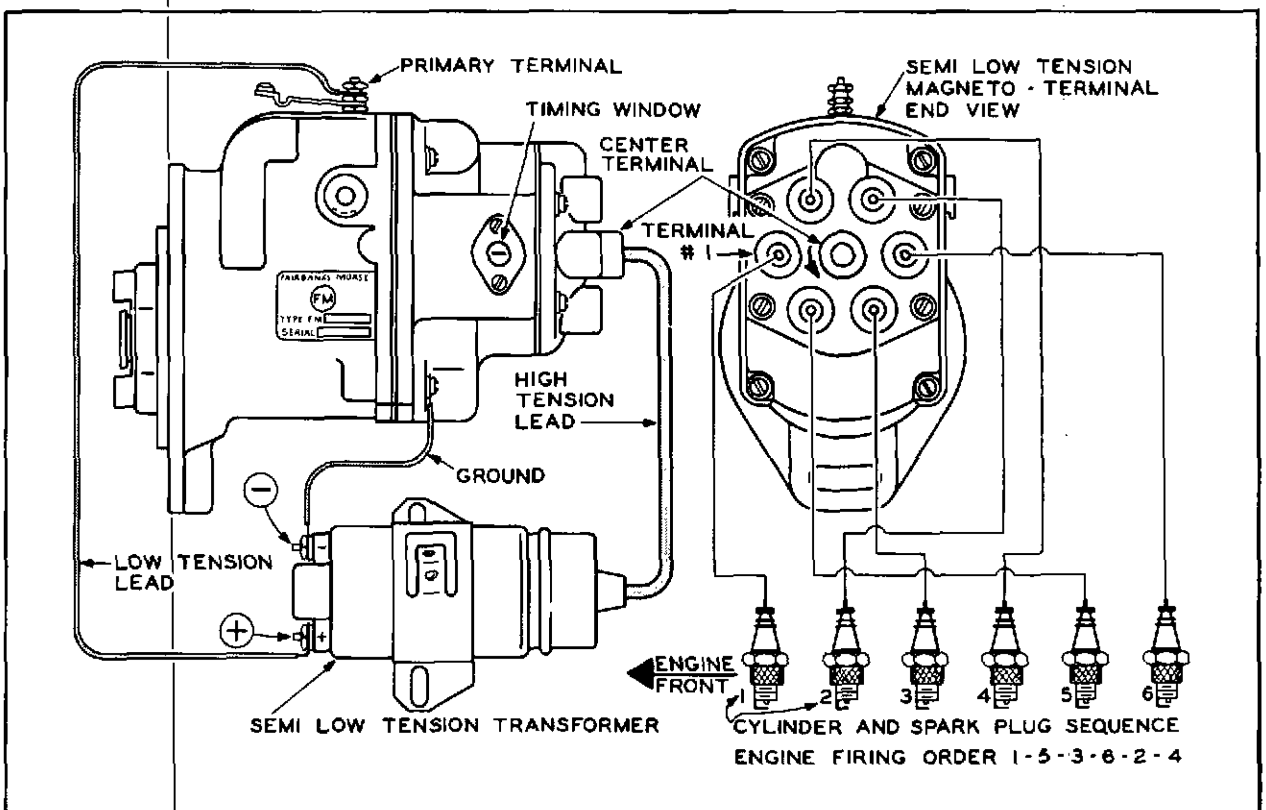
From the maintenance standpoint, most of the principles applying to distributors can be applied to magnetos as well. Cleanliness, freedom from dirt, grease, and burning, and so on, are equally important. Point clearance adjustment to .014" - .016" is accomplished in the same manner as with the distributor.

The cam lubricating felt wick should be relubricated at intervals with a small quantity of SAE 50 or 60 oil. Avoid overlubrication. The magnet rotor ball bearings and the distributor gear oil-less bearings require no lubrication between overhauls.

Low and Semi-Low Tension Magneto

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

Be sure that the felts attached to the cam followers are properly lubricated. If oil appears



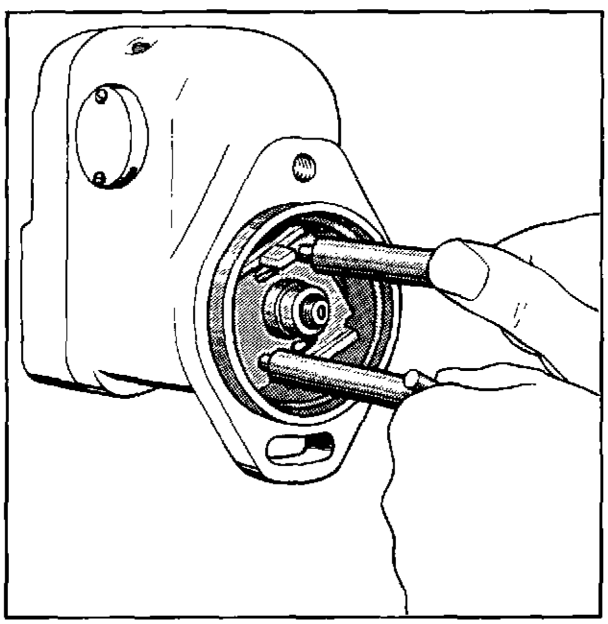
SEMI LOW TENSION IGNITION, WIRING SCHEMATIC on the surface when the felt is squeezed between the fingers, no oil is needed. If the felts are dry, moisten with two or three drops of SAE 50 or 60 lubricating oil. Avoid an excess of oil.

IMPULSE COUPLING-HIGH TENSION MAGNETO

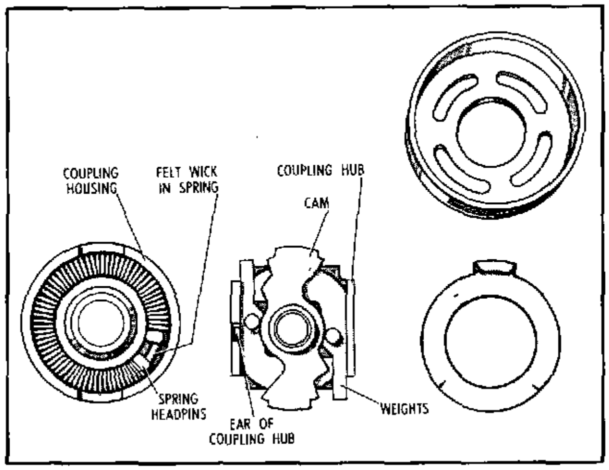
The impulse coupling is engaged only when starting. Its purpose is to snap the magneto rotor over faster than the relatively slow engine cranking speed. In addition, the impulse coupling automatically retards the spark for as many degrees as it has been adjusted to do so. Thus, the spark occurs after the piston has passed top center and kickback is eliminated. The gain in spark intensity resulting from snapping the rotor over makes boosters and auxiliary starting devices unnecessary.

Once the engine starts and attains a speed of about 180 RPM the impulse automatically disengages and the magneto is driven directly from the engine in normal timing.

The coupling employs sliding "L" shaped weights and a curved coil spring which absorbs the impulse shock. The vertical movement of the sliding weights is guided by ears of the impulse member hub which engages the housing into which are assembled the spiral spring and cam. The coupling is released by the arrester plate mounted at the shaft end of the magneto frame. The majority of the parts are designed so that they can be assembled for either clockwise or anti-clockwise rotation.



MAGNETO IMPULSE COUPLING REMOVAL



IMPULSE COUPLING ASSEMBLY

When disassembling the coupling to check parts for wear or damage, use a puller to remove the coupling hub from the magneto shaft. Damaged or worn parts must be replaced. Reassemble pins and spiral spring with felt wick to the coupling housing. Pins must rest against groove in housing channel. With ear of coupling hub facing you, locate weights in elongated hub slots. IMPORTANT: If the coupling is being assembled for clockwise rotation, letter "C" stamped on weights must be face up; for anti-clockwise rotation letter "A" must be face up. Place cam on coupling hub with letter "A" or "C" facing upward as required. Engage ear of coupling hub between pins in housing and mesh the two assemblies.

Installing Coupling on Magneto

To provide accurate setting of the coupling retard, marks spaced 5° apart have been placed adjacent to the upper left-hand slot of the arrester plate. When the heavy center mark lines up with the fastening hole in the magneto housing, the automatic retard or lag angle of coupling is approximately 30° for either clockwise or anti-clockwise rotation.

Turning the arrester plate in a clockwise direction increases the automatic retard or lag angle and turning it in an anti-clockwise direction decreases the automatic retard or lag angle for clockwise magnetos. The opposite is true if the magneto operates in an anti-clockwise rotation. The coupling arrester plate has only two marks indicating coupling rotation when the plate is assembled to a magneto. Graduation marks spaced 5° apart are on the face of the magneto flange. Retards of from 10° to 50° are obtained by moving the arrester plate as outlined above. Fasten the arrester plate to the magneto frame. Adjust plate to required retard and securely fasten in place. Locate impulse member assembly on magneto drive shaft and fasten in place with rotor shaft nut and lock washer. NOTE: Hub of the impulse member assembly is provided with two keyways one for clockwise rotation marked "C", the other for anti-clockwise rotation marked "A". Be sure to select the proper keyway.

DUAL IGNITION VACUUM SPARK RETARD

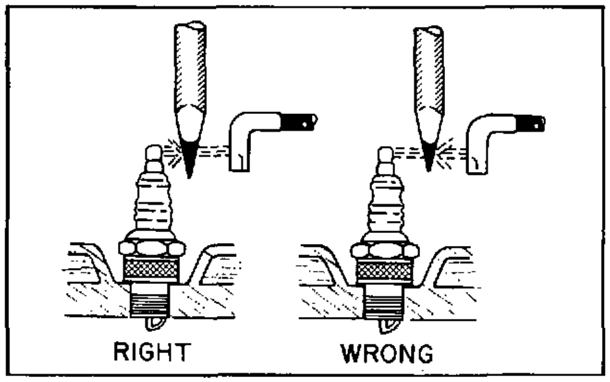
Some dual-ignition engines have been equipped with vacuum controlled spark retarding devices. This retards the spark under idling conditions and makes the manual control unnecessary. Also, the magneto and centrifugally controlled distributor tend to parallel each other without attention from the operator. The diaphragm type vacuum control has been worked out especially for the installation involved. Do not replace it with a vacuum unit intended for conventional automotive applications.

To adjust such an installation, the breaker plate arm should be located on the serrated shaft at such an angle that the magneto is fully retarded with the engine at idling vacuum. Check this by pulling the diaphragm linkage rod back against the internal spring pressure until it comes against the stop. The breaker should be fully retarded.

After snapping the impulse coupling or rotating the magneto backwards in the usual manner for timing, the points should just break in the above-described full retard position with the flywheel set at 4° BTC. The battery ignition distributor is timed on TDC. On a 16-7/8" flywheel 4° is slightly more than 1/2" measured on the flywheel rim. On the 19-3/8" flywheel, 4° is about 5/8" on the flywheel rim. Since the vacuum unit provides about 20° travel of the breaker plate, full advance with the engine at full-load vacuum is about 24°.

IGNITION-ELECTRICAL SYSTEM POLARITY

The basic objective of observing polarity in the ignition system is to deliver negative voltage at the spark plug center electrode. If improper wiring causes positive voltage to be delivered to the plug the voltage required to jump the gap may be increased as much as 45%. Obviously, if the ignition system is not capable of delivering this increased voltage requirement the plug will not fire and fouling or missing will occur.



POLARITY CHECK

Negative voltage at the spark plug center electrode is desirable because the electron flow in the circuit is from negative to positive. Since the center electrode normally runs at a substantially higher temperature than the shell electrode, the space immediately surrounding it tends to ionize more readily and the spark path is, in a sense, better prepared for the final discharge of the spark. Sometimes this fact is explained by the theory that the hotter center electrode is able to discharge a spark better than a colder one in the same way that the heated filament in a radio or TV tube emits electrons only when glowing. Regardless of the theory involved, actual tests show better plug performance with the negative voltage applied to the center electrode.

In instances where spark plug troubles, hard starting, and ignition complaints are under investigation, this is one of the first things to check. If a high voltage voltmeter is available, simply ground the positive lead and momentarily touch the negative lead to the spark plug terminal with the engine running. The voltmeter needle should swing up scale. If it does not, reverse the coil leads so the opposite coil lead comes to the distributor.

Lacking a voltmeter, an ordinary wooden pencil inserted as shown into an air gap drawn between the plug lead and the terminal will show a slight orange flare on the plug slide if the polarity is correct. A flare towards the wire side indicates that the coil wire is incorrect and should be reversed.

Sometimes a cupped appearance of the ground electrode may be a symptom of reversed coil polarity. Very often coils will be marked with positive and negative terminals. A letter from Delco Remy is quoted below and covers the reason for this... "In a negative grounded system, the minus (-) terminal (of the coil) is connected to the distributor whereas in a positive grounded system, the positive (plus) terminal is connected to the distributor. By connecting the coil in this manner the magnetic lines always cut across the primary and secondary windings in the same direction when the lines collapse at the time the contact points break, regardless of the system polarity, to deliver negative voltage at the center electrode of the spark plug through the secondary wire." Thus, if the rule given in the first sentence of this quotation is observed when coils are marked, and, if a check is made when they are not, many stubborn cases of ignition trouble may be improved or eliminated.

Generator Polarity

The Waukesha Motor Company has received frequent inquiries about how to polarize a generator properly after it has been repaired or tested. If the generator is not properly polarized serious damage will result.

The Delco-Remy Company covers this matter in their Training Chart Manual DR-5133E. The following information is taken from that manual. An "A" circuit may be considered a heavy duty circuit and a "B" circuit as a standard circuit.

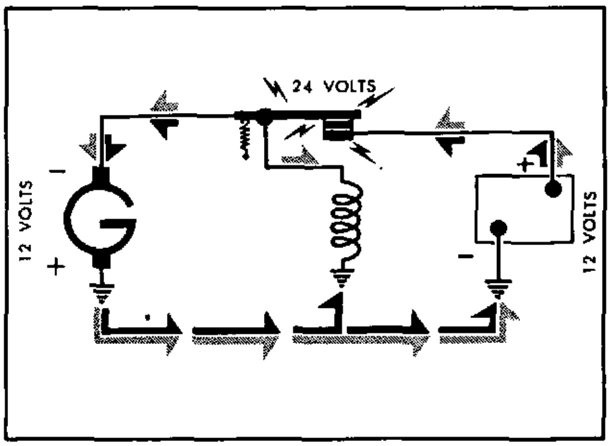
The magnetism of the pole pieces is determined by the field coil's current and its direction of flow. The residual magnetism and the polarity of each pole will remain the same as induced from the magnetism of its field coil the last time current was passed through it. Generators, therefore, will build up voltage that will cause current to flow in either direction depending upon residual magnetism in the poles. When working on electrical units, and when "ringing out" circuits with a small battery and bell, it is possible for current to accidentally flow through the field coils in the wrong direction and the generator will become improperly polarized with respect to the battery in the vehicle. An instantaneous flash is all that is required to create a reverse polarity of the generator.

After a generator has been repaired and installed on a vehicle, or at any time after a generator has been tested, it must be polarized. This is to make sure that it has correct polarity to develop voltage that will cause current to flow in the proper direction to the battery it is to charge. Failure to polarize the generator in agreement with the battery on the vehicle may result in burned cut-out relay points, a run-down battery, and possible serious damage to the generator itself. If the direction of current flow from the generator to the battery is correct, the battery will be charged. However, if the direction of current flow from the generator to the battery is wrong, voltages of the battery and generator will be added together to give approximately double voltage across the contact points of the cut-out relay.

What can happen when the generator is of the opposite polarity from that of the battery is shown in the illustration. Plus and minus symbols are used to indicate the direction of current flow. It is assumed that current will flow from plus to minus.

As the generator builds up in voltage, current will flow in the operating coil of the cut-out relay causing the contact points of the relay to close, completing the circuit between the battery and generator. The battery and generator are now connected together in series and their respective voltages are added together. Approximately double system voltage is now obtained across the contact points and extremely high currents will result from the high voltage short circuited in the battery and generator circuit. This high current produces heat that can weld the contact points together instantly.

However, as the illustration shows, at the instant the points of the relay close, there is battery voltage on the insulated side of the operating coil of the cut-out relay and generator voltage (which will be approximately the same as battery voltage) on the ground side of the operating coil. Since there is little or no difference in voltage between the ends of the coil, the current flow in the coil is insufficient to hold the points of the relay closed and spring pressure may open them.



OPPOSITE POLARITY DIAGRAM

Generator voltage will again close the points and the action is repeated. The points of the relay thus open and close very rapidly with voltage and current present. Eventually heat and arcing from the high current and voltage will cause the points to actually weld together.

Relay points welded together allow the battery and generator to be connected together at all times. Since resistance of the generator is low, the battery has a very low resistance path back to the battery and large discharge current will flow from the battery through the generator and back to the battery. This, in a short time, completely discharges the battery and the large current may develop enough heat to burn the armature of the generator and render it inoperative for future use.

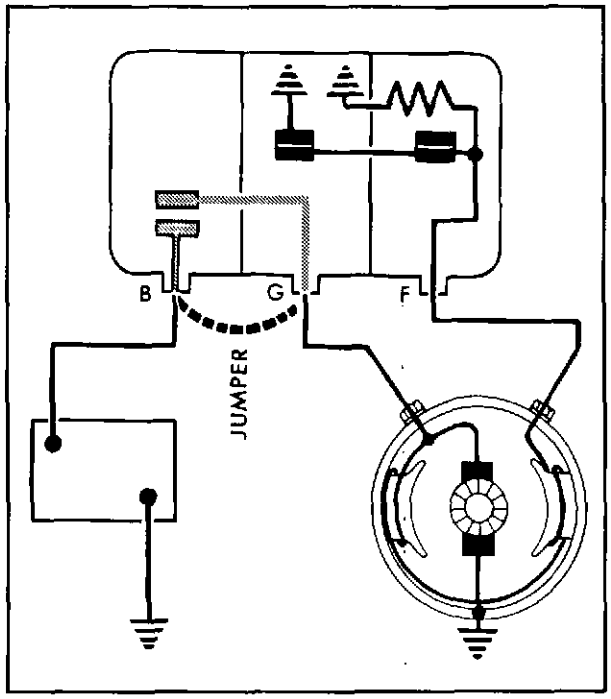
The importance, therefore, of polarity cannot be stressed too highly. Lack of understanding generator polarity and its relationship to the vehicle battery has been responsible for many unnecessary electrical failures in the cut-out relay, battery and generator.

The procedure to follow in correcting generator polarity depends upon the generator regulator wiring circuits--that is, whether the generator field is internally grounded or is grounded through the regulator. Procedures for polarizing "A" and "B" type circuit generators differ.

Polarization of "A" Circuit Generators

Generators using an "A" circuit are polarized by connecting a jumper lead from the insulated or "hot" side of the battery to the armature or "A" terminal of the generator. The battery, generator and regulator grounds must be connected. On the vehicle this is done through the frame. This causes current to flow in the normal direction through the field coils which will correctly polarize the generator's pole shoes. A touch of the jumper lead is all that is required and a flash or arc will be noted when the lead is removed.

Insulating the brushes is recommended with all 24 or 32 volt generators of circuit "A" construction during polarizing. If the brushes are not insulated, low resistance of the generator armature will cause an extremely high discharge current through the armature when the jumper lead is connected between the battery and generator terminal. This can result in a badly burned armature. With the brushes insulated, only field current will flow.



POLARIZATION OF "A" CIRCUIT (HEAVY DUTY) GENERATORS

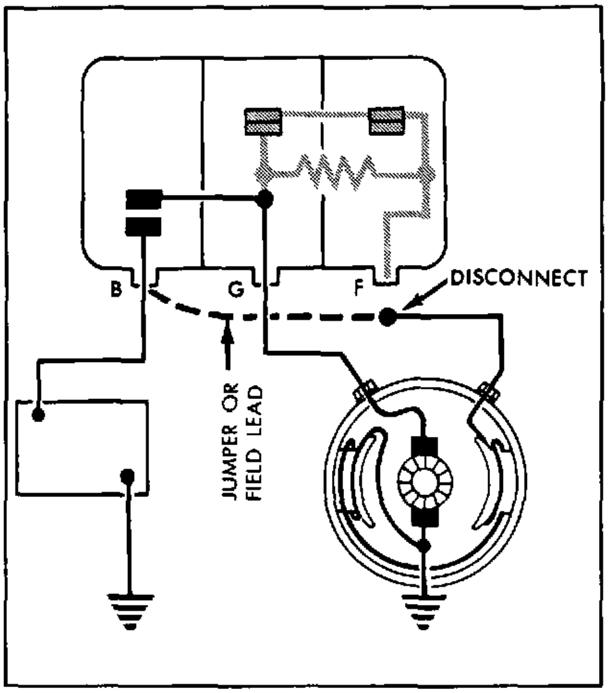
An easily accessible place to polarize the generator when it is located on a vehicle is at the regulator. A short jumper lead between the battery and armature terminals of the regulator is all that is required.

Polarization of "B" Circuit Generators

Generators designed for a "B" circuit are polarized by disconnecting the field lead from the regulator and momentarily flashing this lead to the battery terminal of the regulator. Battery and generator ground circuits must be connected together. Current will flow through the field coils in the proper direction to correctly polarize the generator's pole pieces. A touch of the field lead is all that is required and a flash or arc will be noted when the lead is removed.

It is important to remove the field lead from the regulator. Failure to do so will result in burned regulator points if a jumper lead is used between the battery and field terminals of the regulator. A very low resistance circuit from the battery through the points to the generator armature to ground and back to the battery would carry high current if the connection were not broken.

The importance of generator polarity cannot be stressed too greatly. For proper polarization,



POLARIZATION OF "B" CIRCUIT
(STANDARD) GENERATORS

the rule should be to pass current through the field coils in a direction that will have the ground side of the coils connected to the ground side of the vehicle battery.

FUELS

Fuels for internal combustion engines are composed principally of hydrogen and carbon in such proportions that in the presence of a suitable proportion of oxygen they will burn and liberate heat energy. This heat energy is transformed into mechanical energy. The heat value of a given fuel is a measure of the heat energy which can be liberated with perfect combustion, and is measured in BTU (British Thermal Units). One BTU is the heat required to raise the temperature of one pound of water one degree Fahrenheit. Therefore a thousand BTU, which is a common heat value assigned to natural gas, will raise the temperature of 1,000 pounds of water one degree Fahrenheit, or 100 lbs. of water ten degrees Fahrenheit. Most fuels used to power internal combustion engines are petroleum derivatives, and are classified as either gaseous or liquid by their physical properties. Gasoline is a liquid fuel that must be atomized (carbureted) before it can be burned in an internal combustion engine. Butane and propane are also liquid fuels when stored under pressure. At most atmospheric pressures and temperatures they become a gas. Natural gas, as the name implies, is a gaseous fuel. Butane gas, and propane gas are often referred to as LPG, or liquified petroleum gas.

One of the most important characteristics from the engine builder's and engine user's standpoint is the anti-knock value (octane rating) of the fuel, although other physical properties are important from a practical standpoint. Volatility affects easy starting. Gum and carbon content will affect the valve and ring mechanism. Sulphur will affect some bearing materials.

Dealers in LPG control the volatility with the season so that any reputable brand will give satisfactory performance in Waukesha gas engines. The octane rating, which is a measure of the anti-knock value, must be higher with high compression ratios, and may be lower with low compression ratios. Be sure to use a fuel that does not detonate under load in your engine. The proportion of propane to butane is very important. A minimum of 60% propane-40% butane is recommended for most applications. Do not take chances. Insist that your fuel supplier certify the fuel proportions.

An engine that is designed to operate on natural gas, butane or propane gas has gas type cylinder heads and cannot be operated on low octane gasoline. However, in an emergency, an engine with a gas type head can be operated on gasoline of 85 octane or better.

GASOLINE CARBURETORS

The 140-145 series engines have been built with a considerable variation in carburetor details to provide for specialized operating conditions. Therefore, carburetors should not be interchanged or replaced indiscriminately. Remember, a few thousandths of an inch in jet size can make the difference between normal engine operation and burned valves, ring sticking, poor economy, and so on. The carburetors are identified by stamped tags riveted to the top of the float bowl cover. When ordering replacement carburetors, always give all information on the tag plus the engine serial number and specification number.

The carburetors generally used on these engines are of Zenith manufacture in three basic types...Of these types, the 63AW-16, 63AW-14, and 29AW-16, and IN167SJ are typical, although a number of variations of them, with respect to venturi and jet sizes, installation details, and so on, will be found.

Carburetor service consists largely of maintaining the fuel supply in a clean condition, making proper adjustments at rare intervals, and leaving the carburetor 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 operations, the carburetor manufacturer's special bulletin for the unit at hand should be followed without deviation.

Gasoline Carburetor Adjustments

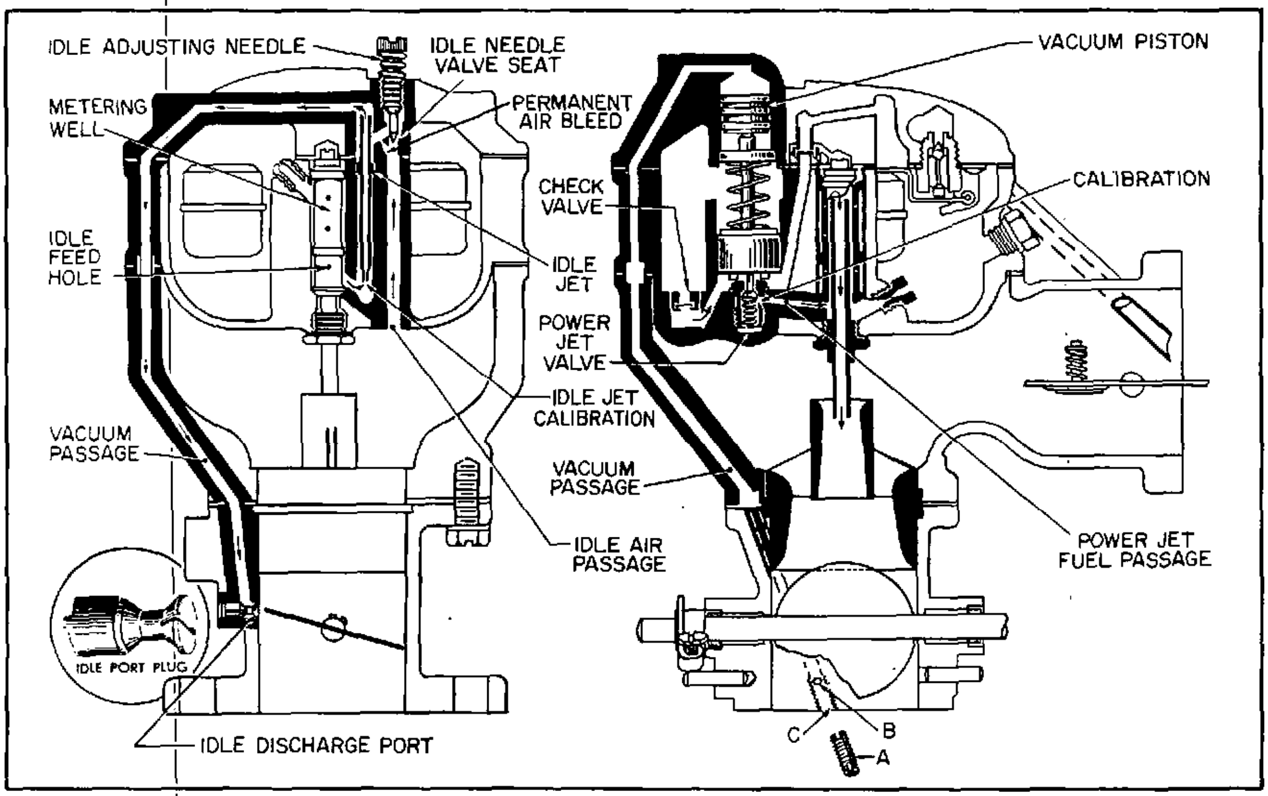
The throttle stop screw should be screwed in (clockwise) against the stop pin to hold the throttle just slightly open. Adjust the throttle stop screw to obtain the desired idling speed of the engine.

Adjust the idling adjusting screw to obtain smooth idling when engine has become thoroughly warmed up. Turning the screw in (clockwise) cuts off air, making the idling mixture richer; while turning it out (anti-clockwise) admits more air, making the mixture leaner.

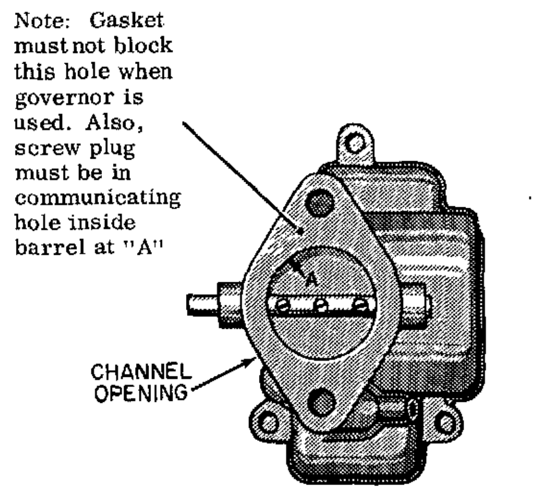
If it becomes necessary to turn the screw in to less than 1/2 turn off the seat to obtain good idling of the engine, it would indicate either an air leak or a restriction in the flow of fuel for idling. Look for air leaks at the manifold flange; at carburetor throttle body to intake gasket, and at carburetor bowl to cover gasket, due to loosened assembly screws or damaged gaskets. A badly worn throttle shaft will produce sufficient air leakage to affect the idling mixture.

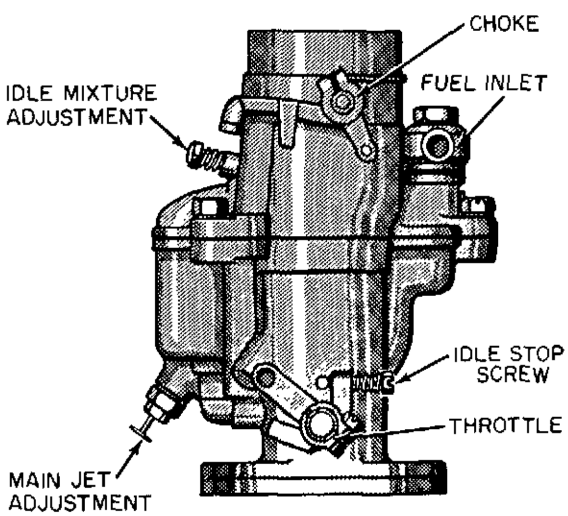
Dirt or other foreign matter in the idling jet calibration will restrict the flow of fuel for idling and affect the mixture. If the idling jet becomes completely clogged, it will be impossible to run the engine at idling speed regardless of adjustment of the idling adjustment screw.

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

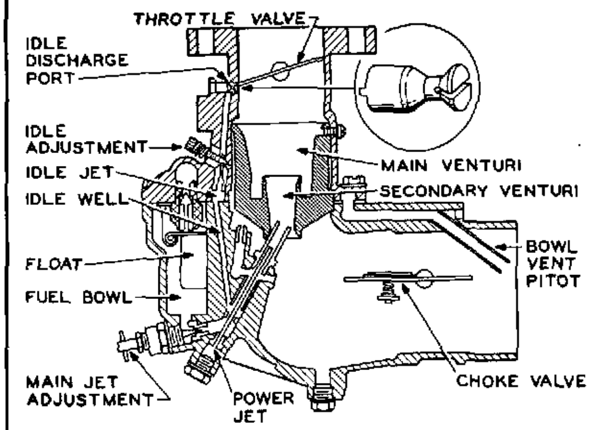


DOWNDRAFT GASOLINE CARBURETOR, ZENITH TYPE 29-AW





DOWNDRAFT GASOLINE CARBURETOR
ZENITH TYPE IN167SJ



UPDRAFT GASOLINE CARBURETOR
ZENITH TYPE 63-AW

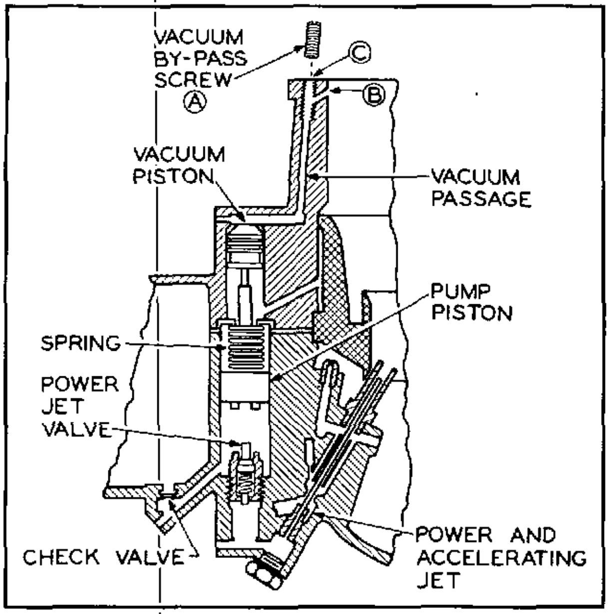
Accelerating Power Jet

When a speed governor is used it is installed between the carburetor and the intake manifold. A vehicle so equipped is usually operated with the carburetor throttle held wide open relying on the governor throttle plate to regulate the speed. It is necessary in this case to use the suction in the intake manifold rather than the suction between the carburetor and the governor butterfly. Generally, in all applications where speed control is through the governor butterfly, the vacuum by-pass screw should be installed in the carburetor as shown.

The restriction caused by the partially closed governor butterfly will cause a higher suction to exist in the manifold than that which exists below the throttle valve in the carburetor. For example: When a vehicle is operated at a speed of 50 miles per hour with the carburetor throttle held wide open and the engine speed *is being regulated by the governor butterfly* there will be approximately 10" of mercury suction in the intake manifold and only about 4" of mercury suction in the carburetor. Under these conditions the power jet will be in operation because the low suction in the carburetor is not strong enough to offset the tension of the vacuum piston assembly spring.

The power jet system is so arranged that the passages to the vacuum cylinder can be by-passed around the governor butterfly thus using the suction in the intake manifold to control the power jet system under all operating conditions. This is accomplished by installing the vacuum passage by-pass screw (A) in the threaded end of the vacuum passage in the flange of the carburetor. The screw will shut off the short passage (B) from the vacuum passage into the throttle body bore but being hollow will leave the vertical vacuum passage (C) open to the face of the flange.

Speed governors are designed with a vacuum passage in the governor butterfly body that will line up with the passage in the carbu*retor flange. A flange gasket must be used* when making the carburetor-governor installation which is cut out to permit connecting the passage in the carburetor flange to that in the governor butterfly.



ACCELERATING PUMP SYSTEM
(63-AW CARBURETOR SHOWN)

GAS-GASOLINE COMBINATION CARBURETOR

The Ensign Type "KGN1" is a combination gasoline and dry gas (butane or natural gas) carburetor for updraft use only.

A choke automatically produces the correct gas mixture when set in starting position, which will start the engine at slow cranking speeds.

The key to the "combination" operation of the "KGN1" is the gasoline shut-off and float lock "W" which, when set for operation on gas, as illustrated, shuts off the gasoline supply at valve "U" and locks float "S" in a rigid position to protect it from destructive vibration in the dry float bowl.

Operation

To start on gas, choke disc "F" is closed; valve lever "M" closing main orifice "N". Air is drawn in through orifice "G" in disc "F" and gas through orifice "L". Starting gas mixture is adjusted at "H" which should then be locked in position as gas to air ratio will remain constant. Choke lever "J" is used in changing from starting to running position. Load adjustment "K" regulates the passage of gas through orifice "N". When once properly adjusted, "K" should be locked in position as gas to air ratio will remain constant. Gas inlet "L" is connected to gas outlet of the regulator. Balance tube connecting "E" on the carburetor to the fuel regulator compensates for increased air cleaner resistance thereby maintaining a constant mixture in the carburetor. "R" is the connection for the idle tube from the regulator.

To change from gas to gasoline operation: Gas supply is shut off and float control "W" is turned to unlock float valve "U" which allows gasoline to fill the float bowl as controlled by float "S". When starting on gasoline, the carburetor is choked in the conventional manner by choke lever "J". "P" is the gasoline idle fuel adjustment screw. "C" is the gasoline load adjustment screw which controls flow of fuel through orifice "Y". Gasoline enters the venturi at nozzle "Q".

In a thorough check-up on this carburetor it should be thoroughly cleaned making sure all the bleeds are open before reassembling. The throttle bearing bushings and shaft should be replaced when worn excessively.

Inspect the float valve assembly, float lever pivot, and the float assembly. If the float has too much side play, indicating worn pivot bearing, replace the float assembly. When the float valve leaks no attempt to reseat it should be made; install a new valve. In putting a new float assembly in the bowl see that the letters "TOP" are on top. For gravity fuel feed the top of the floats should be at the same height and parallel to the upper mark in the fuel bowl. For pressure type fuel feed the top of the floats should be at the same height and parallel to the lower line in the bowl. To adjust the float bend the lever. Check by holding the bowl upside down.

The special fuel bowl referred to above is the same as the standard type "K" fuel bowl except for the float control device attached. This device in one of its positions provides for closing the float valve and holding the float off the bottom of the bowl thereby preventing wear on the floats and float valve when gasoline is not being used for fuel. The other position with screw screwed all the way out counterclockwise allows the float and float valve to operate normally. When the screw is screwed all the way out the head of the screw in the bowl contacts a seat to prevent fuel leaking around the threads.

New gaskets should be installed, making sure the air horn gasket is installed so it will clear properly between the balance passage in the throttle tube, and the annulus in the air horn casting.

In the proper working of the starting feature it is necessary that the choke disc move exactly 90° from the wide open position and at the same time move the cam lever so that the gas nozzle passage and small hole in the air horn are covered by the large and small end of the lever respectively. The purpose of this lever motion is to stop any flow of gas through these holes which means that these two surfaces need be flat and smooth.

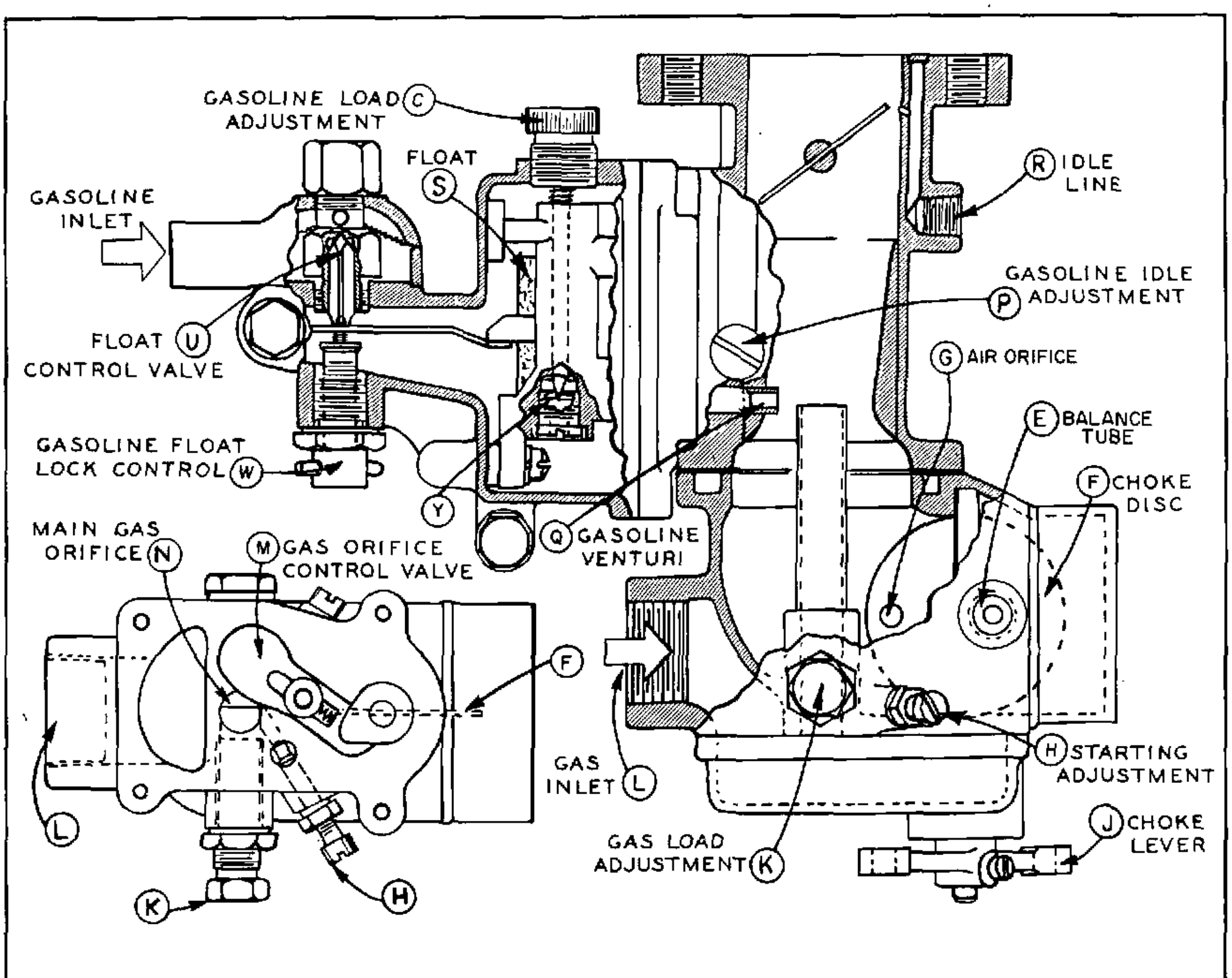
The wide open and choke positions of the disc are controlled by the choke lever contact with positive stops on the air horn cover. Any error in the choke position which is straight across the bore, must be corrected otherwise hard starting will result.

In reconditioning a carburetor for use on an engine other than the one it was supplied for, check the size of the venturi. If it is not of the correct size for the engine it is to be used on, replace with the correct one. Do not use a carburetor larger than 2" on either the 145 or 140 engines.

GAS CARBURETOR

The Ensign Model "KG1" gas carburetor is designed to enable internal combustion engines operating on straight gas, natural gas, manufactured gas and LP gas to be started directly on gas without any form of priming. It is equipped with the patented Ensign easy starting device. This consists of a unique type of choke which automatically produces the correct gas-air mixture and when set in "starting position" permits easy starting at slow engine speeds.

Extensive testing and experimentation has indicated different batches of the same type fuel (also different types LPG vs. natural gas) may vary sufficiently in heating value to require starting mixture readjustment and also wide variations in air temperature can affect the mixture sufficiently to require readjusting.



GAS - GASOLINE COMBINATION CARBURETOR (ENSIGN KGN1)

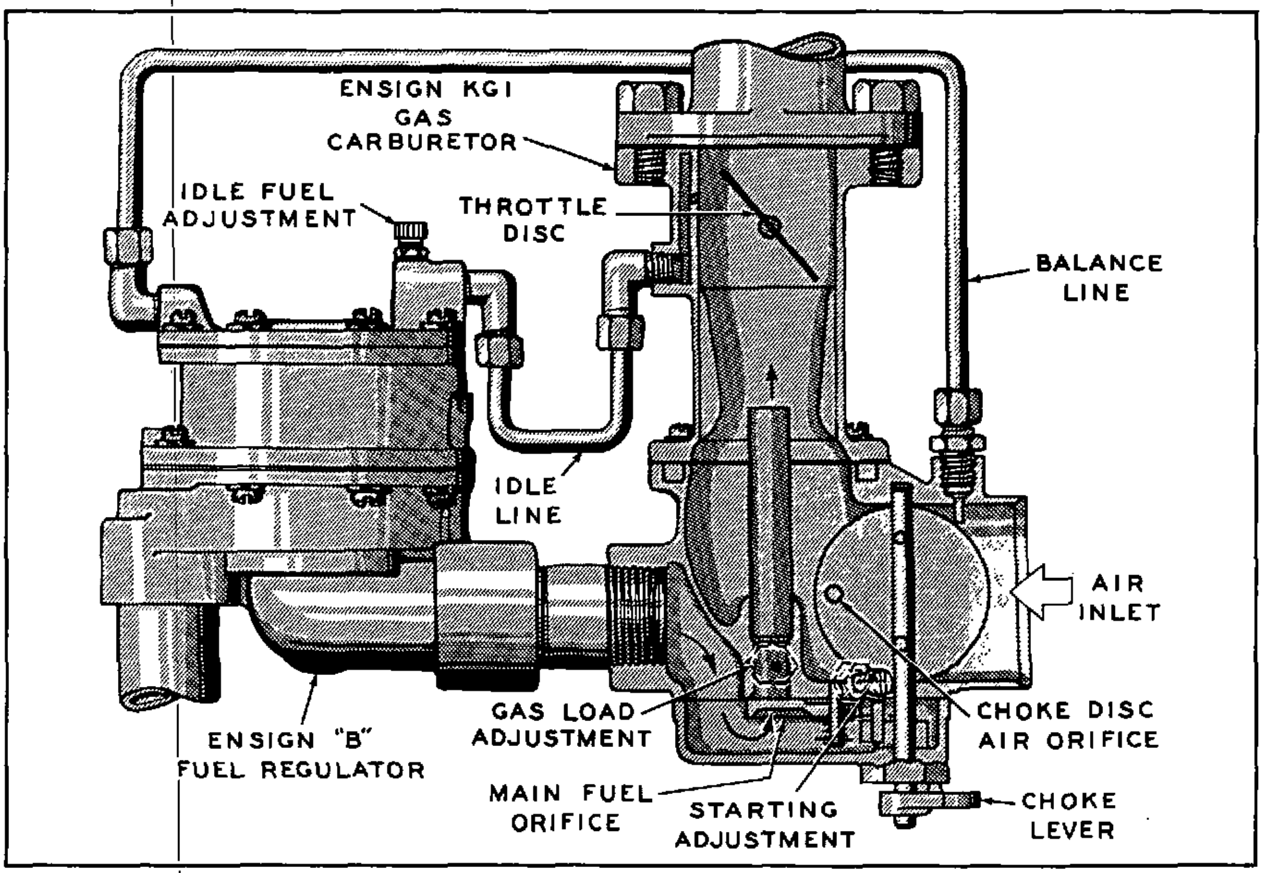
Principle of Operation

The Ensign patented easy starting feature provides a separate set of gas air orifices for starting which produces a slightly richer mixture for this purpose. The starting mechanism is not intended to function in an intermediate position. It is strictly a two position choke control either wide open or fully closed. When the choke disc is closed a valve closes off the main gas supply to the venturi. Air for starting is drawn through the orifice in the choke disc and gas for starting is taken through a small orifice adjusted by the starting adjusting screw which is locked when best position is found. The choke lever is used in changing from starting to running position.

Gas load adjustment regulates the passage of gas through main fuel orifice. The gas inlet is connected to the gas outlet of the Ensign Fuel Regulator or LP-Gas vaporizer-regulating unit. The balance line connection communicates air horn depression to the Ensign Fuel Regulator thereby automatically balancing the system against variations in air cleaner and other air entrance losses.

Initial Adjustment

1. Throttle should be at least one-half open while starting and adjusting starting mixture.
2. Set starting adjustment 1-1/4 turns open. Good results can be obtained by turning the adjusting screw while cranking in order to seek the proper mixture. Turning the adjusting screw clockwise leans the mixture and turning it counter-clockwise richens the mixture.
3. Set load adjustment 4 turns open.
4. Set idle adjustment 1-1/2 turns open.
5. Close the choke.
6. Crank the engine.
7. After the engine starts and with the choke still closed, adjust the starting mixture for maximum engine speed and then enrich slightly until engine speed just begins to drop. Tighten lock nut.



KG1 GAS CARBURETOR "B" REGULATOR HOOK UP

8. Open choke and close throttle simultaneously. The choke has no intermediate positions; it is either open or closed.

9. Make temporary adjustment of load screw for highest r.p.m. while holding throttle at about two-thirds rated speed (1400 r.p.m.).

10. With engine warm, set idle stop screw for correct idle speed and adjust idle screw for best idle.

Service Hints

1. Readjustment of the starting mixture is essential when changing from LPG to natural gas or vice-versa.

2. A new supply of the same type of fuel may require readjustment if the heating value varies considerably.

3. Wide ambient temperature variations may necessitate starting mixture readjustment even with the same fuel.

To Set Load Screw Without Load

A reasonable adjustment can be made when it is not possible to load the engine, as follows: Disconnect economizer and plug intake manifold connection. Bring engine to a high speed. Adjust load screw to maximum r.p.m., then carefully screw in to the point where the r.p.m. just begins to fall. Set screw to the midpoint of these two positions and tighten locknut. The idle adjustment must be carefully made before using this method as it influences the mixture under this engine condition.

To Set Load Screw Without Analyzer

Open throttle wide and load engine to obtain an engine speed of 1/2 to maximum operating speed. (If engine has a governor, keep speed below any governor action). Find the two load screw settings where the engine speed begins to drop, when going richer and leaner, and set at the midpoint. Recheck idle.

To Set Load Screw With Analyzer

1. Open throttle wide and load engine to obtain an engine speed of from one-half to maximum operating speed (if engine has a governor, keep speed below any governor action). Set load screw to give a reading of 12.8 on a gasoline scale or 14.3 on an analyzer with LPG scale.

2. To check the part throttle analyzer reading, a vacuum gauge should be used. With engine loaded, set the throttle to give a manifold vacuum of 10 to 13 Hg at similar speed to the previous check. The analyzer should then read 13.8 to 14.5 gasoline scale or 14.9 to 15.5 LPG scale.

3. Recheck idle adjustment 12 to 12.8 on gasoline scale or 13.5 to 14.2 on LPG scale, or best idle.

NOTE: The KG1 Gas Carburetor information has been compiled from Ensign Form Sheet #7060C, dated Sept. 1957 with approved deviations submitted by Waukesha Motor Company.

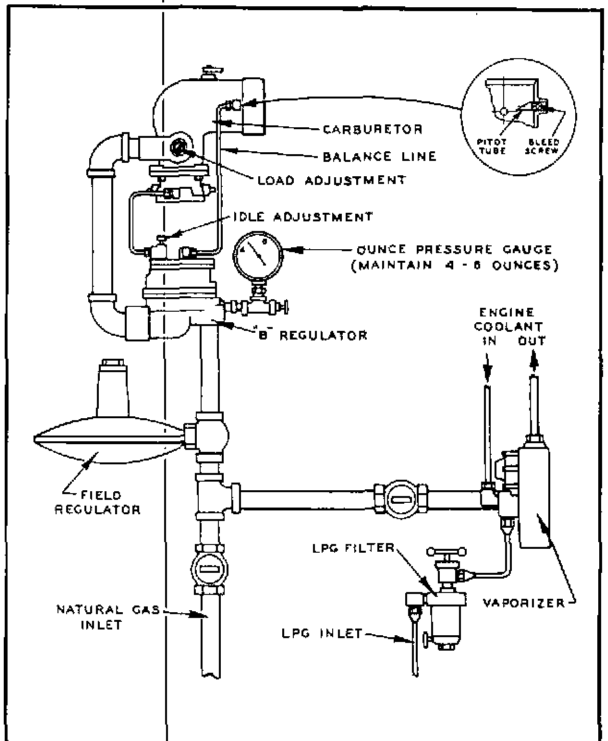
GASEOUS FUEL OPERATION

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 illustration will show that a gas fuel system consists of a primary or "field" regulator, a secondary or "B" regulator, 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 and secondary 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. In addition, it is extremely important to use a fuel with an adequate anti-knock characteristic for the engine involved.

NATURAL GAS FUEL SYSTEMS

Natural gas, whenever available, is an ideal fuel for stationary type internal combustion engines. It is inexpensive and easily obtainable in many areas throughout the United States. For this reason it is very practical to operate these engines on natural gas when the engines are installed in areas where natural gas is readily available.

The desirability of natural gas is not only enhanced by its low cost as a fuel but also by the minimum of carbon produced and the elimination of crankcase dilution. These factors



COMBINATION NATURAL GAS
LPG FUEL SYSTEM

considerably reduce the cost of engine repairs as well as permitting much longer periods of time to elapse between engine overhauls and general maintenance. When natural gas is used as a fuel, operators have found the crankcase lubricating oil can be used considerably longer under like conditions. Due to the elimination of crankcase dilution, however, the oil may have a tendency to increase in viscosity if used too long.

Natural gas is commonly referred to as a "dry" gas to differentiate between it and liquid fuels. Natural gas has a higher octane rating.

The heat and energy of a gas is measured in terms of its B.T.U. value. Consumption and horse power is based on 1000 B.T.U. gas for these engines. Efficiency with natural gas increases with increased engine cylinder compression which makes it particularly adaptable to engines with high compression ratios.

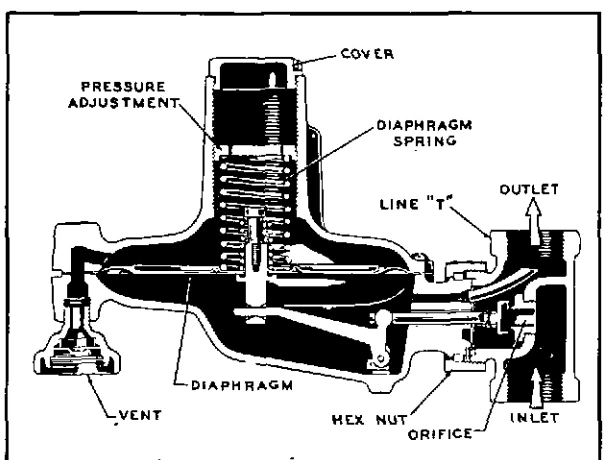
Field Regulators (Primary)

Field regulators noted in this discussion are manufactured by the Fisher Governor Company, Marshalltown, Iowa. The purpose of the field regulator is to reduce the gas supply line pressure to a value low enough to be easily controlled by the sensitive "B" regulator. The tabulation shows the Fisher Series 730 regulators which will control pressures up to 150 psi. It is recommended, however, that the maximum and minimum inlet pressures listed in the tabulation be definitely maintained. Failure to supply gas within the recommended pressure range will result in insufficient gas volume for optimum performance and field experience has proven that damage to the regulator is a possibility. If the line pressure is greater than that recommended for the inlet to the Fisher 730 Series, a Fisher Model 630 regulator can be used. This Model will handle pressures up to 1500 psi and if the situation warrants the control of higher pressure, the regulator can be converted further.

	Fisher Regulator Model	Regulator Pipe Size	Diaphragm Spring Number	Orifice Size	Inlet Pressure Range PSI	Re'qd. Outlet Pressure Ounces
140	733C-1	1-1/4"	1B6539	7/16"	20-50	4-6
145	730-B-32	2"	B-194	3/4"	20-50	4-6

The Fisher 730 series field regulators will gradually be superseded by the Fisher Model S-202 in many production Waukesha gas engines. Both faster response and more convenient mounting make this desirable in most applications, and in the case of generators where accurate speed control is imperative the Model S-202 will be specified immediately.

The S-202 regulator body may be rotated 360 degrees around the Tee connection without disturbing its operating characteristics. An aircraft type flange union is used and only



FISHER FIELD REGULATOR

two bolts need be loosened to rotate the regulator body. In addition, the aluminum regulator body, valve stem, and orifice reduce weight and add ease of handling.

Outlet pressures from the field regulator regardless of engine size, speed, or load must be 4 to 6 ounces pressure measured at the inlet to the "B" regulator. The outlet pressure is determined by the diaphragm spring in the regulator and its adjustment. The correct springs are listed in the tabulation and the pressure is adjusted by removing the large hex-head cover screw at the top of the regulator and turning the screw within to the right or left to establish the recommended pressure at the inlet to the "B" regulator. Remember, an ounce pressure gauge is to be used at the "B" regulator.

Sufficient volume of gas for maximum performance is determined by the orifice size in the "T" connection to the regulator. Orifice sizes increase as engine size increases and failure to provide adequate gas volume will not only impair performance but will cause damage because of lean mixtures. Orifices are easily changed by loosening the large nut between the "T" connection and the regulator body which permits the body to be removed to provide access to the orifice. The orifice is removed with a socket wrench and the correct size is easily reinstalled.

In the illustration of the field regulator note that the vent assembly is mounted in the downward position. The vent permits atmospheric pressure to affect movement of the regulator diaphragm and must be installed in the position shown to provide a weather proof opening. This unit may be installed outside of the building or wherever atmospheric pressure is most stable. This vent is used only on the 733C-1 series regulators in that the 730-B-32 series and the S-200 incorporate a combination stabilizer and vent within the regulator body.

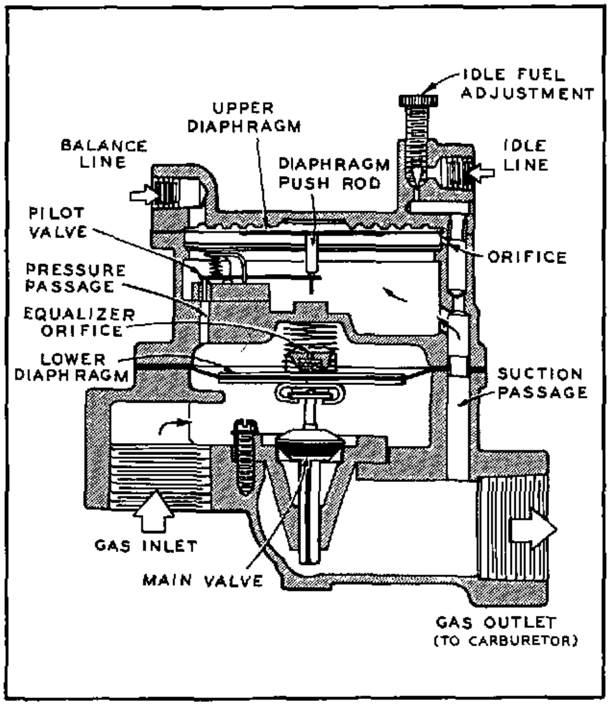
Low Pressure "B" Regulators

Low pressure regulators presently used on production engines are manufactured by the *Ensign Carburetor Company*. The regulator and carburetor may be considered as a unit in that the regulator serves a function similar to the float valve in the fuel bowl of a gasoline carburetor. The regulator must accurately control low pressure gas fuel according to the needs of the engine. The name "B" which is generally used in reference to the low pressure regulator is a model designation given by the manufacturer.

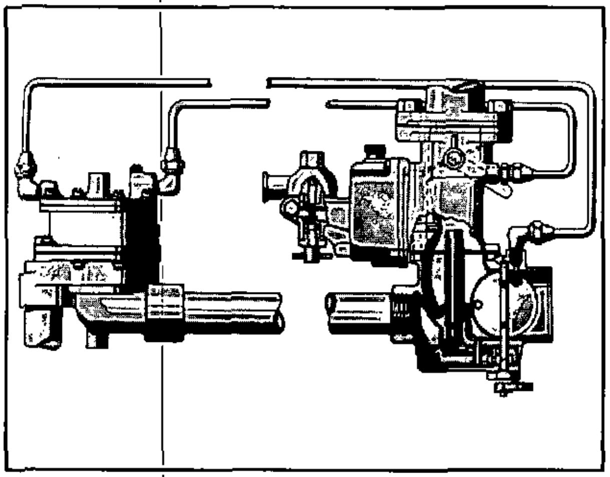
Engine Model	Ensign Model	Ensign Number	WMCO Number	Pipe Size	Inlet Pressure - Oz.
140	B	5069	50573	1"	4-6
145	B	5121	50582	2"	4-6

These low pressure regulators are specified for engines according to size and the corresponding fuel requirements. The chart points out the particular regulator model required and the inlet and outlet pipe size to be used. Note also that the inlet pressure to the regulator must be 4-6 ounces for all engines and regulators.

Low pressure regulators are equipped with an idle adjustment consisting of a gas line between the regulator and the carburetor and a screw type adjustment at the regulator. Idle adjustment under operating conditions is covered in the fuel system adjustment section. Another similar line called a balance line is also used to equalize the atmospheric pressure between the regulator and the carburetor air horn and compensate for air cleaner restriction. It is important that both these lines be a minimum 3/16 O.D. copper tubing. Failure to follow this recommendation will not permit sufficient movement of the regulator diaphragm and will result in erratic engine operation.



ENSIGN LOW PRESSURE "B" REGULATOR



ENSIGN "B" REGULATOR AND TYPE KGN1 CARBURETOR

"B" Regulator Operation

With the engine at rest the main valve is closed and gas supply through the inlet exerts a pressure below the lower diaphragm and equally above this diaphragm through equalizer orifice. Atmospheric pressure through the carburetor air intake is exerted on the upper side of the upper diaphragm through opening the balance line and on the under side of upper diaphragm through suction orifice.. The "B" regulator is connected to the carburetor air intake by a small tube known as the "balance tube connection." This connection compensates for increased air cleaner resistance, thereby maintaining a constant mixture in the carburetor.

When the engine is started, suction from the carburetor is applied to the regulator at the gas inlet and communicated by way of the suction passage and the orifice to the under side of the upper diaphragm which is pulled down. As this diaphragm moves down, the push-rod opens a pilot valve. The reduction in pressure of gas over the lower diaphragm is bled through pressure passage which permits the lower diaphragm to lift and to open the main valve which in turn passes gas through to the carburetor.

At idle engine speed the carburetor throttle is nearly closed and therefore little suction is applied at the gas outlet. The differential type regulator functions accurately at slow idle speed by means of a patented "idle fuel connection system." This system applies suction from the engine side of the carburetor throttle through the idle connection tube directly to the under side of upper diaphragm. Fuel for the engine at idle, is controlled therefore, by the idle fuel adjustment. Part of the idle fuel is supplied directly through the idle tube.

The fuel regulator should be protected from all foreign matter which might injure the regulator's valve seat.

Line Sizes

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 high and low pressure regulators must not be reduced in size from that provided for at the regulator inlet and outlet.

FUEL SYSTEM

Adjustments-Natural Gas

1. Install vacuum gauge in manifold between carburetor and the engine.

2. With the engine stopped, adjust the gas pressure to the inlet of the "B" regulator to read 4 to 6 ounces.

3. On initial start-up back out the carburetor load adjustment approximately 5 turns and the regulator idle adjustment out approximately 3-1/2 turns.

4. Start engine and allow it to warm up ten to fifteen minutes.

5. Open throttle 1/3 and apply a partial load to the engine. Loosen the load adjustment lock nut and turn the screw in or out for highest vacuum reading. Check the adjustment by turning the screw out (rich position) until the reading drops and then in for highest vacuum reading. A slightly rich setting is preferred. Tighten the lock nut.

6. Operate the engine without load at low idle speed (approximately 500 rpm) and adjust the idle screw on the "B" regulator the same as the load adjustment above.

7. Operate the engine throughout its speed and load range and note the gas pressure at the inlet to the "B" regulator. The pressure must be 4 to 6 ounces at all times. If it is low on acceleration or load the engine is operating on a dangerously lean mixture and the following should be checked.

(a) Make sure the "B" regulator is of ample capacity as stated earlier.

(b) Check the gas supply line sizes. They must all be the same size from the inlet to the field regulator to the carburetor.

(c) The field regulator must be the correct model, have the correct spring and orifice, be adjusted properly, and be installed as close to the "B" regulator as possible.

(d) In applications where a volume tank is used the pressure at the inlet to the tank must be the same throughout the speed and load range as the pressure at the "B" regulator.

LPG FUEL SYSTEMS

Operation of Waukesha engines on LPG (liquefied 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. LPG usually consists of a mixture of propane and butane. In some areas one or the other may be sold separately but for Waukesha engines 100% propane is recommended and a mixture of 60% propane and 40% butane is the minimum for safe operation.

A complete LPG fuel system consists of a high pressure liquid regulator, a vaporizer, and a low pressure gas regulator. All of these components are usually contained in one unit with the addition of idle and balance lines to the carburetor. In some applications the vaporizer is a separate component and the complete system must then include a field regulator and a "B" regulator as in the natural gas system.

Vaporizers

The vaporizer-regulator combinations frequently used on 140-145 engines are given the Ensign model designation "NS". These units make up a complete LPG fuel system in that they provide high pressure regulation, vaporization of the liquid, and final low pressure regulation of the gas fuel for efficient mixing with air in the carburetor. 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.

Engine Model	Ensign Vaporizer Regulator Model	WMCO Number	Ensign Vaporizer Model	WMCO Number
140	NS	154409	M*	118652
145	NS	154409	HD*	116886

*Require use of "B" and field regulator in system.

The balance and idle lines used with the combination vaporizer-regulator units must be large enough in diameter to provide adequate movement of the regulator diaphragms. Correct balance and idle line sizes are listed in the chart. Larger balance lines, than those listed, may be required where vaporizer-regulators are placed some distance from carburetor. A line too small in this instance results in erratic operation and poor acceleration.

	Balance Line	Idle Line
NS vaporizer-regulator	1/4" I. D.	3/16" O. D.
B regulator	3/16" O. D.	3/16" O. D.

When Model HD or M vaporizers are used they do not incorporate pressure regulating devices that reduce pressure to ounce values or lower which are required for efficient mixing of fuel in the carburetor. In this type of application the system must include a field or high pressure regulator and a low pressure or "B" regulator as in the natural gas system. The "HD" or "M" vaporizer will vaporize the liquid and reduce the pressure of the gas to 8 to 10 pounds.

All Ensign carburetors are equipped with a pitot tube in the air horn at the carburetor end of the balance line. Reference to the inset in the combination natural gas LPG fuel system illustration will show that the pitot tube is fitted with a small bleed orifice. When the carburetor is used with the Ensign "B" regulator the orifice should remain in the tube. When the carburetor is used with a combination vaporizer-regulator however, the orifice must be removed to permit adequate movement of the LPG regulator diaphragm. Failure to remove the screw will result in backfiring and missing on acceleration.

LPG Carburetor Adjustments

Carburetor adjustments for LPG systems follow the same recommendations as for natural gas systems. Carburetors are equipped with load adjustments and the combination vaporizer-regulator has an idle adjustment identical to that of the "B" regulator. Low pressure fuel requirement to the "B" regulator is 4 to 6 ounces throughout the entire speed and load range of the engine.

SUGGESTIONS FOR LOCATING TROUBLE ON GASEOUS FUEL ENGINES

When Engine Fails to Start

No Fuel to Carburetor

Lines plugged.

Tank empty.

Fuel regulator main diaphragm broken thereby preventing valve opening. (Model "B" fuel regulator only).

Check pressure at tank, on "B" regulator.

Too Much Fuel

Fuel regulator leaking.

Valve stuck open.

Starting adjustment set too rich.

Choke at fault causing wrong mixture.

When Engine Fails to Idle Properly

If the range of the idle adjustment screw will vary the mixture from too lean to too rich without an improvement in the idling of the engine the trouble is outside the carburetion equipment.

Model "B" Fuel Regulator

If in adjusting the idle, the mixture is found to be too rich with idle screw closed tight it may be the regulator is leaking more gas than is required to idle the motor. If in adjusting idle, the mixture is found to be too lean with the idle screw out several turns you will find one of the following:

1. Idle connections between regulator and carburetor leaking.

2. Idle connection plugged, such as: small hole in carburetor bore above throttle disc, small hole above brass plate in regulator bowl and adjusting screw seat.

3. Upper diaphragm too stiff.

4. Upper diaphragm ruptured.

5. Pilot valve pin low.

Balance tube (or vent, if used) plugged or badly restricted.

When Engine Fails to Operate Properly Under Load

Improper fuel adjustment.

Intake manifold too hot.

Fuel supply restricted or valve closed.

Fuel lines too hot.

Varying pressure in vaporizer due to high pressure regulator valve sticking, caused by using dirty fuel.

Regulator discharging in surges.

Liquid butane passing through fuel regulator and carburetor.

Balance tube plugged or badly restricted.

Diaphragm by-pass bleed, partially plugged. (On Model "B" fuel regulator.)

Fuel Regulator Leaks ("B" Regulator)

Main valve or seat scored.

Pilot valve leaks.

Diaphragm by-pass bleed, plugged.

Lower diaphragm too stiff or too tight.

Main Valve Sticks Open

Guides and stem gummy.

Springs on top of main diaphragm broken.

Particles lodged between valve and seat.

Diaphragm by-pass bleed, plugged.

Diaphragm too stiff.

Butane Fuel Regulator Discharges in Surges

Pressure on vaporizer is excessive. May be helped by reducing pressure.

Discharging of high pressure regulator erratic because of sticky valve.

Four leaf springs on top of main diaphragm do not conform to dimension in manufacturer's data.

Balance tube connection in carburetor air intake plugged or too large.

Liquid Butane Passing Through Fuel Regulator and Carburetor

Water circulation through heater impaired.

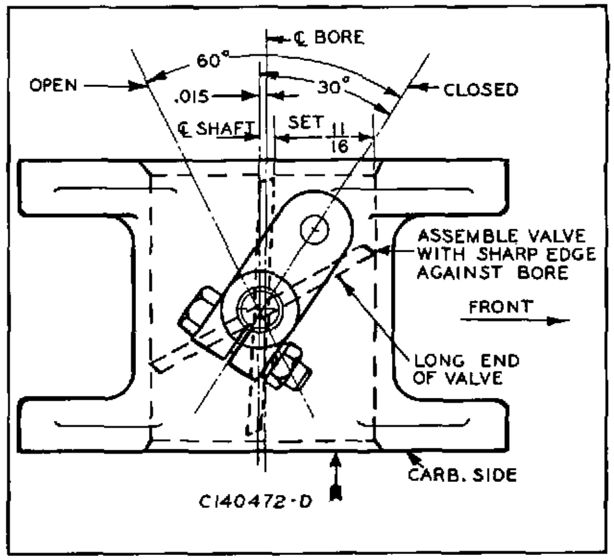
1. Connections improperly made.
2. Water pump damaged. No thermostat.
3. Hot water connection too high on engine so as to allow it to be uncovered when cooling system loses water.
4. Heater and water passages become plugged due to dirt in water.
5. Heating coil leaks. Butane leaks into water space expelling water. Observed by butane vapor bubbling in radiator top tank.

MECHANICAL GOVERNOR

There are several types of mechanical governors used on the 140-145 series engines. The particular method of governing depends directly on the engine application. In the case of a generator set application, extremely close speed control is necessary. This is often controlled by means of a vacuum compensator.

Resetting the Mechanical Governor

If it should be necessary to dismantle the governor at any time for other adjustments--and it is only for that purpose that it should ever be necessary to disturb this mechanism--there are some basic requirements which should be observed. These requirements can all be met if the governor parts are carefully marked before they are removed so that they will be reassembled with the same adjustment and in the same places from which they were removed. 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 valve. 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 valve so that it goes back exactly as before. Close it, and with a pencil, mark the top side and the adjacent wall of the intake so that it is not re-assembled 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 tension of the governor spring 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 butterfly stands a trifle towards the closing position when the engine is stopped. Variation from the proper speed can be corrected by tension of the regulating spring. Increasing the tension increases the maximum speed, and decreasing the tension decreases the maximum speed.



GOVERNOR BUTTERFLY VALVE
BASIC POSITION (TYPICAL-140)

Governor Butterfly Valve Position

Due to the diversified application of engines in this series a great variation in governor butterfly valve positioning exists. For this reason it will be impractical to attempt to illustrate all the proper positions of the valves in the space allowed in this manual. If a question arises regarding the positioning of the butterfly in any given engine, information will be supplied upon request. Contact the Service Department of the Waukesha Motor Company. If possible state the part number of the butterfly assembly used and the serial number of the engine involved.

VACUUM COMPENSATOR (For Close Governor Regulation)

The vacuum compensator, located on the engine side plate. is a tempering device which works in combination with the engine governor to provide closer speed regulation that is possible with the governor alone. Its operation is a function of the intake manifold vacuum which reflects the load on the engine. (At full load, vacuum is low; at no load, vacuum is high.) Thus the governor's action is controlled not only by speed, as in ordinary operation, but by load as well. This close regulation is necessary in generator operation to permit proper control of generator frequency and voltage.

The governor is a flyball type in which, as the speed increases, the lever, S, is moved to the left, toward a closed throttle position. The movement of S is restricted by the spring, R, maximum tension of which is controlled by the screw, Q, and should not be disturbed. It will be noticed that spring tension can also be decreased or increased as the transfer lever, P, moves up or down respectively. This movement is controlled by the intake manifold vacuum and the compression of the compensator spring, D, as follows:

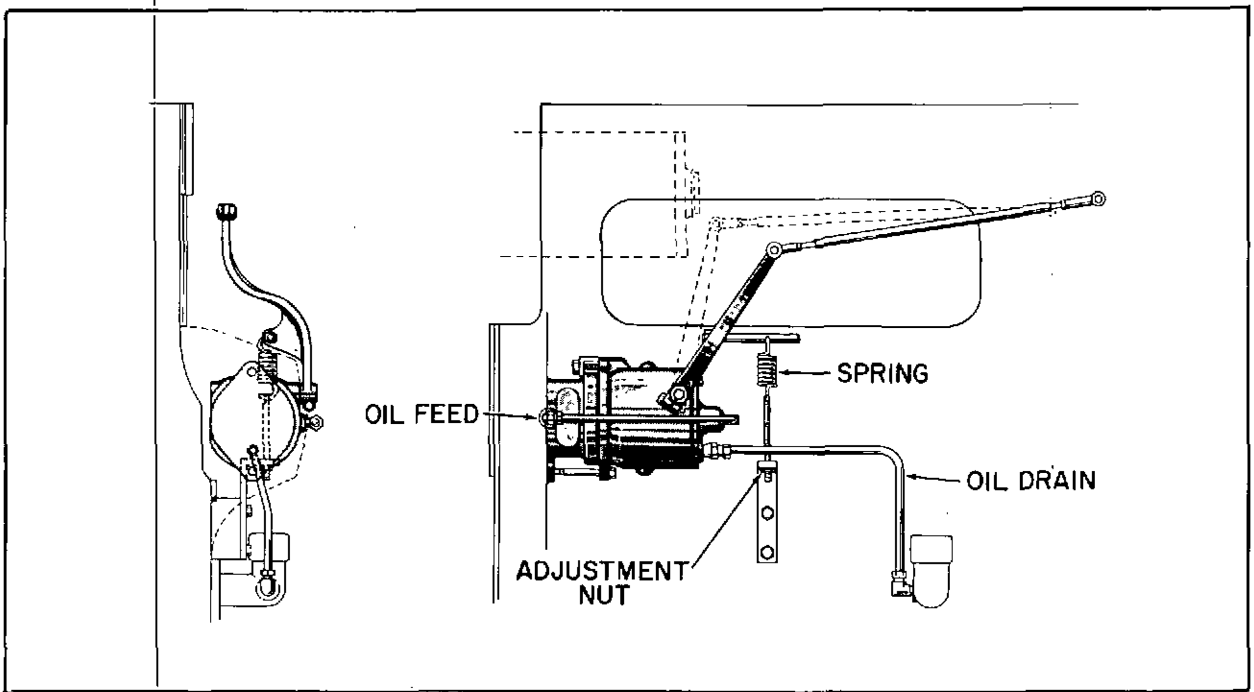
Assembly

Relieve the tension on the vacuum compensator spring, D, by backing off the adjusting screw, C. Remove the vacuum cylinder cover assembly. Position the diaphragm, F, and washers, G, on the push rod, L, by adjusting T, and lock nuts, H, located on either side of the diaphragm, so when the diaphragm is held against the vacuum cylinder base the distance between the cylinder base and the stop collar, K, is 1/2 inch. With the diaphragm in place, slip the spring, D, on the adjusting screw, C, and position the cover assembly on the vacuum cylinder base. Install the cap screws and tighten evenly. The above procedure must be followed so that the diaphragm has the proper amount of wrinkle for 1/2 inch travel.

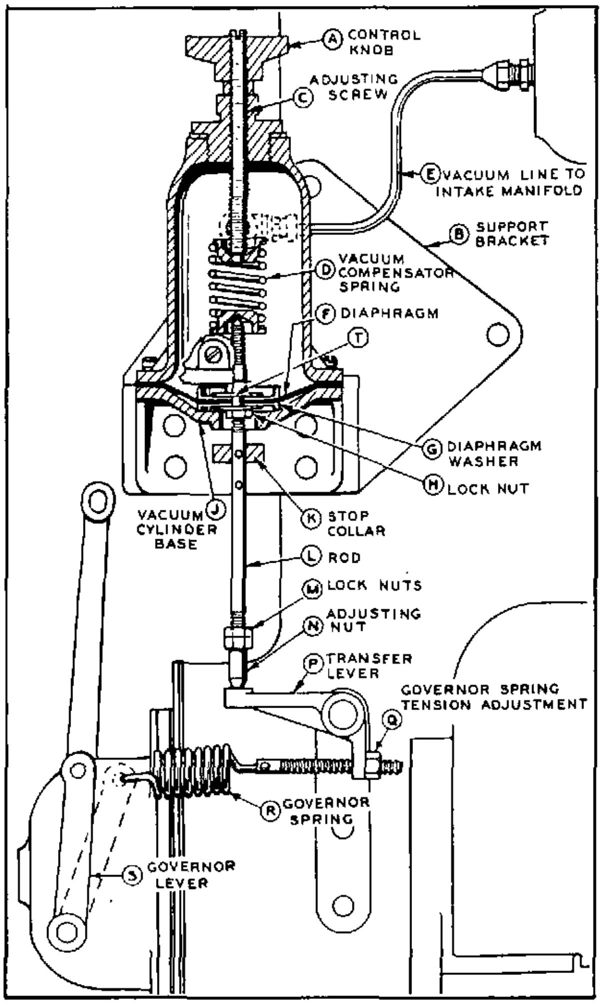
Adjustment

Be sure the vacuum line does not leak. With the engine running at governed idle speed, adjust the screw, C, until the stop collar, K, clears J by 3/32 inch. Check speed and correct by adjustment at M. Make sure the stop collar, K, clears J by 3/32 inch.

When the vacuum in the manifold increases, due to reduced load, the diaphragm, F, moves up against the compensator spring, D. This upward movement is transmitted by the rod, L, to the lever, P; and as a result, the tension of the governor spring, R, is decreased to permit the lever, S, to move to the left toward closed throttle position. Knob, A, sometimes



REAR-MOUNTED MECHANICAL GOVERNOR INSTALLATION



VACUUM COMPENSATOR - GOVERNOR ADJUSTMENT

located on the instrument panel, controls the compression of spring, D, and the degree to which it affects governor spring tension and engine speed. Clockwise rotation of the knob increases speed; counterclockwise rotation decreases speed. The compensator reduces the speed drop from no load to full load operation to about 3% of maximum speed.

In cases where two engine driven generators must be synchronized, the compensator permits close manual regulation of speed by means of the knob, A.

VARIABLE SPEED GOVERNOR

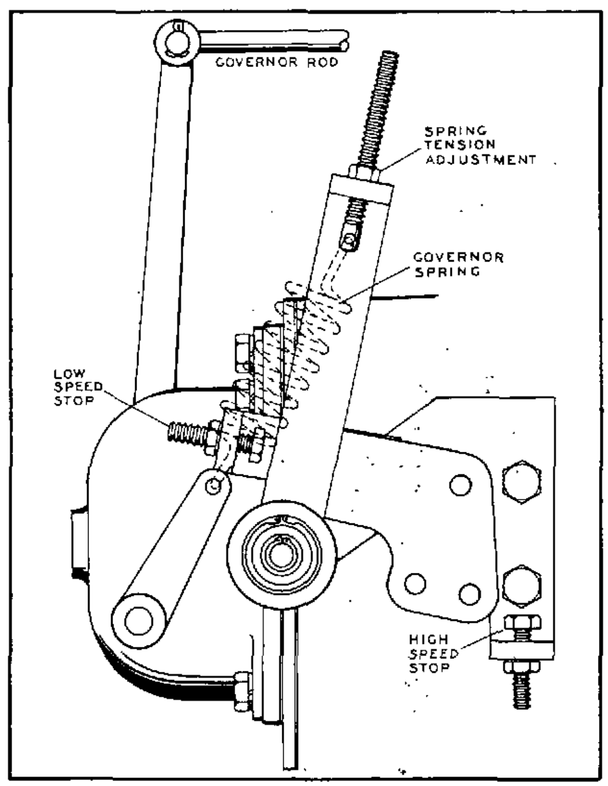
On engines equipped with the variable speed "swinging spring" type governor as illustrated, the following procedure may be used when adjustment becomes necessary:

1. Before starting engine, with tension on the governor spring so that the governor is in the full throttle position, adjust governor rod length so that throttle fly is cocked toward the closing side from wide open. Throttle butterfly can be cocked so that the ends are even with the sides of the throttle shaft without power loss.

2. Back off the low speed stop and move governor control lever forward to low speed position so that governor rod and throttle go to the low speed position. Low idle adjusting screw on carburetor should contact the stop.

3. Start engine and adjust low speed stop to limit governor control lever forward travel to the point where it permits return to low idle, but no more. Allowing the lever to go farther forward than necessary for low idle only makes it necessary to move the throttle control farther to get response when higher speed is desired. This is done with reasonable tension on governor spring.

4. Swing governor control lever back in the high speed direction until spring is almost perpendicular to the lever it hooks into on



VARIABLE SPEED "SWINGING SPRING" GOVERNOR the governor cross shaft. Adjust high speed stop to limit travel at that point. Additional travel is useless.

5. Adjust governor spring tension for proper high idle speed.

6. Re-check low speed position of control lever and readjust stop screw if necessary to permit return to low idle.

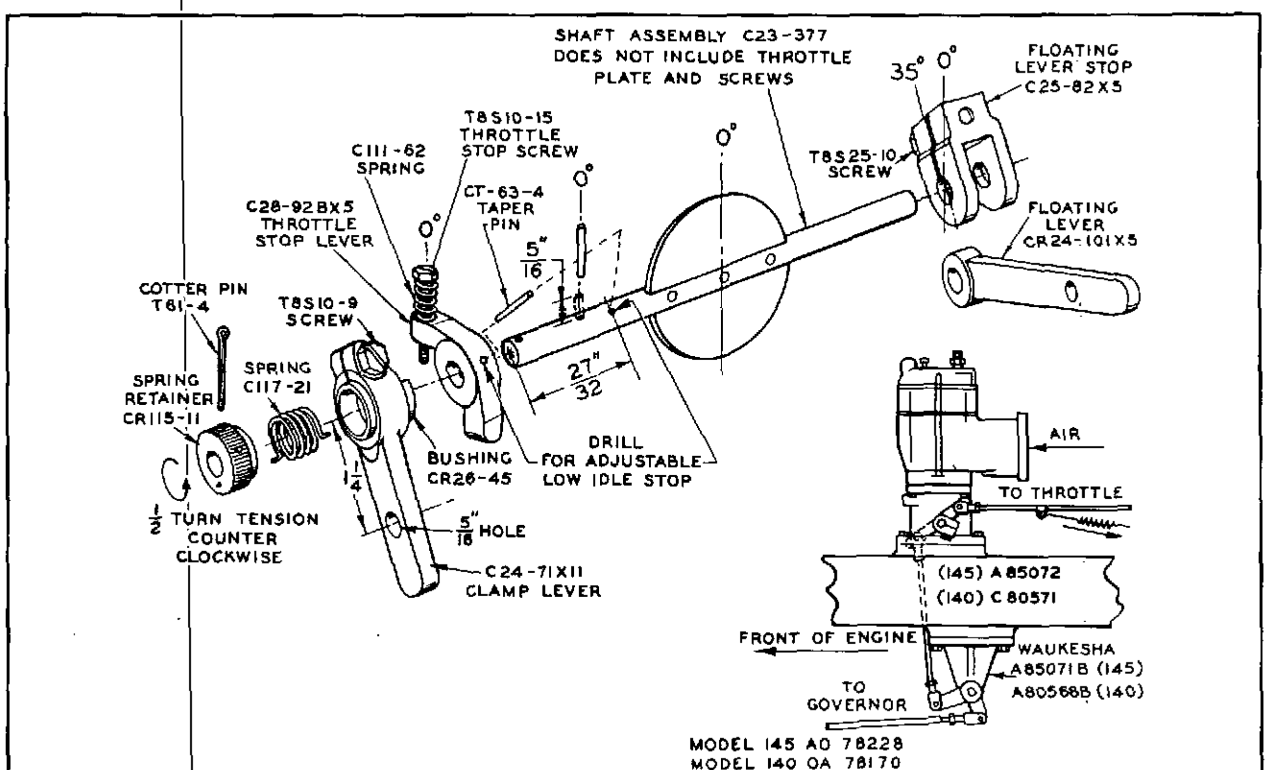
7. Select radius on control lever which matches travel of operator's control and connect linkage. If operator's control does not have sufficient travel to accommodate full range of governor control lever, it may be necessary to settle for less travel. In that case more governor spring tension will be required to obtain full speed.

CARBURETOR TYPE GOVERNOR

This governor is intended for use in those automotive applications where the clearance available between the intake manifold and the hood does not permit the installation of the standard governor butterfly housing. Thus, the governing action must be obtained by connecting the governor rod from the centrifugal governor directly to the carburetor butterfly. Since the truck operator's foot feed control is also connected to the butterfly valve of the carburetor, it is apparent that some sort of floating connection must be provided so the governor can override a wide open foot feed and hold the engine speed to the allowable maximum. On the other hand, the operator must be able to maintain complete and instant control of engine speed throughout the operating range without interference from the governor.

Examination of the accompanying carburetor type governor illustration will show that both of the above requirements are satisfied in this installation. As the operator opens the foot feed, the floating lever moves forward and allows the butterfly to move towards the open position to any extent desired by the driver. If, however, the operating conditions and load tend to make the engine exceed the safe maximum speed, the governor rod will move forward in response to governor action, the bell crank will translate the forward motion into vertical motion and move the clamp lever upward so that its shoulder moves against the small pin shown installed at zero degrees, thereby moving the butterfly towards the closing position until the engine speed stabilizes at the set maximum RPM of governor setting.

The engine governor is mounted on the front of the gear cover and the governor rod ad-

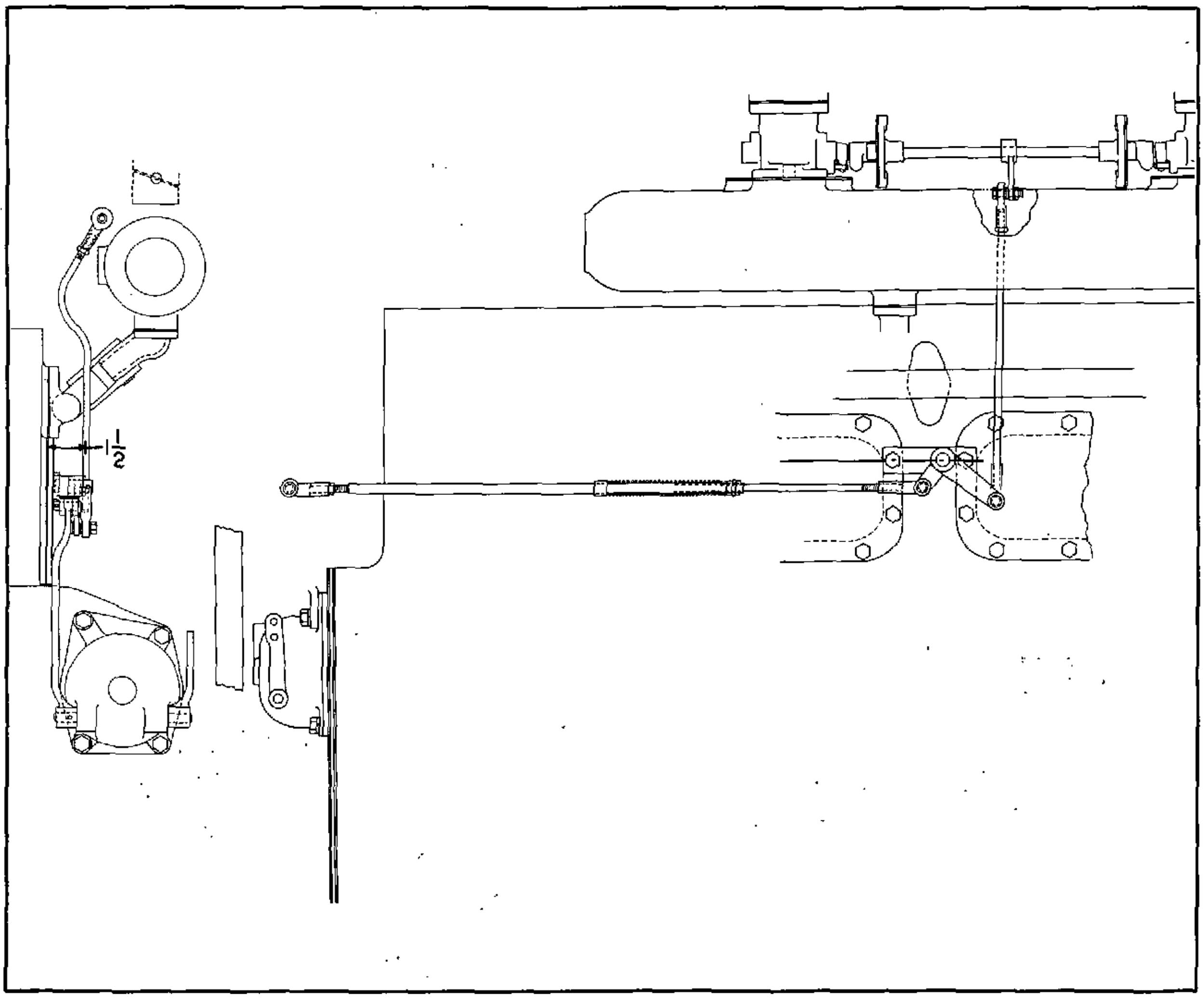


CARBURETOR TYPE GOVERNOR

justed to the proper length to hold the bell crank at approximately the angle shown in the small drawing at the lower right. This is the wide open position which the governor naturally assumes when the engine is not running. Before installing the carburetor, examine the position of the butterfly valve and mark or scratch a line on the end of the shaft exactly in line with the valve so that the position of the valve may easily be determined with the carburetor in place. Now install the vertical control rod and adjust the length so that the butterfly valve is about 10° towards the closing side when the governor is in the wide open position as described. Do not make an adjustment that will position the butterfly absolutely straight up and down in the carburetor since this will cause it to give excessive governor drop.

The truck throttle control rod may now be installed and checked for action. The butterfly valve should respond to the movement of the foot feed in a perfectly normal manner if all connections are aligned properly and are free running.

Install a tachometer and after allowing the engine to warm up, open the foot throttle to determine the point at which the governor takes over control of maximum speed. This should be at 2600 RPM for Model 140 and 2400 RPM for Model 145 when the governor stabilizes although a momentary overrun of 80 to 90 RPM will usually occur if the throttle is opened quickly. If the governed speed is too high, reduce the tension on the governor spring; if it is too low, increase the tension by tightening the adjustment nut slowly until the desired speed is reached.



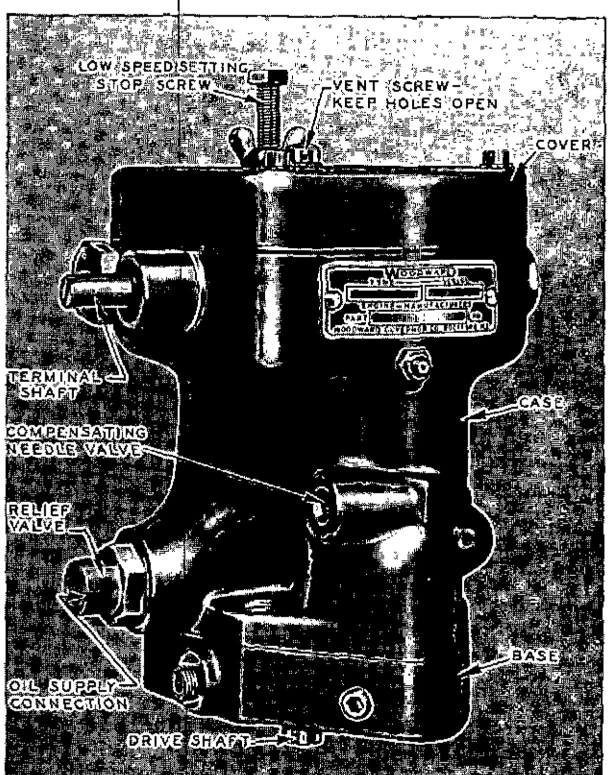
GOVERNOR LINKAGE FOR DUAL CARBURETORS

HYDRAULIC GOVERNOR - WOODWARD TYPE PSG

When the PSG governor is installed on the engine, particular care should be exercised to see that it is mounted squarely and that the drive connection to the engine is properly aligned. A gasket should be used between the base of the governor and the engine mounting pad. Be certain the gasket does not block off any holes in the governor base. Install fuel control linkage, making sure that the governor in its closed position can cut fuel flow off completely and that it is capable of opening fuel control mechanism to its full load position. Be sure linkage is free from friction or lost motion.

The governor is single acting, that is, it utilizes oil pressure in one direction only and depends upon spring force to move the fuel control linkage in the fuel off direction. This spring is incorporated in the governor cover in some models, particularly those used with completely enclosed linkage, but most governors require an external spring exerting a torque of 50 lb. in. on the terminal shaft.

Unless the engine pad is drilled for oil supply to the governor through the mounting flange a 3/8" oil line must be connected from the engine lubricating oil pump pressure line or separate oil sump. An automotive type oil filter must be installed in the line to eliminate the possibility of dirty oil reaching the governor. It should be a 40 micron filter with a minimum capacity of 2 G.P.M.



WOODWARD PSG GOVERNOR
EXTERNAL VIEW

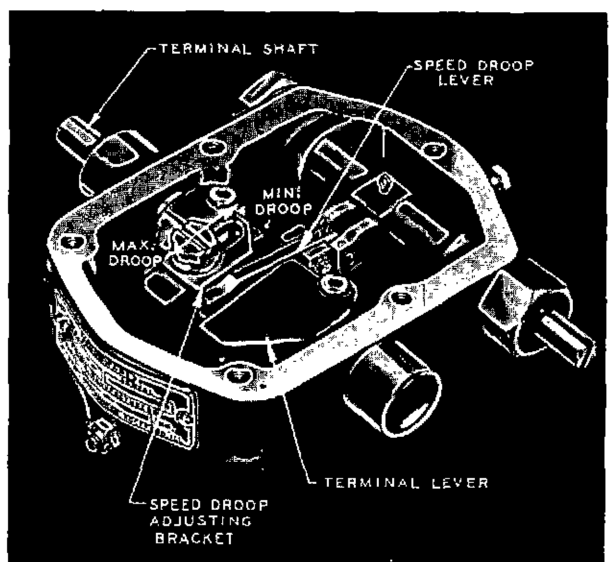
Free discharge of oil from the governor pilot valve must be assured by provision of adequate (1/4" diameter or equivalent in multiple holes) drain holes from the drive coupling. No back pressure can be tolerated. Also, the drain passages from the governor ballhead cavity must be free in the engine adapter housing.

The governor may be mounted with the drive shaft horizontal if desired but the control and terminal shafts must also be horizontal and the servo side down in this case. If the horizontal mounting is used a 1/4" pipe tapped hole must be provided in the low end of the governor cover and connected to the engine sump or to the separate governor sump.

Regular engine lubricating oil is usually satisfactory for the governor. Special conditions such as low temperature starting in an installation using a separate sump may require use of a lower viscosity than engine lubricating oil.

Installation Adjustment

Start the engine and position the speed adjusting shaft for desired running speed and allow the engine to warm up. Open the compensating needle valve two or three turns and allow the engine to hunt or surge for about one-half



PSG GOVERNOR, COVER REMOVED

minute to bleed trapped air from the governor oil passages. Gradually close the needle valve until hunting just stops. Closing the needle valve farther than necessary will make the governor slow to return to normal speed after a load change. Test action by manually disturbing engine speed. Engine should return promptly to original steady speed with only a small overshoot.

Speed Adjustment

Several different means for speed adjustment may be supplied with this governor. A speed control shaft is attached to the speed adjusting lever through a serrated connection. The outer end of this lever forms a pivot point for the speed droop lever, the purpose of which will be explained later. Rotation of the control shaft and speed adjusting lever will raise or lower the end of the speed droop lever and change the compression of the speeder spring. Extreme limits of travel, and therefore maximum and minimum speed settings, are established by adjustment of the stop screws in the governor body and cover. The high speed stop is the horizontal screw in the body and the low speed stop the vertical screw in the cover. Rotation of the control shaft in the low speed direction beyond minimum rpm will shut the engine down by positively raising the pilot valve plunger through the speeder spring, which is attached rigidly to the upper and lower seats.

For local manual speed adjustment, the governor is sometimes furnished with a stub speed control shaft and adjustment is made through the low speed stop screw.

Synchronizing motor speed adjustment is supplied as a special auxiliary. This motor is a split field universal motor which drives the speed adjusting shaft through a worm and gear with a friction clutch to protect the motor if the adjustment is run against the stops.

Speed Droop

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

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

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

Speed Droop Adjustment

The governor is shown with the top cover removed to expose the speed droop mechanism and adjustments. The speed droop bracket is clamped to the terminal lever by the slotted hexagonal head screw. When loosened, it can be moved radially to the terminal shaft. The bracket carries a pivot pin for the speed droop lever and this pin can be adjusted from a position on the terminal shaft centerline to a location and a radius of about one-half inch. When the pin is at the shaft center rotation produces no vertical movement of the pin and therefore no movement of the speed droop lever. As the pin is moved out away from the shaft center, rotation produces movement of the end of the speed droop lever which is pivoted on the speed droop pin. This speed droop lever movement thus produces a speed setting which is a function of terminal shaft position with speed decreasing as fuel flow increases. This is speed droop.

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

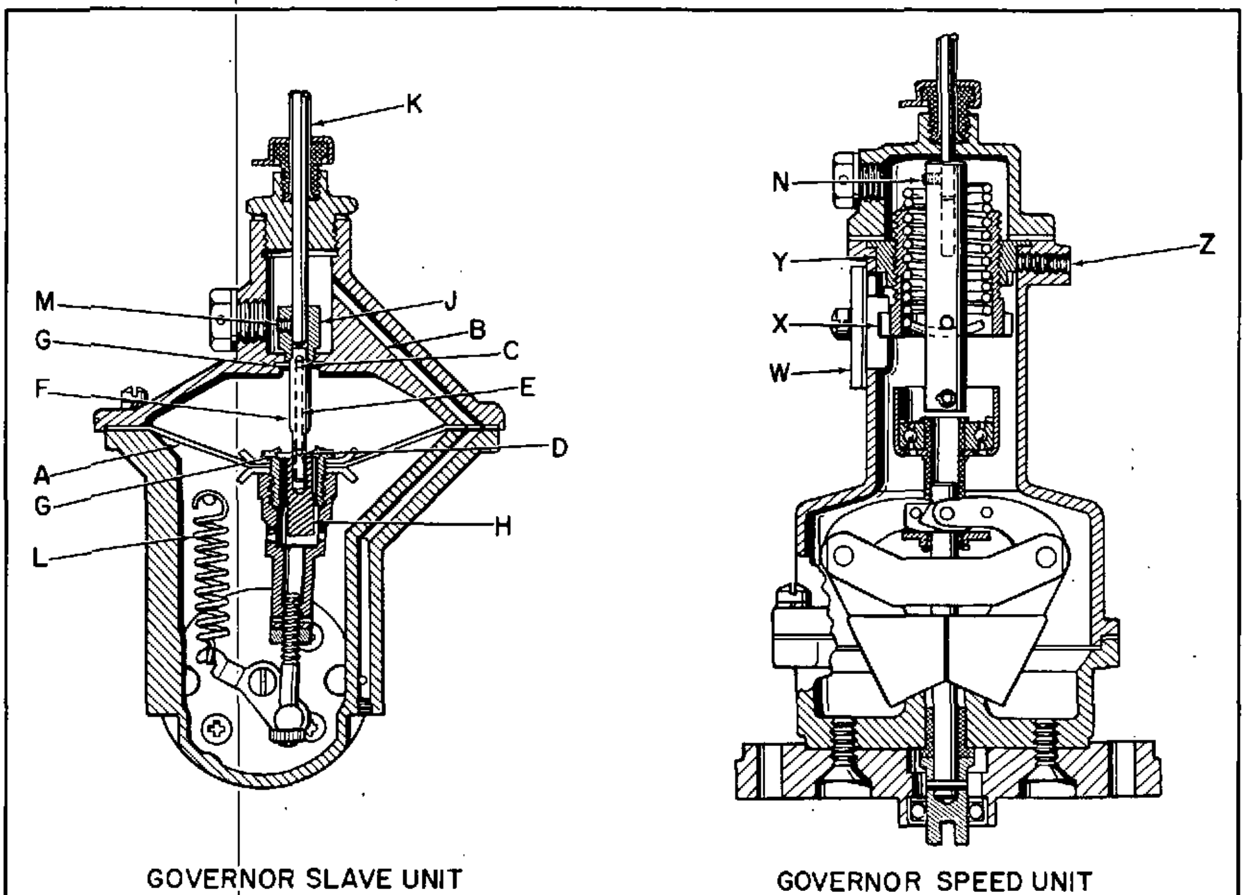
ZENITH MECHANOVAC GOVERNOR

Operation

The Zenith governor consists of a conventional flyweight governor mechamism and a slave or power unit. The purpose of the two units is to obtain sensitivity and control with moderate weight force in the speed sensing mechanism and to have this force amplified by means of a booster unit which will overcome throttle plate frictional and velocity forces without affecting governor sensitivity. An important feature of this governor is that all speed and regulation adjustments may be made while the engine is running.

The drawing shows the governor slave unit in the position for wide open throttle carburetor operation. The throttle plate is moved towards wide open throttle position by return spring L and vacuum behind the diaphragm (A) opposes this spring force. Air is evacuated from behind the diaphragm by means of vacuum channel B, holes C and D and passage E. Vacuum for channel B is obtained from any point below the throttle plate, no calibration being required. Holes C, D and passage E are drilled in valve F which is guided by bearings G. Valve F consists of three sections; a central part which is held to very close tolerances and two sections of larger diameter H and J. One end of control cable K is fastened to section J of the valve and the other end of the cable is fastened to the speed sensing unit.

In operation, assuming full load condition, the flyweights are in and the slave unit is in the position shown with the butterfly wide open. As load is removed and speed increases the flyweights will swing out and this motion is transmitted to the valve by means of cable K. The chamber behind the diaphragm will be evacuated and bearing G in diaphragm will follow hole D in valve and will locate itself with respect to hole D, bleeding air into the diaphragm chamber, so that the diaphragm force will automatically be in balance with the throttle return spring force. Thus, the rate and load of return spring L are relatively unimportant. This



ZENITH MECHANOVAC GOVERNOR, SECTIONAL

design of the valve also serves as a vacuum safety device. If for some reason diaphragm A becomes inoperative, mechanical force would be available to prevent runaway engine speed, although the no load speed will be above governed speed.

Installation and Adjustment

For a general description of the operation of this unit, refer to the Description Section of this book.

Installation of the governor must be made with the slave and speed units both in wide open throttle position. If the speed unit has been properly set, there will be sufficient spring tension to hold the weights closed. If there is any doubt as to whether or not the weights are closed, spring tension may be increased by turning nut X counterclockwise when looking into the adjusting port and away from the governor weights.

The slave unit is in wide open throttle position when the shoulder of section J of valve F butts against stationary bearing G.

The cable housing should be bent to the required shape using a minimum bend radius of 2-1/2". The housing should remain straight for a minimum of 1" beyond the fitting used to secure the housing to speed or slave units and the housing shape must be such that the housing need not be forced into place. After the fittings have been placed over the housing the ends should be carefully flared so that the housing remains free from burrs and so that there is no reduction in inside diameter. The cable should be cut approximately 2-3/8" longer than the housing and the cable ends filed to remove any burrs. A very light coating of grease should be applied to the cable.

The cable should first be locked into the valve of the slave unit by means of the Allen set screw M in section J and then the housing should be fastened into place at this end. By pushing on the other end of the cable the valve is brought into wide open throttle position. If cable friction is insufficient to hold the valve in position, an Allen wrench held in the set screw may be used. The end of the cable should then be inserted into the control rod of the speed unit and the housing secured to the speed unit cap before locking the cable by means of the Allen set screw N. The slave unit cap which exposes the valve must be replaced before operating.

Adjusting nuts X and Y of the speed unit control speed and regulation. When the given regulation is obtained and in production this will be set in the plant, the one adjustment X will control speed. This is done by the combination of internal and external thread pitch and the spring wire diameter. The external thread of nut X is a left hand thread, therefore, to increase governed speed this nut must be turned counterclockwise when looking into the adjusting port and away from the governor weights.

To eliminate a surge or broaden regulation, the spring rate must be increased and the spring load decreased. To accomplish this, adjusting nut Y, which controls spring load, must be turned in a counterclockwise direction reducing load. Turning adjusting nut X in a counterclockwise direction increases rate and at the same time increases load. However, when the desired speed is again reached, the net spring load will have been reduced and the spring rate increased. This operation must be continued until the required regulation is obtained. Conversely, to reduce regulation or decrease the difference between no load and full load speeds, spring load must be increased and spring rate decreased. This is accomplished, of course, by the reverse of the above directions.

When the desired regulation is obtained, adjusting nut Y should be locked in position by means of the set screw Z located in the side of the housing. Although shown as a set screw in the illustration, when the Zenith Mechanovac governor is used on the Model F-817G this adjusted will be permanently fixed by a plug. When the desired speed is obtained, adjusting nut X is locked by means of the key on the cover plate W which engages a slot in the adjusting nut.

The speed unit should be filled with approximately 3 ounces of S.A.E. 20 oil at time of installation on engine.

SYNCHRONIZATION PROCEDURE (ENGINES IN COMPOUND)

The following procedure is listed for applications where more than one engine is used in compound to overcome a load.

1. First adjust carburetors as outlined earlier in this section under Carburetor and Fuel System Adjustment.

2. Put engines in compound and adjust low idle stop on carburetor until all engines have the same vacuum. (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 per cent. Adjust governor spring tension 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 adjusting screw so that the vacuum reading on the other engine or engines is the same as the one adjusted in Step 3.

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

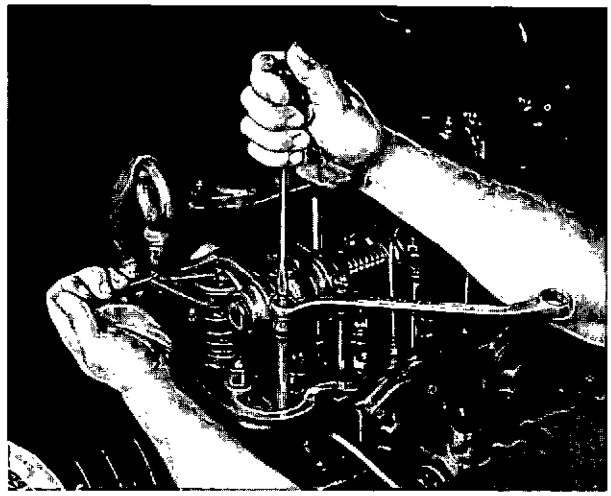
   NOTE: If after the above adjustment, you cannot get the engines to run together, check the relative position of the governor butterfly valve of each engine (stopped). If you find a slight difference in the position of the governor butterfly this can be adjusted by changing the length of the governor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

6. Do not attempt to make adjustments on the carburetor to obtain equal vacuum 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.

VALVE RUNNING CLEARANCES

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

Valve clearances specified in the tables of clearances and on the engine nameplates are for engines cooled to normal ambient temperatures . . . NOT FOR HOT ENGINES. When checking clearances or timing, the rocker arms must be contacting the valve tips evenly and not be hollow. When the rocker arm to valve tip surfaces are worn hollow, it is impossible to make an accurate check with a feeler gauge. Never attempt to adjust valve clearances without loosening the adjusting screw lock nut and re-tightening it when completed.



ADJUSTING VALVE RUNNING CLEARANCES

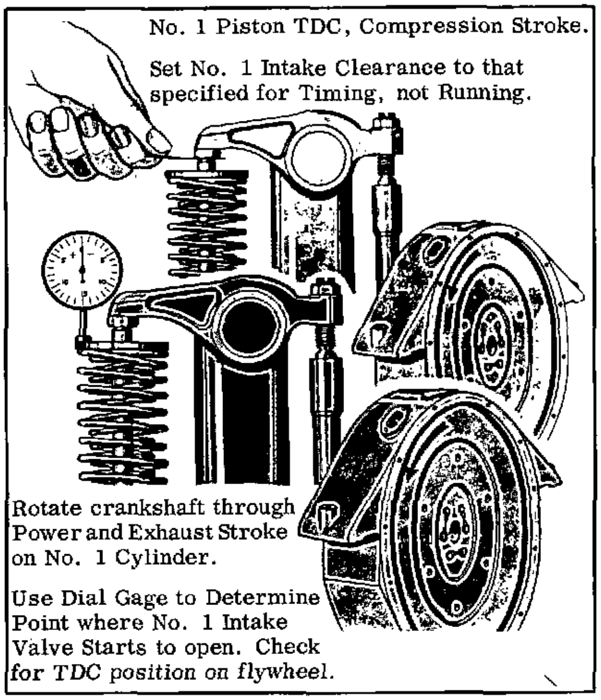
Whenever the rocker covers are removed, the valve and spring mechanism should be examined for evidence of inadequate lubrication due to sludging or plugged oil lines. Excessive sludge in the rocker arm area is an indication of too low oil operating temperatures, poor filtering action, or an oil that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

VALVE TIMING CHECK

It is very seldom necessary to check valve timing. The timing of the camshaft is established at the time of assembly by the proper matching of the timing marks on the timing gears. Since there are no couplings or other adjustment mechanisms to slip, there is no way in which the timing can be changed. Moreover, it is often difficult for a person inexperienced in this operation to check for proper timing with absolute accuracy even though the engine is correctly timed. This is because of the many factors such as gear backlash, manufacturing tolerances, cam wear, rocker arm wear, and personal judgment that vary.

Since however, improper valve timing may have very serious effects on engine performance and service life, any symptoms of low power, overheating, backfiring, or similar troubles showing up after repair or overhaul procedures should be investigated and a valve timing check made to prevent damage to the engine.

The initial opening of the intake valve and exhaust valve, as well as the final seating action are accomplished very gradually in order to hold the mechanical load on the valve and lifter parts to a minimum. For this reason,



VALVE TIMING SEQUENCE

it is more practical to check timing at a different point in the cam action where the movement is quite pronounced. This is done by setting the valves to a special timing clearance temporarily. Use the timing clearance given on the rocker cover, or in the back of this book. Re-set after checking.

The actual steps in making a timing check for these engines are as follows:

1. Bring number one piston to top center on the compression stroke so intake and exhaust valves are both closed.

2. Adjust the clearance of number one intake valve to that given on the engine instruction plate or the rear of this book for checking valve timing - not operating clearance.

3. Rotate the engine in the direction of normal operation (to remove backlash from the gear train) through the power and exhaust stroke until the number one piston is again approaching top center, this time for the beginning of the intake stroke.

4. Very carefully feel for the instant that the rocker arm starts to bear against the valve stem. This is easiest to determine by rotating the upper end of the push rod between the fingers.

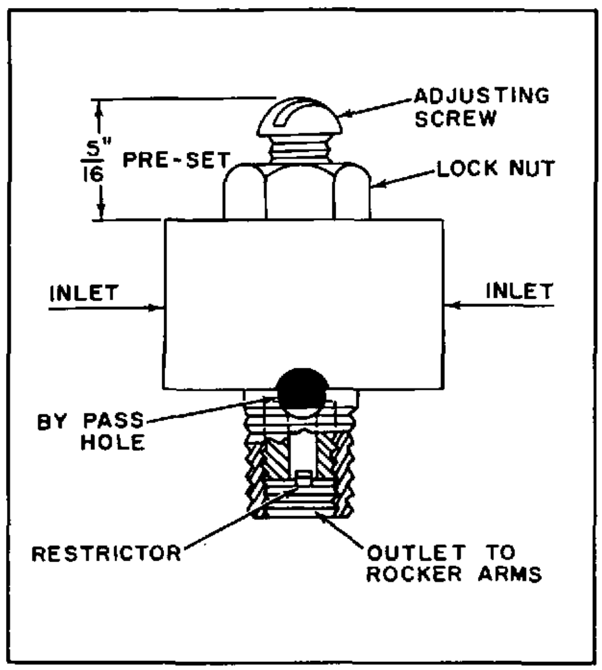
5. When the push rod just becomes snug, the intake valve is starting to open. Check the flywheel position through the inspection opening. It should be on or about TDC. If the flywheel markings are inaccessible, TDC may be determined visually by watching the piston through the spark plug hole with the aid of a flashlight.

6. Reset the intake valve to normal cold clearance for running.

It should not be concluded from this method of checking that the intake valve actually opens on TDC. This location is merely used for a convenient check point. Because the cam design starts the valve mechanism moving in a gradual manner, the actual point where the tappet is first lifted by the intake slope of the cam is difficult to detect without precision equipment. Later, in the valve opening process the rate of valve movement is increased and the movement is large enough to detect easily. Hence, using a mathematically calculated clearance and this location on the cam is more practical from a field standpoint.

ROCKER ARM OIL CONTROL

Adjustable rocker arm oil control valves are used on recent Waukesha 145 engines. The purpose of the valve is to control the oil flow to the rocker arms. A valve is mounted on the center rocker arm support on each head and is



ADJUSTING SCREW LOCATION

interchangeable with the brass "tee" fitting previously used.

The control valve screw is factory pre-set to a height of 5/16 inch. This allows a minimum oil flow to the rocker arms. If the operator loosens the lock nut and turns the screw down, oil will be partially shut off from the by-pass hole and an increased quantity will be forced through the restrictor and into the rocker arms. Conversely, backing the screw out will by-pass or "spill" more oil and less oil will flow to the rocker arms. It is impossible to shut the oil flow off completely. This may be more clearly understood by following the accompanying illustration.

In operations requiring long periods of idle or light load conditions, the factory setting is recommended. In operations requiring continuous heavy loads or full load conditions, the valve setting may be adjusted slightly, as described above, to increase oil flow. The amount of the setting should be determined by experience. Avoid heavy smoking and large increases in oil consumption. The valve assembly is available as a service part.

NEW ENGINE PRECAUTIONS

There are a few special precautions that should be taken before and after starting and applying the load to a new engine. The following are recommended:

A. See that the fan hub is lubricated.

B. Remove the spark plugs and squirt approximately a teaspoonful of light cylinder oil into each cylinder to insure lubrication of the pistons and cylinders when the engine first starts.

C. Using an external pressure source, such as a pump or air tank, force oil through the lines and filters to avoid prolonged operation before the line, passages, and filters fill.

D. Allow the engine to idle the first fifteen minutes to fill all the bearings with oil.

E. Check for water leaks after the engine warms up and take corrective steps if leaks are found.

F. Tighten all the cylinder head nuts after the engine is hot. THIS IS IMPORTANT. RE-TORQUE TO THE VALUES SPECIFIED in the Clearance section.

In recognition of the fact that it is often impractical if not impossible to provide a "break-in" period for a new engine, the engine manufacturer has designed this engine with sufficient clearances and tolerances so that it can be put to work as soon as the previously mentioned precautions have been taken. However, if it is at all possible, the engine should be operated for a short time at approximately 50% power before applying the full load.

If the engine has been overhauled, and the engine application will permit it, run the engine at idle for 4 or 5 hours, then if possible with half load for a day or more, then for a few days at 50% power. If the engine overheats, reduce the load.

OPERATING INSPECTION SCHEDULE

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, oil pan and gear-cover gaskets, and so on, should be examined for tightness. Re-torque cylinder-head hold-down nuts in order to ensure top performance at approximately the first fifty hours of operation.

The following 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. 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. Drain sump traps and strainers. Be sure gas pressure at "B" regulator if used, is maintained between 4 and 6 ounces.

5. Air-cleaners and breathers--inspect for cleanliness; under some operating condi-

tions 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. IGNITION: visually check spark and ignition wires for cracks or signs 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 the 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 OVER-GREASE.

6. Fan belts--inspect this and other belt drives for proper tension, incipient breakage, fraying or other damage. (Replace belts in matched sets.)

7. Water-pumps--examine for evidence of leakage.

Monthly Inspection

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

1. Valve clearances--remove valve covers and measure with feelers. Re-set any tappets not within correct limits.

2. Top water manifold, thermostat housing--remove from main engine and water cooled exhaust manifold, if used, and clean away any scale or deposit in thermostat area.

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

4. Remove, clean and re-gap spark plugs.

500-Hour Inspection

1. Spark plugs--remove and check the gap with a feeler gauge. Correct gap for a new plug is 0.025". Re-set after service to 0.018" - 0.020".

2. Magneto--check for correct magneto breaker point clearance and condition.

3. Compression--check each cylinder. Be sure to close the fuel shut-off valves, have the ignition switch in "off" position, and have the throttle wide open. Uneven compression or pressures lower than those stated in clearance section 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 cooler--if increase in oil temperature is noticed, remove and clean cooler unit, if used.

TROUBLE SHOOTING

In the operation of any mechanical equipment, situations arise that require the operator to analyze the source and take appropriate corrective measures. Such situations are normally called "trouble shooting" and range from such elementary problems as locating a grounded wire or closed valve to complex installation engineering decisions. A certain amount of common sense and ordinary reasoning can eliminate many false starts and much wasted time in attempting to correct symptoms rather than the trouble source. Troubles may arise generally from the following sources:

1. Misapplication or improper installation of the engine

Under this heading may be considered the problems associated with incorrect gear ratios, extensive idling at low temperatures, constant overloads, inadequate cooling, unusual exposure to weather and sand or other elements, and innumerable other situations which may sometimes benefit from the help of the Waukesha Motor Co. Service Division or its authorized dealers. The Waukesha Motor Company is always ready to make available the experience of over 50 years of industrial engine building and application.

2. Normal wear and service

In the course of normal service, any engine will lose the precise adjustments it had when new. These conditions arise from such things as small deposits and constant movement in the carburetion and ignition system; combustion chamber deposits; wear of the piston rings, valves, bearings and other running surfaces; and an occasional failure of a minor part such as a spark plug or fuel regulator diaphragm. Normal adjustment and maintenance will prevent most of these conditions from becoming "troubles" and careful thought about any symptom that does appear will usually lead to its immediate repair.

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

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

OVERHAUL AND MECHANICAL ADJUSTMENT

GENERAL

The overhaul and adjustment of the 140-145 series engines, like any other mechanical operation on precision machinery is best accomplished by experienced personnel using equipment built for accurate work. On the other hand, assembly and disassembly present no unusual features requiring special tools or techniques. For this reason, no effort has been made to detail in this manual the steps that are self evident or well established mechanical practices. In those instances where a considerable number of these engines are being overhauled, the WAUKESHA MOTOR COMPANY will be glad to make suggestions on permanent type tooling such as pullers, jigs, and other fixtures.

There are a number of good practices that should be followed in overhauling any engine, some of these are listed below.

Do Not Mix or Confuse Engine Parts

Mark for position on disassembly; tag assemblies from different engines; stamp or otherwise identify parts reground to special sizes.

Do Not Mix Bolts, Capscrews, and Washers

Capscrews and like parts are of a length, material, and heat-treatment suited to the place they are used. Numerous instances have been reported where too long or too short a capscrew has resulted in leakage or interference with internal parts. Washers of various materials and types are selected according to application. Standard soft steel washers, for example, when used to retain a bearing cap are known to have caused complete engine failures. Hardened washers are used at that particular point.

Inspect as Engine is Disassembled

Once engine parts have been disassembled and cleaned, many valuable indications of engine condition are lost. Materials found in the oil or on burned or carboned surfaces at disassembly often point to operating, service, or maintenance improvements of genuine value to the operator.

Protect Delicate Parts and Surfaces

Do not pile engine parts, ignition equipment, carburetors, and bearings, indiscriminately. Oil surfaces likely to rust. Tape surfaces subject to scratching or nicking during repair operations. Plug off passages likely to accumulate dust, abrasives, and machining chips. Some heavy-duty detergents and cleaning compounds will etch or corrode bearing materials and bushings. Test any cleaner before using it on good parts.

Clean Thoroughly

No engine is completely overhauled if it is not cleaned internally and externally to "new part" condition. Dirty parts can not be inspected nor fitted; neither do they conduct heat properly nor allow top engine performance. Modern chemical cleaners easily remove all engine grime; but don't forget to remove the cleaners from oil passages and casting pockets when the job is completed.

Work Accurately

Use precision gauges where needed; follow tables of limits and tightening torque values for best performance.

DISASSEMBLY

Vibration Dampner and Fan Pulley

The vibration dampner, used on high output models, is easily removed by taking out the capscrews holding it to the fan pulley. Torque for the vibration dampner retaining capscrews is 1050 inch pounds. To remove the fan pulley from the crankshaft it is necessary to remove the fan pulley nut and employ a three-jaw puller of suitable size since the pulley is pressed on the shaft.

When replacing the fan pulley, it will be found practical to make up an installing tool capable of sliding over the shaft and driving squarely against the pulley hub. The installation will be much easier, particularly on the high-output models if the pulley is heated to approximately 400-500°, F.

Gear Cover

Remove the capscrews securing the gear cover to the crankcase and oil pan. The crankshaft fan pulley key must be removed and any incidental burrs honed from the shaft before sliding the cover oil seal over it. Ordinarily the oil seal may be left in place and used again.

Flywheel

Before loosening the flywheel retaining screws, make up a "dogleg" hoist eye to support the weight and permit swinging the wheel out without canting. Take up some of the weight on the hoist, remove the capscrews, and using suitable threaded pullers if necessary, pull the wheel free and swing it out of the housing. It is recommended that new bolts be used whenever a flywheel is re-installed.

Water Pump

The water pump is removed as a unit after removal of the six through bolts extending through the gear housing. It is not necessary to disturb the bolts holding the two halves of the pump together. Neither, is it necessary to remove the inspection plate in the gear housing cover, found on earlier models.

Cylinder Heads

Both front and rear cylinder heads, including the intake and exhaust manifolds may be removed as a unit if desired. First, loosen the hose connection at the upper end of the water by-pass line. Remove the crown nuts retaining the water manifold and lift off the manifold. Loosen the rocker arm oil lines and remove the rocker arm support bracket retaining nuts so the rocker arm assemblies and push rods may be lifted free.

The cylinder head hold-down nuts will now be accessible.

When the cylinder heads are replaced after the intake manifold has been removed for any reason, it is important to carry out the steps below in the order given.

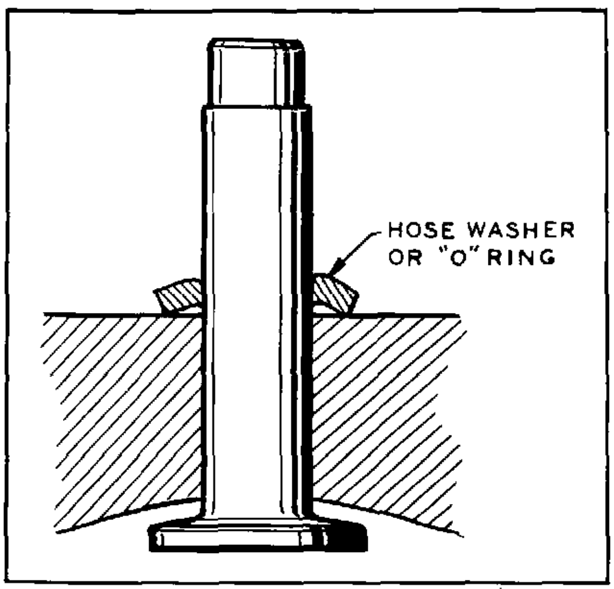
1. Place the heads in position and run down three or four retaining nuts just enough to pull the heads squarely in place against their gaskets. Do not overtighten.
2. Install the intake manifold and tighten all nuts evenly.
3. Torque down the head nuts to the values specified in the table at the back of this manual. Always tighten evenly, starting at the center of the head and working outward.
4. Install the exhaust manifold, rocker arms and push rods, oil lines, and water manifold.

The point to note about the above procedure is that the heads are left partly loose when installing the intake manifold. Thus, they are free to move slightly and square up with the manifold mounting flanges. If the heads are pulled down first, tightening the intake manifold nuts may put a strain on the manifold that will cause cracking or leaking in service.

Idler Gear and Camshaft

The idler gear is easily removed by pulling it forward and out of its bushing after the gear cover has been removed. Do not lose the small thrust button and spring set in the recess at the center of the idler shaft. If replacement of this gear or its shaft is necessary, be sure the press fit of the shaft in the gear is very snug. Use a new shaft when needed, since looseness may cause the shaft to back out in operation. Late model idler gears and shafts are welded assemblies.

Camshaft removal requires prior removal of the oil pump and its drive assembly, the distributor and drive assembly, and in the case of a fuel pump with the shoe riding directly on

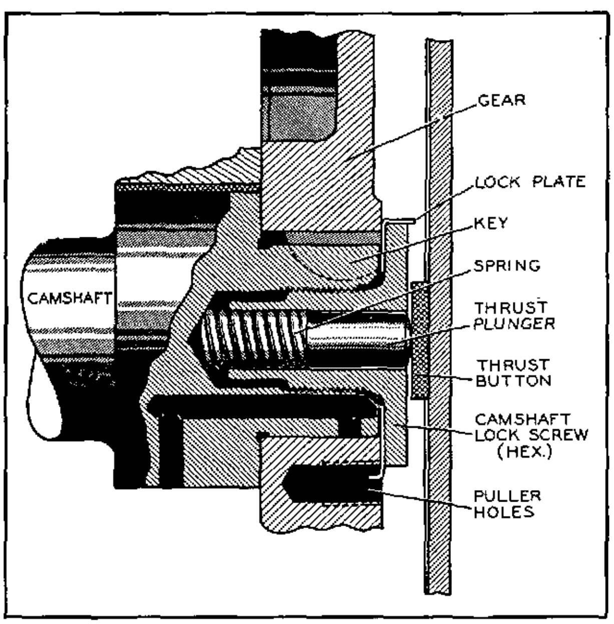


CAM FOLLOWER RETENTION

the camshaft this too must be removed. Unless the engine is inverted on a work stand or tipped on its side on a table, provision must be made to keep the cam followers lifted clear of the cam lobes while the cam is withdrawn. Various methods have been devised to hold the followers clear of the cam lobes. These range from wooden or plastic spring clip clothes pins, to tape or pieces of snug fitting hose slipped over the shank of the follower. If care is taken to wipe most of the oil from the exposed surface, simply slipping "O" rings or hose washers of suitable size down the shanks of the followers with the followers held at the upper limit of travel will prevent them from dropping down against the cam lobes or falling out after the camshaft is removed. In those engines using a push rod to actuate the fuel pump, don't forget to clear the cam lobes by holding this member up.

Withdraw the camshaft from its bushings by pulling gently and making sure that the lobes are not catching in the bushings or case. If the edges of the cam lobes are allowed to drag across the bushings, grooves and scratches may be formed that will impair lubrication and service life. Removal of the gear from the camshaft requires an arbor press and a suitable support plate to hold the gear. Do not attempt to remove the gear by makeshift methods that may distort the shaft or gear.

Subsequent inspection of the camshaft bushings may indicate the need to replace them with pre-sized service bushings.



CAM GEAR RETAINING SCREW

Cam Followers

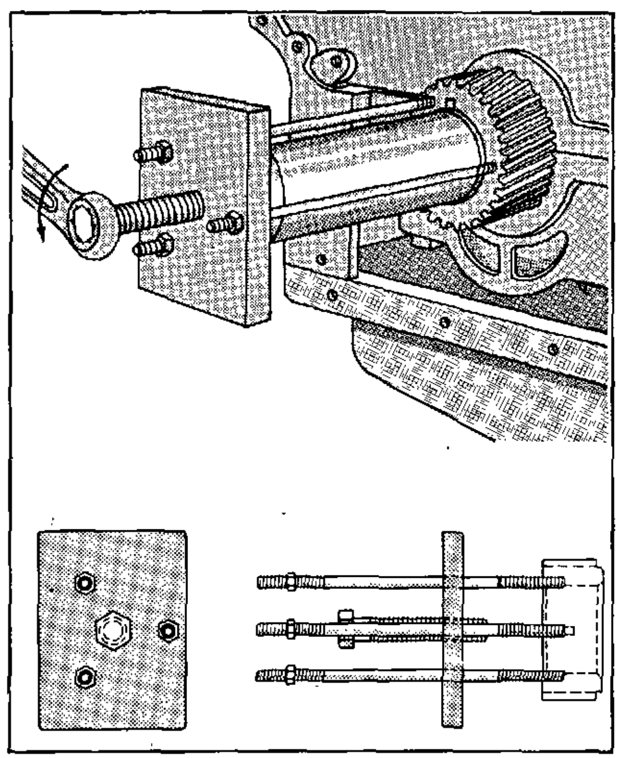
The cam followers may be removed by working from the underside of the crankcase after the camshaft is removed. Keep each cam follower in order as removed and re-install in the same place. When a worn or damaged cam follower is found, always inspect with particular care the cam lobe upon which it was operating.

Camshaft Gears

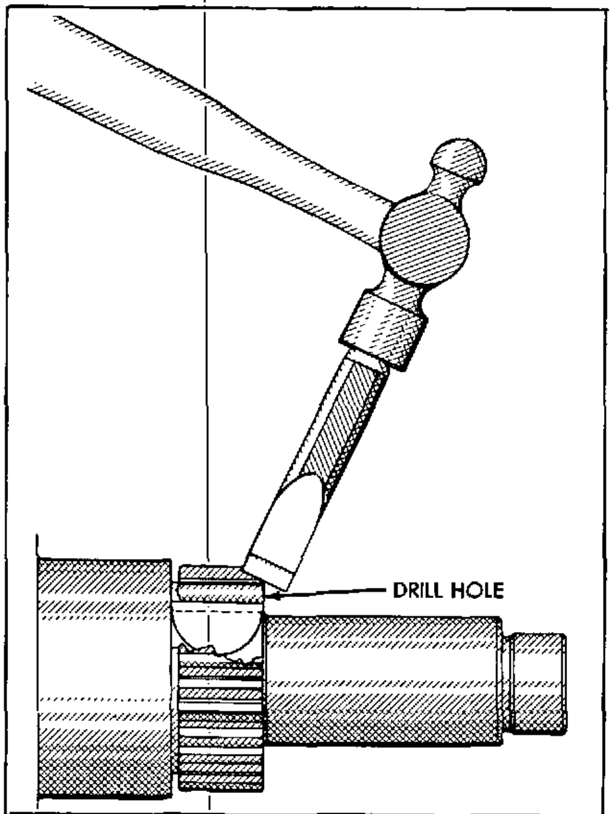
Late model 140 and 145 series engines are equipped with a camshaft incorporating a threaded bore to receive a camshaft gear lock screw. As shown, the lock screw is hollow and provides a means of locating the thrust plunger and spring which bears against the thrust button. It should be noted that this assembly insures positive retention of the cam gear, however, the parts involved, including the camshaft, gear, spring, and plunger, are different from those used with pressfit gear and shaft assemblies. Hence, if it is desired to convert an existing engine to the positive-lock cam gear type, it will be necessary to replace all the parts shown here. Torque for the lock screw is 1200 inch pounds.

Crankshaft Gear

In those instances where replacement of the crankshaft gear is necessary, it is easiest



CRANKGEAR PULLER



REMOVING CRANKGEAR BY SPLITTING

to remove the gear with a puller as shown in the accompanying illustration. If such a puller is not available, or if the gear has no puller holes it is necessary to split the gear as shown. First drill a hole of approximately 1/4-inch diameter lengthwise of the gear and between the keyway and the teeth. Thus, a variation in drill direction will result in nothing more than damage to the replaceable key. After drilling, a light blow with a cold chisel will spread the gear a few thousandths and permit removal.

VALVES AND MECHANISM—REPAIR

Valves require grinding at various intervals during the engine service life. These intervals cannot be specified exactly because a host of variable factors enter the picture, often without the engine operator's knowledge. Of these factors, the following have been found to a greater or lesser degree to make for reduced valve life.

1. Fuels that break down to form deposits that impair seat contact and prevent heat conduction and valve cooling.
2. Deposits from either fuels or oils that accumulate on the valve stems and cause sticking and burning.
3. Oil not reaching rocker arms due to clogged lines or improper fittings.
4. Shutting down a hot engine without idling for a few minutes. Exhaust valves that happen to be off their seats when engine stops may warp so that burning occurs on restarting.
5. Tappet clearances not properly maintained so that at least .008 to .010 is available when running.
6. Lean mixtures due to improper carburetor or adjustment.
7. Pre-ignition due to wrong plugs, carbon deposits, excessive operating temperatures.

Compression Checks

A compression check is the best method of determining whether valves need grinding. Since different pistons will develop different cranking compression pressures due to compression ratio variations, no specific figures are given for this test. The most significant thing is for the pressures on the individual cylinders to match with a fair degree of evenness. If it is felt that compression may be leaking past the piston rings, inject some heavy engine oil through the spark plug hole before making the test. This will seal the rings temporarily. In addition, a quick knowledge of valve condition may be gained by listening at the carburetor entrance (disconnect air cleaner) and the exhaust outlet while the engine is cranked over. Piston ring blow-by may be heard at the oil-filler opening as the pistons are slowly brought onto compression and the air allowed to seep past. If valves are leaking badly, the piston ring leakage may not be noticeable. Another indication of leaking valves is an unsteady vacuum reading, particularly at idle.

Valve Mechanism

When the push rods have been withdrawn they should be tagged or otherwise marked so that each rod may be replaced in its own tappet. Examine each rod to make sure it is straight, and that both upper and lower ends are in good condition. Replace--do not straighten--any that are bent, and if there are any of the ball and socket fittings, pressed into the ends of the rods, that show signs of wear beyond the case hardening, replace these fittings also.

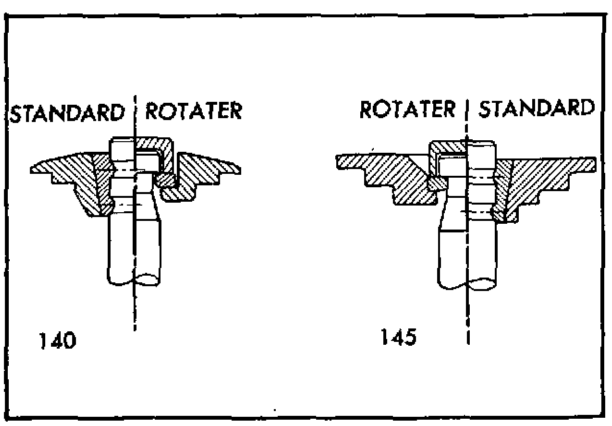
Sockets at the rocker arm end must not be used if they are worn so deep that the upper edge rides the adjusting lock nut or the rocker arm at any point.

The end of each valve stem is fitted with a shallow steel retainer that accommodates the end of the valve spring, and is held to the stem by a pair of split tapers. The locking tapers must be removed before the valve can be withdrawn. To release the lock from the recess in the spring retainer, it is only necessary to push the retainer down against the spring until the tapers fall away from the valve stem. Weak or cocked springs should be discarded and new ones installed when re-assembling. Free-type rotators are available for exhaust valves on commercial engines when required.

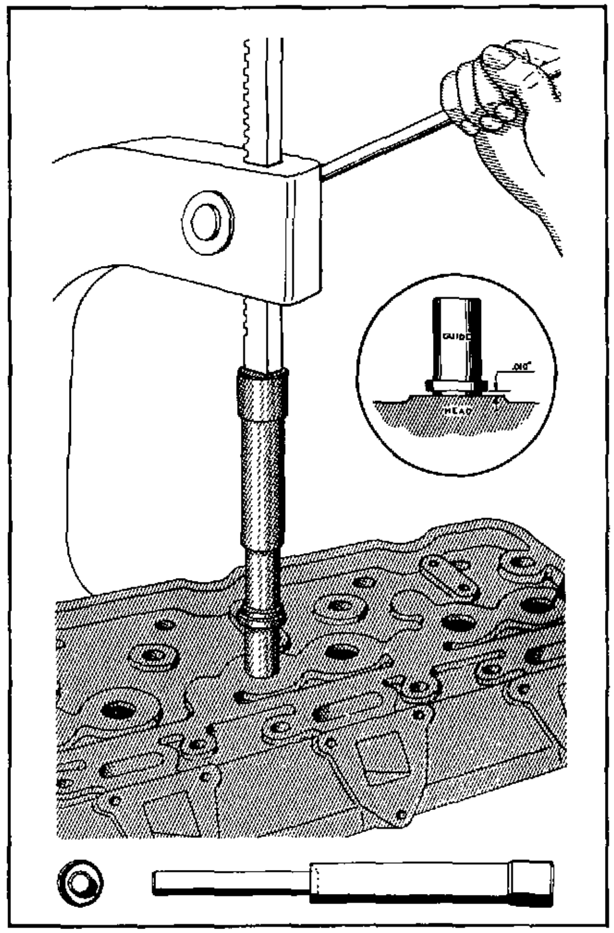
GUIDES AND SEATS

Upon removing each valve examine it carefully. Remove all carbon and burned oil and check the valve stem and its fit in the guide. Excessive wear in either the stem or guide will make it impossible to secure a tight seat by grinding unless the valve or guide, and possibly both, are replaced. Special notice of the exhaust valve guide and valve stem shoulder should be taken to make sure the guide does not project into the valve gas passage, and that the shoulder on the valve stem is sharp. This shoulder should be slightly below the top of the valve guide when the valve is seated. Thus, any accumulation of carbon around the guide and stem will be sheared off each time the valve is lifted, and in this way prevent valve sticking.

Worn valve guides and valve seat inserts should be replaced with new ones. The guides are a pressed fit in the head casting, and service



TYPICAL ROTATOR AND STANDARD VALVES



INSTALLING VALVE GUIDE

guides are especially machined to press in place, and give proper stem clearance without further machining. On the other hand, the valve seat in the head MUST be re-cut concentric with the new guide whenever new guides are installed. The valve seat inserts are furnished in 1/64, 1/32, and 1/16 oversize for a press fit, but require shrinking to anchor them in place.

To obtain the optimum service life from replaced inserts, the use of Waukesha Stellite-faced, die steel seat inserts especially made for this job is strongly recommended. The steel and heat-treatment of these inserts has been developed by long service and laboratory experience for the very best characteristics of heat resistance and expansion control to provide the correct shrink fit and maintain this fit under hard usage.

The accuracy of the machine method of valve grinding depends entirely upon the condition of the valve guide and the pilot mandrel's fit, both in the guide itself, and the hub of the grinder stone. It is vitally important, therefore, to make sure that the mandrel is a snug push fit in the valve guide, and will not wobble at the upper end. If it does have any upper-end movement the seat will not be ground true. Guides that are worn too much to give the mandrel solid support should be replaced before grinding is attempted. The maker's instructions for dressing the grinding wheel must be followed to secure smooth, accurate seats.

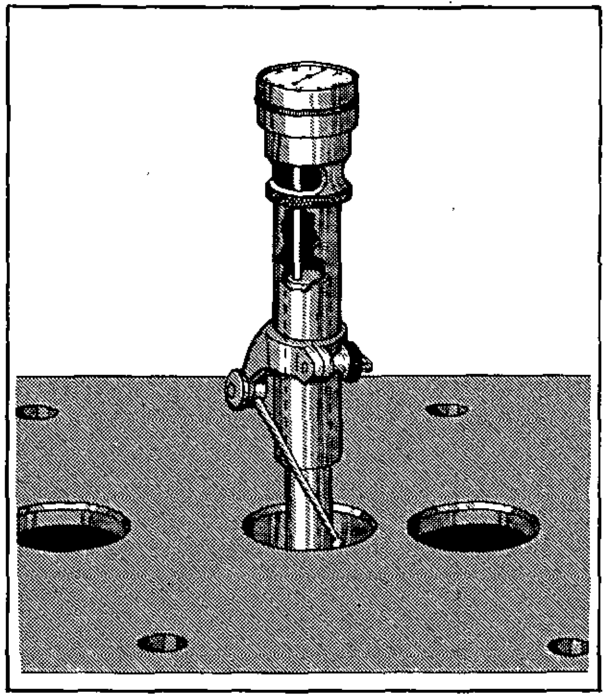
VALVE GRINDING

Modern valves are much harder than formerly so that a valve grinding machine is much quicker and more accurate than hand grinding. If machine grinding equipment for both valves and seats is not immediately at hand, it will often save time and money, as well as getting a better job if the head and valve assembly are sent to a local specialist. Even if hand grinding is employed, the valve stems and guides must be a good fit without wobble to insure a concentric seat and a tight valve.

Hand Grinding Method

Apply a good, medium grinding compound sparingly around the entire valve seat, slip a light lifting spring over the stem, lubricate the stem, and drop the valve into its original place in the cylinder head. The spring should just barely hold the valve off its seat. Place the grinding tool in the two holes or slot in the head of the valve to be ground. Press down until the valve is seated. Turn the valve a quarter turn, first in one direction then in the other. Do this three or four times. Release the pressure on the valve, and the little spring will lift it off its seat. Now turn the valve about 10 or 15 degrees to another position, and repeat the grinding. Do this until all the compound is rubbed off the valve seat. Withdraw the valve, and put on some fresh compound. Repeat the grinding operation.

Clean the valve and its seat occasionally to see how the grinding is progressing. When all pits and grooves have disappeared, clean the valve and valve seat, and place eight or ten equally spaced marks with a soft lead pencil on the seat. Then drop the valve in place, give it a quarter turn, and remove it. A perfect seat will be indicated if every pencil mark shows where the valve has rubbed it. If any pencil marks are left untouched, continue the grinding. When the grinding is completed, check the valve seat for concentricity with a dial indicator, then oil the valve stem, clean all traces of the grinding compound from the valve chamber and ports, and RE-ASSEMBLE EACH VALVE IN ITS OWN OPENING.



CHECKING SEAT FOR CONCENTRICITY

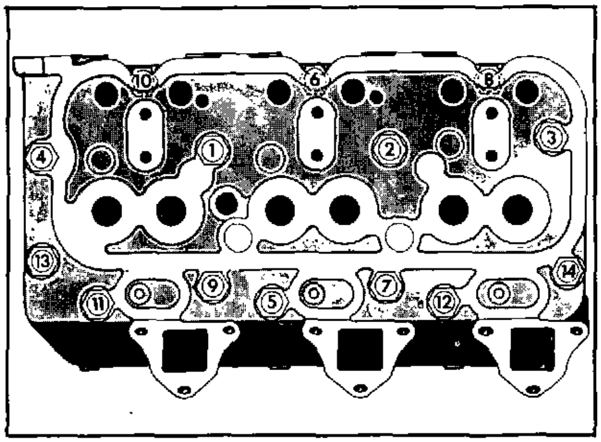
REPLACING CYLINDER HEAD

First, make sure that any oil leads which may be drilled in the head to feed the rocker arms, as well as the drilled oil leads in the cylinder block, are clean to insure full oiling of the valve mechanism.

A torque wrench when used according to the table at the rear of this book will prevent over-straining studs, while insuring a tight joint. The order of tightening is also important. As shown in the typical case, the hold-down studs should be tightened in two or three successive stages starting with the center and working toward each end alternately. This will insure even pressure over the entire surface of the cylinder head and gasket. If the outside nuts are pulled up first instead of the center ones, the head will be cocked, and the gasket will not fit tight enough to prevent blowing out between cylinders. A torque wrench, where used according to the maker's directions, is the best way of setting up cylinder head nuts to insure full tension without excessive strain that might stretch the studs.

Do not neglect to connect the oil lead to the rocker arm shaft. Test it to be sure it is not clogged.

Cylinder heads should be re-tightened to the specific torque and sequence after first warm up and after approximately fifty hours of operation.



HEAD TIGHTENING SEQUENCE
(145 *ENGINE SHOWN - SEE CLEARANCE)*

BEARING ADJUSTMENT

All main and connecting rod bearings in the 140-145 engines are of the steel-backed precision type. Because of the extremely close machining of this type bearing, no fitting, filing, scraping, boring, or other adjustment is required or permissible. Special treatment of shimmed bearings is discussed later in this section. Replacement must be in complete bearing units. Never replace only one half of a bearing. Service bearings are available in .020 and .040 under size for use on reground crankshafts. Never attempt to adjust a bearing by filing, grinding, or lapping, the bearing cap. The bearing seats are precision bored with the caps in place. Hence, any metal removed from either side *forever prevents proper fitting of a connecting* rod bearing in the rod, and in the case of a crankcase makes the entire case unsuited for further use.

Be sure that the bearings seat on absolutely clean surfaces and that the back of the bearing is wiped perfectly clean. The slightest bit of dirt or carbon squeezed between the back of a bearing and its seat can cause rapid bearing failure due to a localized high spot.

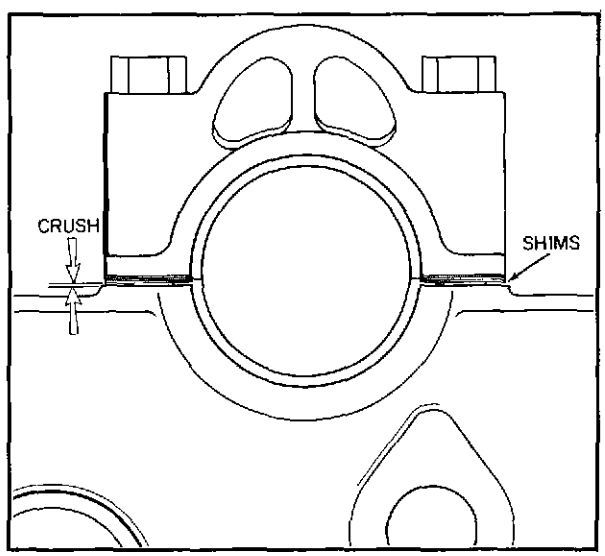
Equally important in obtaining maximum bearing life is the correct tension on the bearing cap nuts. Pull down on all nuts evenly, going from one side of the bearing to the other. Apply final tension with a torque wrench using a slow steady pull and holding the wrench "on torque" for a few seconds when the proper value *is reached. Desired torque values will* be found in the Clearance Section at the end of this manual. Never back off on a bearing nut to install a cotter pin. It is preferable to go to a slightly higher tension if necessary. If it is apparent that the cotter pin cannot be installed without bringing the tension dangerously near the limit of the bolt, remove the nut and try again with another nut at that location. Previous over-torquing, or some other damage to the bolt or nut is sometimes encountered and will be felt by the torque "softening up" so that the nut can be turned without appreciable increase in wrench tension. Never allow a bolt and nut in this condition to remain *in an engine.*

On 140 and early 145 series engines, crankshaft end thrust is controlled by the rear main bearing flanges and is established by the bearing dimension itself. Therefore, there is no necessity for adjustment of this at assembly. Excessive *end play requires bearing replacement.* Recent 145 engines use thrust rings instead of the flanged thrust bearings.

145 Series Thrust Rings

Thrust rings are now furnished in the 145 series main bearing replacement kits for use with the new flangeless rear main bearing inserts. Flanged rear main bearings were formerly used. The thrust rings offer more convenience in service especially with re-ground shafts.

Furnished as four identical halves with 9/64" pre-drilled locating holes, the ring sections may be used as locating templates to guide the drilling of locating pin holes in the bearing cap faces. These holes receive roll pins that project *into the thrust ring hole so the rings cannot* turn. The procedure for drilling and installing the pins is outlined on the following page.



BEARING CRUSH

1. Put both upper and lower halves of the ring in place at front and rear so the split lines are parallel to the cap split line. Snug the cap down to seat the rings.

2. Use a 9/64" centering punch through the predrilled hole to locate the hole center.

3. Remove the bearing cap and clamp it squarely in a drill press. Drill a 1/8" hole 3/8" deep on each side.

4. Install a roll pin on each side, locate a ring over each pin, and check to be absolutely sure the pin does not project to or beyond the thrust face. The pin should be about 0.010" below the face to permit normal service wear without contact between the crankshaft and the pin end.

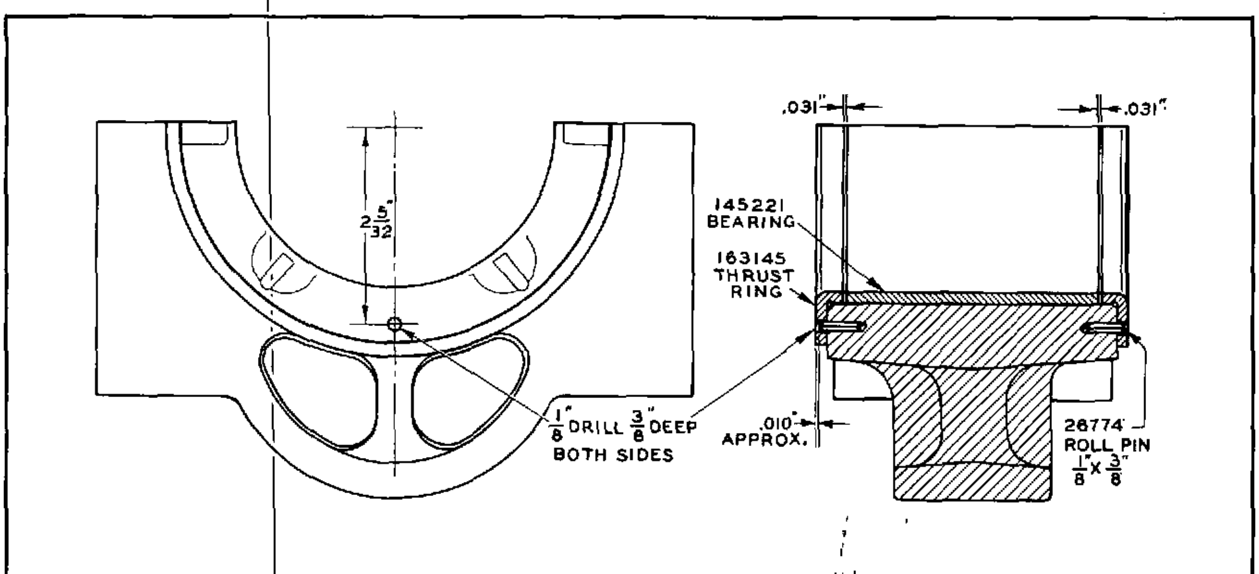
5. With the thrust rings temporarily clamped lightly in place, slip a bearing insert in place to check for clearance between the ends of the insert and the inner edges of the rings. About 0.031" is normal. The crankshaft and bearing cap may now be installed in the usual manner. ALWAYS CHECK FOR NORMAL CRANKSHAFT END THRUST OF 0.007-0.011" after placing shaft and again after tightening bearing caps.

The Waukesha Motor Company 145 Engine Series bearing replacement kits are available with standard, 0.020" and 0.040" undersize bearings. The bearings are designed to give a theoretical oil clearance of 0.0015" to 0.0045". The thrust rings included in the 0.020" and 0.040" undersize bearing kits are furnished with a 0.010" oversize thrust flange to compensate for normal thrust area wear encountered on crankshafts requiring undersize bearings.

Shimmed Rod Bearings

Although the connecting rod bearings in these engines are of the precision type, they are provided with laminated shims to permit a slight amount of adjustment. These shims do not extend into the bearing itself and are clamped between the cap and the rod but not between the crush edges of the bearing shells. When assembling bearings use caution to properly align these shims this way. When the rods are machined, the shims are clamped in place and the bolts tightened to the proper torque so that the final bearing seat is the exact diameter required to accommodate the two bearing shells plus the desired crush with all shims in place.

For this reason, whenever a shim is removed, and such adjustment should only be considered in an emergency, it is also necessary to remove the same amount from the crush edge of one of the bearing shells. For example, the shims are laminated in three thicknesses of .002 each. If it were decided to take up .002 on the bearing, one layer on each shim would be peeled away. Never remove shim stock on one side only. After removing the shim stock, the bearing shell must be reduced .002 on the crush edges of one shell, or .001 on all four crush edges of both shells if desired. This may be done on a lapping plate, or by carefully



145 SERIES REAR MAIN BEARING THRUST RINGS

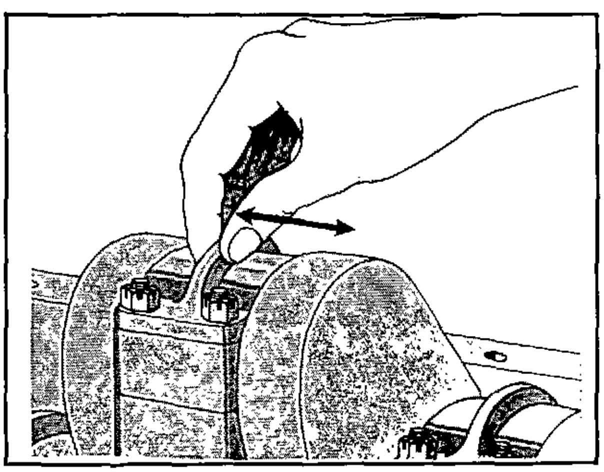
dragging the shell edges across a flat mill-cut file clamped to a flat surface. Obviously this is a job requiring both skill and experience. For this reason, it is considered best practice to replace the bearings completely rather than attempt to adjust them. New engines will no longer have shims.

Side Clearances

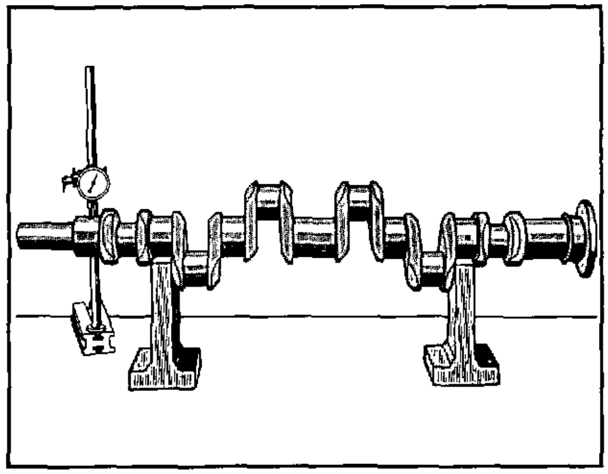
Although less critical than the bearing running clearances, no bearing should be assembled without checking side clearance. This may be done by forcing the rod fully to one side or the other and inserting a feeler between the crankcheek and the bearing end. Shaft end play is measured with a feeler between the shaft flange and the rear main bearing flange when the shaft is at full forward or rearward position. A dial indicator may also be used for this purpose. Consult the table of limits for the proper clearances.

Running Clearances

Even in the case of precision bearings, it is good mechanical practice to check running clearances when installing bearings. There are several methods of doing this, some of which are merely checks of whether any clearance exists and others that give an indication of how much clearance is present. The familiar test of connecting rod bearing clearance consists of manually gripping the rod cap after the bearing bolts are tightened and attempting to move the bearing from side to side in the direction of end clearance. A well-fitted bearing is usually just loose enough to be "snapped" from side to side without actually feeling so loose as to push easily. Sometimes a slightly snug bearing will not move under finger pressure but will move readily under light blows from



TESTING BEARING FOR TIGHTNESS



CHECKING CRANKSHAFT RUN-OUT

a soft-face hammer. This is usually considered as satisfactory providing the engine is given adequate break-in time. In the final analysis, this test is a matter of judgment and is not altogether suitable for general use.

A similar test on main bearings consists of tightening each bearing cap in turn and turning the shaft to detect binding. Again, the difference between tight and "about right" is a matter of judgment.

More accurate tests may be carried out with fuse wire or with a special crushing gauge material that squeezes between the shaft and the bearing to flatten into a measurable gauge.

It is emphasized that any unusual bending or run-out in a crankshaft makes it impossible to fit bearings accurately. For this reason, the time spent in making a run-out check at overhaul is well worth while. Also, magnetic inspection of the crankshaft and other stressed parts is recommended if the proper equipment is available.

DO NOT FORGET TO COAT ALL RUNNING SURFACES WITH CLEAN, FRESH ENGINE OIL WHEN INSTALLING NEW BEARINGS!

REAR MAIN BEARING MODIFICATION

A recent production change to plug or eliminate the oil drain holes in the rear main bearing cap of Waukesha Model 145 series engines, together with the elongation of the bearing oil channels, takes advantage of the improved rear seal design and retainer incorporated some time ago and provides additional oil flow to the thrust surfaces. It is quite easy to make this modification at overhaul, however, it is pointed out that in those instances where maximum thrust load capabilities are required it is equally important to be absolutely sure the thrust areas of the crankshaft are polished to an extremely smooth running surface. Careful analysis of unsatisfactory thrust bearing life in the field has often shown that this factor has been neglected in rebuilding operations.

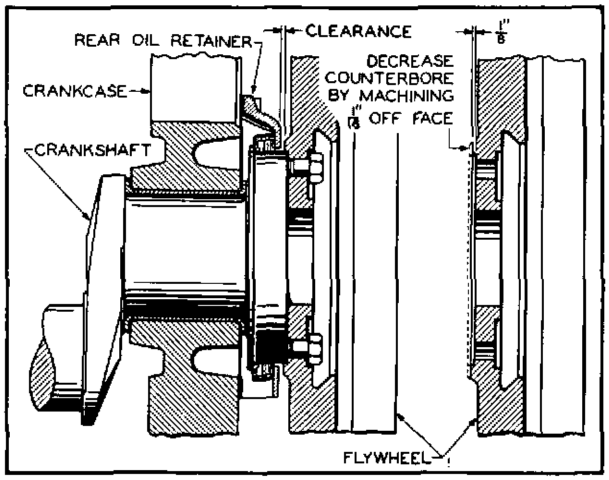
The drain hole in the bearing cap can easily be filled by pressing a brass dowel into the 1/4" diameter hole. Although field conditions may not permit, it is suggested that a 5/16" diameter counterbore be drilled approximately 1/4" deep into the lower end of the cap. Pressing a 5/16" metal dowel into place from the bottom will then provide a perfect oil seal.

All rear main bearings purchased from the factory, will have been reworked to provide for the longer bevel on the bearing edges as seen in the illustration. In instances where a new reworked bearing is not available, the bevel can be elongated by hand filing, although a machining operation is desirable. The bevel on each end of both the upper and lower bearing shells should be lengthened from the previous dimension of 15/16", to the new dimension of 1-5/16". Extreme care must be exercised in the hand filing procedure to prevent possible marring of the bearing surface.

Installation of the reworked bearing and a cap which still contains the drain hole, or the use of a cap that has the hole plugged with an old style bearing, will not be detrimental. All bearing caps supplied from the factory will not contain the drain hole, but the bearings will continue to contain the hole to prevent confusion.

Before replacement of the bearing, inspect the crankshaft thrust surface for signs of wear and abrasion. This surface must be smooth and free from all marks. Whenever the situation permits machine finishing of the shaft, it should be mounted in a lathe and the thrust surface polished with crocus cloth. The shaft should be rotated in two directions, and the crocus drawn across the thrust face.

The increased oil volume and pressure now applied to the rear main bearing requires that the latest design oil seal be used. Seal #156197-B, and retainer #135090, can be used with all 145311 and 145411 series crankshafts.



FACE TYPE REAR OIL SEAL

STANDARDIZED CRANKSHAFT AND REAR SEAL

In the future, all Waukesha Model 140 and 145 series engines will be serviced with a single, hardened, non-counterweighted crankshaft, except for special applications.

In addition, it will be necessary to supply new, spring-loaded, face-type rear oil seals and associated retainers when these shafts are used to replace former shafts using the packing type seal.

In some engines interference may occur between the flywheel and the new rear oil retainer outer face. This may be expected if the flywheel counterbore is 3/16" deep and in such cases it is suggested that the flywheel be mounted in a suitable lathe and the outer lip of the counterbore faced off 1/16".

A measurable clearance must exist at the point marked "Clearance" in the accompanying illustration. Be sure to move the crankshaft to its full forward position when checking. If only a very slight clearance exists, it is better to machine the flywheel enough to leave a margin for minor thrust bearing wear during service life.

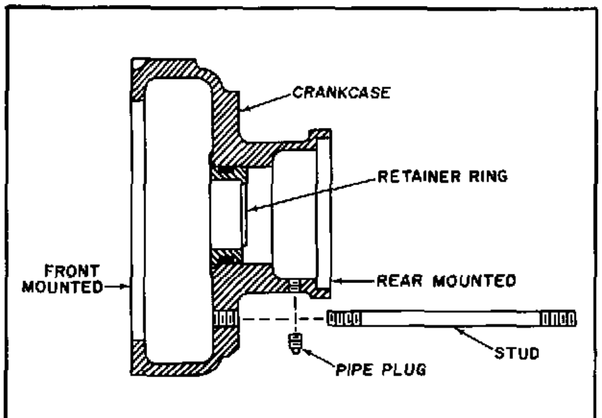
When replacing a counterweighted shaft which used a vibration dampner, the vibration dampner should also be used on the new non-counterweighted shaft. Always examine the dampner for evidence of deterioration, overheating, excessive run-out, or mechanical damage. Replace it with a new dampner if its condition is doubtful. Never heat a crankshaft front pulley with the dampner attached and never mount a dampner on a pulley which has been heated until the pulley cools to approximately room temperature.

For those users who continue to use the original crankshaft at time of rebuilding the original packed type retainers and seal packings are available for service although it is seldom necessary to replace more than the packing. The new face-type retainer cannot be installed on the old style shaft.

GOVERNOR RETAINER RING

Either of two types of governors may be used on Waukesha 140 and 145 engines, however, it is necessary when rebuilding or ordering a short block to either provide or omit the governor retainer ring depending upon which governor, front-mounted or rear-mounted, is used. Removal of the retainer ring after the engine is installed may necessitate many hours of labor which can be avoided by close attention to the following...

Since it is not usually known which type of governor will be involved when a new short block is ordered, the retainer ring for the rear-mounted governor is pressed into place. Reference to the illustration will show that this ring cannot be removed towards the rear because of the small flange at the front. Moreover, although not apparent from this illustration, the cam gear, and, of course, the front cover, would prevent removal of the ring after the engine is assembled and installed. Obviously, it is undesirable to encounter these facts in the final steps of installing a rear-mounted governor. Secondly, the small pipe plug which is omitted with a magneto and front-mounted governor must be in place securely when the rear-mounted governor is used. Omission of the plug will result in a severe oil leak which may not be apparent in some equipment and vehicles until the engine runs out of oil. The proper procedure for adapting a new short block to either governor is given here.



METHOD OF RETAINING RING

When the front-mounted governor is used:

1. Do not install the 1/8" pipe plug in the bottom of the housing. The hole must be left open.

2. Install the magneto mounting stud in the housing. The stud is shipped with loose parts.

When the rear-mounted governor is used:

1. Remove the drive shaft bearing retainer ring. Do this by sliding the camshaft forward about 1" to allow the ring to drop out. Drive the ring forward with a hammer and drift pin, carefully, to avoid damaging the ring seat or cam gear. (Caution: Some means must be provided to support the lifters while the cam is being moved. If this is not done, the lifters may fall off the cam lobes.

2. Install the 1/8" pipe plug in the provided hole. The plug is shipped with loose parts.

3. Install the magneto mounting stud in the housing.

The Waukesha Motor Company custom builds short blocks upon request; otherwise the blocks are removed from stock and shipped. If, when ordering a custom built block, the type of governor to be used is indicated, the necessary work to suit it to the governor will be completed at the factory.

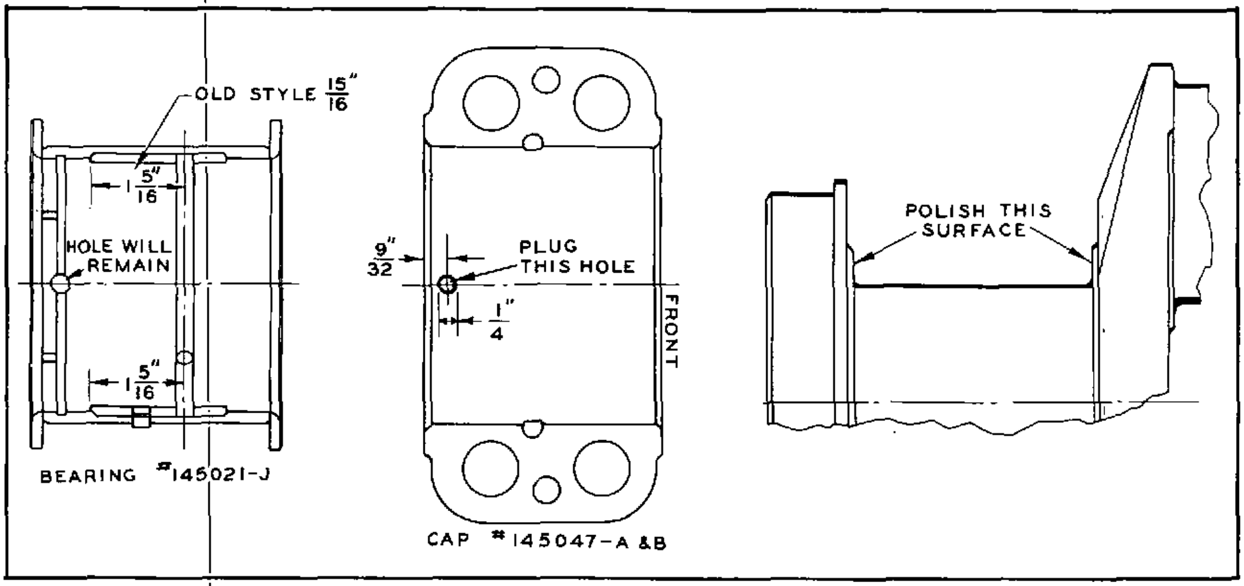
CYLINDERS AND PISTONS

Matching Replacement Pistons, Sleeves, and Pins

The precision and skill with which pistons are re-fitted during overhaul is sure to have a very great effect on later engine performance.

Unusually loose pistons will soon show up as noisy, with excessive blow-by, high oil consumption and sluggish power characteristics. Overly tight pistons may be even more dangerous because of the possible severe damage to sleeves or cylinder walls and other running parts. Less well understood, but very definitely important, is the necessity for using pistons that match each other within specified weight limits. Off-balance conditions established by relatively slight variations in piston weight can bring about effects ranging from merely annoying vibrations to fatigue failure within a short time.

The vital point about the above details is that an overhaul job where they are ignored or improperly handled is often worse than no overhaul at all. It is not enough to use new



145 SERIES REAR MAIN BEARING MODIFICATION

pistons and sleeves assembled from open service parts stock. The pistons should all come within the specified weight range and the piston-to-sleeve clearances must fall within a selective fit tolerance as actually measured by a person skilled in this operation.

All of the above facts are borne out by the long experience of the Waukesha Motor Company both in production and in providing service parts. We therefore believe that the very best way to obtain properly matched and fitted pistons, sleeves and pins, is to order factory selected sets as complete units for a given job.

When ordering parts of the above type, the following points should be remembered:

1. Pistons, sleeves, and pins, ordered as separate items for stock cannot, of course, be fitted at the factory and will be selected at random. To ensure a sufficiently wide assortment of parts to select the correct fit on the above basis requires a large inventory. To use assemblies that have not been so fitted is an injustice to the engine.

2. Complete assemblies ordered as such, that is . . . all pistons and sleeves; pistons, sleeves, pins and retainers; or other combinations for a given engine, will be selected for both weight and clearances at the factory and will be equivalent to new factory-production assemblies when properly installed. An extra charge is made for labor involved to make this service possible. We are sure your experience will prove this extra cost is more than justified.

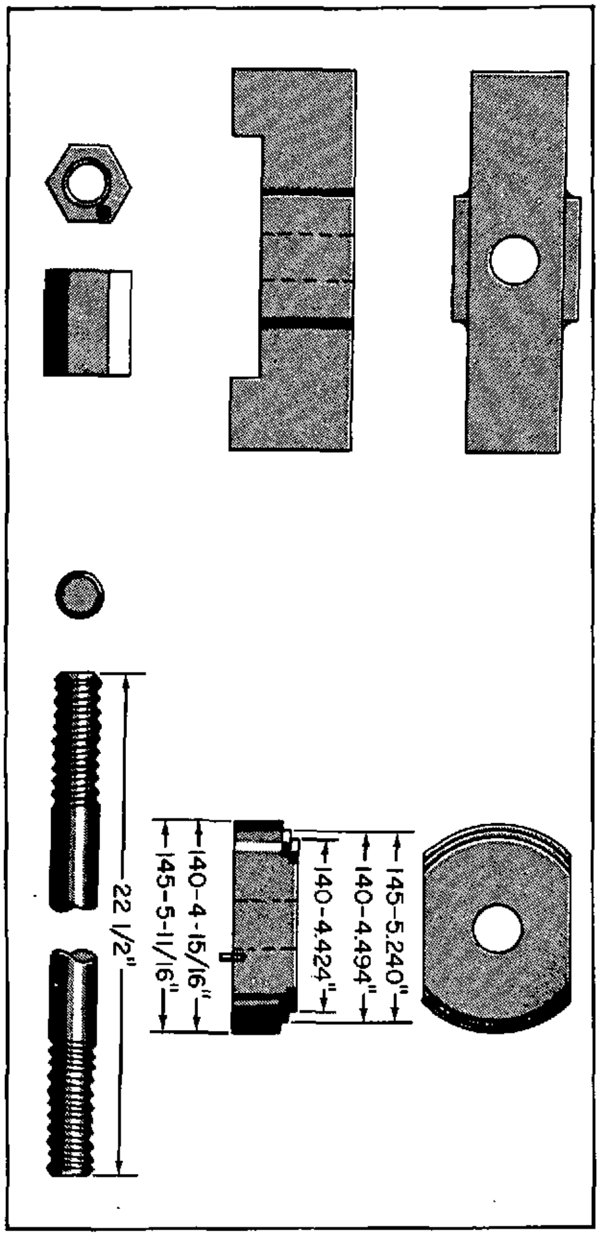
3. Instances where a portion of a factory assembly, for example, one sleeve and piston; several pistons in an engine; and so on is replaced and is to run in conjunction with some of the original parts, it is good practice to order replacement pistons that will match the original weights. To do this, clean the original piston until the weight figure stamping becomes legible, or, if these markings are obscured, weigh the piston to the nearest quarter ounce without the pin or retainers. This may be done on a postal scale.

If the weight is not reported with the order, open stock parts must be supplied and consequently there is no assurance of a good match between old and new parts.

Identification Marking

To aid accurate fitting of pins to pistons, and pistons to sleeves, each piston, pin, and sleeve, is checked with precision equipment and marked for size classification within the following limits.

Sleeves, Pistons		Pins and Piston Bosses	
Am't. Oversize	Letter Mark	Example of Size	Color Mark
Standard to .0003"	A	.8748-.8749"	Red
.0003" + to 0007".	B	.8749-.8750"	White
.0007" + to .001"	C	.8750-.8751"	Blue
.0010" + to .0015"	D		



HEAVY-DUTY SLEEVE PULLER

Ordinarily, sleeves and pistons with the same letter, and pistons and pins with the same color are fitted together, although merely matching letters or colors is not considered a sufficient check for correct fit. Instead, the letters and colors should be used as a guide to save time in eliminating unnecessary trial fits of parts dimensionally impossible to fit properly because they are in the wrong range.

In addition to the letter classification mark on a piston another numerical marking will also be found. This is the piston weight and may be stamped as total ounces of weight, for example, "97", 97-3/4, 96-1/2, or it may be stamped as pounds and ounces, for example, 5-10, 5-11-1/2, or whatever the weight may be. Ordinarily this mark will be found on the top of the piston, as will be the letter size marking. In some cases, however, weight markings are located in such places as the lower edge of the skirt, the lower side of the pin boss, or elsewhere.

Other markings will be found on some pistons. Some of these will appear as letters other than A, B, C or D and others will be merely devices or designs. These are inspector's marks and may be disregarded. In the case of pistons installed in an engine at the factory, the numerical order of the cylinders, 1 through 6, will also be found. Pistons with such designations should always be re-installed in proper order and facing the original direction.

Many pistons will be found with a small arrow, the word "front", or both, stamped on top. In such cases the word "front" or the arrow must always point towards the gear-cover end of the engine when installing the piston. This is important.

Piston part number marks are usually stamped on the top of aluminum pistons and cast on the inside of the skirt of iron pistons.

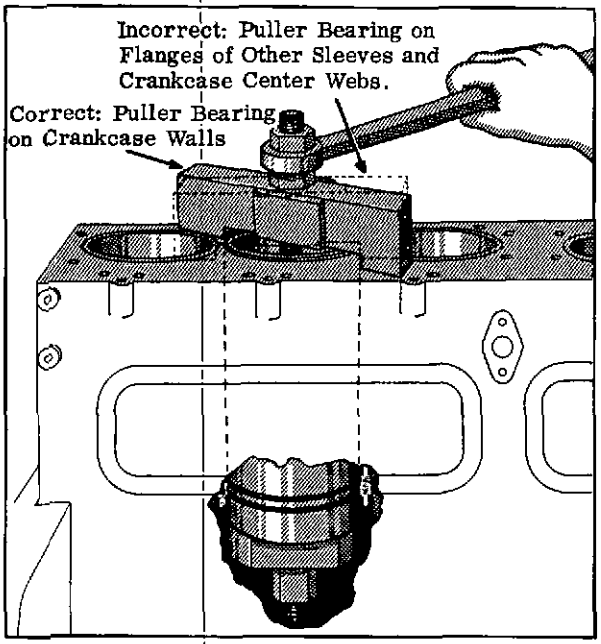
Selecting a Piston, Sleeve, and Pin Set

Presuming it is desired to fit a set of pistons and pins to new sleeves or a new block already in stock, the general procedure is as follows:

1. Select enough sets of pistons within the specified weight range to permit a careful fitting to the best obtainable clearances. A tabulation of the factory recommended weight range is included at the end of the manual.

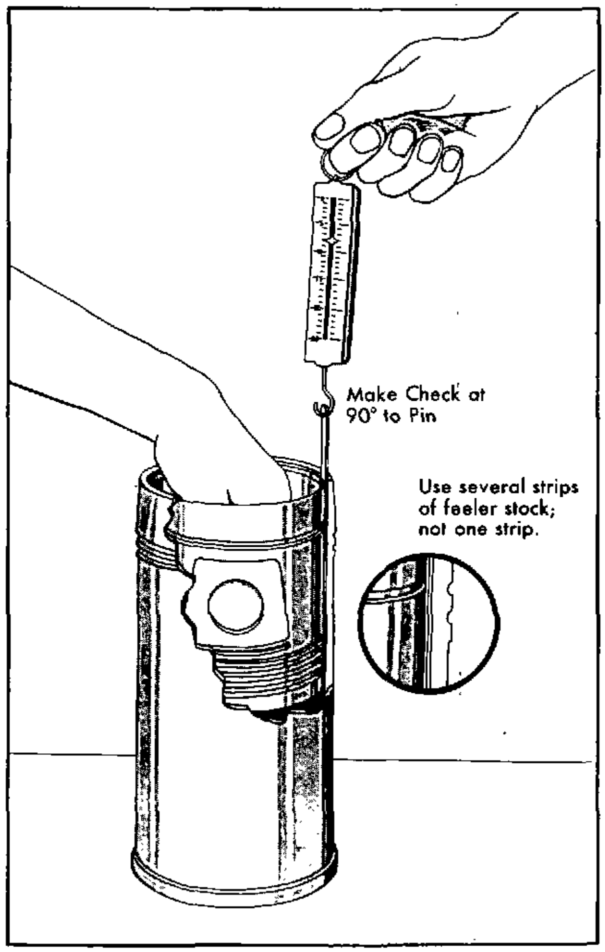
2. Note the letter sizes A, B, C or D on each of the new sleeves or opposite the bore in the block and select several pistons in each letter size required. All extra pistons and weight ranges can now be returned to stock.

3. Use a dial bore gauge, or inside micrometer to check the sleeve bore for distortion due to handling. Here, a maximum permissible out-of-round of .001" had been established as a practical limit. Eccentricities slightly in excess of this may be corrected by careful application of a wooden or plastic face mallet as needed to round up the sleeve.



SLEEVE PULLER IN USE

4. Using several strips of one-half inch wide feeler stock to make up a gauge as specified in the clearance limits for the engine being overhauled, attach a spring scale to this gauge and take the measurement of piston clearance as shown in the accompanying illustration.

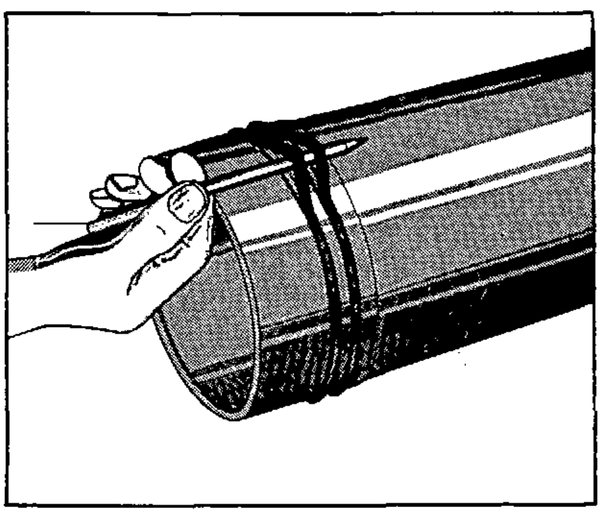


FITTING PISTON TO SLEEVE

Removing and Installing Sleeves

Removal of the wet-type cylinder sleeve is a comparatively easy operation since the only substantial force required is that needed to loosen the lower rubber seal rings. A screw-jack type puller may be made up with a plate seating against the lower end of the sleeve and connected by a through bolt to a bridge-like structure at the top of crankcase. Once the rubber rings have been freed, the sleeve is readily lifted out. Rubber rings cannot be re-used.

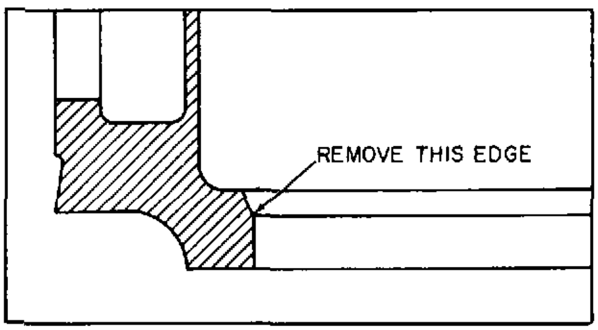
There are several important points to note on installing the sleeves. First in importance is the use of seal rings that are fresh and elastic. Do not use aged and hardened rings since these will not compress evenly and sleeve distortion will result. Also, the ring seating surfaces must be clean and well lubricated with liquid soap. Do not use engine oil on rubber rings. After slipping the rings over the sleeve and into the grooves, run a pencil or like instrument around under the ring to distribute the rubber material around the sleeve more evenly.



EVENING UP RUBBER RINGS

Inspect all seating surfaces at the upper end of the sleeve and in the crankcase counterbore to ensure that no dirt will interfere with accurate seating.

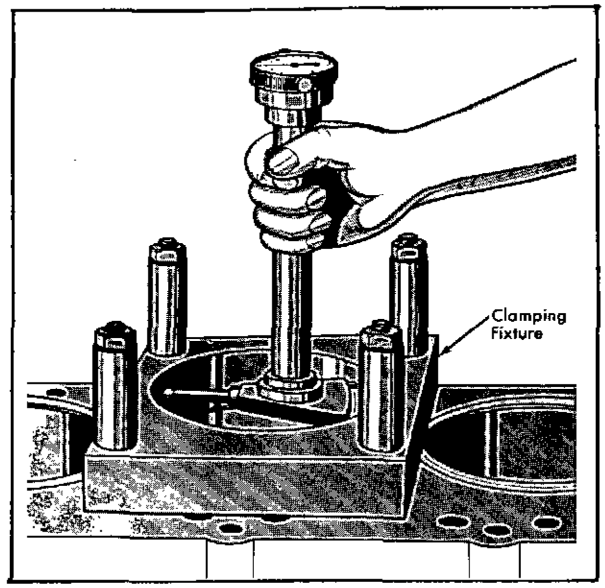
New, slightly larger seal rings made of black, Buna-N type, synthetic rubber are completely interchangeable with the previously used red silicone type; however, the diameter of the new ring will necessitate polishing of the cylinder sleeve bore in the early model crankcases. (See illustration.) The sharp edge left where the chamfer intersects the bore must be eliminated to prevent cutting or slicing the ring upon installation. Use emery cloth to polish the edge until physical inspection indicates it has been removed. Carefully avoid letting polishing residue fall into the crankshaft and crankcase area. Wipe frequently while polishing.



EARLY MODEL CRANKCASE

After the rubber rings and surrounding area are well soaped, align the sleeve in the crankcase and force it home with a smart, firm thrust of the hands. No hammering or driving is necessary or desirable.

When all sleeves are in place, check the sleeve bores for distortion that might have occured due to inaccurate placement of the seal ring material. This must be done with a clamping load on the top of the sleeve and a dial indicator of the extension arm, three contact type. Practical limits for maximum out-of-round permissible are .001"-.0015". The clamping action may be obtained from any accurately built ring that simulates the cylinder head pressure and is retained by the head studs. If a considerable number of sleeves are to be replaced over a period of time, it may prove convenient to make up a clamping tool from a discarded cylinder head with openings cut out to allow the gauge to drop through into the cylinder.



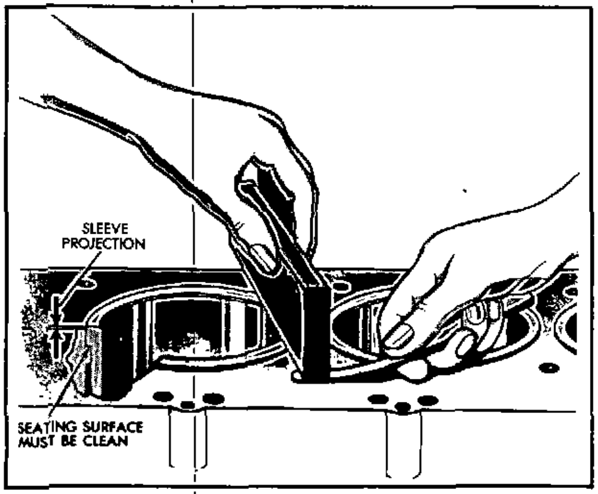
CHECKING SLEEVE FOR DISTORTION

It is not unusual when fitting this type of sleeve to find it necessary to withdraw the sleeve, re-soap and even up the rings, and re-install it several times before obtaining an out-of-round reading within the limits in the back of this manual. Uneven distribution of the rubber rings causes this trouble. Always make this check in the seal ring area.

In connection with the above check for out-of-round, it may be more convenient to make a gauging piston by re-grinding an oversize piston to just slide through the sleeve within the proper tolerances. Such a gauge requires some skill and judgment in use since forcing it through a distorted sleeve will not correct the distortion and may cause score marks or scratches.

Cylinder Head Gasket Crush

In order to prevent sleeve movement and seal the water at the joint between the upper sleeve flange and the crankcase, the sleeve must project a few thousandths above the crankcase deck. This distance is important and a definite and measurable amount must exist. In effect, this projection provides a localized crush in a concentrated area around the top of each sleeve. Improper tightening of the cylinder head or detonation may cause this crush to be lost. If this occurs, the thrust action of the piston may cause enough rocking action of the sleeve to wear the sleeve seating counterbore in the case unevenly. Thus, even though the sleeve



CHECKING SLEEVE PROJECTION ABOVE CRANKCASE DECK

indicated a projection as specified above the deck, it would actually be riding on a high spot and the clamping action would not be satisfactory. Check for such wear with a depth micrometer or dial indicator. The counterbore depth of a 145 engine should be .373"-.374", for a 140 .310"-.311". If measurement shows these dimensions to be incorrect, re-machine the counterbore so that the addition of a .004 to .005 shim will bring the counterbore back to proper depth. Shims for the 145 engine are available under part number 118228; for the 140 under part number 118822.

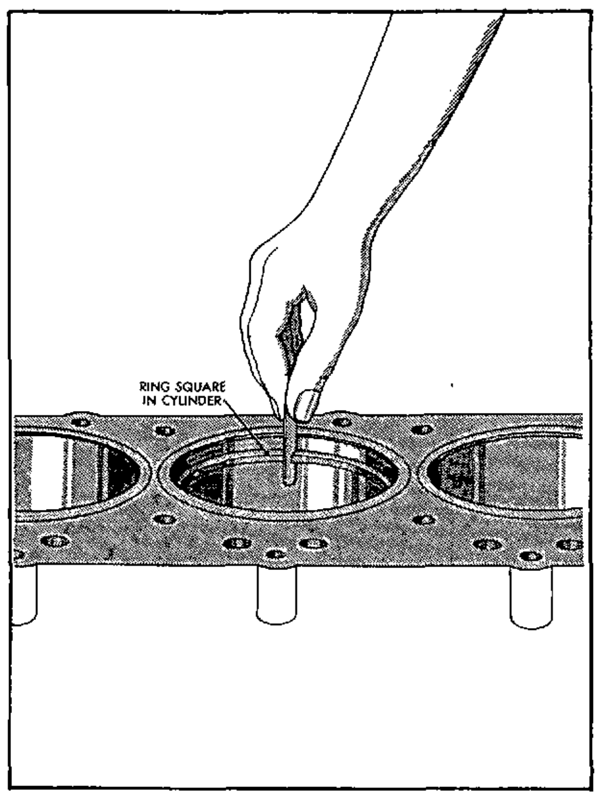
The operator is cautioned against using head gaskets other than those specified by the WAUKESHA MOTOR COMPANY. Cases have been reported where gaskets of somewhat harder material have overloaded the sleeve flange and started cracks in this area. By the same token, tighten cylinder hold-down nuts to the correct torque value. A cylinder head gasket in obviously good condition may be re-used. It is poor economy, however, to risk engine damage and extra labor if the gasket is at all doubtful.

Piston Fitting

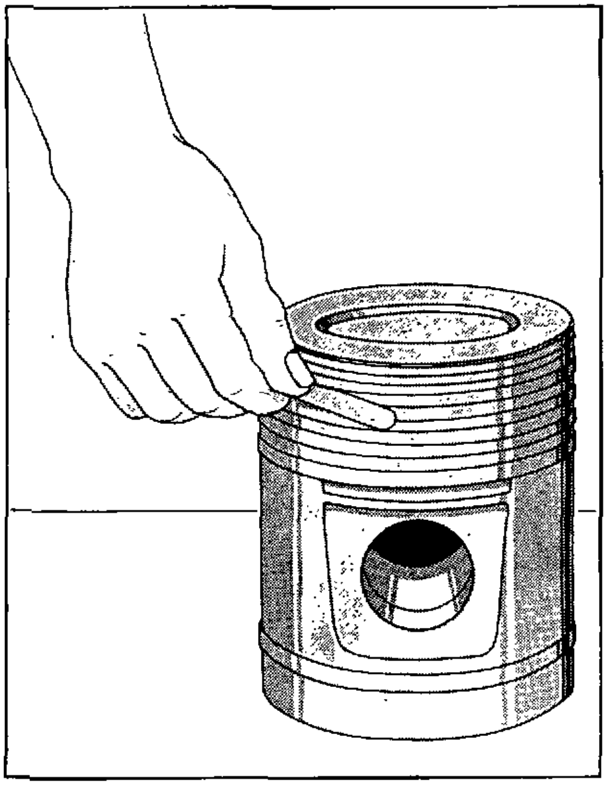
Proper fitting of pistons requires at least four different precision checks. These are: Ring gap, ring side clearance, pin clearance in boss, and piston skirt to sleeve clearance.

Ring gaps are easily checked with a feeler gauge. Slip a piston ring into the sleeve. Slide a piston into the sleeve above it. Push the piston up against the ring to square the ring with the bore. Move the piston out of the way and measure the gap in the ring with a feeler gauge. Those rings with gaps less than specified in the table of limits in the back of this manual should be carefully dressed off with a flat cut file until the correct clearance is obtained. Contrary to popular impression, fairly wide ring gaps, near the top limit, are far less detrimental to engine performance than gaps which are too tight.

Piston ring side clearance must always be checked when fitting rings to pistons which have been in service. In this case, the object of the check is to spot any pistons in which the ring grooves may have worn excessively wide. A piston in this condition must be replaced. To check side clearance, select a piece of feeler stock of the maximum clearance specified in the table of limits. With the ring in place, insert the feeler if possible between the ring land and the ring held well back in the groove. If the feeler slides in at any point, it indicates the clearance is at or over allowable maximum. A snug fit of the feeler points to further consideration by the operator as to whether the piston warrants reinstallation since the groove wear is at the top limit. On all pistons passing the above check, make an inspection for mini-



MEASURING PISTON RING GAP



PISTON RING SIDE CLEARANCE

mum clearance with a feeler of the minimum thickness specified in the table of limits. This feeler should slide freely all around the groove as the piston and ring are rotated.

A recent revision in the ring set-up of the 140 series engines incorporates a "K" section ring, chrome-plated, in the top groove. This type of ring is still 1/8-inch thick, but somewhat wider than the former ring. Thus, the ring groove is deeper for the top ring. If it is desired to re-fit a piston grooved for the previous rings, it will be necessary to increase the groove depth to the following dimensions: 3.998 diameter at bottom of groove on the 140 GK and GKB piston, and 4.110 on the 140 GZ piston. Since the GZ engines formerly used a 5/32 ring, it will be necessary to employ a locked-in type ring groove insert to bring the groove width to the correct .127-.126 dimensions.

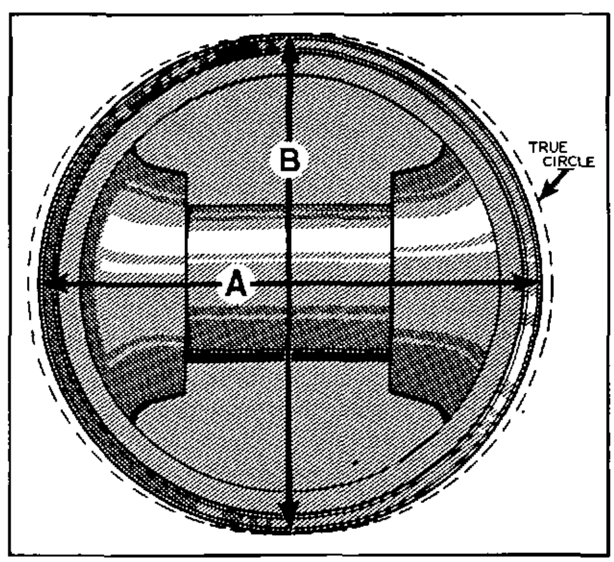
Piston pin fitting is a job requiring great precision and pin and piston assemblies are usually sold in matched sets. Oversizes of .003" and .005" are available, however, if desired. The specified pin clearance will permit a hand "push" fit at ordinary room temperatures. Some engines with aluminum pistons, however, have been fitted with pins that cannot be pushed in by hand until the piston has been heated to about 100° F.

A pin that is loose enough to drop through the piston by its own weight, is ordinarily considered too loose. From the service standpoint, a fit of this variety, if not due to severely worn parts, will cause an engine to be somewhat noisy but will not necessarily impair performance or reduce engine life.

If oversize pins are installed, do not forget to check the fit of the pin in the connecting rod bushing since the new pin will be too snug in a standard rod.

Piston to sleeve clearance is probably the most critical dimension in the entire piston fitting sequence. For this reason, pistons and sleeves are sold in matched sets. Also, pistons are sold for re-dimensioned sleeves in .010", .020", and .040" oversizes. They are not sold in semi-finished condition for these engines, and it is not recommended that a piston of given oversize be re-ground to a smaller oversize.

There are several reasons for this, including such factors as the nature of the equipment required, the necessity for specialized knowledge and skill, and the characteristics of cam-ground pistons. By cam-grinding, it is meant that the piston area below the rings is not round but slightly cam shaped or "oval". The long axis of the oval is located at 90° to the piston pin. Consequently, a micrometer measurement of the piston skirt diameter along the axis of the pin will be slightly less than a measurement taken across the thrust faces. The amount of "cam" for any piston is carefully

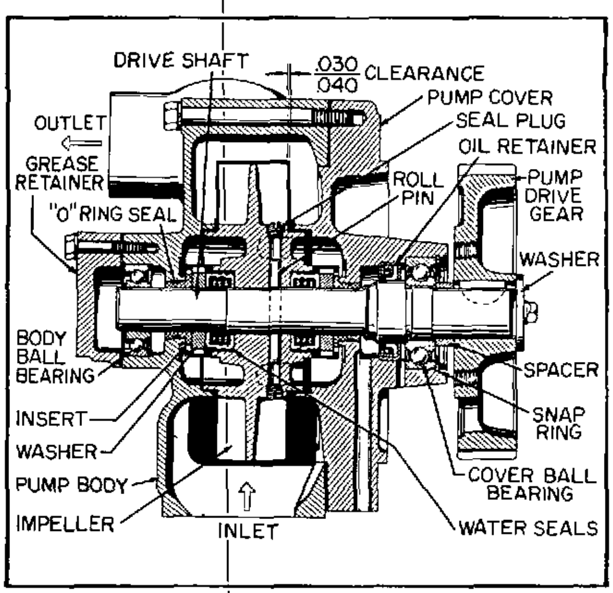


CAM GROUND PISTON (Exaggerated)

worked out to compensate for the metal mass, the engine temperature, and so on, that control piston expansion. Hence, the additional material at the piston pin bosses brings about an expansion that rounds out the piston under operating conditions.

Because of the foregoing facts, it is clear that piston skirt to sleeve clearance can only be taken on an axis 90° to the piston pin. That is, across the thrust faces. To take the clearance, select the pieces of 1/2"-wide feeler stock 8 to 10" long and totaling the desired skirt clearance. A single strip is not satisfactory because it is too stiff to conform to the curve of the sleeve bore and thus gives an erroneous reading. Attach the feeler stock to an accurate spring scale as shown in the previous illustration. Invert the piston and support it with one hand while holding the feeler and spring scale in the other hand. Place the feeler stock in the sleeve and lower the piston into position in such a manner that the feeler stock is spaced 90° from the piston pin. Hold the piston and withdraw the feeler stock. If the correct clearance is present, the tension required to withdraw the feeler should read 4-8 pounds.

When fitting a piston to a new or accurately re-sized sleeve, the sleeve inner diameter should be the same at top and bottom and the clearance may be taken at either end. In sleeves that are worn, but not re-sized, some taper is likely. In such cases, the clearance must be checked at the bottom of the sleeve where the wear is least and the fit is closest. Remember to check skirt, not land, clearance.



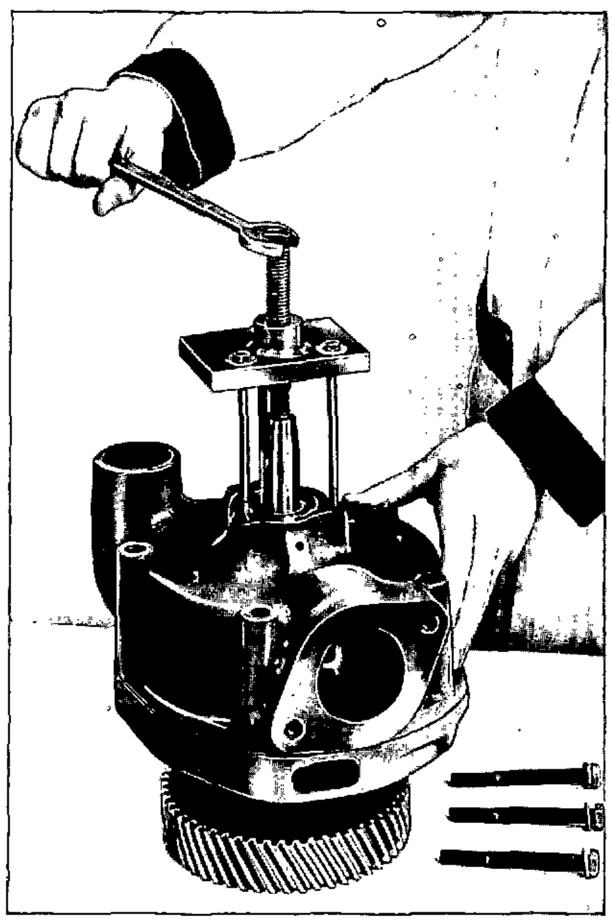
145 WATER PUMP, SECTIONAL VIEW

WATER PUMP RE-BUILDING

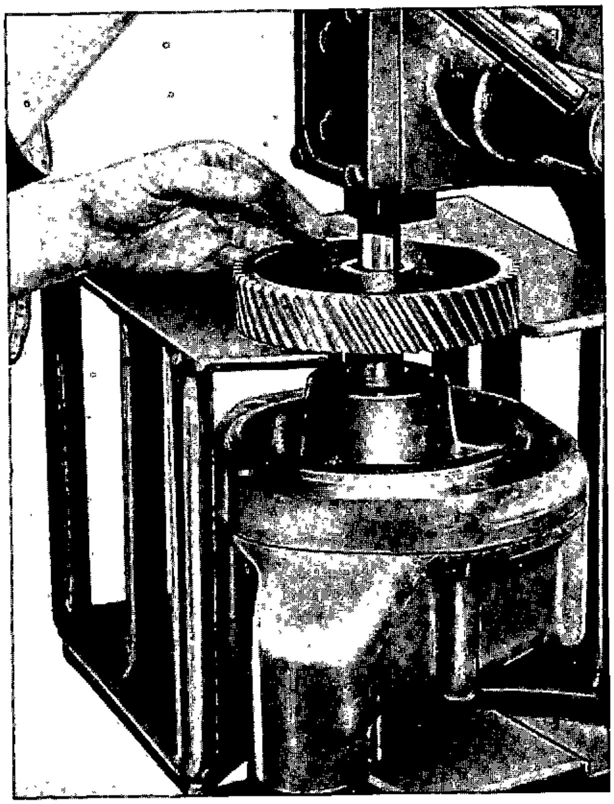
Although the re-building procedure as discussed and illustrated in this section pertains specifically to the current 145 series blind end and through shaft ball bearing type water pumps, the same general re-building procedure may be followed with the water pumps of similar type as used on the 140 engine series.

Disassembly

Field overhaul or repair of this type of water pump should not be attempted unless a large manual or a small hydraulic press is available. After removing the water pump from the engine, bench disassembly may proceed as follows. Remove the three retainer to body capscrews and lightly tap the grease retainer to remove from the pump assembly. To facilitate removal of the body which is held to the shaft by the fit of the bearing and "O" ring retainer, it will be necessary to fabricate a simple puller. With the three body to cover capscrews removed and utilizing the puller,



WATER PUMP BODY REMOVAL

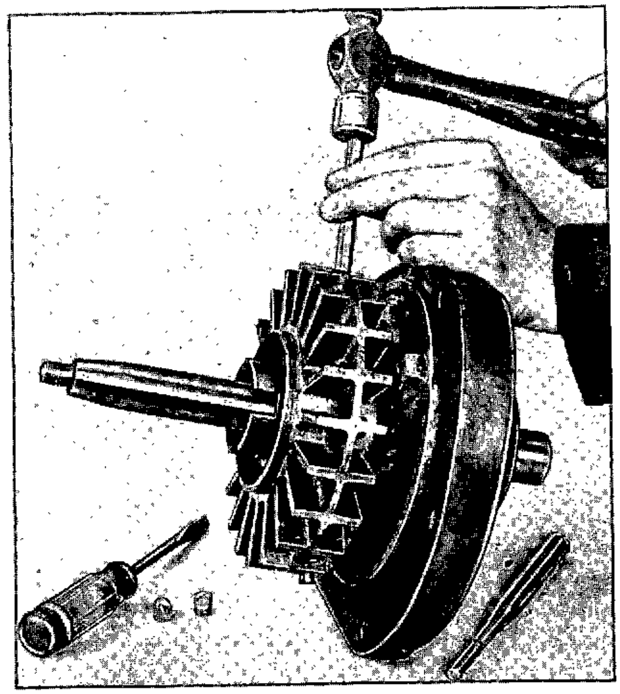


REMOVING PUMP DRIVE GEAR

pull and remove the body from the remaining assembly. Slip the exposed seal parts off the shaft and discard immediately to avoid reusing upon reassembly.

Although a standard gear puller may be used, it is suggested that the gear, which is a .002" press fit and is also keyed to the shaft, be removed using an arbor or hydraulic press. Pressing the gear off is accomplished by suspending the pump assembly by the gear in such a manner that the shaft and assembly may be pressed out of the gear. As the shaft assembly is pressed free of the gear, avoid damage to the shaft and assembly which could result from dropping.

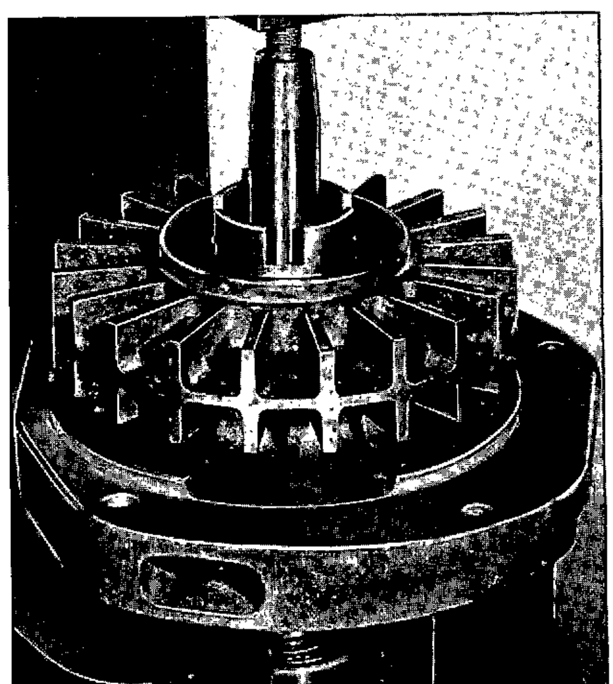
Before the impeller is removed the 5/16" roll pin which secures the impeller to the shaft must be driven out with a hammer and punch as illustrated. The roll pin hole is sealed with two pipe plugs. Block the impeller from turning and use a screwdriver to remove the two plugs. To free the roll pin, use a starter punch then follow up with a longer shank punch to drive the pin completely out. Since the cover ball bearing snap ring positions and locks the impeller and bearing, it must also be



REMOVING IMPELLER ROLL PIN

removed before the shaft and assembly is pressed through the impeller.

With the impeller roll pin and bearing snap ring removed, place the pump assembly, gear end down, on the base of the press. Since the



IMPELLER REMOVAL

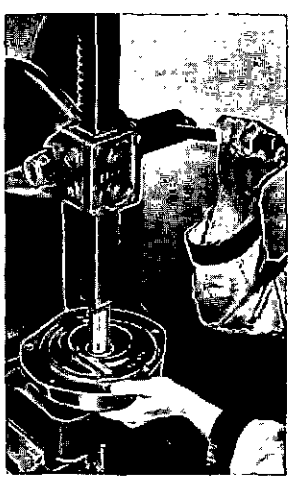
bearing will be pressed free of the cover along with the drive shaft, allow sufficient clearance for this bearing to clear the press base as the shaft and bearing are pressed out of the assembly and impeller. Prevent the shaft and bearing from falling as they are pressed free of the pump assembly. Upon removing the impeller, again immediately discard the automatic seal part to prevent its re-use.

To complete disassembly of the water pump, remove and destroy the cover oil retainer, then using a dowel of slightly less diameter than the "O" ring retainer, press both the cover and body retainers out. With the pump thus assembled, completely wash all parts to be used in rebuilding in a clean solvent. If the ball bearings are to be re-used, dip them in clean light oil immediately after cleaning to prevent rust formation. Do not air spin these bearings. Inspect all parts to be re-used for evidences of unusual wear or damage and replace any parts found to be defective.

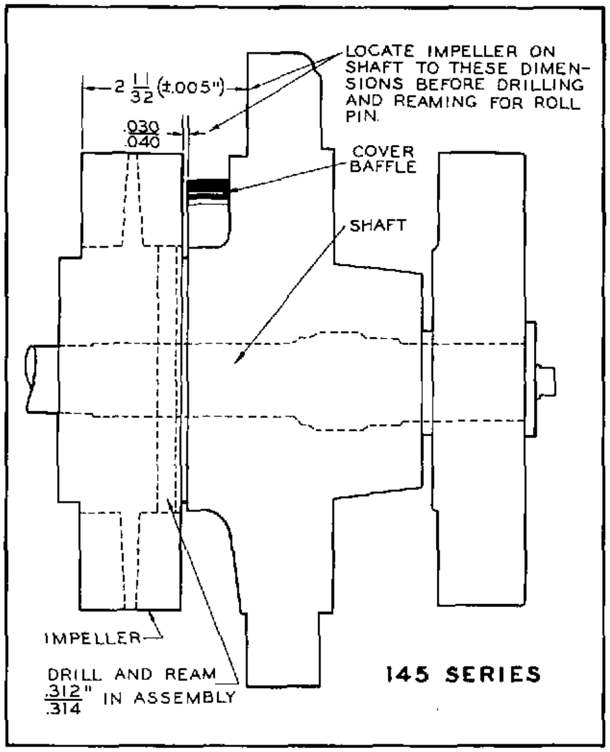
Reassembly

Although water pump reassembly is almost the exact reverse of disassembly, reassembly procedure will be covered, as several steps which are particularly important to either facilitate rebuilding or to water pump service life, should be emphasized.

Reassembly begins with the insertion of a new oil retainer in the pump cover. Be careful not to damage the oil retainer by applying excessive pressure when installing. A new rubber "O" ring must be installed on each of the two "O" ring retainers before they are



LUBRICATE RUBBER "O" RINGS WITH LIQUID SOAP BEFORE INSTALLING



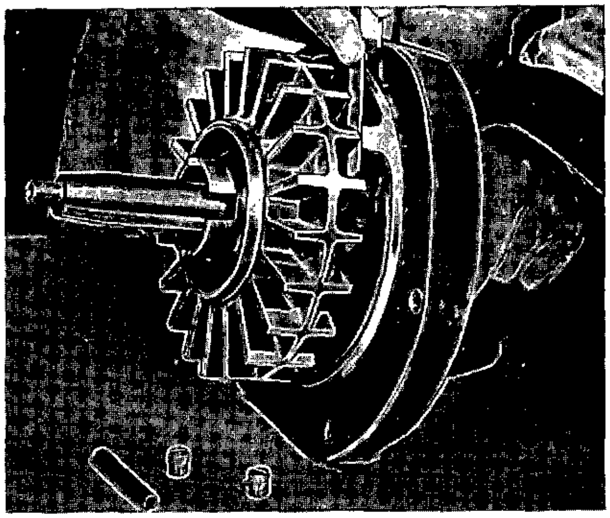
IMPELLER LOCATION ON THE SHAFT (145 SERIES PUMP)

pressed into the body and into the cover. To prevent tearing or cocking of these "O" rings as they are pressed into position, a lubricant such as liquid soap must be applied to the "O" rings. With the "O" rings thus lubricated, only a slight pressure is required to press the retainers into the cover and body.

With the "O" ring retainers installed in the cover and body, proceed to press the cover ball bearing on the pump drive shaft until the bearing inner race seats firmly against the shaft flange.

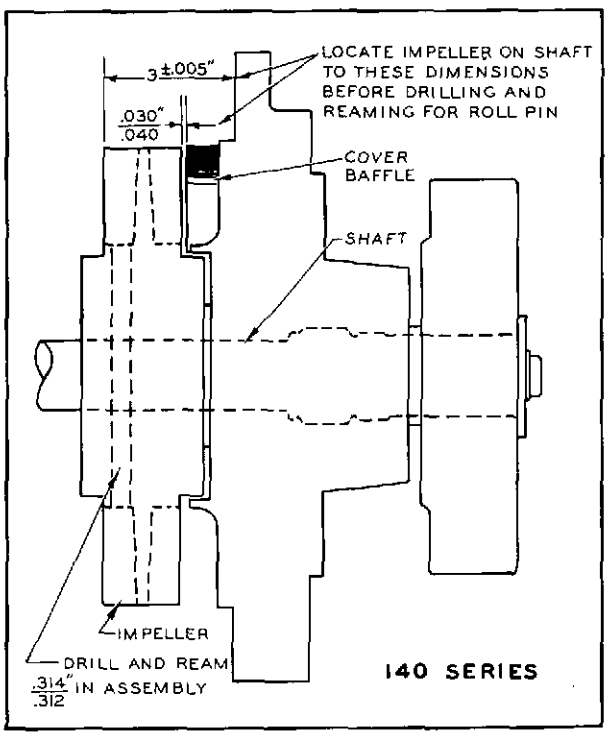
Carefully insert the shaft and bearing assembly into the cover and place the cover on the press base and press the shaft into the cover until the bearing outer race is firmly seated in the cover bearing recess. Lock the bearing and shaft in position with bearing snap ring.

With the drive shaft thus locked in position by the bearing snap ring, install the cover end seal and washer in the proper position on the shaft and slip the impeller on the shaft. Now place the pump assembly, impeller resting on the press base and the gear end of the shaft up, and press the shaft into the impeller until the 2-11/32" (±.005") dimension on the



CHECK IMPELLER TO COVER CLEARANCE

145 or 3.0" (±.005") on the 140 series is measured between the cover and the outside of the impeller vanes as shown on the separate impeller location drawings. Make sure that the correct impeller locating illustration is used for the particular engine series as the different configuration of the impeller plus the different location of the roll pin would, if improperly installed, cause

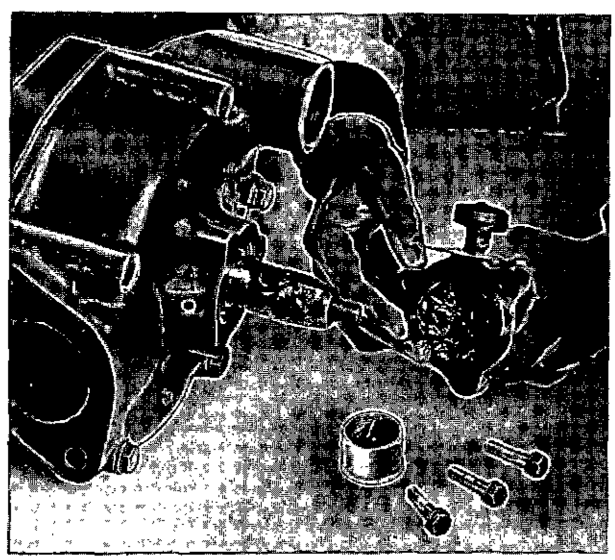


IMPELLER LOCATION ON SHAFT (140 SERIES PUMP)

seal leakage due to unequal pressure. With this dimension established, check and reposition the impeller if necessary to satisfy the required .030-.040" clearance between the inside (cover side) of the impeller vanes and the cover baffle. Turn the pump impeller and use a feeler gauge to measure this clearance on each vane.

Proceed to drill and ream the .312" to .314" roll pin hole through the impeller and shaft. Thread the impeller roll pin hole openings with a 1/8" pipe tap to provide for the two seal plugs. Drive the roll pin into the shaft and impeller and seal the roll pin holes by inserting and securely tightening the two seal plugs. Position the gear and spacer on the press base and press the pump cover, impeller and shaft assembly through the gear until the gear and spacer are drawn tight against the cover ball bearing inner race. Install a new cover to body gasket, slip the remaining automatic water seal and washer in position on the shaft. Press the body ball bearings in position in the body recess and carefully guide the body into position on the shaft, then securely tighten the body to cover capscrews. With the body installed, check that the ball bearing outer race is flush with the body--grease retainer face. Repack the grease retainer with a good grade of ball and roller bearing grease and install, using a new retainer to body gasket.

With the pump completely reassembled turn pump over by hand and observe for freedom of movement. Pressure test if possible.



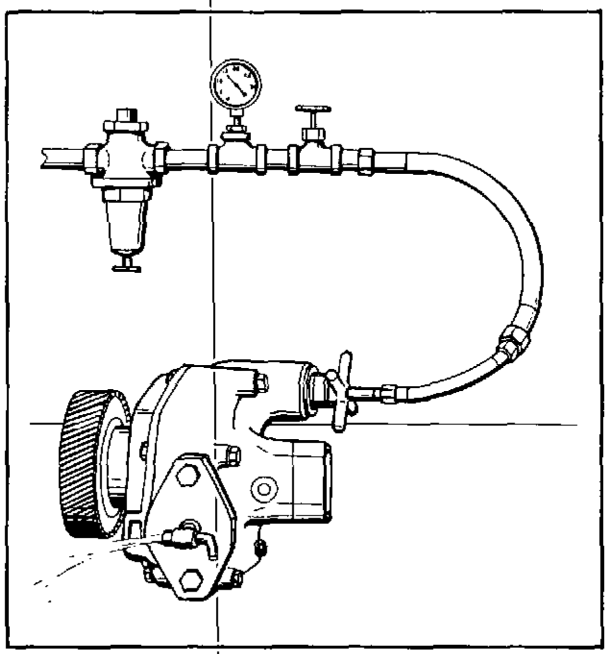
REPACK GREASE SEAL RETAINER

Water Pump Testing

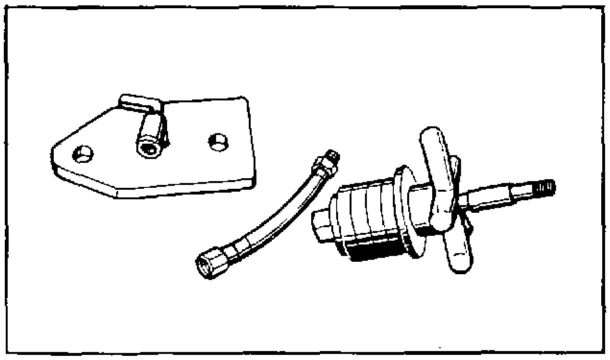
Water pumps used on the 140-145 series are of the spring loaded permanent seal type and depend upon an extremely precise surface contact between the sealing parts for effective sealing. During rebuilding operations it is sometimes quite easy to break the seal parts, or mis-align them, with the result that the seal leaks. Breakage is also common during shipping and shelf storage. To avoid the loss of time resulting from installation of a new pump only to find the seal defective, the following practical test procedures are suggested.

Water is introduced under moderate pressure, 8-15 pounds, through an expansion type adapter fitting gasketed with rubber. A similar adapter with a vent cock allows removal of air until the pump is full of water and release of pressure after test. It is suggested that permanent plates for commonly used pumps be made up and identified for convenient use.

Water pressure from standard sources may be used if a small reducer valve and gauge is provided to prevent accidental build up of dangerous pressures. If desired, a small pump with a pressure relief valve offers the advantage of being able to use a water with corrosion inhibitor added, and, to make the test somewhat more severe by adding about 50% permanent type anti-freeze. This arrangement requires a reservoir and return circuit from the relief valve.



WATER PUMP SEAL TEST



WATER PUMP TEST EQUIPMENT

Normally, holding the pressure in the pump for one minute will disclose even slight leaks. Carefully examine the pump around the shaft and in any drain holes or cavities. If a few drops of water appear, remove the fittings and recheck. No water at all should pass the seal.

The expansion adapter is made by sliding round sections of fairly soft rubber over a threaded pipe and clamping them with a nut and large washer. Obviously, a suitable selection of rubber discs will be required for various pumps. The vent plate is self explanatory. Do not overlook the possibility of several seal vents on this type pump; the 145 series, for example has three. Check them all.

The illustrations show typical adapter parts which must be fabricated locally as they are not available from Waukesha Motor Company.

INSTALLING FLYWHEEL

The dowels formerly used in the rear flanges of the crankshafts for Waukesha 140 and 145 series engines have been eliminated in production assembly. The .498-.499 holes into which the dowels were pressed are now drilled and tapped 1/2-20 NF for two additional flywheel retaining bolts. Considerable testing has shown that the resulting assembly with eight bolts is more secure as the result of the increased holding action of the bolts.

From the service standpoint, replacement crankshafts will also be drilled and tapped as described and for this reason it will be impossible to install dowels even in engines originally built with them. Users should be advised of this to avoid confusion. A suitable tag is attached to service crankshafts when shipped from the factory.

After extensive physical checking it has been found that the bolts will usually pass through the former dowel holes in the flywheel without any difficulty, however, this should be tried before mounting the wheel in place. If some slight binding or interference is encountered, ream the flywheel holes to 17/32" (.5312) which will ensure adequate clearance. In addition, the outer edge of the bolt hole should be broken sufficiently to accommodate small fillet radius between the head and the shank of the bolt. Two additional flywheel bolts will be required. These are especially heat treated bolts and standard hardware should never be used. In a few instances, an extra long bolt will be needed because of bosses or raised pads in this area of the flywheel. The bolts used most frequently are Part Numbers B4515 and B6044.

In those applications using stub shafts two possibilities exist to avoid the interference which will be encountered in attempting to install a six-hole stub shaft on an eight-bolt flywheel. First, if sufficient time is available, a stub shaft may be returned to the factory for drilling two additional holes. This also applies to stub shafts which may be in stock in the field. If this is not possible it will be necessary to drill two additional 17/32" holes in the stub shaft. This may be done by using the flywheel as a template. Either of the following methods may be used....

1. If a suitable heavy duty drill press is available locate the stub shaft on the flywheel and temporarily bolt it in place securely with bolts through several of the present holes.

2. With the shaft and flywheel inverted on the drill press table, spot the drill accurately in the bore of the hole in the flywheel using a 17/32" drill as a centering guide. Without changing the location of the press and flywheel, replace the 17/32" drill with a small pilot drill and drill a pilot hole. Redrill to 17/32" and repeat for the opposite bolt hole.

3. Lacking a suitable drill press, make a 17/32" OD drill bushing with an ID of a size suitable for a small pilot drill. Repeat step one, above, and install the bushing in the flywheel hole. Drill with an electric drill, re-drill to 1/2" using the pilot hole as a guide, and ream by hand to 17/32".

Step dowels, Part No. 76457, having a small diameter of 1/2" and a larger diameter of 9/16", offer a convenient means of adapting the new eight-bolt flywheels to the former doweled crankshafts when it is necessary to make such a replacment. Two factors are involved...

1. The current flywheels contain eight 17/32" bolt holes and make no provision for the previously used 1/2-inch dowels.

2. The two .489-.499 dowel holes in the older crankshafts do not offer enough tapping metal to permit tapping threads for two additional bolts.

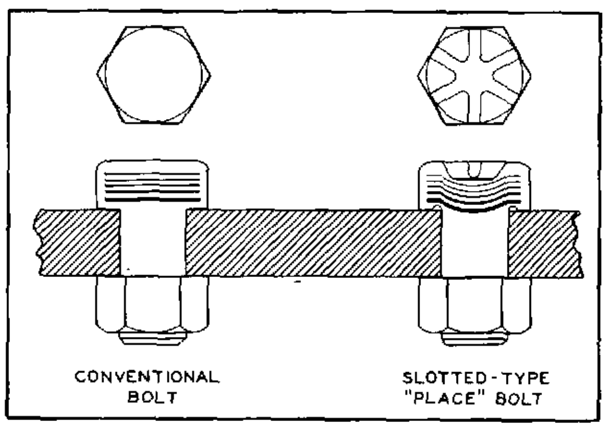
Thus, the most practical modification consists of reaming the two appropriate holes in the flywheel to .5645-.5655 to receive the large ends of the dowels. After doing this and removing the original dowels, it is suggested that the flywheel be located by partially snugged bolts and the new dowels driven home. This will help avoid the burring or scraping which might result from slight errors in reaming. After the dowels are seated, the bolts should be torqued to the recommended value.

A run-out check should always be made after a flywheel is replaced. Causes for excessive run-out might be nicks or burrs on the crankshaft flange, foreign material between the flange and the wheel, raised areas around the flange threads or dowel holes, or sheared metal fragments from a misaligned dowel intruding between the crankshaft flange and the flywheel seating surface.

If this type of replacement is quite common, a supply of No. 76457 step dowels should be ordered.

FLYWHEEL BOLTS

New "Place" type self-locking bolts are now being specified to secure the flywheels on Waukesha 140 and 145 model engines. The new bolts replace the drilled head type and eliminate the use of lockwire. The "Place" type bolts are used with a hardened flat washer. The torque value of the bolts remains the same (1350-1400 inch pounds) on all engines.



FLYWHEEL BOLTS

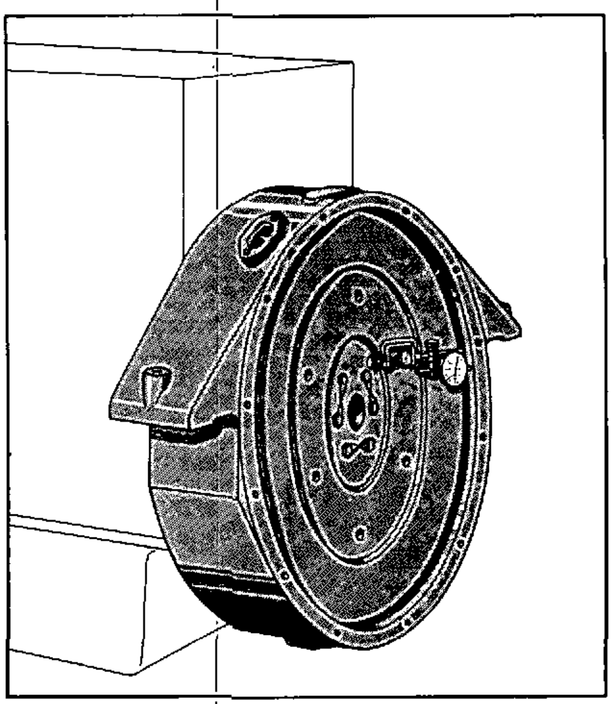
The self-locking principle of the "Place" bolt can be seen in the accompanying illustration. A circular recess on the lower face of the head, plus six slots in the upper face, direct the load to the outside edge. This, in turn, allows extra bolt elongation as indicated by the stress lines in the drawing. The elongation assures a constant torque on the bolt, even after settling and imbedding. The new bolts are SAE Grade No. 8 and have the same principle dimensions as the conventional cap screws.

Listed below, in tabulated form, are the numbers of the previous cap screws, their sizes, and the corresponding numbers of the "Place" type bolts. The new bolts should be used for all field replacements and will be available from the factory after July 1, 1964.

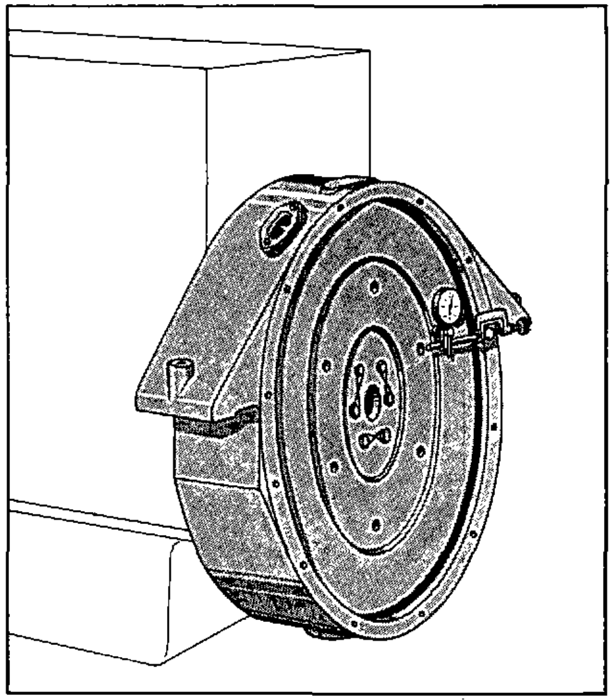
Previous Bolt	Size	"Place" Bolt
B-6044	1/2" x 1-3/8"	28244
B-4515	1/2" x 1-1/8"	28251
B-4515-A	1/2" x 2-1/16"	28247
B-4515-B	1/2" x 1-9/16"	28247

ALIGNING FLYWHEEL HOUSING

Whenever the flywheel or flywheel housing have been removed, or whenever a clutch assembly is installed, the run-out of both the flywheel and flywheel housing should be checked. These parts are carefully aligned at the factory and the housing face and bore are finish machined in place. Severe shocks and jars during shipment or transporting, however, may cause deflection to some degree. Moreover, it is well to check the fit of the pilot bearing in the pilot bearing bore and for lubrication of the pilot. For the sake of safety, always check the flywheel retaining cap screw torque at this time.



CHECKING HOUSING BORE RUN-OUT



CHECKING FLYWHEEL RUN-OUT

Runout maximums are .005" for the pilot bearing, .008" for the flywheel face, .010" for the housing bore and .006" for the housing face. These are total indicator readings.

In order to be sure that grease is going to reach the pilot bearing when the clutch is in use, it is necessary to be sure that the grease channel through the clutch shaft is full of the proper grease at installation. By packing this channel, the operator can eliminate doubt and overlubrication or, equally bad, no lubrication at all. In any case, the recommendations and instructions from the clutch manufacturer should be used.

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 fuel pumps, 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 gumming and the effects of stale gasoline, oil, and 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.

Protecting New Engines

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

Nucle-Oil

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

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

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

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

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

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

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

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

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

The following procedure for preservation is suggested:

1. Start with a cold engine.
2. Add the required amounts of Nucle-Oil to the crankcase, air filters, and fuel tanks.
3. Turn engine over 20 seconds.
4. Allow engine to cool, if necessary.
5. Add the required amounts of Nucle-Oil to each cylinder through the spark plug openings and replace plugs. Apply to rocker area by light brushing or pouring. Replace rocker covers.
6. Drain carburetor and fuel pump of gasoline if practicable. Be sure to remove water from butane vaporizer if freezing is likely.
7. Remove distributor cap or magneto cover and apply small amount of petroleum jelly to polished surface of breaker cam. Where dampness in storage is expected, removal of magneto may be worthwhile.
8. Wipe engine clean and dry. Apply wax type masking tape or like material to all openings such as intake openings in air cleaner, exhaust outlets, breathers, magneto vents and open line fittings.
9. Relieve tension on fan belts and generator drive belts. This is important because continual tension on these parts without the working action that occurs in normal operation causes deterioration of the rubber.
10. Apply a coating of heavy preservative compound with brush to all exposed machined surfaces such as flywheels, clutch shafts and like areas.
11. Store engine up to one year.

	Upper Cylinder				Crankcase		Air Filter	Fuel Tank	Total Ounces
Engine Model	No. Cyl.	Displ.	Ozs. of Nucle-Oil Per Cyl.	Ozs. of Nucle-Oil All Cyls.	Oil Cap. Qts.	Ozs. Nucle-Oil	Ozs. Nucle-Oil	Ozs. Nucle-Oil	Nucle-Oil Required
140-GK, GKB	6	525	1/2	3	10	6-1/2	2	32	43-1/2
140-GZ, GZB, GZC	6	554	1/2	3	10	6-1/2	2	32	43-1/2
145-GL	6	707	3/4	4-1/2	18	11-1/2	2	32	50
145-GK, GKB	6	779	3/4	4-1/2	18	11-1/2	2	32	50
145-GZ, GZB, GZC	6	817	3/4	4-1/2	18	11-1/2	2	32	50

Storing Engines That Have Been in Service

In the course of normal engine operation residues of various combustion products such as lead and sulfur 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.

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 sulfur, 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.

Specifications for Protective Materials

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

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 starter 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.

CLEARANCES AND WEAR LIMITS
140-G SERIES ENGINES

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	Six-in line
Bore & Stroke 140-GK	4-1/2 x 5-1/2"
Bore & Stroke 140-GZ	4-5/8 x 5-1/2"
Displacement (cubic inches)	
140-GK	525
140-GZ	554
Valve arrangement	Overhead
Firing order	1-5-3-6-2-4

TORQUE VALUE RECOMMENDATIONS

*Cylinder head	2400-2500
Main bearings	1550-1600
Connecting rods	1150-1200
Flywheel	1350-1400
Cam gear nut	1200
Front support	1050
Vibration dampner	1050
Oil filter	360-480

Above values stated in inch pounds.
Divide by 12 for foot pound values.

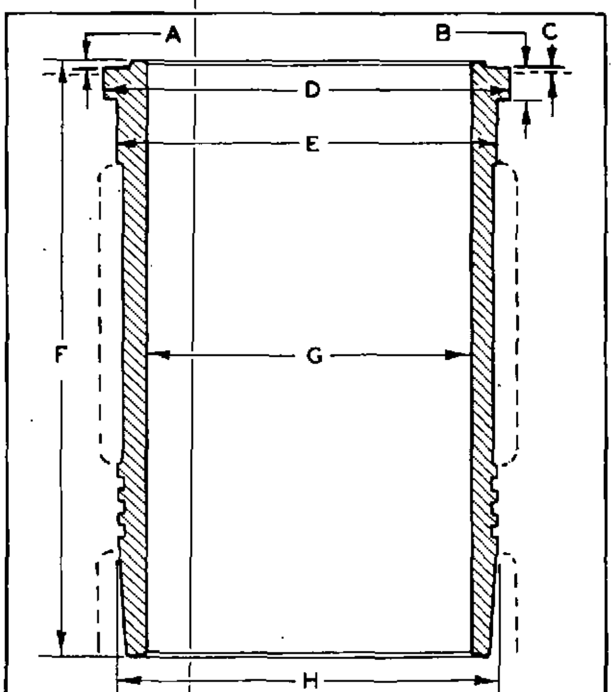
*Note: Consult the Valve Sequence and Cylinder Head Bolt Tightening Diagram for the proper head bolt tightening sequence.

CYLINDER SLEEVES

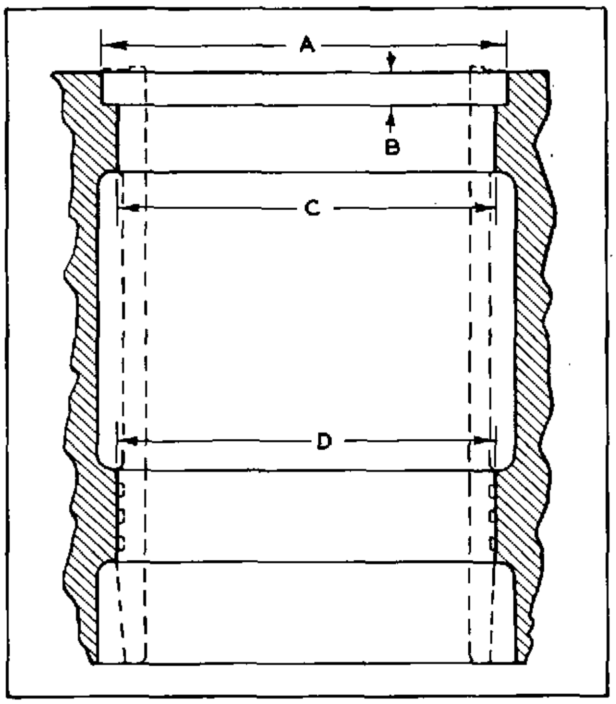
Type	Wet type, replaceable
(A) Heat dam projection	None
(B) Flange height	.315-.316"
(C) Sleeve projection above crankcase	.003-.006"
(D) Flange diameter	5.429-5.431"
(E) Sleeve dia. (below flange)	5.130-5.140"
(F) Sleeve length	11-5/16"
(G) Sleeve bore diameter	
140GK	4.5000-4.5015"
140GZ	4.6250-4.6265"
(H) Sleeve diameter lower seal area	5.1215-5.1230"
Sleeve out of round limits	.001-.0015"

CRANKCASE

Main bearing number & type	Seven-precision
Camshaft bearing number & type	Four, line bore
(A) Sleeve counterbore dia.	5.437-5.438"
(B) Sleeve counterbore depth	.310-.312"
(C) Crankcase upper bore	5.1825-5.1925"
(D) Crankcase lower bore	5.125-5.126"
Crankcase main bearing journal bore	3.5025-3.5032"
Crankcase camshaft bushing bore	2.2495-2.2505"



TYPICAL CYLINDER SLEEVE



TYPICAL SECTION THROUGH CRANKCASE

PISTON PIN

Piston pin diameter

Red	1.3743-1.3744"
White	1.3744-1.3745"
Blue	1.3745-1.3746"

Piston pin length . . . . 3.995-4.000"

Piston pin fit: Pin selected (color) to provide a loose hand push fit at normal room temperature . . .0002-.0004"

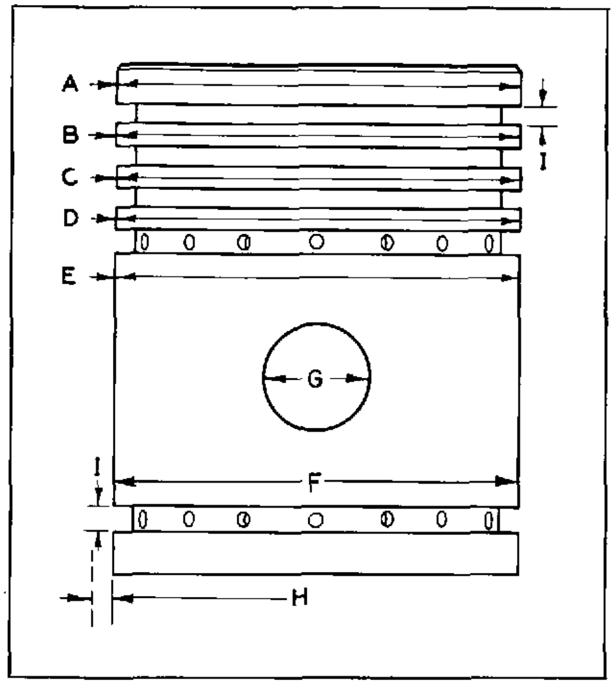
PISTON

Piston material . . . . Aluminum alloy

Piston fit: (Aluminum) Use three strips of 1/2" .002" wide feeler stock. Feelers inserted at thrust side, bottom of skirt and must pull with four to six pounds pull.

Pistons are removed from top of cylinders.

When applicable, piston stamped with arrow and/or word front indicating gear end of engine.



TYPICAL PISTON

(PISTON LAND TO CYLINDER SLEEVE BORE CLEARANCE)

			Land dia.	Sleeve bore dia.	Clearance
(A)	Top land	140-GK	4.466-4.470"	4.5000-4.5015"	.0300-.0355"
		140-GZ	4.591-4.595"	4.6250-4.6265"	.0300-.0355"
(B)	2nd land	140-GK	4.475-4.479"	4.5000-4.5015"	.0210-.0265"
		140-GZ	4.600-4.604"	4.6250-4.6265"	.0210-.0265"
(C)	3rd land	140-GK	4.475-4.479"	4.5000-4.5015"	.0210-.0265"
		140-GZ	4.600-4.604"	4.6250-4.6265"	.0210-.0265"
(D)	4th land	140-GK	4.475-4.479"	4.5000-4.5015"	.0210-.0265"
		140-GZ	4.600-4.604"	4.6250-4.6265"	.0210-.0265"

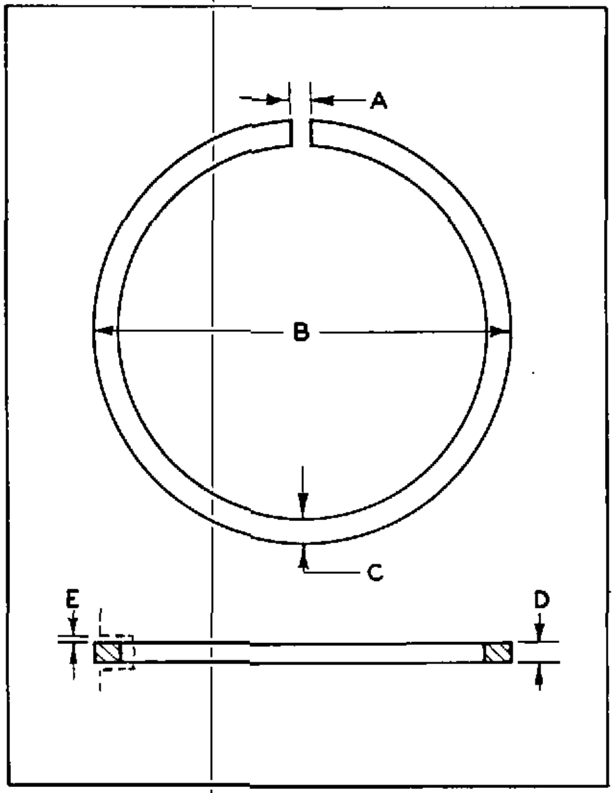
(E)	Piston skirt diameter (top)	140-GK	4.4923-4.4927"
		140-GZ	4.6173-4.6177"
(F)	Piston skirt diameter (bottom)	140-GK	4.4938-4.4942"
		140-GZ	4.6192-4.6195"
(G)	Piston pin hole bore	Red	1.3746-1.3747"
		White	1.3747-1.3748"
		Blue	1.3748-1.3749"
(H)	Piston skirt to sleeve clearance (thrust area)	140-GK	4.4935-4.4950"
		140-GZ	4.6185-4.6200"

		Top	2nd	3rd	4th	5th
(I) Groove width	140-GK	.1575-.1585"	.1255-.1265"	.1255-.1265"	.1880-.1895"	.1880-.1895"
	140-GZ	.1565-.1575"	.1565-.1575"	.1565-.1575"	.1880-.1895"	.1880-.1895"

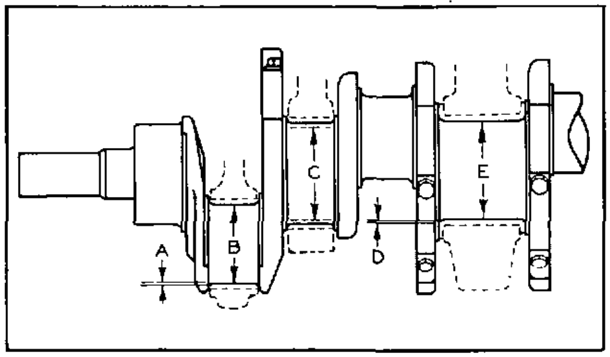
Weight . . . . Maximum recommended weight variation 1/2 ounce

PISTON RINGS

Top ring	Chrome plated compression
Second ring	Plain compression
Third ring	Notched compression
Fourth ring	Oil control
Fifth ring	Oil control



TYPICAL PISTON RING



TYPICAL CRANKSHAFT

CRANKSHAFT

Crankshaft end play . . . . . . .005-.009"
End play adjustment . . . Replacement of rear main thrust bearing
(A) Connecting rod bearing running clearance (fitted). . . . . . . .001-.003"
(B) Connecting rod bearing journal diameter . . . . 2.624-2.625"
(C) Main bearing journal maximum undersize . . . . .040"
(D) Main bearing running clearance . . . . .002-.004"
(E) Main bearing journal diameter . . . . 3.249-3.250"

PISTON RINGS

		Top	2nd	3rd	4th	5th
(A) Ring gap	140-GK	.013-.025"	.013-.025"	.015-.025"	.013-.025"	.013-.025"
	140-GZ	.013-.025"	.013-.023"	.013-.023"	.013-.025"	.013-.025"
(B) Ring diameter	140-GK	4.500"	4.500"	4.500"	4.500"	4.500"
	140-GZ	4.625"	4.625"	4.625"	4.625"	4.625"
(C) Ring wall	140-GK	.255" max	.189" max	.180" max	.189" max	.189" max
	140-GZ	.231" max	.180" max	.180" max	.193" max	.193" max
(D) Ring width	140-GK	.123-.124"	.123-.124"	.123-.124"	.186"	.186"
	140-GZ	.123-.124"	.123-.124"	.123-.124"	.186"	.186"
(E) Side clearance	140-GK	.002-.004"	.001-.003"	.001-.003"	.002-.003"	.002-.003"
	140-GZ	.002-.004"	.001-.003"	.001-.003"	.002-.003"	.002-.003"

MAIN BEARINGS

Number . . . . Seven
Type . . . . Precision
Material . . . . Steel backed, tri-metal
Undersize bearings available . . . . .020 and .040"
Adjustment . . . Replacement (precision type)
Running clearance (theoretical oil) . . . . .0015-.0045"
Rear main thrust flange thickness
- Standard . . . . .122-.124"
- .020 Under . . . . .128-.130"
- .040 Under . . . . .128-.130"

CAMSHAFT

Camshaft bushing bore* . . . . . 2.127-2.1275"

Camshaft journal diameter . . . . 2.124-2.125"

Camshaft running clearance in bushing . . . . .002-.0035"

Camshaft end play adjustment . . Thrust button (Replacement)

Cam lift (Intake) . . . . .322"
(Exhaust) . . . . .287"

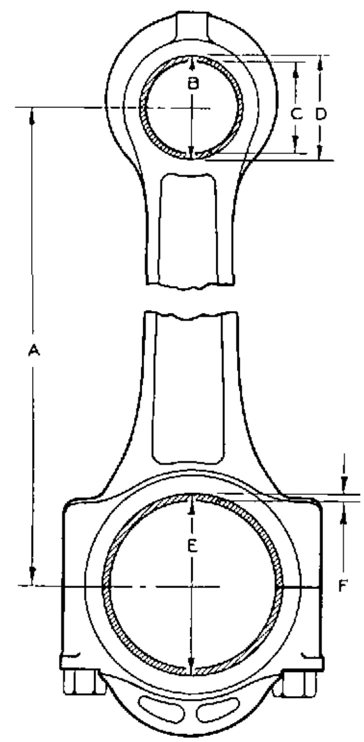
*Replacement bushing available in either pre-sized precision type or undersized for line boring.

FLYWHEEL AND HOUSING

Pilot bearing run-out	.005" Total Indicator Reading
Face run-out on wheel	.008" Total Indicator Reading
Housing bore run-out	.010" Total Indicator Reading
Housing face run-out	.006" Total Indicator Reading

CONNECTING ROD, BUSHING AND BEARING

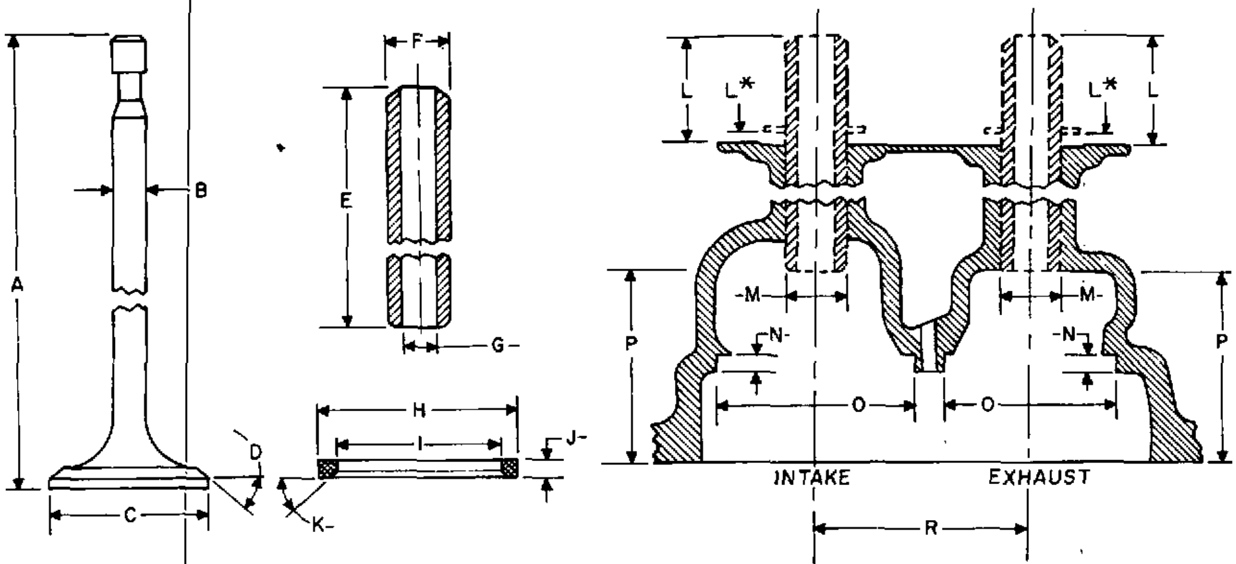
Rod material	Heat treated-steel forging
Rods, permissible weight variation	1/4 oz.
(A) Rod length, center to center	10.245-10.255"
(B) Rod small end finish size	1.4295-1.4305"
(C) Bushing bore diameter	1.3750-1.3755"
(Burnish in place 1.3655-1.3665")	
(D) Bushing in rod	Press fit
(E) Rod large end finish size	2.8465-2.8470"
(F) Bearing running clearance (theoretical oil)	.001-.003"
Rod width	1.990-1.992"
Rod bearing width	1.713-1.723"
Rod bearing undersizes available:	
Standard (Non-counterbalanced) crankshafts	.020, .040
Counterbalanced crankshafts	.020, .040



TYPICAL CONNECTING ROD, BUSHING AND BEARING

VALVE TRAIN, VALVE PORT CLEARANCES

	Intake	Exhaust
(A) Valve Length	6-21/32"	6-23/32"
(B) Valve Stem Diameter	.4345-.4355"	.4335-.4345"
(C) Valve Head Diameter (Nominal)	2-3/32"	1-9/16"
(D) Valve Seat Angle	30°	45°
(E) Guide Length	4-1/8"	3-11/32"
(F) Guide Outside Diameter	.688-.689"	.688-.689"
(G) Guide Inside Diameter (new)	.435-.437"	.435-.437"
Pre-sized Service Guides	.438-.439"	.438-.439"
(H) Insert Outside Diameter	None	1.7535-1.7545"
(I) Insert Inside Diameter	None	1.370-1.380"
(J) Insert Depth	None	.373-.375"
(K) Insert Seat Angle	None	45°
(L)* Guide Shoulder Extends Above Head	.010"	.010"
(M) Guide Bore in Head	.6865-.6875"	.6865-.6875"



VALVE TRAIN, VALVE PORT CLEARANCES

	Intake	Exhaust
(N) Insert Counterbore Depth	None	.385-.390"
(O) Insert Counterbore Diameter	None	1.7495-1.7505"
(P) Valve Port Depth (nominal)	15/16" No insert	1-3/4" *Insert flush
(R) Valve - Centerline to Centerline (approx.)	2-1/4"	2-1/4"
	Outer	Inner
Valve spring free length	2-17/32"	2-21/64"
Valve closed, spring length	2-3/16"	1-29/32"
Compression pressure (valve closed)	31#	26#
Valve open, spring length	1-21/32"	1-7/16"
Compression pressure (valve open)	86#	55#

VALVE CLEARANCES

	Intake	Exhaust
Valve Running Clearance (cold) (standard valves)	.014-.016"	.027-.029"
(sodium cooled valves)	.010-.012"	.019-.021"

Note: Valve clearances to be adjusted with engine stopped and cooled to normal ambient temperatures.

VALVE TIMING

	Intake	Exhaust
Valve Timing Clearance	.015" (valve opens TDC)	.038" (valve closes TDC)

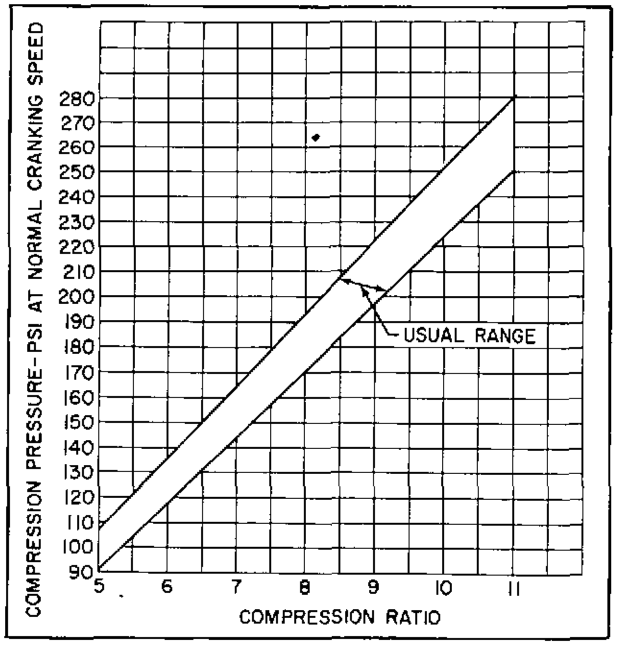
Note: Valves must be re-adjusted to the proper valve cold clearance setting after the timing check.

TIMING NOTE: For checking valve timing:

Set intake valve clearance .015" at valve. Intake valve should open at top dead center. Set exhaust clearance .038" at valve. Exhaust valve should close at top dead center.

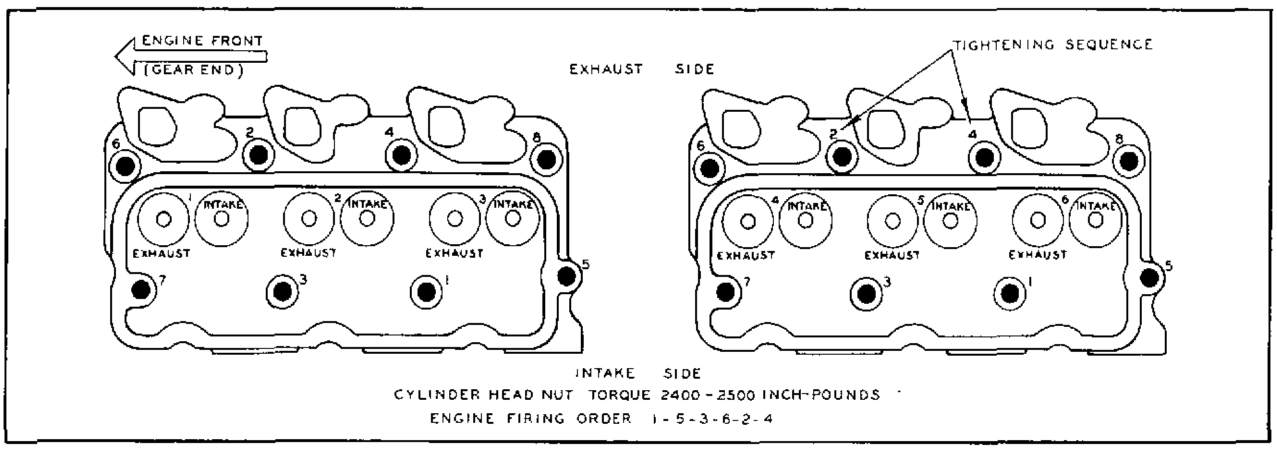
	Intake	Exhaust
Cam lift (measured at push rod)	.322"	.287"

COMPRESSION PRESSURE



COMPRESSION PRESSURE VS RATIO

VALVE SEQUENCE AND CYLINDER HEAD BOLT TIGHTENING DIAGRAM



Note: Re-torque cylinder head stud nuts on a new or overhauled engine after first start and after approximately 50 hours of operation with engine warm.

SPARK ADVANCE RECOMMENDATIONS

Compression Ratio	Fuel	Distributor Timing	Magneto Timing @ Engine RPM 12-1500	12-1600	12-1800	16-2000	18-2400	24-2600
6.4 to 1	Gasoline	7° BTDC	24° BTDC			28° BTDC		32° BTDC
7.3 to 1	Gasoline	4° BTDC	22° BTDC			24° BTDC		27° BTDC
7.3 to 1	LPG	4° BTDC	22° BTDC			24° BTDC		27° BTDC
7.3 to 1	Nat. Gas	7° BTDC	26° BTDC			28° BTDC		
7.3 to 1 Dual Ignition	Gasoline	4° BTDC		22° BTDC			25° BTDC	
9.0 to 1	Nat. Gas	7° BTDC			24° BTDC	26° BTDC* *(2000 RPM)		

IGNITION DATA

Electrical System . . 12-Volt Negative Polarity unless specified otherwise

Spark Plug Size . 14mm, 13/16 Hex, Champion

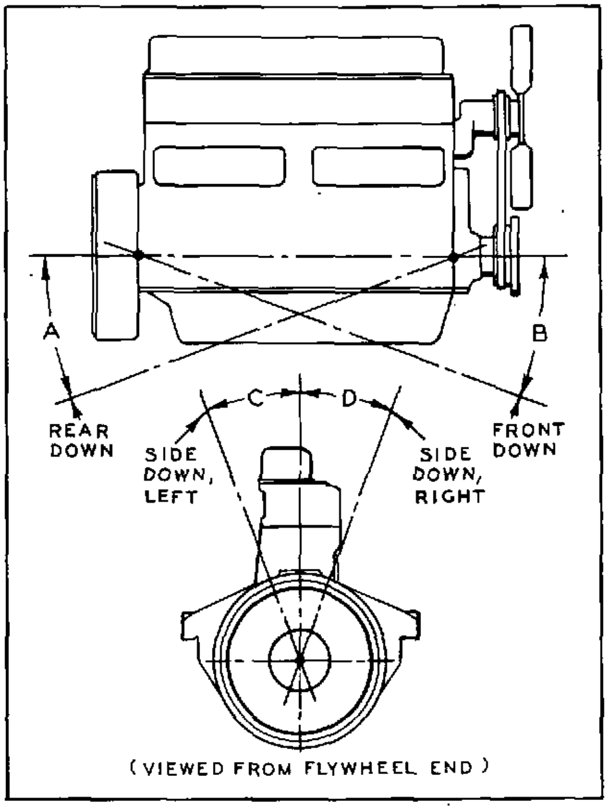
Spark Plug Type . . J-11, H-8, J-6 gasoline*
Stitt 497 Gaseous Fuel
Crane Carrier Champion UJ-12 or UJ-8

Spark Plug Gap (new) . . . . .025"
(after service) . . .018"-.020

Distributor Breaker Point Gap . . .018-.020"

Magneto Breaker Point Gap
(most) . . . . .014-.018"

*Light, Medium, & Heavy Duty Respectively.



MAXIMUM ANGLE OF OPERATION

MAXIMUM ANGLE OF OPERATION

The Maximum figures stated are for intermittent duty only. Consult the Waukesha Motor Company if continued operation at angles approaching the maximum are anticipated.

Pan Type	Pump Type	A Rear Down	B Front Down	C Side Down, Left	D Side Down, Right
STD (Rear Sump)	STD Pressure	30° 57%	10° 17%	30° 57%	15° 26%
Deep Sump	Scavenger	30° 57%	33° 65%	20° 36%	20° 36%
Center Sump	Scavenger	40° 84%	43° 95%		

CLEARANCES AND WEAR LIMITS
145-G SERIES ENGINES

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

GENERAL

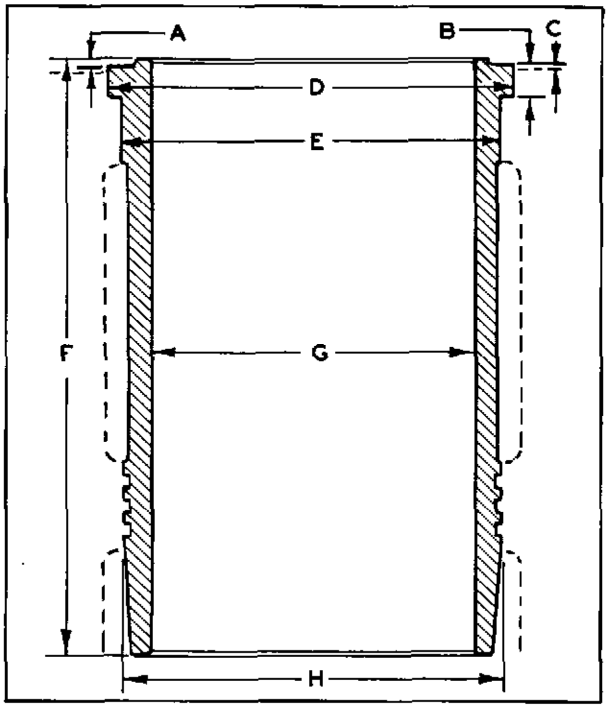
Cylinder number and arrangement	Six-in line
Bore and stroke	
145-GZ	5-3/8 x 6"
145-GK	5-1/4 x 6"
Displacement (cubic inches)	
145-GZ	817 cu. in.
145-GK	779 cu. in.
Valve arrangement	Overhead
Firing order	1-5-3-6-2-4

TORQUE VALUE RECOMMENDATIONS

*Cylinder head (long)	2400-2500
Cylinder head (short)	1800-1850
Main bearings	3200-3300
Connecting rods	800-825
Flywheel	1350-1400
Cam gear nut	1200
Front support	1050
Vibration damper	1050
Oil filter	360-480

Above values stated in inch pounds. Divide by 12 for foot pound values.

*Note: Consult the Valve Sequence and Cylinder Head Bolt Tightening Diagram for the proper head bolt tightening sequence.



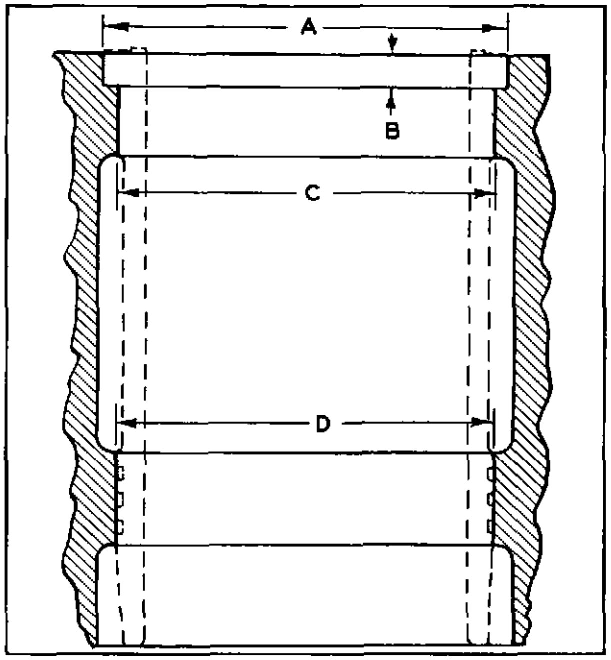
TYPICAL CYLINDER SLEEVE

CYLINDER SLEEVES

Type	Wet type, replaceable
(A) Heat dam projection	None
(B) Flange height	.378-.379"
(C) Sleeve projection above crankcase	.003-.006"
(D) Flange diameter	6.179-6.181"
(E) Sleeve diameter (below flange)	
145-GZ	5.850-5.860"
145-GK	5.802-5.812"
(F) Sleeve length	12-1/2"
(G) Sleeve bore diameter	
145-GZ	5.3753-5.3757"
145-GK	5.2503-5.2507"
(H) Sleeve diameter lower seal area	5.871-5.873"
Sleeve out of round limits	.001-.002

CRANKCASE

Main bearing number & type	Seven-precision
Camshaft bearing number & type	Four-line bore
(A) Sleeve counter bore dia.	6.187-6.188"
(B) Sleeve counterbore depth	.373-.375"
(C) Crankcase upper bore	5.937-5.942"
(D) Crankcase lower bore	5.875-5.876"
Crankcase main bearing journal bore	3.7525-3.7532"
Crankcase camshaft bushing bore	2.6245-2.6255"



TYPICAL SECTION THROUGH CRANKCASE

PISTON PIN

Piston pin diameter
- Red . . . . 1.6243-1.6244"
- White . . . . 1.6244-1.6245"
- Blue . . . . 1.6245-1.6246"

Piston pin length . . . . 4.465-4.475"

Piston pin fit: Pin selected (color) to provide a loose fit at normal room temperature . .0002-.0004"

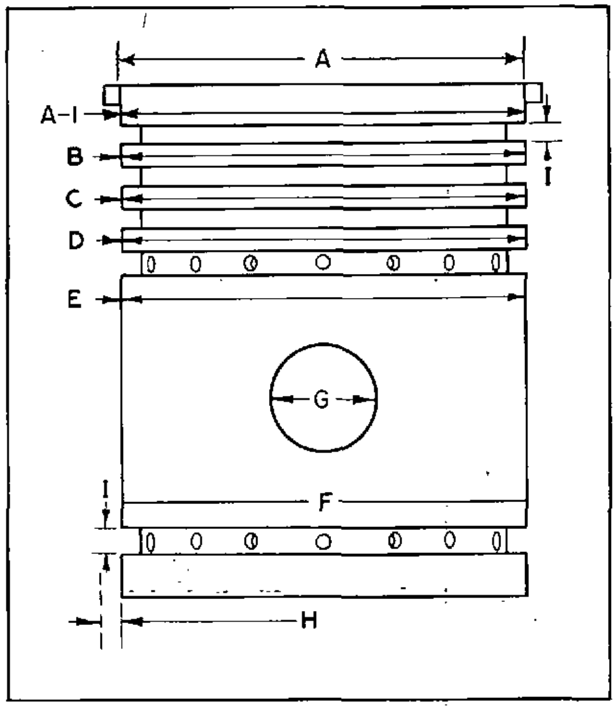
PISTON

Piston material . . . . Aluminum alloy

Piston fit: (Aluminum) Use two strips of 1/2" wide .002" *feeler stock and one strip .003"* feelers inserted at thrust side, bottom of skirt and must pull out with four to eight pounds pull.

Pistons are removed from top of cylinders.

When applicable, piston stamped with arrow and/or word front indicating gear end of engine.



TYPICAL PISTON

(PISTON LAND TO CYLINDER SLEEVE BORE CLEARANCE)

		Land dia.	Sleeve bore dia.	Clearance
(A) Top land	145-GZ	5.338-5.342"	5.3753-5.3757"	.033-.037"
	145-GK	5.211-5.215"	5.2503-5.2507"	.035-.039"
(A-1) Relief	145-GZ	5.315-5.320"	5.3753-5.3757"	.055-.060"
	145-GK	none	none	none
(B) 2nd land	145-GZ	5.315-5.320"	5.3753-5.3757"	.055-.060"
	145-GK	5.222-5.226"	5.2503-5.2507"	.024-.028"
(C) 3rd land	145-GZ	5.343-5.347"	5.3753-5.3757"	.028-.030"
	145-GK	5.222-5.226"	5.2503-5.2757"	.024-.028"
(D) 4th land	145-GZ	5.343-5.347"	5.3753-5.3757"	.028-.030"
	145-GK	5.222-5.226"	5.2503-5.2507"	.024-.028"

(E) Piston skirt diameter (top) . . . 145-GZ . . . . 5.363-5.364"
145-GK . . . . 5.242"

(F) Piston skirt diameter (bottom). . 145-GZ . . . . 5.367-5.368"
145-GK . . . . 5.243"

(G) Piston pin hole bore . 145-GZ and 145-GK .
- Red . . . . 1.6246-1.6247"
- White . . . . 1.6247-1.6248"
- Blue . . . . 1.6248-1.6249"

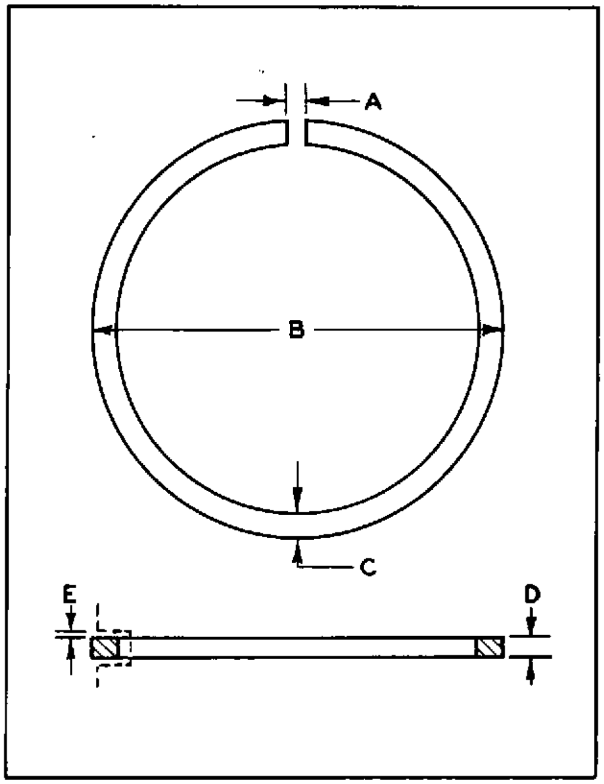
(H) Piston skirt to sleeve clearance (thrust area) . 145-GZ . . . . .007-.008"
145-GK . . . . .007"

(I) Groove width		Top	2nd	3rd	4th	5th
	145-GZ	.1265-.1275"	.1265-.1275"	.1265-.1275"	.2505-.2520"	.2505-.2515"
	145-GK	.1285-.1295"	.1275-.1285"	.1275-.1285"	.2505-.2515"	.2505-.2515"

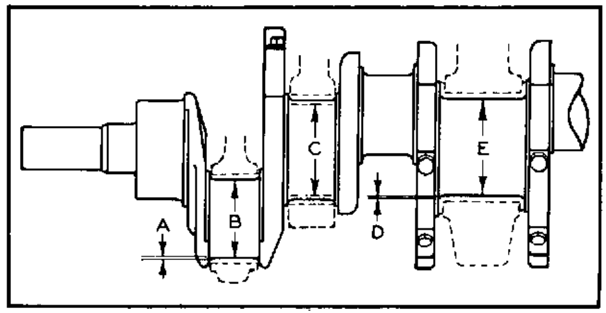
Weight . . . . Maximum recommended weight variation 1/2 ounce

PISTON RINGS

Top ring . . . . Chrome plated compression
Second ring . . . . Compression
Third ring . . . . Compression
Fourth ring . . . . Oil control
Fifth ring . . . . Oil control



TYPICAL PISTON RING



TYPICAL CRANKSHAFT

CRANKSHAFT

Crankshaft end play . . . . . . .005-.013"
End play adjustment . . . Replacement of rear main thrust bearing
(A) Connecting rod bearing running clearance (fitted) . . . . . . .001-.003"
(B) Connecting rod bearing journal diameter . . . . 2.999-3.000"
(C) Main bearing journal maximum undersize . . . . .040"
(D) Main bearing running clearance . . . . .003-.005"
(E) Main bearing journal diameter . . . . 3.499-3.500"

	Top	2nd	3rd	4th	5th
(A) Ring gap 145-GZ	.017-.032"	.017-.032"	.017-.032"	.017-.032"	.017-.032"
145-GK	.017-.032"	.030-.040"	.020-.040"	.020-.030"	.020-.030"
(B) Ring diameter 145-GZ	5.375"	5.375"	5.375"	5.375"	5.375"
145-GK	5.250"	5.250"	5.250"	5.250"	5.250"
(C) Ring wall 145-GZ	.269" max	.218" max	.218" max	.218" max	.218" max
145-GK	.262" max	.200" max	.200" max	.200" max	.200" max
(D) Ring width 145-GZ	.123-.124"	.123-.124"	.123-.124"	.248-.249"	.248-.249"
145-GK	.123-.124"	.123-.124"	.123-.124"	.248-.249"	.248-.249"
(E) Side clearance 145-GZ	.002-.004"	.002-.004"	.002-.004"	.001-.003"	.001-.003"
145-GK	.004-.006"	.003-.005"	.003-.005"	.001-.003"	.001-.003"

MAIN BEARINGS

Number . . . . Seven
Type . . . . Precision
Material . . . . . . Steel backed, tri-metal
Undersize bearings available . . . . .020 and .040"
Adjustment . . . Replacement (precision type)
Running clearance (theoretical oil) . . . . . . .0019-.0049"
Thrust ring thickness (No. 7)
Standard . . . . .120-.122"
.020 Under. . . . . .125-.128"
.040 Under. . . . . .125-.128"

CAMSHAFT

Camshaft bushing bore* . . . 2.502-2.5025"
Camshaft journal diameter . . . 2.499-2.500"
Camshaft running clearance in bushing . . . . .002-.0035"
Camshaft end play adjustment . Thrust button (Replacement)
Cam lift (Intake) . . . . .351"
(Exhaust). . . . . .351"

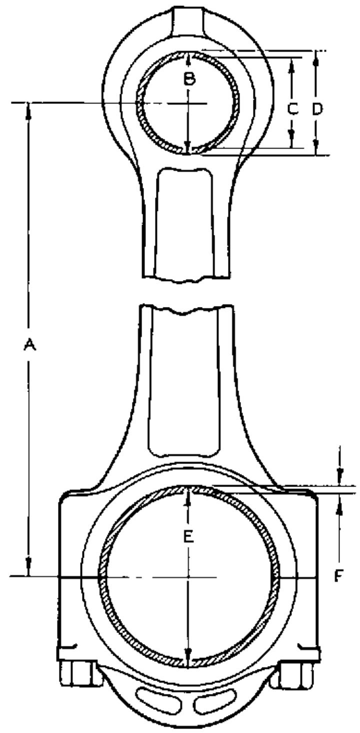
*Replacement bushing available as either pre-sized precision type or undersized for line boring.

FLYWHEEL AND HOUSING

Pilot bearing run-out . . . . 0.005" Total Indicator Reading
Face run-out on wheel . . . . 0.008" Total Indicator Reading
Housing bore run-out . . . . 0.010" Total Indicator Reading
Housing face run-out . . . . 0.006" Total Indicator Reading

CONNECTING ROD, BUSHING AND BEARING

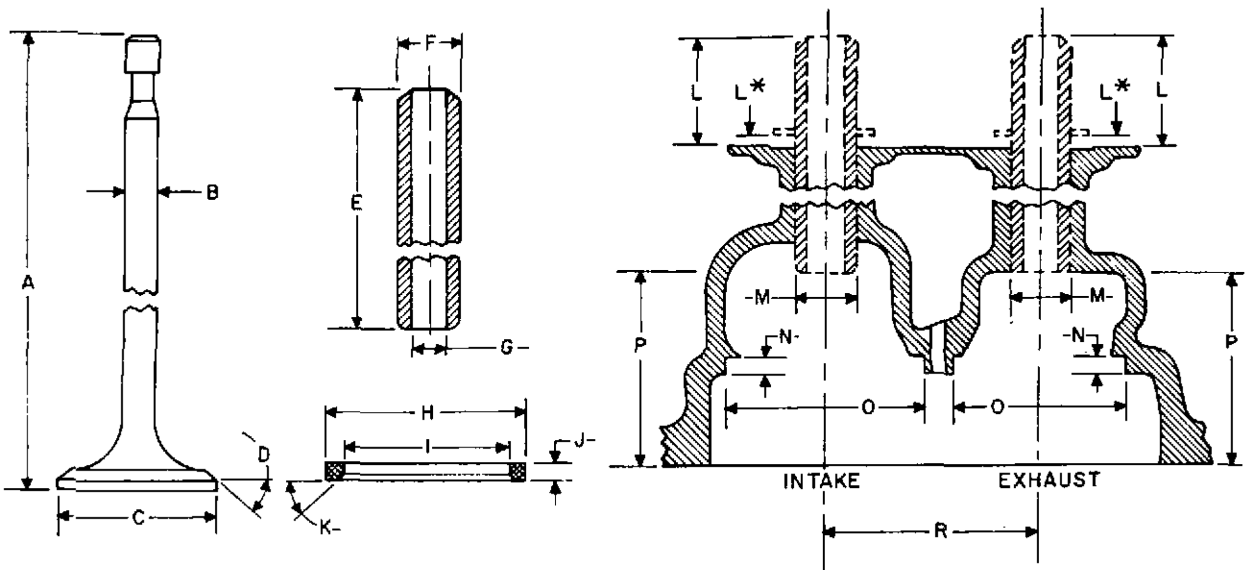
Rod material . . . Heat treated-steel forging
Rods, permissible weight variation . . . . 1/2 oz. in sets
(A) Rod length, center to center. . . . . 11.751-11.752"
(B) Rod small end finish size . 1.6865-1.6875"
(C) Bushing bore diameter . . 1.6252-1.6257" (Burnish in place)
(D) Bushing press in rod . . . . .005-.007"
(E) Rod large end finish size . . . . 3.2215-3.2220"
(F) Bearing running clearance. . .001-.003" (theoretical oil)
Rod width . . . . 2.240-2.242"
Rod bearing width . . . . 1.966-1.973"
Rod bearing undersizes available:
Standard (Non-counterbalanced) crankshafts . . . . .020, .040"
Counterbalanced crankshafts . .020, .040"



TYPICAL CONNECTING ROD, BUSHING AND BEARING

VALVE TRAIN, VALVE PORT CLEARANCES

	Intake	Exhaust
(A) Valve Length	8-5/16"	8-13/64"
(B) Valve Stem Diameter	.4965-.4975"	.4955-.4965"
(C) Valve Head Diameter (nominal)	2.562 +.000" -.010"	2.00 +.010" -.000"
(D) Valve Seat Angle	30°	45°
(E) Guide Length	4-5/16"	4-5/16"
(F) Guide Outside Diameter	.875"	.876-.877"
(G) Guide Inside Diameter (new)	.499-.500"	.499-.500"
Pre-sized Service Guides	.500-.501"	.500-.501"
(H) Insert Outside Diameter	none	2.253-2.254"
(I) Insert Inside Diameter	none	1-3/16 ±.005"
(J) Insert Depth	none	.4355-.4375"
(K) Insert Seat Angle	none	45°
(L*) Guide Shoulder Clearance Above Head	.010"	.010"



NOTE: ILLUSTRATION FOR LOCATION PURPOSES ONLY—CONFIGURATIONS ARE NOT INTENDED TO BE ACCURATE

VALVE TRAIN, VALVE PORT CLEARANCES

	Intake	Exhaust
(L) Guide, Straight Type - Extends Above Head (Used on Standard Automotive Head)	none	1-11/16"
(M) Guide Bore in Head	.874-.875"	.874-.875"
(N) Insert Counterbore Depth	none	.448-.453"
(O) Insert Counterbore Diameter	none	2.249-2.250"
(P) Valve Port Depth (Nominal)	Flush	1-7/8"
(R) Valve-Centerline to Centerline	2.843"	2.843"

VALVE SPRING COMBINATIONS AND IDENTIFICATION DATA

	VALVE SPRING FREE LENGTH	NO. COILS	SPRING PRESSURE Valve open	SPRING PRESSURE Valve closed
Standard Engine-Non Rotator				
1800 rpm and above				
145035A Inner Spring	3-15/32"	7-1/2	2-3/8"@158#	2-31/32"@67#
145135A Outer Spring	3-5/32"	9	2-1/16"@100#	2-31/32"@42#
Below 1800 rpm				
145035A Single Spring	SAME AS ABOVE			
Engines Equipped with Rotators				
1800 rpm and above				
145235B Single Spring	3-1/16"	8.2	1-63/64"@265#	2-37/64"@101#
Below 1800 rpm				
145335 Single Spring	3-3/32"	8-1/4	1-63/64"@158#	2-37/64"@67#

VALVE CLEARANCES

	Intake	Exhaust
Valve Running Clearance (cold)		
Standard Valves . .	.014-.016"	.034-.036"
Sodium Cooled Valves	.010-.012"	.019-.021"

Note: Valve clearances to be adjusted with engine stopped and cooled to normal ambient temperatures.

VALVE TIMING

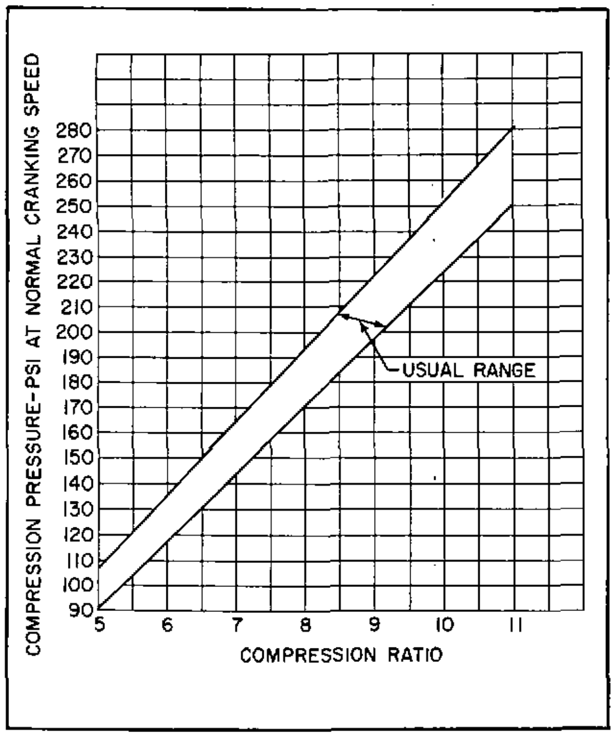
	Intake	Exhaust
Valve Timing Clearance	.064" (valve opens TDC)	.070" (valve closes TDC)

Note: Valves must be re-adjusted to the proper valve cold clearance setting after the timing check.

TIMING NOTE: For checking valve timing: Set intake valve clearance .064" at valve. Intake valve should open at top dead center. Set exhaust valve clearance .070" at valve. Exhaust valve should close at top dead center.

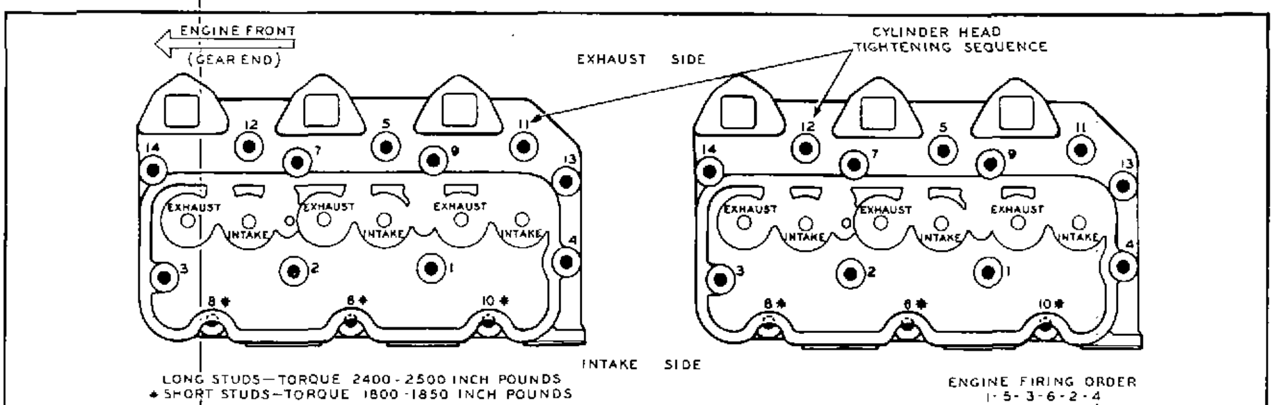
	Intake	Exhaust
Cam lift (measured at push rod)	.351"	.351"

COMPRESSION PRESSURE



COMPRESSION PRESSURE VS RATIO

VALVE SEQUENCE AND HEAD BOLT TIGHTENING DIAGRAM



Note: Re-torque cylinder head stud nuts on a new or overhauled engine after first start and after approximately 50 hours of operation with engine warm.

SPARK ADVANCE RECOMMENDATIONS

Comp. Ratio	Fuel	Distributor Timing	Magneto Timing @ Engine RPM								
			12-1400	12-1500	12-1600	15-2000	16-1800	16-2000	18-2100	20-2400	21-2400
6.2 to 1	Gasoline	TDC		15° BTDC				20° BTDC			26° BTDC
6.3 to 1	Gasoline	2° BTDC			18° BTDC				24° BTDC		
6.3 to 1*	Gasoline	2° BTDC			18° BTDC				24° BTDC		
7.3 to 1	Gasoline	TDC		18° BTDC			21° BTDC			25° BTDC	
7.3 to 1	LPG	6° BTDC	23° BTDC			26° BTDC					
7.3 to 1	Nat. Gas	8° BTDC	30° BTDC	30° BTDC	30° BTDC	30° BTDC	30° BTDC	30° BTDC	30° BTDC	30° BTDC	30° BTDC
7.3 to 1*	Gasoline	TDC		18° BTDC			21° BTDC			25° BTDC	
9.0 to 1	Nat. Gas	3° BTDC		22° BTDC				24° BTDC			

*Engines Equipped with Sodium Cooled Valves.

IGNITION DATA

Electrical System . 12-Volt Negative Polarity unless specified otherwise

Spark Plug Size . 14mm, 13/16 Hex, Champion

Spark Plug Type . . J-11, H-8, J-6 *gasoline**
Stitt 497 Gaseous Fuel
Crane Carrier Champion UJ-12 or UJ-8

Spark Plug Gap (new) . . . . .025"
(after service) . . .018-.020"

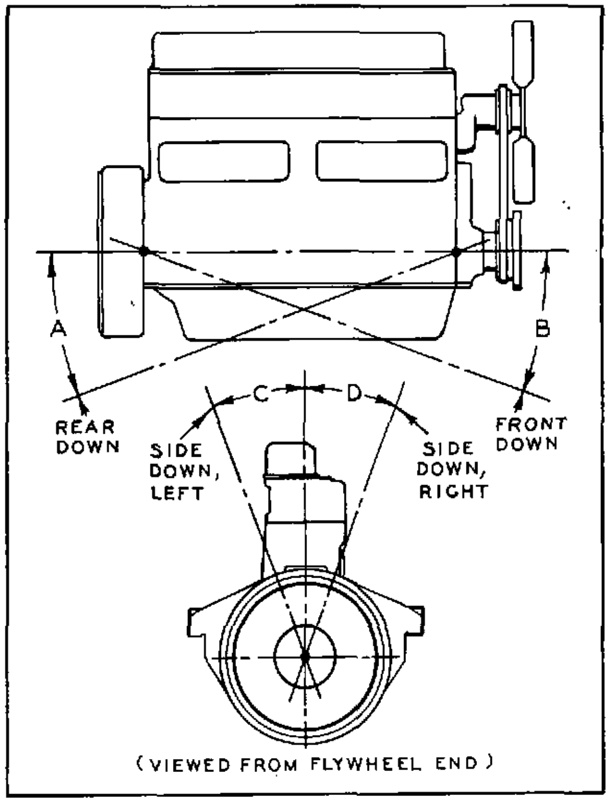
Distributor Breaker Point Gap . . .018-.020"

Magneto Breaker Point Gap
(most) . . . . .014-.018"

*Light, Medium, & Heavy Duty Respectively.

MAXIMUM ANGLE OF OPERATION

The maximum figures stated are for intermittent duty only. Consult the Waukesha Motor Company if continued operation at angles approaching the maximum are anticipated.



MAXIMUM ANGLE OF OPERATION

Pan Type	Pump Type	A Rear Down	B Front Down	C Side Down, Left	D Side Down, Right
STD (Rear Sump)	STD Pressure	30° 57%	10° 17%	30° 57%	15° 26%
STD (Rear Sump)	Scavenger	31° 60%	25° 46%	40° 84%	25° 46%

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

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 countries. In addition, the Waukesha Motor Company owns and operates branch warehouses and servicing facilities in New York, Tulsa, and Los Angeles, so that owners and operators are thus always within easy reach of a "Waukesha man."

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 the model as NKR-221, 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 Shipping 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 119 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 CO