CATERPILLAR®

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Service Manual

3304 & 3306 Natural Gas Engines

7Y291-Up
37Y1-Up

3304 & 3306 NATURAL GAS ENGINES

SERIAL NUMBERS
3304: 37Y1-UP
3306: 7Y291-UP

INTRODUCTION

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When the words "use again" are in the description, the specification given can be used to determine if a part can be used again. If the part is equal to or within the specification given, use the part again.

When the word "permissible" is in the description, the specification given is the "maximum or minimum" tolerance permitted before adjustment, repair and/or new parts are needed.

A comparison can be made between the measurements of a worn part, and the specifications of a new part to find the amount of wear. A part that is worn can be safe to use if an estimate of the remainder of its service life is good. If a short service life is expected, replace the part.

NOTE: The specifications given for "use again" and "permissible" are intended for guidance only and Caterpillar Tractor Co. hereby expressly denies and excludes any representation, warranty or implied warranty of the reuse of any component.

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SPECIFICATIONS (Section 1)

SYSTEMS OPERATION (Section 2)

TESTING AND ADJUSTING (Section 3)

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⚠ WARNING

IMPORTANT SAFETY NOTICE

Proper repair is important to the safe and reliable operation of this product. This Service Manual outlines basic recommended procedures, some of which require special tools, devices or work methods. Although not necessarily all inclusive, a list of additional skills, precautions and knowledge required to safely perform repairs is provided in the SAFETY section of this Manual.

Improper repair procedures can be dangerous and could result in injury or death.

READ AND UNDERSTAND ALL SAFETY PRECAUTIONS AND WARNINGS BEFORE PERFORMING REPAIRS

Basic safety precautions, skills and knowledge are listed in the SAFETY section of this Manual and in the descriptions of operations where hazards exist. Warning labels have also been put on to provide instructions and identify specific hazards which if not heeded could cause bodily injury or death to you or other persons. These labels identify hazards which may not be apparent to a trained mechanic. There are many potential hazards during repair for a untrained mechanic and there is no way to label the product against all such hazards. These warnings in the Service Manual and on the product are identified by this symbol:

⚠ WARNING

Operations that may result only in mechanical damage are identified by labels on the product and in the Service Manual by the word **NOTICE.**

Caterpillar can not anticipate every possible circumstance that might involve a potential hazard. The warnings in this Manual are therefore not all inclusive. If a procedure, tool device or work method not specifically recommended by Caterpillar is used, you must saftisfy yourself that it is safe for you and others. You should also ensure that the product will not be damaged or made unsafe by the procedures you choose.

IMPORTANT

The information, specifications and illustrations in this book are on the basis of information available at the time it was written. The specifications, torque, pressures of operation, measurements, adjustments, illustrations and other items can change at any time. These changes can affect the service given to the product. Get the complete and most current information before you start any job. Caterpillar Dealers have the most current information available. For a list of the most current modules and form numbers available for each Service Manual, see the SERVICE MANUAL CONTENTS MICROFICHE REG1139F.

⚠ WARNING

SAFETY

⚠ WARNING

Improper performance of lubrication or maintenance procedures is dangerous and could result in injury or death. Read and understand the lubrication and maintenance procedures, recommended by Caterpillar, that are outlined in the OPERATION GUIDE and/or OWNER'S MANUAL for this product before performing any lubrication or maintenance.

Do not operate this product unless you have read and understood the instructions. Improper operation is dangerous and could result in injury or death.

The servicemen or mechanic may be unfamiliar with many of the components and systems of this product. This makes it important to use caution when performing service work. A knowledge of the system and/or components is important before the removal or disassembly of any component.

Because of the size of some components, the serviceman or mechanic should check the weights noted in this Manual. Use proper lifting procedures when removing any components.

Following is a list of basic precautions that should always be observed.

1. Read and understand all Warning plates and decals before operating, lubricating or repairing this product.
2. Make sure the work area around the product is made safe and be aware of hazardous conditions that may exist.
3. Always wear protective glasses and protective shoes when working. In particular, wear protective glasses when a hammer or sledge is used for pounding to make repairs. Use welders gloves, hood/goggles, apron and other protective clothing appropriate to the welding job being performed. Do not wear loose-fitting or torn clothing. Remove all rings from fingers when working on machinery.

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4. If an engine must be started to make pressure or speed checks, be sure all guards and shields are installed. To help prevent an accident caused by parts in rotation, work carefully around machinery that has been put into operation.
5. If an engine has been running and the coolant is hot, loosen the filler cap slowly and let the pressure out of the cooling system, before any caps, plugs or lines are removed or disconnected.
6. Corrosion inhibitor contains alkali. Avoid contact with eyes. Avoid prolonged or repeated contact with skin. Do not take internally. In case of contact, immediately wash skin with soap and water. For eyes, flush with large amounts of water for at least 15 minutes. CALL PHYSICIAN. KEEP OUT OF REACH OF CHILDREN.
7. Do not smoke when an inspection of the battery electrolyte level is made. Never disconnect any charging unit circuit or battery circuit cable from the battery when the charging unit is operating. A spark can cause an explosion from the flammable vapor mixture of hydrogen and oxygen that is released from the electrolyte through the battery outlets. Do not let electrolyte solution make contact with skin or eyes. Electrolyte solution is an acid. In case of contact, immediately wash skin with soap and water. For eyes, flush with large amounts of water for at least 15 minutes. CALL PHYSICIAN. KEEP OUT OF REACH OF CHILDREN.
8. Disconnect battery and discharge any capacitors before starting any repair work. Hang "Do Not Operate" tag in the Operator's compartment or on the controls.
9. Do not work on anything that is supported only by lift jacks or a hoist. Always use blocks or proper stands to support the product before performing any service work.
10. Relieve all pressure in air, oil or water systems before any lines, fittings or related items are disconnected or removed. Be alert for possible pressure when disconnecting any device from a system that utilizes pressure. Do not check for pressure leaks with your hand. High pressure oil or fuel can pierce the skin.

⚠ WARNING

11. Never bend a fuel injection line, or install a line which has been bent. Keep the fuel injection lines and connections clean. Be sure to install caps and covers anytime a line is removed or disconnected.

12. During service work, do not hit the fuel injection lines with wrenches or other tools. When lines are installed, use the correct torque to tighten connections and be sure all clamps and dampers are correctly installed.

13. Make sure all fuel injection lines and pressure oil lines have enough clearance to prevent contact with any other component. Do not put any fuel or oil lines close to a hot component.

14. To avoid back injury use a hoist or get help when lifting components which weigh 50 lb. (23 kg) or more. Make sure all chains, hooks, slings, etc., are in good condition and are of the correct capacity. Be sure hooks are positioned correctly. Lifting eyes are not to be side loaded during a lifting operation.

15. To avoid burns, be alert for hot parts on products which have just been stopped and hot fluids in lines, tubes and compartments.

16. Be careful when removing cover plates. Gradually back off the last two bolts or nuts located at opposite ends of the cover or device and pry cover loose to relieve any spring or other pressure, before removing them completely.

17. Be careful when removing filler caps, breathers and plugs on the product. Hold a rag over the cap or plug to prevent being sprayed or splashed by liquids under pressure. The danger is even greater if the product has recently been stopped because fluids can be hot.

18. Always use tools that are in good condition and be sure you understand how to use them before performing any service work. Use only Caterpillar replacement parts.

19. Reinstall all fasteners with same part number. Do not use a lesser quality fastener if replacements are necessary.

20. Repairs which require welding should be performed only with the benefit of the appropriate reference information and by personnel adequately trained and knowledgeable in welding procedures. Make reference to "Techniques of Structural Repair Course" form number JEG03719. Determine type of metal being welded and select correct welding procedure and electrodes, rods or wire to provide a weld metal strength equivalent at least to that of parent metal.

21. Before doing electrical work, disconnect battery. Do not damage wiring during removal operations. Reinstall the wiring so it is not damaged nor will it be damaged in operation by contacting sharp corners, or by rubbing against some object or hot surface. Do not connect wiring to a line containing fluid.

22. Be sure all protective devices including guards and shields are properly installed and functioning correctly before starting a repair. If a guard or shield must be removed to perform the repair work, use extra caution. After the repair is completed, reinstall any guard or shield that was removed.

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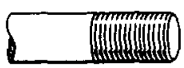
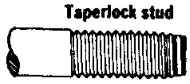
GENERAL TIGHTENING TORQUE FOR BOLTS, NUTS AND TAPERLOCK STUDS

The following charts give the standard torque values for bolts, nuts and taperlock studs of SAE Grade 5 or better quality. Exceptions are given in other sections of the Service Manual where needed.

THREAD DIAMETER		STANDARD TORQUE	
inches	**millimeters**	**lb. ft.**	**N·m***
Standard thread 		Use these torques for bolts and nuts with standard threads (conversions are approximate).	
1/4	6.35	9 ± 3	12 ± 4
5/16	7.94	18 ± 5	25 ± 7
3/8	9.53	32 ± 5	45 ± 7
7/16	11.11	50 ± 10	70 ± 15
1/2	12.70	75 ± 10	100 ± 15
9/16	14.29	110 ± 15	150 ± 20
5/8	15.88	150 ± 20	200 ± 25
3/4	19.05	265 ± 35	360 ± 50
7/8	22.23	420 ± 60	570 ± 80
1	25.40	640 ± 80	875 ± 100
1 1/8	28.58	800 ± 100	1100 ± 150
1 1/4	31.75	1000 ± 120	1350 ± 175
1 3/8	34.93	1200 ± 150	1600 ± 200
1 1/2	38.10	1500 ± 200	2000 ± 275
		Use these torques for bolts and nuts on hydraulic valve bodies.	
5/16	7.94	13 ± 2	20 ± 3
3/8	9.53	24 ± 2	35 ± 3
7/16	11.11	39 ± 2	50 ± 3
1/2	12.70	60 ± 3	80 ± 4
5/8	15.88	118 ± 4	160 ± 6
Taperlock stud 		Use these torques for studs with Taperlock threads.	
1/4	6.35	5 ± 2	7 ± 3
5/16	7.94	10 ± 3	15 ± 5
3/8	9.53	20 ± 3	30 ± 5
7/16	11.11	30 ± 5	40 ± 10
1/2	12.70	40 ± 5	55 ± 10
9/16	14.29	60 ± 10	80 ± 15
5/8	15.88	75 ± 10	100 ± 15
3/4	19.05	110 ± 15	150 ± 20
7/8	22.23	170 ± 20	230 ± 30
1	25.40	260 ± 30	350 ± 40
1 1/8	28.58	320 ± 30	400 ± 40
1 1/4	31.75	400 ± 40	550 ± 50
1 3/8	34.93	480 ± 40	650 ± 50
1 1/2	38.10	550 ± 50	750 ± 70

***1 newton meter (N·m) is approximately the same as 0.1 mkg.**

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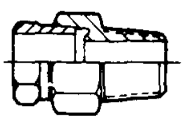
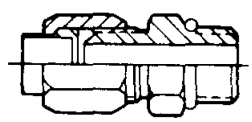
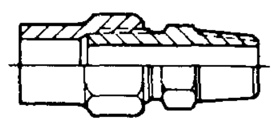
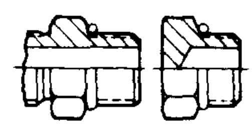
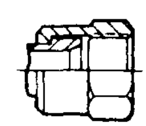
TORQUE FOR FLARED AND O-RING FITTINGS

The torques shown in the chart that follows are to be used on the part of 37° Flared, 45° Flared and Inverted Flared fittings (when used with steel tubing), O-ring plugs and O-ring fittings.

				
INVERTED 45° FLARED	37° FLARED	45° FLARED	O-RING FITTING – PLUG	SWIVEL NUTS

TUBE SIZE (O.D.)	mm	3.18	4.78	6.35	7.92	9.52
	in.	.125	.188	.250	.312	.375
THREAD SIZE (in.)		5/16	3/8	7/16	1/2	9/16 5/8
TORQUE N·m		5 ±1	11 ±1	16 ±2	20 ±2	25 ±3
TORQUE lb.in.		45 ±10	100 ±10	145 ±20	175 ±20	225 ±25

TUBE SIZE (O.D.)	mm	12.70	15.88	19.05	22.22	25.40	31.75	38.10	50.80
	in.	.500	.625	.750	.875	1.000	1.250	1.500	2.000
THREAD SIZE (in.)		3/4	7/8	1 1/16	1 3/16 1 1/4	1 5/16	1 5/8	1 7/8	2 1/2
TORQUE N·m		50 ±5	75 ±5	100 ±5	120 ±5	135 ±10	180 ±10	225 ±10	320 ±15
TORQUE lb.ft.		35 ± 4	55 ± 4	75 ± 4	90 ± 4	100 ± 7	135 ± 7	165 ± 7	235 ± 10

ASSEMBLY OF FITTINGS WITH STRAIGHT THREADS AND O-RING SEALS

1. Put locknut (3), backup washer (4) and O-ring seal (5) as far back on fitting body (2) as possible. Hold these components in this position. Turn the fitting into the part it is used on, until backup washer (4) just makes contact with the face of the part it is used on.

NOTE: If the fitting is a connector (straight fitting) or plug, the hex on the body takes the place of the locknut. To install this type fitting tighten the hex against the face of the part it goes into.

2. To put the fitting assembly in its correct position turn the fitting body (2) out (counterclockwise) a maximum of 359°. Tighten locknut (3) to the torque shown in the chart.

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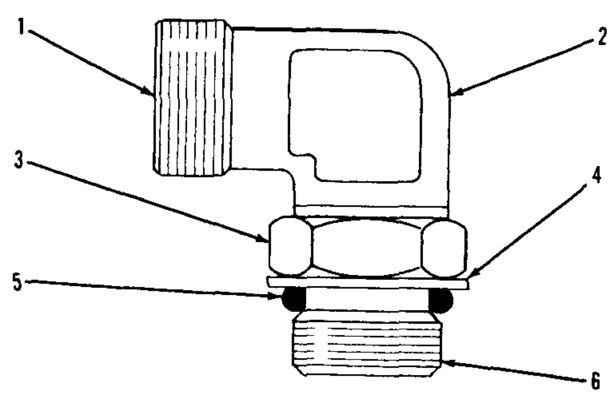

ELBOW BODY ASSEMBLY

1. End of fitting body (connects to tube). 2. Fitting body. 3. Locknut. 4. Backup washer. 5. O-ring seal. 6. End of fitting that goes into other part.

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SPECIFICATIONS (Section 1)

ENGINE DESIGN 3304

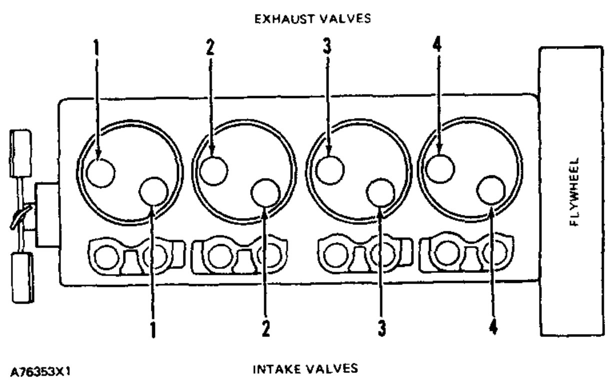
Bore	4.75 in. (120.7 mm)
Stroke	6.0 in. (152.4 mm)
Number of Cylinders	4
Cylinder Arrangement	*in-line
Firing Order (Ignition Sequence)	1, 3, 4, 2
Direction of Rotation (when seen from flywheel end)	Counterclockwise

*No. 1 Cylinder Is Opposite Flywheel End.

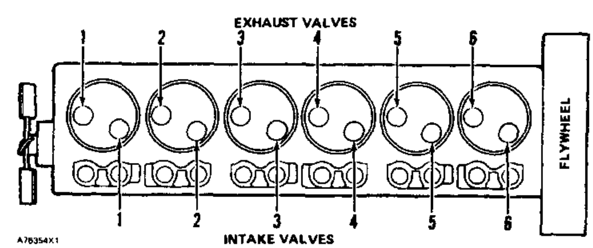
ENGINE DESIGN 3306

Bore	4.75 in. (120.7 mm)
Stroke	6.00 in. (152.4 mm)
Number of Cylinders	6
Cylinder Arrangement	*in-line
Firing Order (Ignition Sequence)	1, 5, 3, 6, 2, 4
Direction of Rotation (when seen from flywheel end)	Counterclockwise

*No. 1 Cylinder Is Opposite Flywheel End.



CYLINDER AND VALVE IDENTIFICATION



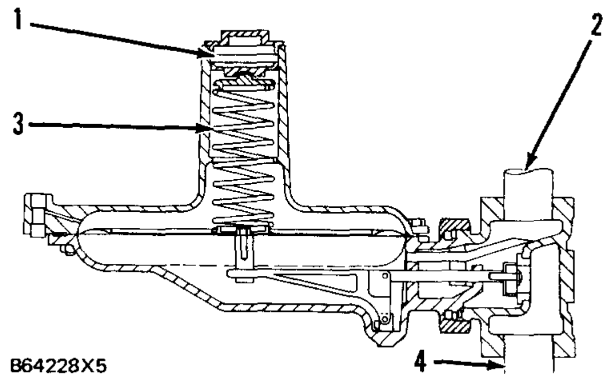
CYLINDER AND VALVE IDENTIFICATION

GAS PRESSURE REGULATOR
2W6022

(1) Adjustment screw.
(2) Regulator outlet.
(3) Regulator springs:

FISHER PART NUMBER	OUTLET (2) PRESSURE RANGE	COLOR CODE
1D8030	3.5 to 6 in. H_2O (88.9 to 152.4 mm H_2O)	PURPLE
1B5585	1.3 to 3.5 in. H_2O (33 to 152.4 mm H_2O)	ORANGE
1B5584	1 to 1.6 in. H_2O (25.4 to 40.6 mm H_2O)	PINK

(4) Regulator inlet.



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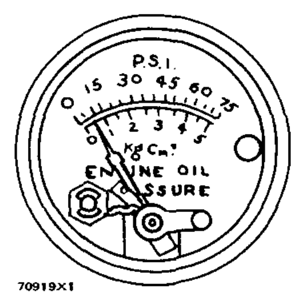
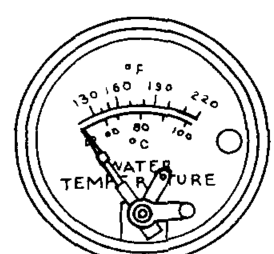
GAUGE FOR OIL PRESSURE
(3N2780)



70919X1

Switch adjustment range .... 0 to 75 psi (0.0 to 520 kPa)
Pressure setting of the contact point .... 8 ± 1 psi (55 ± 7 kPa)
Pressure setting of the lockout .... 15 psi (105 kPa)

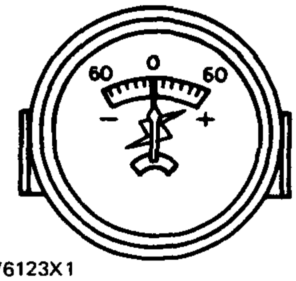
GAUGE FOR WATER TEMPERATURE
(3N2781)



70918X1

Switch adjustment range .... 100 to 220°F (38 to 104°C)
Temperature setting of the contact point .... 210°F ± 3°F (99°C ± 2°C)

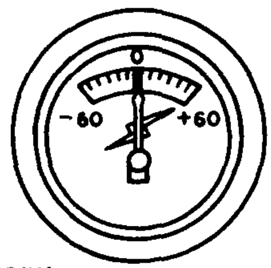
AMMETER



A76123X1

8M7892 Gauge (Stewart-Warner Number 337CA)

CALIBRATION CHART		
POINTER POSITION	OA	± 30 A
TOLERANCE	± .020 in. (0.51 mm)	± 4.5 A

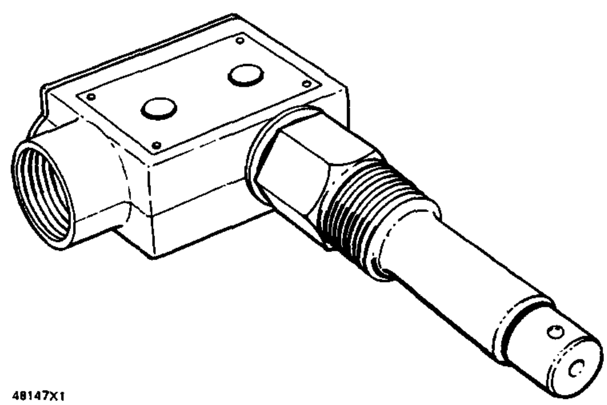


A76124X1

8M7892 Gauge (Datcon Instrument Co. Number 01004-2-99)

CALIBRATION CHART			
POINTER POSITION	*+ 30 A*	*− 30 A*	*± 60 A*
TOLERANCE	± 3.0 A	± 4.5 A	± 9.0 A

CONTACTOR SWITCH FOR WATER TEMPERATURE



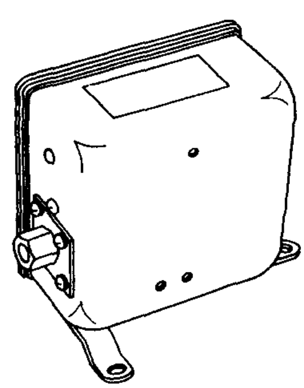
48147X1

(Robert Shaw-Fulton Number 99168-E2)

SWITCH OPERATING TEMPERATURE		
	with increase in temperature	with decrease in temperature
5L6435*	209 ± 1°F (98 ± 0.6°C)	197 ± 1°F (92 ± 0.6°C)

*Standard for sea level operation.

CONTACTOR SWITCH FOR OIL PRESSURE



84165X1

Micro Switch Type

2N6955

With an increase of pressure, contacts operate at .... 12 psi (85 kPa)

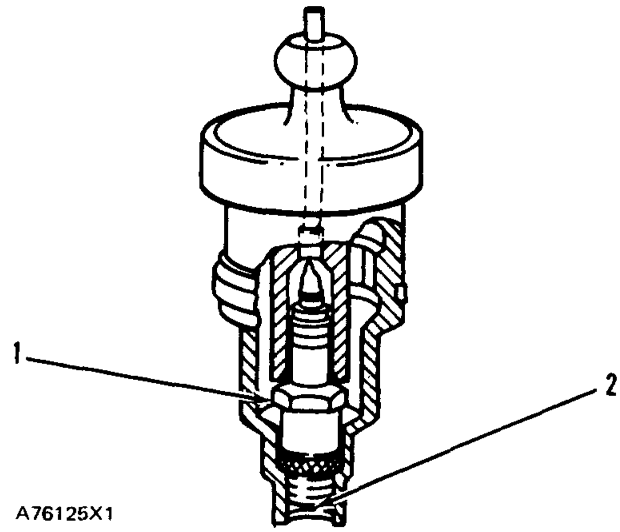
With a decrease of pressure, contacts operate at .... 8 psi (55 kPa)

SPARK PLUG

2N2839 SPARK PLUG

(1) Torque for spark plug .... 25 ± 4 lb. ft. (35 ± 5 N·m)

(2) Gap of the spark plug ..... .013 to .015 in. (0.33 to 0.38 mm)



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MAGNETO DRIVE

(1) Install bearing so oil holes in bearing are in alignment with oil holes in housing.

Bore in bearing after installation .... .6265 ± .0010 in. (15.913 ± 0.025 mm)

Diameter of shaft .... .6235 ± .0003 in. (15.837 ± 0.008 mm)

(2) Distance to install bearing from face of housing .... .000 ± .020 in. (0.00 ± 0.51 mm)

(3) Distance from face of housing to end of dowel .... .252 ± .059 in. (6.40 ± 1.50 mm)

(4) Bore in bearing after installation .... 1.5185 ± .0015 in. (38.570 ± 0.038 mm)

Diameter of magneto drive shaft .... 1.5155 ± .0005 in. (38.494 ± 0.013 mm)

(5) Bore in bearing after installation .... .7530 ± .0005 in. (19.126 ± 0.013 mm)

Diameter of shaft .... .7500 ± .0005 in. (19.050 ± 0.013 mm)

(6) Install bearing so oil holes in bearing are in alignment with oil holes in housing.

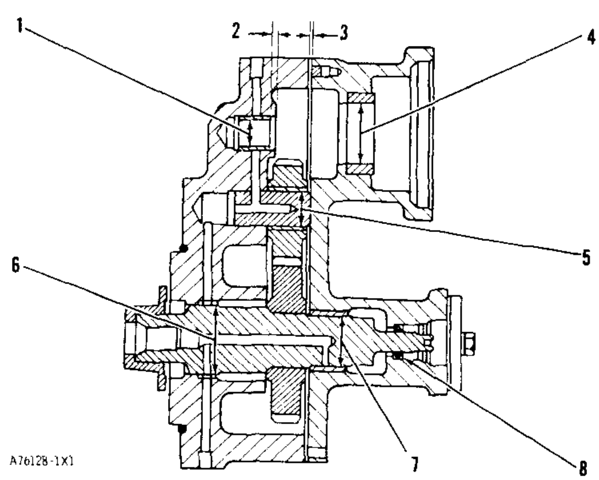
Bore in bearing after it is installed .... 1.5015 ± .0015 in. (38.138 ± 0.038 mm)

Diameter of shaft .... 1.4990 ± .0005 in. (38.074 ± 0.013 mm)

(7) Bore in bearing after it is installed .... 1.1265 ± .0091 in. (28.613 ± 0.231 mm)

Diameter of shaft .... 1.1245 ± .0005 in. (28.562 ± 0.013 mm)

(8) Install seal with lip of seal facing in.



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MAGNETO TIMING
(3304)

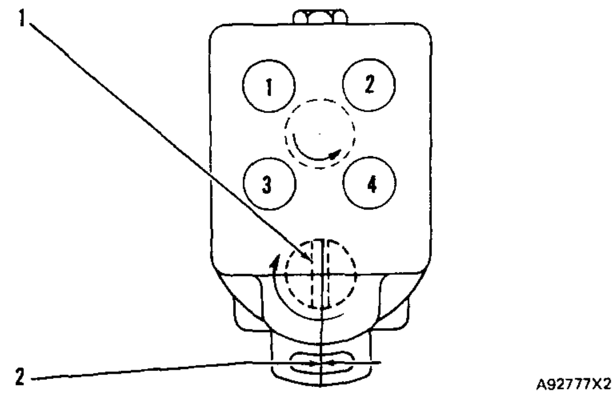
7L3032 Spark Gap Magneto

Ignition Sequence 1, 3, 4, 2

Magneto Point gap .... .017 in. (0.43 mm)

(1) *Drive tang viewed from rear of engine.*

(2) Angle of drive tang from vertical .... 0°



INSTRUCTIONS FOR TIMING MAGNETO TO NO. 1 CYLINDER		
Compression Ratio	Other Conditions	Flywheel Mark — Engine Stopped or Running
10.5:1	N.A. (Natural Gas)	35° BTC
10.5:1	N.A. (Propane)	17.5° BTC
8:1	N.A. (Natural Gas)	40° BTC
8:1	N.A. (Propane)	30° BTC

BTC = Before top center.

MAGNETO TIMING
(3306)

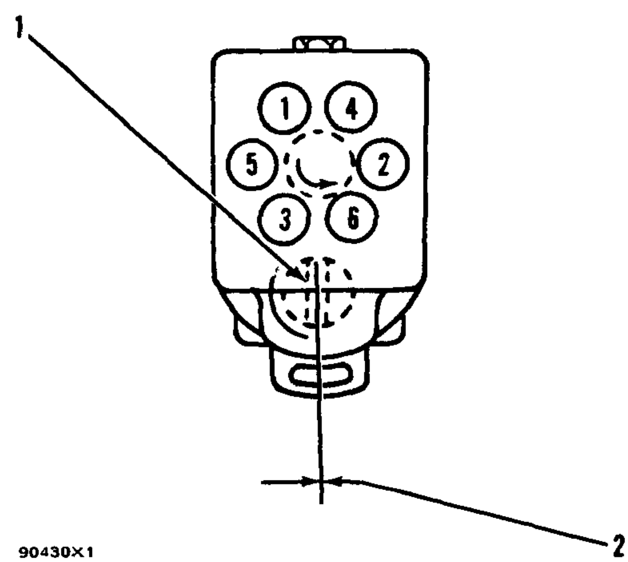
7L3031 Spark Gap Magneto

Ignition Sequence 1, 5, 3, 6, 2, 4

Magneto Point gap .... .017 in. (0.43 mm)

(1) *Drive tang viewed from rear of engine.*

(2) Angle of drive tang from vertical .... 0°



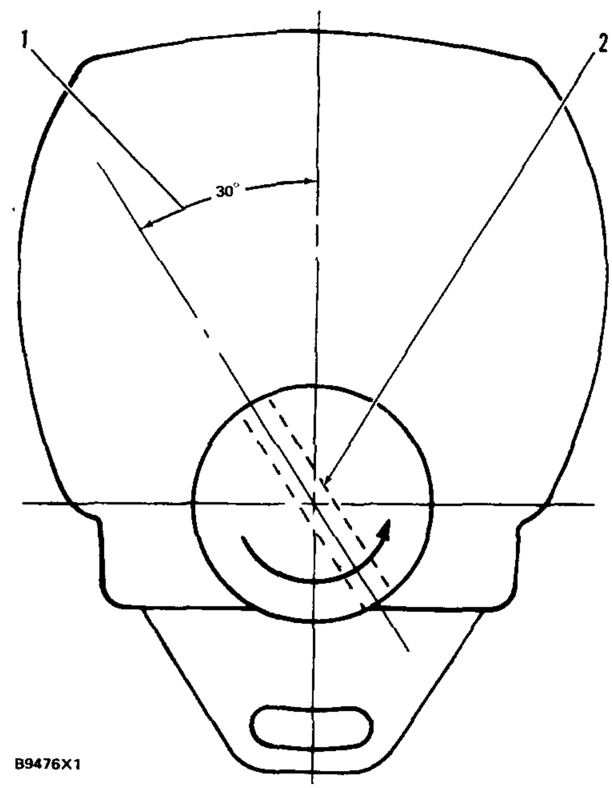
INSTRUCTIONS FOR TIMING MAGNETO TO NO. 1 CYLINDER		
Compression Ratio	Other Conditions	Flywheel Mark — Engine Stopped or Running
10.5:1	N.A. (Natural Gas)	35° BTC
10.5:1	T.A. (Natural Gas)	25° BTC
10.5:1	N.A. (Propane)	17.5° BTC
10.5:1	T.A. (Propane)	15° BTC
8:1	N.A. (Natural Gas)	40° BTC
8:1	T.A. (Natural Gas)	35° BTC
8:1	N.A. (Propane)	30° BTC
8:1	T.A. (Propane)	20° BTC

BTC = Before top center.

IGNITION SYSTEM (FAIRBANKS MORSE SOLID STATE MAGNETO) GENERAL SPECIFICATIONS OF THE MAGNETO					
Magneto Assembly	Number of Magneto Poles	Direction of Rotation*	Sequence	Operating Speed	Wheel Degree Timing Setting
7N9378	6	CCW	Even	2700	45°
8N5973	4	CCW	Even	1800	30°

*Rotation of drive tang when seen from the tang end.

MAGNETO TIMING
(3304)



8N5973 Solid State Magneto (Fairbanks Morse)

Ignition Sequence 1, 3, 4, 2

(1) Angle of drive tang from vertical .... 30°

(2) Drive tang seen from the tang end.

No. 1 CYLINDER TIMING ANGLES (FAIRBANKS MORSE SOLID STATE MAGNETO)			
Compression Ratio	Conditions	Engine Stopped	Engine at Rated Speed
10.5:1	NA	15° BTC	35° BTC
10.5:1	NA (Propane)	2.5° ATC	17.5° BTC
8:1	NA	20° BTC	40° BTC
8:1	NA (Propane)	10° BTC	30° BTC
	(Well Scrubbed field Gas)	0° TC	20° BTC

TC = Top center. BTC = Before top center.
ATC = After top center.

MAGNETO TIMING
(3306)

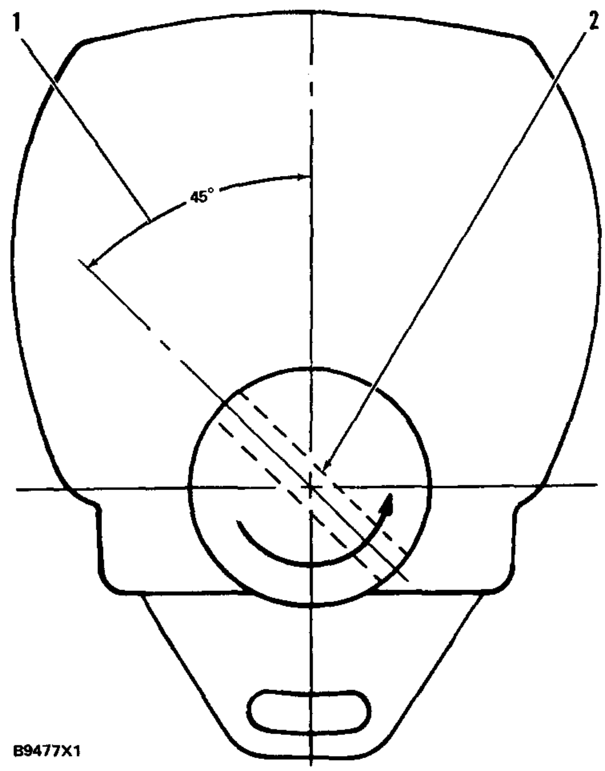
7N9378 Solid State Magneto (Fairbanks Morse)

Ignition Sequence 1-5-3-6-2-4

(1) Angle of drive tang from vertical .... 45°

(2) Drive tang seen from the tang end.

No. 1 CYLINDER TIMING ANGLES (FAIRBANKS MORSE SOLID STATE MAGNETO)			
Compression Ratio	Conditions	Engine Stopped	Engine at Rated Speed
10.5:1	NA	15° BTC	35° BTC
10.5:1	TA (90°F Water)	5° BTC	25° BTC
10.5:1	NA (Propane)	2.5° ATC	17.5° BTC
10.5:1	TA (Propane)	5° ATC	15° BTC
8:1	NA	20° BTC	40° BTC
8:1	TA (130°F Water)	15° BTC	35° BTC
8:1	NA (Propane)	10° BTC	30° BTC
8:1	TA (Propane or Well Scrubbed Field Gas)	0° TC	20° BTC
TC = Top Center. BTC = Before top center. ATC = After top center.			



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MAGNETO TIMING
(3304)

2W3746 Solid State Magneto (Altronic)

Ignition Sequence 1, 3, 4, 2

(1) Timing marks.

(2) Drive tang viewed from rear of engine.

(3) Angle of drive tang from vertical .... 0°

No. 1 CYLINDER TIMING ANGLES (ALTRONIC SOLID STATE MAGNETO)		
Compression Ratio	Other Conditions	Flywheel Mark: Engine Stopped or Running
10.5:1	N.A. (Natural Gas)	35° BTC
10.5:1	N.A. (Propane)	17.5° BTC
8:1	N.A. (Natural Gas)	40° BTC
8:1	N.A. (Propane)	30° BTC

BTC = Before top center.

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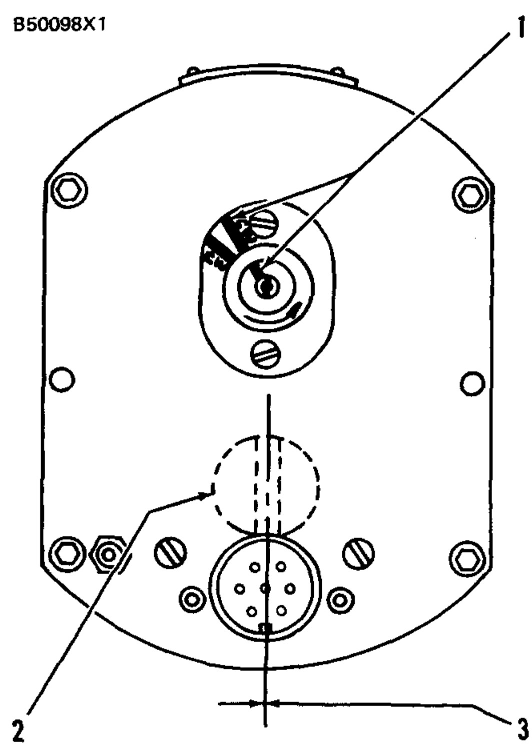

MAGNETO TIMING
(3306)

2W3749 Solid State Magneto (Altronic)

Ignition Sequence 1, 5, 3, 6, 2, 4

(1) Timing marks.

(2) Drive tang viewed from rear of engine.

(3) Angle of drive tang from vertical .... 0°

No. 1 CYLINDER TIMING ANGLES (ALTRONIC SOLID STATE MAGNETO)		
Compression Ratio	Other Conditions	Flywheel Mark: Engine Stopped or Running
10.5:1	NA	35° BTC
10.5:1	TA (90°F Water)	25° BTC
10.5:1	NA (Propane)	17.5° BTC
10.5:1	TA (Propane)	15° BTC
8:1	NA	40° BTC
8:1	TA (130°F Water)	35° BTC
8:1	NA (Propane)	30° BTC
8:1	TA (Propane or Well Scrubbed Field Gas)	20° BTC

BTC = Before top center.

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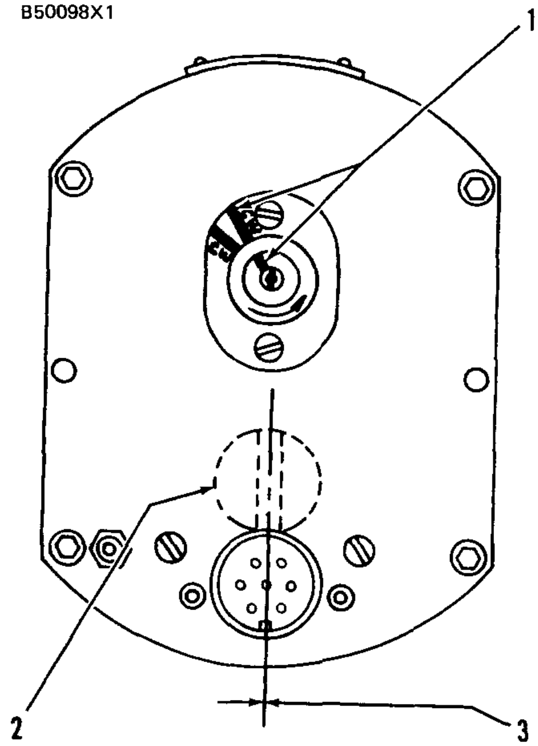


TRANSFORMERS

6L2832 Transformer for Spark Gap Magneto

Resistance:

Primary coil measured between positive post (1) and negative post (2) of transformer.................... 6 ohms ± 5%

Secondary coil measured between negative post (2) of transformer and outlet (3) for the high current (tension) .... 10,500 ohms ± 5%

7L6791 Transformer For Fairbanks Morse Solid State Magneto

Resistance:

Primary coil measured between positive post (1) and negative post (2) of transformer................... .3 to .6 ohms

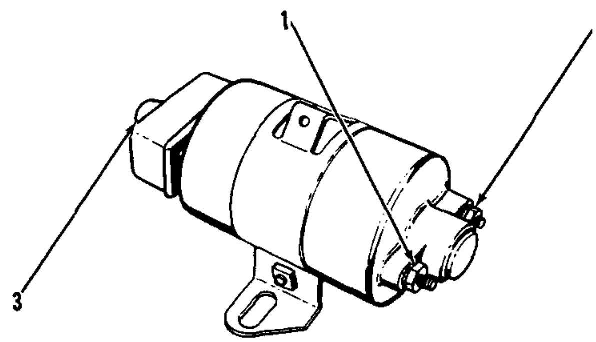
Secondary coil measured between negative post (2) of transformer and outlet (3) for the high current (tension) .... 11,000 to 13,000 ohms

2W3747 Transformer For Altronic Solid State Magneto

Resistance:

Primary coil measured between positive post (2) and negative post (3) of transformer................. 0.1 to 0.2 ohms

Secondary coil measured between negative post (3) of transformer and outlet (1) for the high current (tension) .... 5,000 to 8,000 ohms



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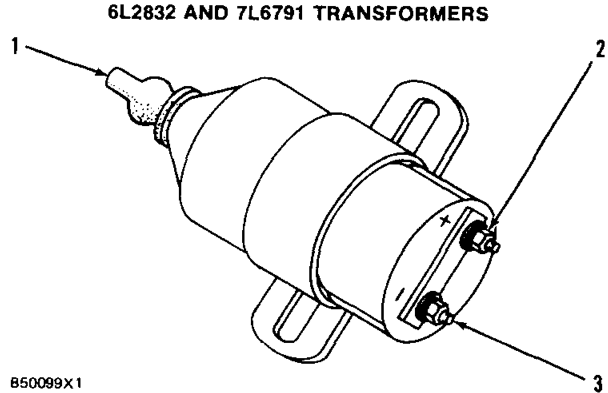
6L2832 AND 7L6791 TRANSFORMERS



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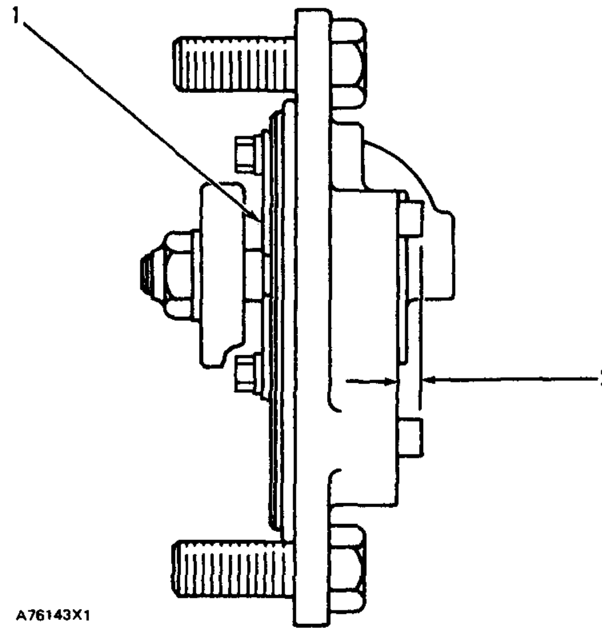
2W3747 TRANSFORMER

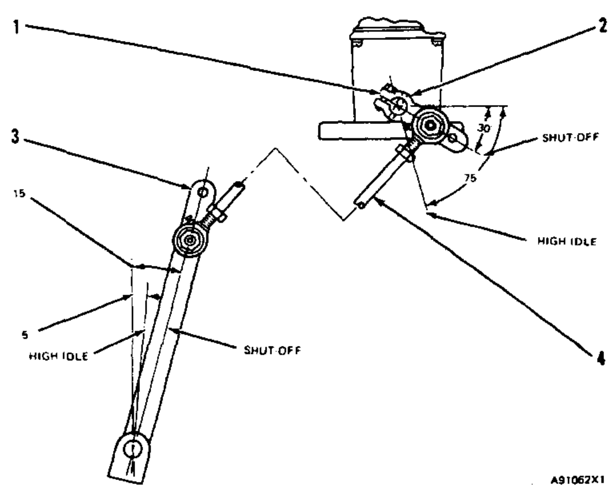
ACCESSORY DRIVE



(1) Install thrust plate in groove of shaft as far as possible using all of the bolt clearance available.

(2) Distance from end of dowels to face of housing .... .252 ± .020 in. (6.40 ± 0.51 mm)

MECHANICAL GOVERNOR LINKAGE ADJUSTMENTS
(3304 ENGINE)



NATURALLY ASPIRATED ENGINE

Adjustment of Linkage to the Carburetor

1. Clamp the carburetor lever (1) on the carburetor throttle shaft at angle indicated when the throttle plate is closed.
2. Drill a .125 in. (3.18 mm) hole thru shaft and lever and install pin (2) in shaft.
3. Adjust the length of linkage rod (4) so the angles at carburetor lever (1) and governor lever (3) are maintained.

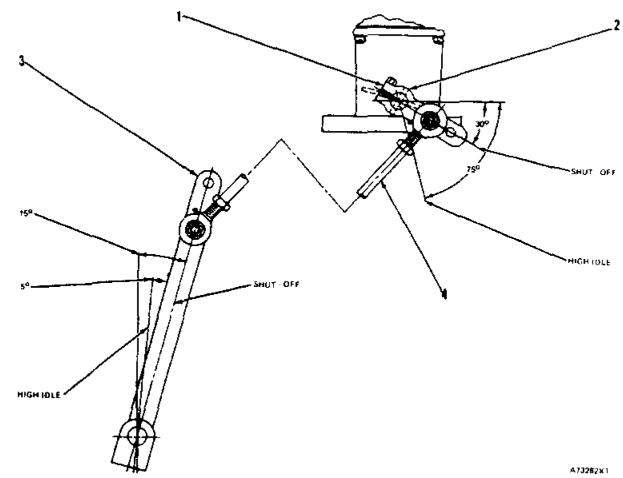
NOTE: *Governor lever in shutoff position and throttle plate closed.*

MECHANICAL GOVERNOR LINKAGE ADJUSTMENTS
(3306 ENGINE)

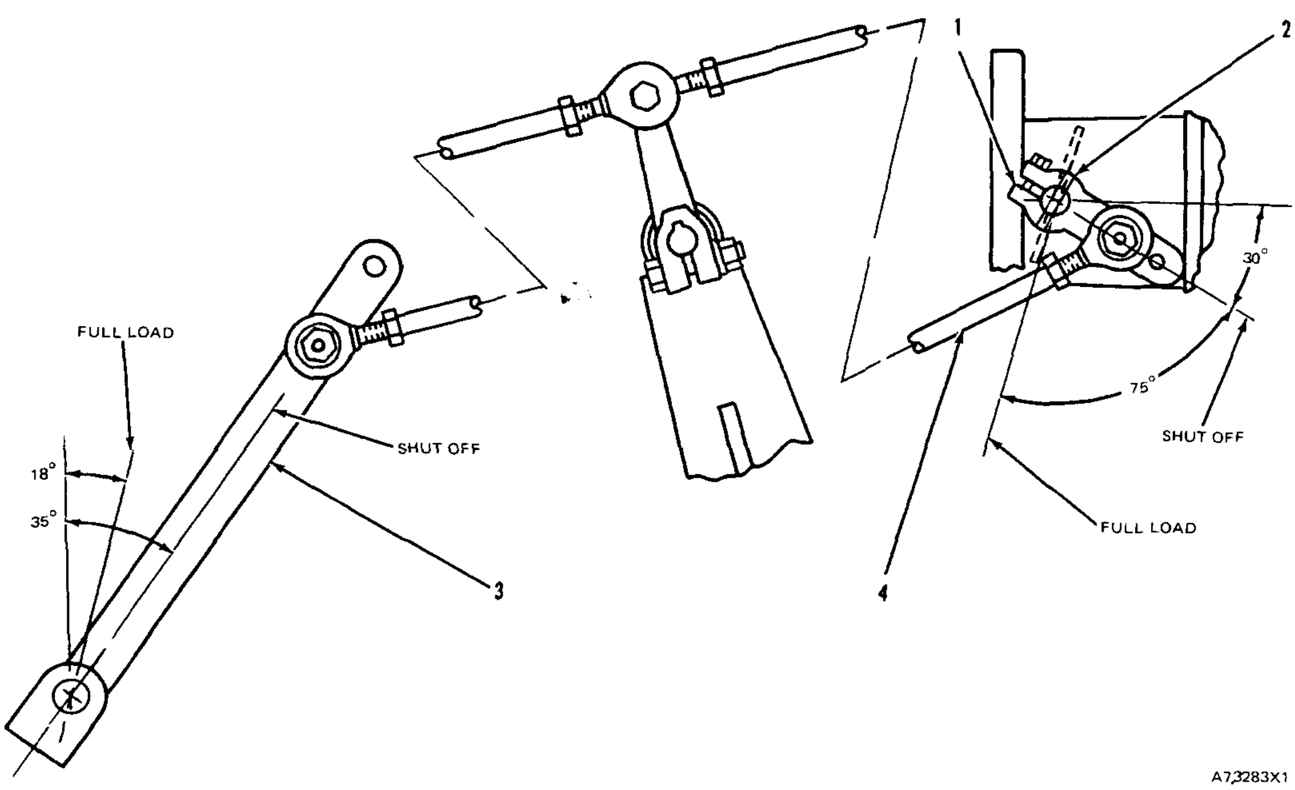
Adjustment of Linkage to the Carburetor

1. Clamp the carburetor lever (1) on the carburetor throttle shaft at angle indicated when the throttle plate is closed.
2. Drill a .125 in. (3.18 mm) hole thru shaft and lever and install pin (2) in shaft.
3. Adjust the length of linkage rod (4) so the angles at carburetor lever (1) and governor lever (3) are maintained.

NOTE: Governor lever in shutoff position and throttle plate closed.

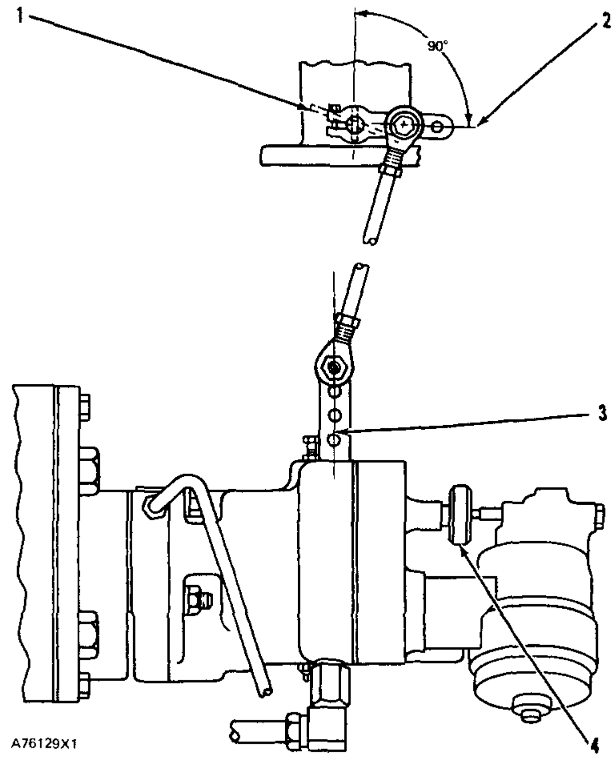


NATURALLY ASPIRATED ENGINE



TURBOCHARGED ENGINE

WOODWARD PSG GOVERNOR AND LINKAGE FOR NATURALLY ASPIRATED 3306 ENGINE



Voltage for governor synchronizing motor .... 24V DC

(1) Throttle plate in closed position.

(2) Position for lever on carburetor .... 90° from vertical

(3) Shutoff position for governor lever .... vertical

(4) Manual control knob.

WOODWARD PSG GOVERNOR AND LINKAGE FOR TURBOCHARGED 3306 ENGINE

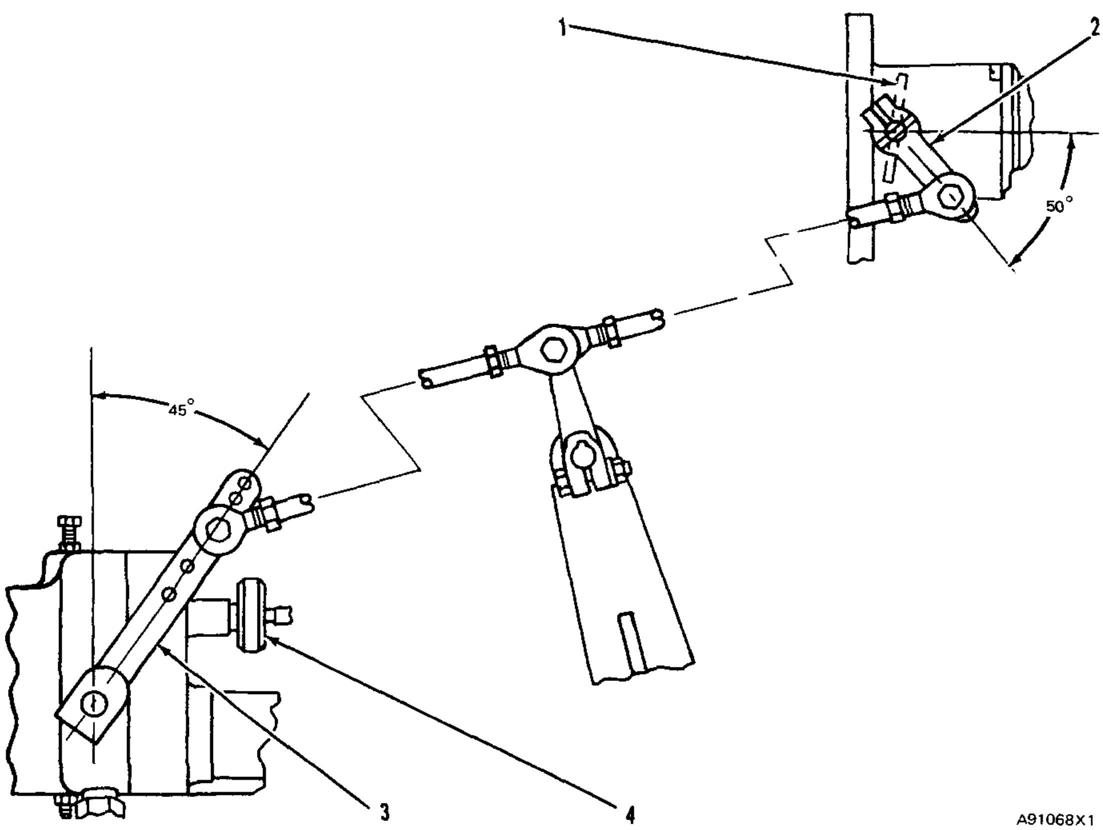
Voltage for governor synchronizing motor .... 24V DC

(1) Throttle plate in closed position.

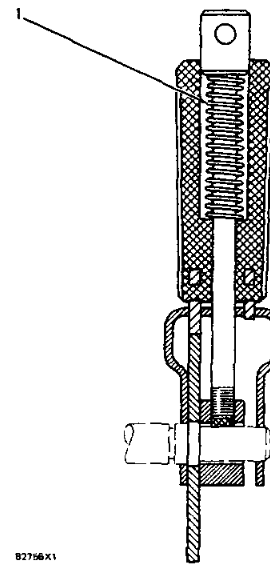
(2) Position for lever on carburetor............................ 50° from horizontal

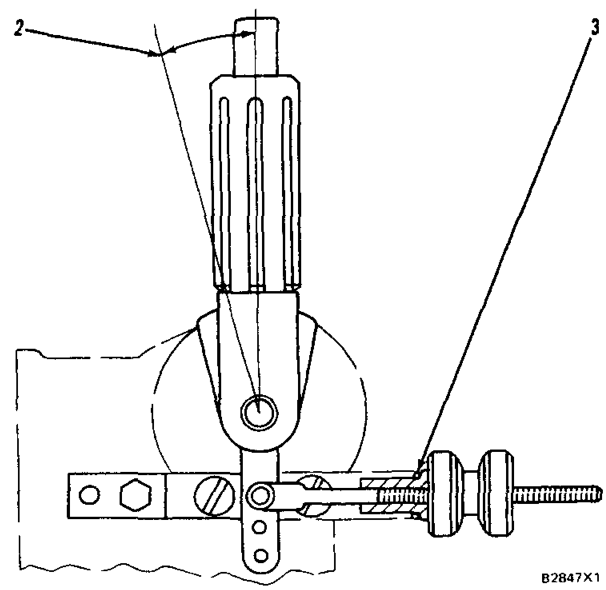
(3) Shutoff position for governor lever .... 45° from vertical

(4) Manual control knob.



GOVERNOR CONTROL





(1) 7M1269 Spring:

Length under test force .... 2.11 in. (53.6 mm)

Test force .... 11.8 ± .94 lb. (52.5 ± 4.2 N)

Free length after test................... 3.27 in. (83.1 mm)

Outside diameter .... .562 in. (14.27 mm)

(2) With governor in Low Idle Position, install governor lever 12° 30' forward of vertical.

(3) 2H210 Spring:

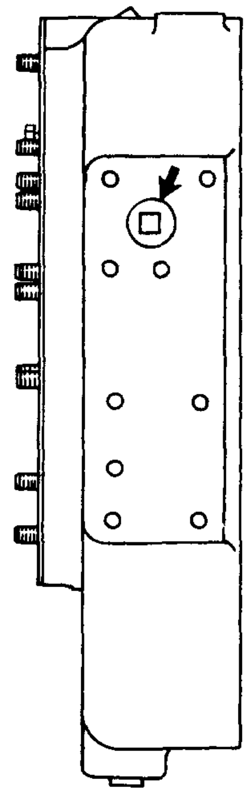
Length under test force .... 1.032 in. (26.21 mm)

Test force .... 5.99 to 6.61 lb. (26.6 to 29.4 N)

Free length after test.................. 4.72 in. (119.9 mm)

Outside diameter .... .75 in. (19.1 mm)

ENGINE TIMING



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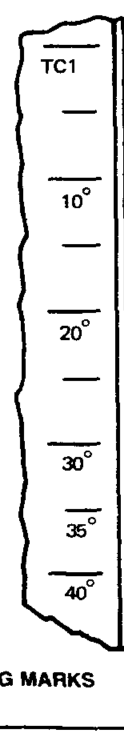
LOCATION TO CHECK TIMING



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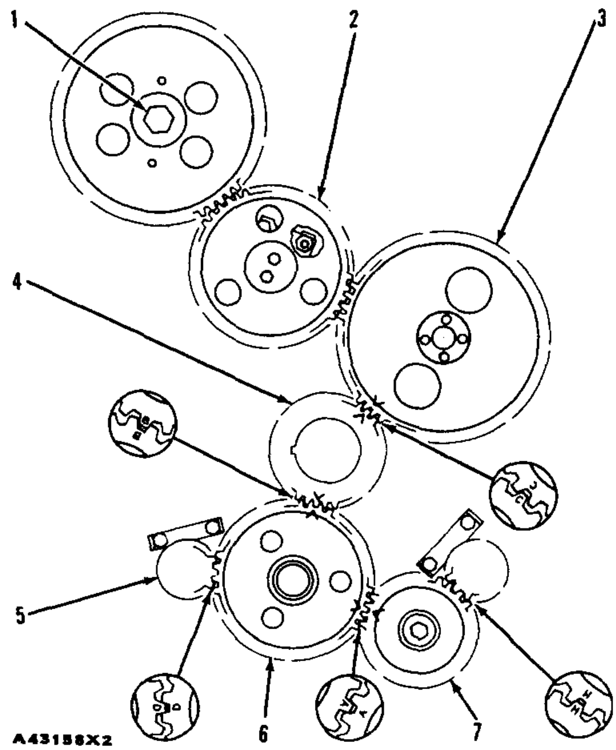
FLYWHEEL TIMING MARKS

NOTE: The location for the timing pointer is under the plug in the flywheel housing. The timing marks are on the side of the flywheel.

TIMING GEARS
(3304)



Tighten bolts which fasten into the front plate to .... 17 ± 3 lb. ft. (23 ± 4 N•m)

Six studs and nuts hold the cover for the magneto drive gear. Put 8H5137 Thread Sealant on the threads of the studs before installing them in the front housing.

Tighten six nuts that hold cover for magneto drive gear to .... 20 ± 5 lb. ft. (25 ± 7 N•m)

(1) Tighten bolt to .... 110 ± 5 lb. ft. (149 ± 7 N•m)

(2) Camshaft gear.

(3) End play for the idler gear (new) .... .004 to .016 in. (0.10 to 0.41 mm)

Maximum permissible end play (worn) .... .034 in. (0.86 mm)

Bore in bearing for the idler gear (new) .... 1.3781 ± .0019 in. (35.004 ± 0.048 mm)

Diameter of shaft for idler gear (new) .... 1.3741 ± .0005 in. (34.902 ± 0.013 mm)

Clearance between shaft and bearing (new) .... .0016 to .0064 in. (0.041 to 0.163 mm)

Maximum permissible clearance between shaft and bearing (worn) .... .009 in. (0.23 mm)

(4) Crankshaft gear.

(5) End play for the balancer shafts (new) .... .0035 to .0075 in. (0.089 to 0.191 mm)

Maximum permissible end play (worn) .... .017 in. (0.43 mm)

Diameter of balancer shaft bearing surface (journal) (new) .... 2.0825 ± .0005 in. (52.895 ± 0.013 mm)

Bore in bearing for balance shaft (new) .... 2.0886 ± .0024 in. (53.050 ± 0.061 mm)

Maximum permissible clearance between balancer shaft and bearing (worn) .... .010 in (0.25 mm)

(6) Idler gear for oil pump.

(7) Drive gear for oil pump.

TIMING GEARS
(3306)

Tighten bolts which fasten into the front plate to .... 17 ± 3 lb. ft. (23 ± 4 N·m)

Six studs and nuts hold the cover for the magneto drive gear. Put 8H5137 Thread Sealant on the threads of the studs before installing them in the front housing.

Tighten six nuts that hold cover for magneto drive gear to .... 20 ± 5 lb. ft. (25 ± 7 N·m)

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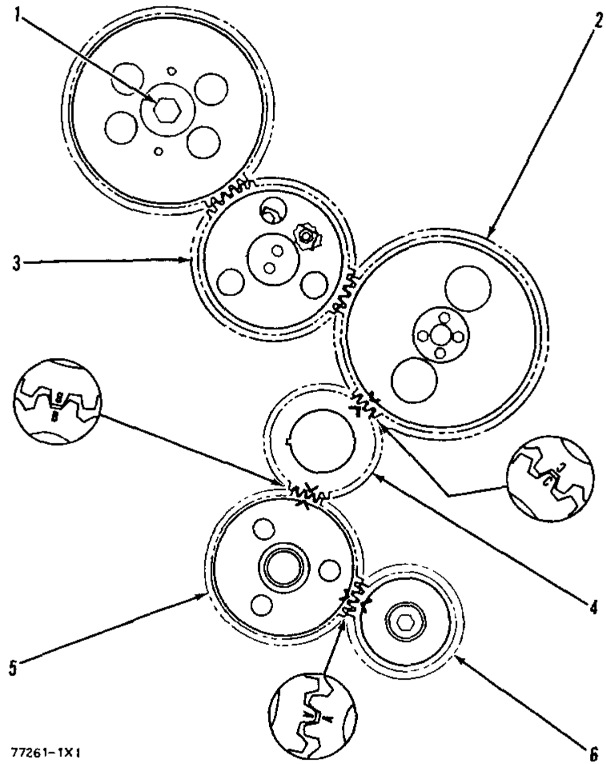
(4) Crankshaft gear.

(5) Idler gear for oil pump.

(6) Drive gear for oil pump.



GOVERNOR

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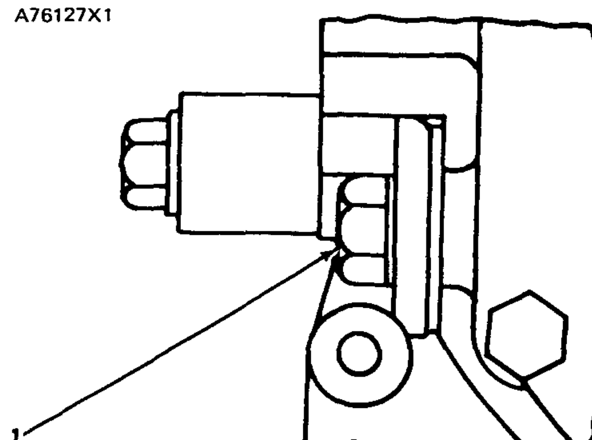

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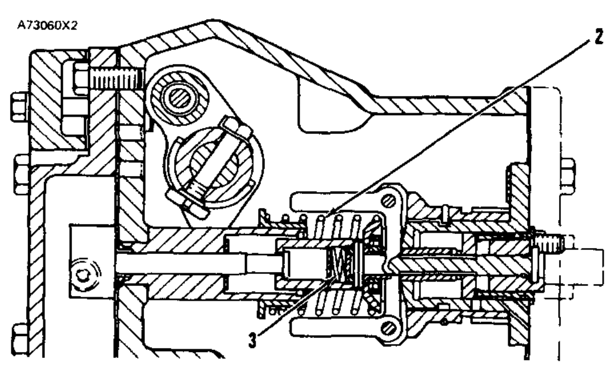


(1) Torque for plug on side of governor .... 27 ± 5 lb. ft. (38 ± 7 N•m)

(2) 9M3160 Spring (governor):

Color code (stripe) .... (1 blue)

Put force on spring of .... 5.0 lb. (22 N)

Then add more force to make spring shorter by .... .90 in. (22.9 mm)

Total test force .... 19.4 ± .5 lb. (86.3 ± 2.2 N)

Free length after test .... 2.34 ± .03 in. (59.4 ± 0.8 mm)

Outside diameter .... 1.39 in. (35.3 mm)

(3) 9M6303 Spring:

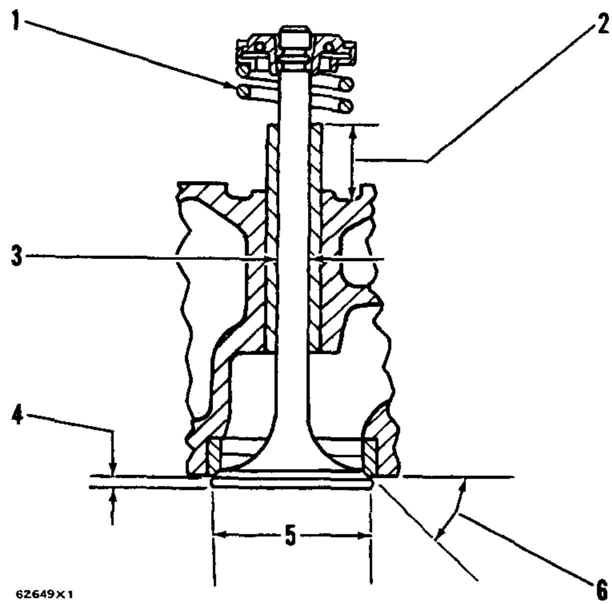
Length under test force .... .180 in. (4.57 mm)

Test force .... 10.0 ± .5 lb. (44.5 ± 2.2 N)

Free length after test .... .344 in. (8.74 mm)

Outside diameter .... .480 in. (12.19 mm)

VALVES



(1) *For valve spring specifications, see the chart VALVE SPRINGS.*

(2) Height to top of valve guide .... .875 ± .010 in. (22.23 ± 0.25 mm)

(3) *Diameter of valve stem (intake and exhaust)* (new) .... .3717 ± .0003 in. (9.441 ± 0.008 mm)

Use again minimum diameter .... .3704 in. (9.408 mm)

Bore in valve guide with guide installed in the head (new) .... .3734 ± .0010 in. (9.484 ± 0.025 mm)

Maximum permissible bore (worn) .... .3772 in. (9.581 mm)

(4) Valve lip thickness:

7N1650 Exhaust Valve

Use again minimum .... .104 in. (2.64 mm)

7S8809 or 9N6117 Intake Valve

Use again minimum .... .106 in. (2.69 mm)

(5) Diameter of valve head:

Exhaust valve .... 1.896 ± .005 in. (48.16 ± 0.13 mm)

Intake valve .... 2.020 ± .005 in. (51.31 ± 0.13 mm)

(6) Angle of valve face .... 29 ¼°

(7) Depth of bore in head for valve seat insert .... .449 ± .002 in. (11.40 ± 0.05 mm)

(8) Diameter of valve seat insert for exhaust valve .... 2.0035 ± .0005 in. (50.889 ± 0.013 mm)

Bore in head for valve seat insert for exhaust valve .... 2.0005 ± .0005 in. (50.813 ± 0.013 mm)

Diameter of valve seat insert for intake valve .... 2.0485 ± .0005 in. (52.032 ± 0.013 mm)

Bore in head for valve seat for intake valve .... 2.0455 ± .0005 in. (51.956 ± 0.013 mm)

(9) Angle of face of valve seat insert .... 30°

(10) *Maximum permissible width of valve seat* (intake and exhaust) .... .076 in. (1.93 mm)

Minimum permissible width of valve seat (intake and exhaust) .... .045 in. (1.14 mm)

(11) Dimension from top of closed valve to face of head:

Maximum permissible dimension for 7N1650 Exhaust Valves .... .140 in. (3.56 mm)

Minimum permissible dimension for 7N1650 Exhaust Valves .... .056 in. (1.42 mm)

Maximum permissible dimension for 7S8809 or 9N6117 Intake Valve .... .140 in. (3.56 mm)

Minimum permissible dimension for 7S8809 or 9N6117 Intake Valve .... .066 in. (1.68 mm)

(12) Outside diameter of the face of the valve seat or valve seat insert:

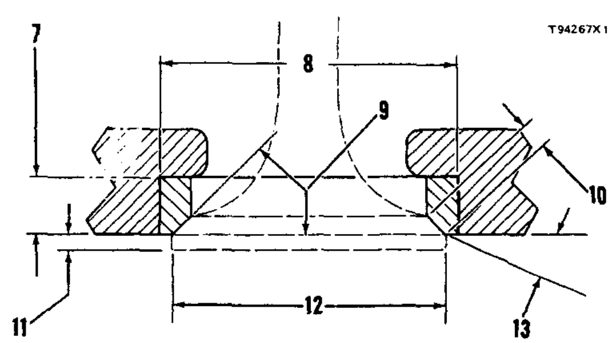
Exhaust seat .... 1.810 in. (45.97 mm)

Maximum permissible, exhaust seat .... 1.860 in. (47.24 mm)

Intake seat .... 1.934 in. (49.12 mm)

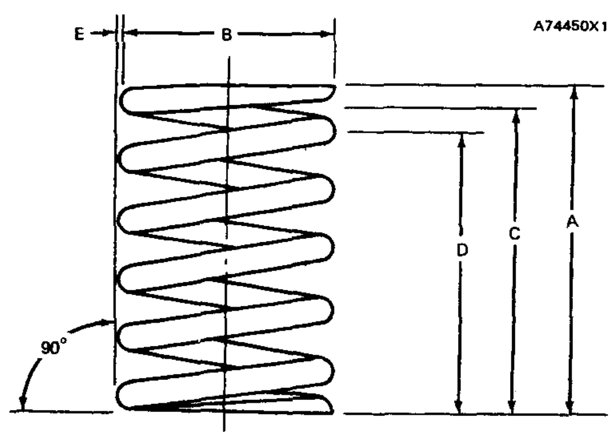
Maximum permissible, intake seat .... 1.984 in. (50.39 mm)

(13) *Angle to grind seat face of the insert to get* a reduction of maximum seat diameter .... 15°

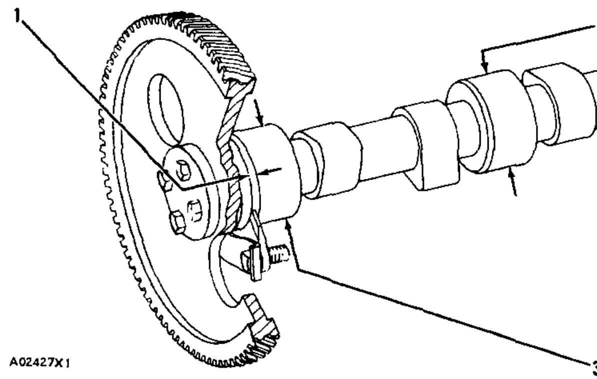


VALVE SPRINGS								
Valve Spring		Approx. Free Length Dim. A	Approx. O.D. Dim. B	Assembled Length Dim. C	Minimum Load at Assembled Length	Length at Valve Open Position Dim.D	Miminum Load at Valve Open Position	Spring Must be Square with ends within: Dim. E
7S7144	New	2.05" (52.1 mm)	1.386" (35.20 mm)	1.766" (44.86 mm)	54.8 lb. (244 N)	1.271" (32.28 mm)	–	0.72" (1.83 mm)
	Use Again	2.05" (52.1 mm)	1.386" (35.20 mm)	1.766" (44.86 mm)	46.5 lb. (207 N)	1.271" (32.28 mm)	144.4 lb. (6425 N)	.072" (1.83 mm)

NOTE: GUIDELINE FOR REUSABLE PARTS; VALVES AND VALVE SPRINGS. Forms SEBF8002 and SEBF8034 have the procedure and specifications necessary for checking used valves and valve springs.



CAMSHAFT



NOTE: Put a layer of 5P960 Grease or graphite grease on lobes of camshaft before the camshaft is installed.

(1) Width of groove in camshaft for thrust washer (new) .... .190 ± .002 in. (4.83 ± 0.05 mm)

Thickness of thrust washer (new) .... .183 ± .001 in. (4.65 ± 0.03 mm)

End play of the camshaft (new) .... .007 ± .003 in. (0.18 ± 0.08 mm)

Maximum permissible end play (worn) .... .025 in. (0.64 mm)

(2) Diameter of camshaft bearing surface (journal) (new) .... 2.3110 ± .0005 in. (58.699 ± 0.013 mm)

(3) *Bore in bearing for camshaft* (new) .... 2.3150 ± .0024 in. (58.801 ± 0.061 mm)

Clearance between bearing and bearing surface (journal) (new) .... .002 to .006 in. (0.05 to 0.15 mm)

Maximum permissible clearance between bearing and bearing surface (journal) (worn) .... .008 in. (0.20 mm)

(5) Height of camshaft lobes.

To find lobe lift, use the procedure that follows:

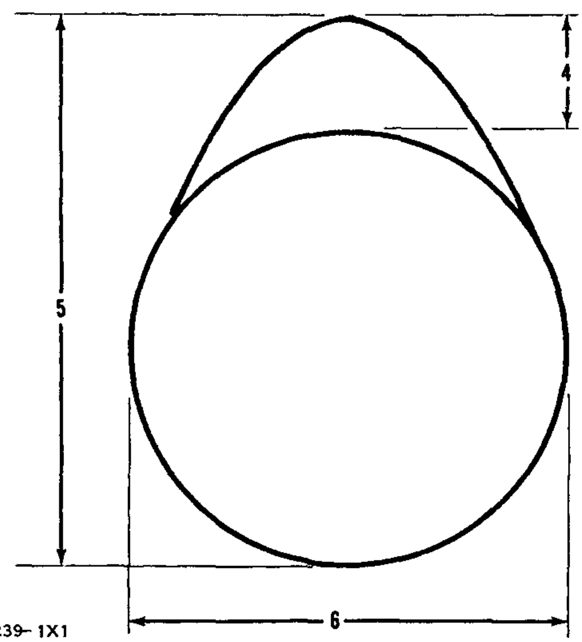
A. Measure camshaft lobe height (5).

B. Measure base circle (6).

C. Subtract base circle (STEP B) from lobe height (STEP A). The difference is actual lobe lift (4).

D. Specified camshaft lobe lift (4) is .3300 in. (8.382 mm).

Maximum permissible difference between actual lobe lift (STEP C) and specified lobe lift (STEP D) is .010 in. (0.25 mm)



VALVE ROCKER ARMS AND LIFTERS

(1) Bore in bearing for shaft (new) .... .7263 ± .0005 in. (18.448 ± 0.013 mm)

Diameter of shaft (new) .... .7245 ± .0005 in. (18.402 ± 0.013 mm)

Maximum permissible clearance between bearing and shaft (worn) .... .008 in. (0.20 mm)

(2) Torque for locknut on valve adjustment screw .... 21 ± 5 lb. ft. (26 ± 7 N·m)

(3) Clearance for valves:

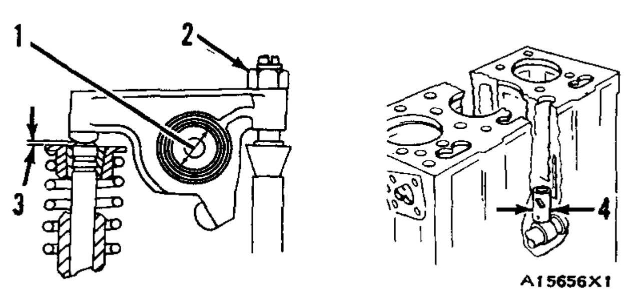
Intake valves .... .015 in. (0.38 mm)

Exhaust valves .... .030 in. (0.76 mm)

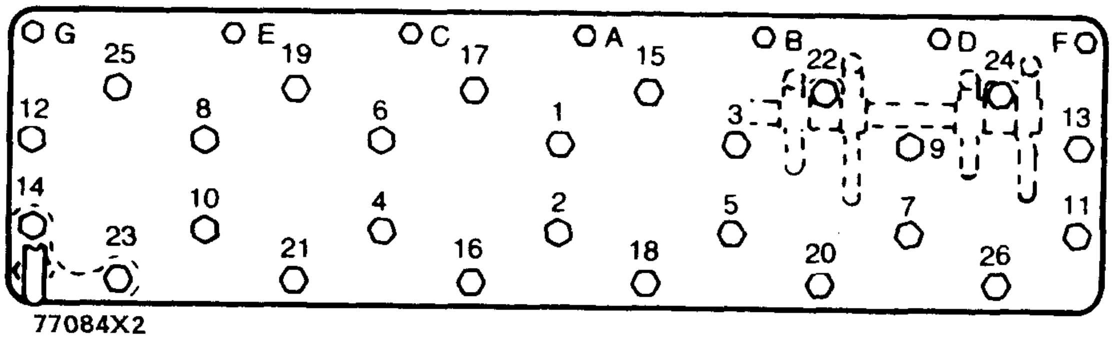
(4) Diameter of valve lifter (new) .... 1.3105 ± .0005 in. (33.287 ± 0.013 mm)

Bore in block for valve lifter (new) .... 1.3145 ± .0010 in. (33.388 ± 0.025 mm)

Maximum permissible clearance between lifter and bore for valve lifter (worn) .... .012 in. (0.30 mm)



CYLINDER HEAD



3306 CYLINDER HEAD

Thickness of cylinder head (new) .... 3.938 ± .030 in. (100.03 ± 0.76 mm)

Put 5P3931 Anti-Seize Compound on threads and tighten bolts in the Step sequence that follows:

Step 1. Tighten all bolts in number sequence to .... 115 lb. ft. (155 N•m)

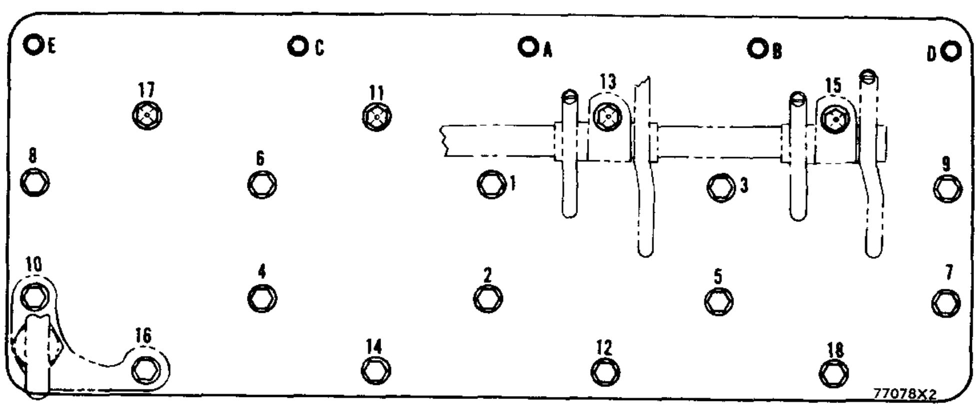
Step 2. Again tighten all bolts in number sequence to .... 185 ± 13 lb. ft. (250 ± 17 N•m)

Step 3. Again tighten all botls in number sequence (hand torque only) to................. 185 ± 13 lb. ft. (250 ± 17 N•m)

Step 4. Tighten all bolts in letter sequence to .... 22 lb. ft. (28 N•m)

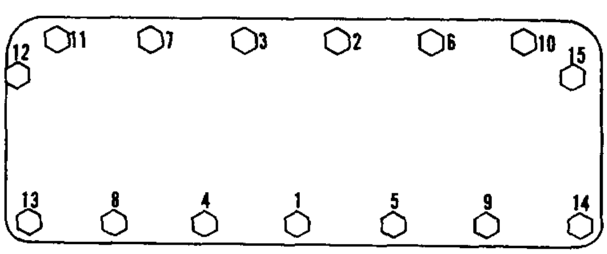
Step 5. Again tighten all bolts in letter sequence to .... 32 ± 5 lb. ft. (43 ± 7 N•m)

Step 6. Again tighten all bolts in letter sequence (hand torque only) to..................... 32 ± 5 lb. ft. (43 ± 7 N•m)



3304 CYLINDER HEAD

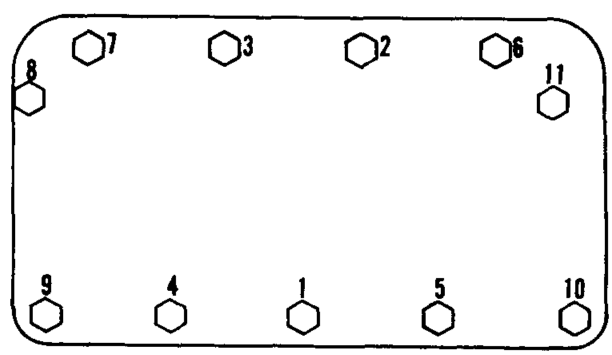
VALVE COVER



3306 VALVE COVER

Put 5H2471 Cement on the face of valve cover and top side of gasket.

Tighten bolts by number in sequence shown to .... 96 ± 24 lb. in. (10.9 ± 2.8 N•m)



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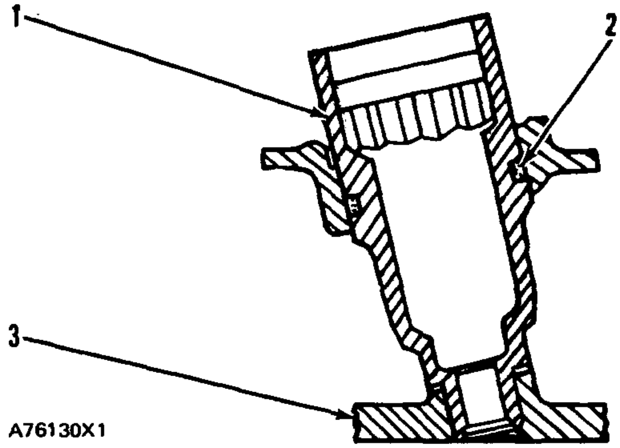
3304 VALVE COVER

SPARK PLUG ADAPTER

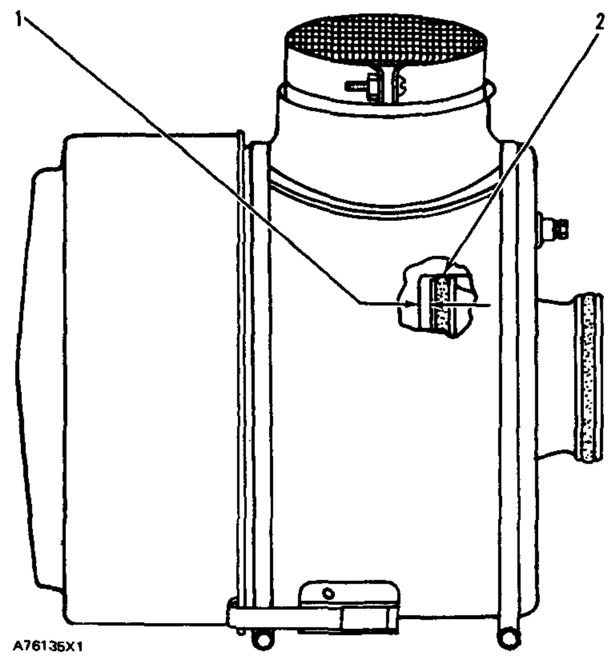


Put liquid soap on seal (2) and 5P3931 Anti-Seize Compound on threads of adapter (1) and on threads in cylinder head (3).

(1) Torque for adapter .... 70 ± 5 lb. ft. (95 ± 7 N•m)

A76130X1

AIR CLEANER

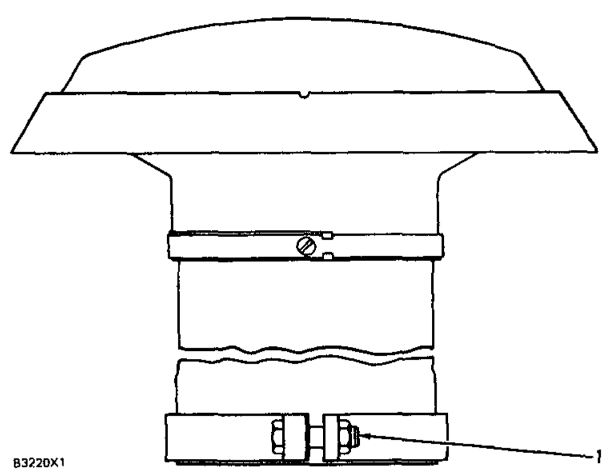


(1) Distance from end of air cleaner to end of coupling (3306 only) .... .250 ± .062 in. (6.35 ± 1.57 mm)

(2) Put engine oil on seals.

A76135X1

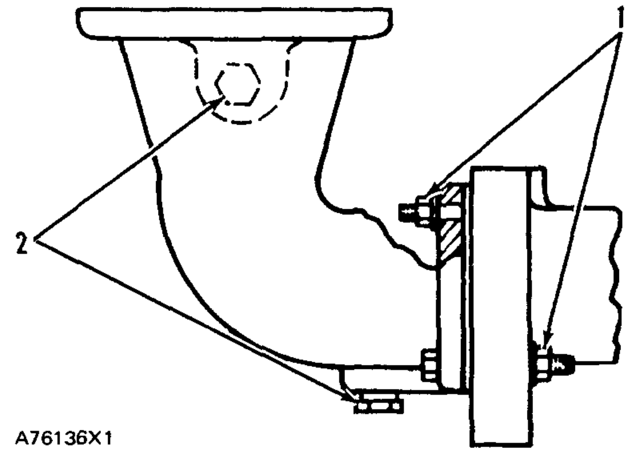
AIR CLEANER CAP



(1) Torque for bolt .... 18 ± 5 lb. ft. (24 ± 7 N•m)

B3220X1

EXHAUST ELBOW

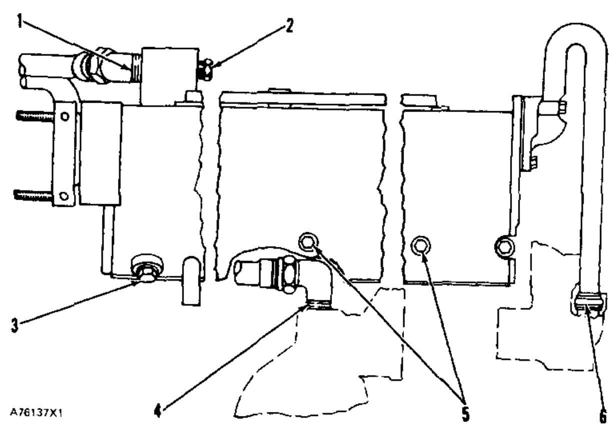


A76136X1

Put 5P3931 Anti-Seize Compound on threads of all nuts, bolts, studs and plugs (2).

(1) Torque for nuts................. 40 ± 4 lb. ft. (55 ± 5 N•m)

WATER COOLED EXHAUST MANIFOLD



A76137X1

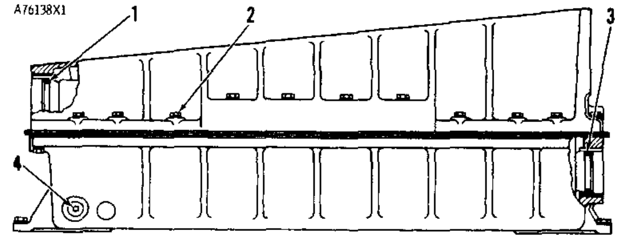
(1), (2), (3), and (4) Put 5P3931 Anti-Seize Compound on threads of plugs and fittings before installation.

(5) Put 5P3931 Anti-Seize Compound on threads of six bolts before installation.

(6) Put a thin layer of engine oil in bore before installation of seal.

AFTERCOOLER

A76138X1



(1), (3) Put a thin layer of engine oil in bores before installation of seals.

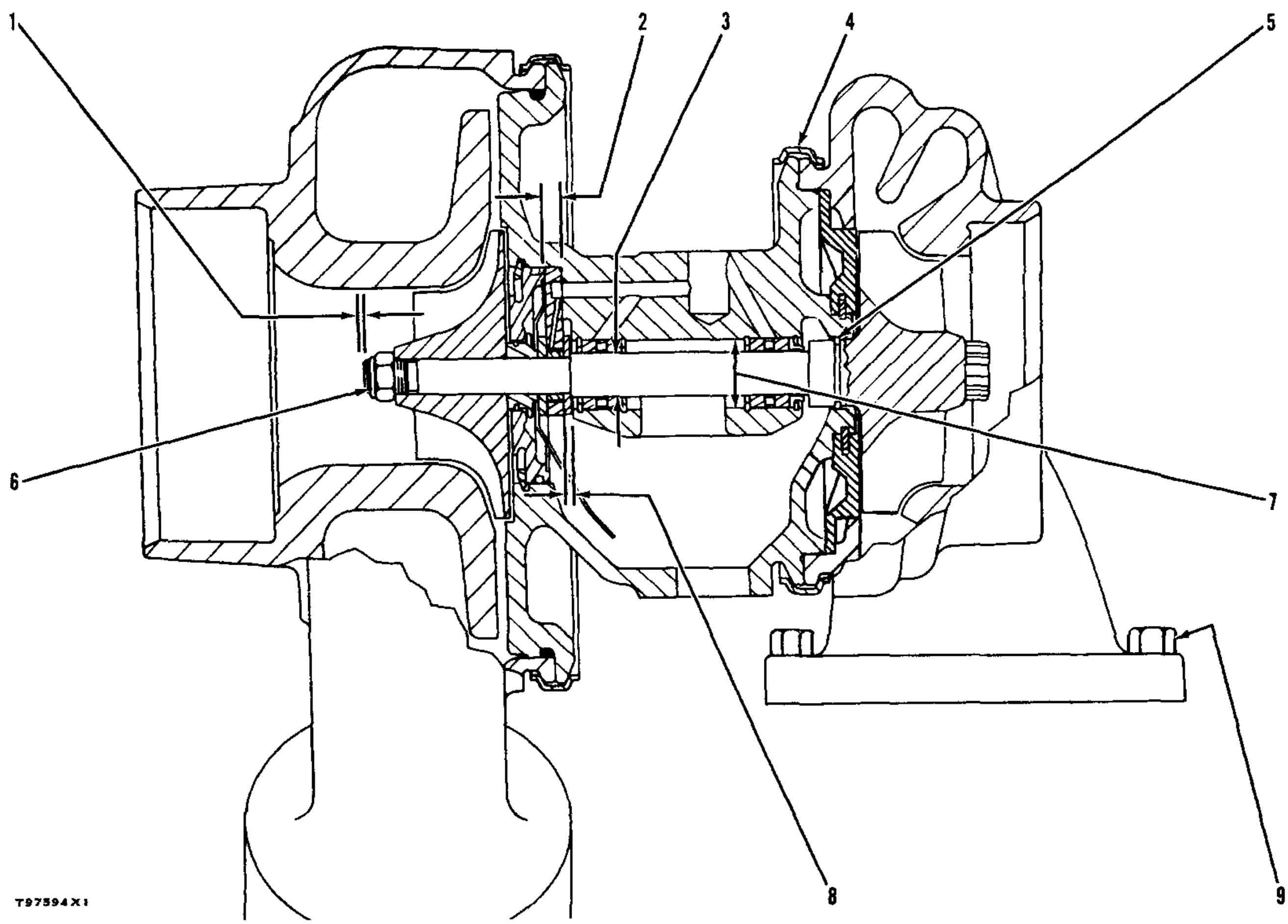
(2) Torque for bolts that hold the cover:

Tighten bolts to .... 18 ± 5 lb. ft. (24 ± 7 N•m)

Run engine and tighten bolts again to......................... 18 ± 5 lb. ft. (24 ± 7 N•m)

(4) Put 5P3931 Anti-Seize Compound on threads of plug.

TURBOCHARGER
(Schwitzer E Models)



Make reference to ANALYZING TURBOCHARGER FAILURE, Form No. FEG45138.

(1) End play for shaft (new) .... .0045 ± .0015 in. (0.114 ± 0.038 mm)

Maximum permissible end play (worn) .... .008 in. (0.20 mm)

(2) Thickness of thrust bearing .... .211 ± .001 in. (5.36 ± 0.03 mm)

(3) Diameter of surface on shaft (journal) *for the bearing (new) .5612 to .5615 in. (14.254 to 14.262 mm)*

Bore in the bearing (new) .... .5627 to .5630 in. (14.293 to 14.300 mm)

Maximum permissible clearance between bearing and shaft (worn) .... .003 in. (0.08 mm)

(4) Put 5P3931 Anti-Seize Compound on threads and tighten the bolt that holds band clamp to .... 120 lb. in. (13.6 N·m)

(5) Maximum permissible gap of oil seal ring, measured in bore of housing .... .009 in. (0.23 mm)

(6) Torque for nut .... 22 ± 2 lb. ft. (28 ± 3 N·m)

NOTE: Do not bend or add stress to the shaft when nut is tightened.

(7) Bore in housing (new) .... .8762 to .8767 in. (22.255 to 22.268 mm)

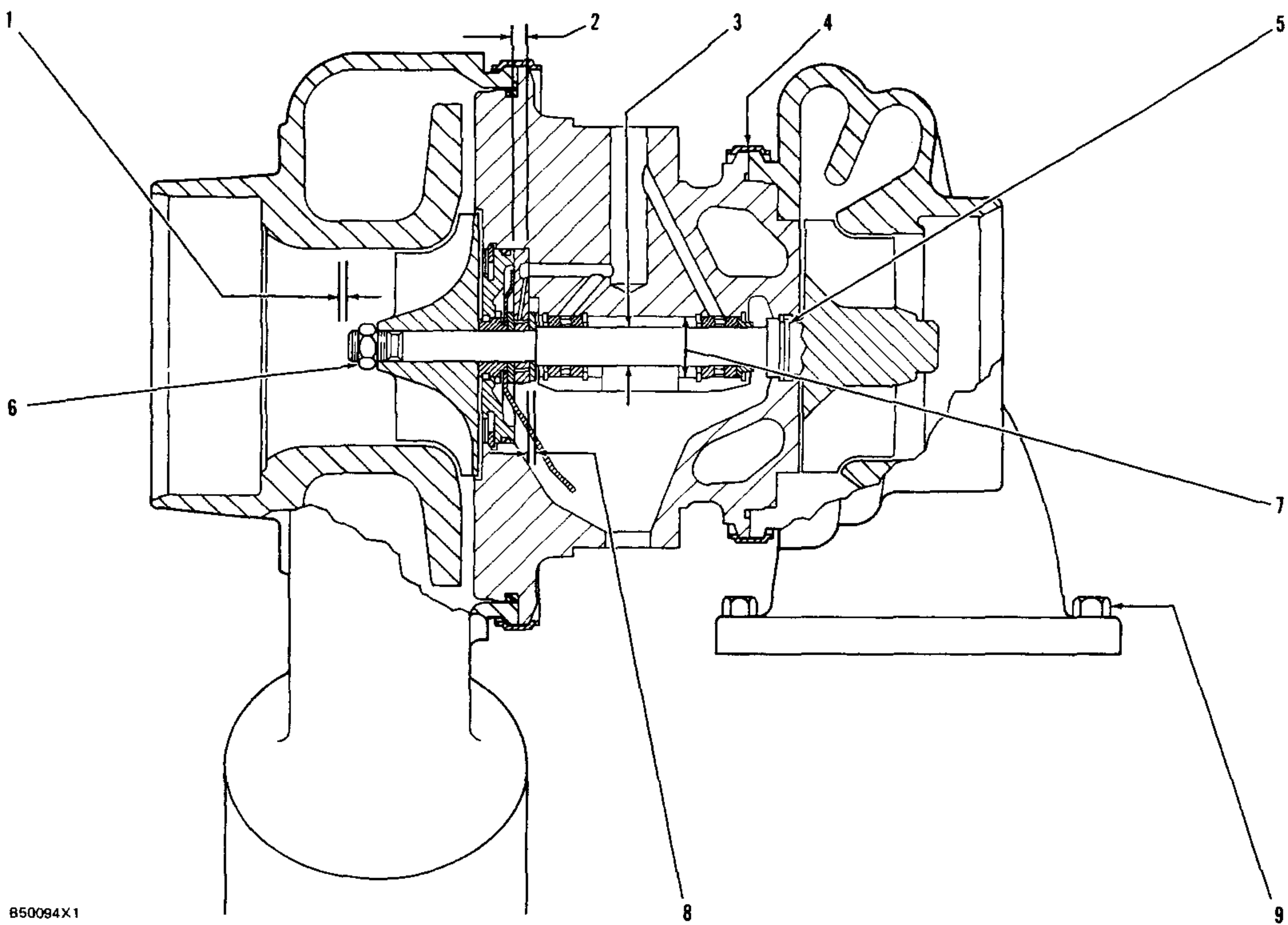
Outside diameter of the bearing (new) .... .8718 to .8722 in. (22.144 to 22.154 mm)

Maximum permissible clearance between bearing and bore in housing (worn) .... .006 in. (0.15 mm)

(8) Thickness of each thrust ring .... .1005 ± .0005 in. (2.553 ± 0.013 mm)

(9) Put 5P3931 Anti-Seize Compound on threads and tighten the bolts that hold turbocharger to manifold to .... 40 ± 4 lb. ft. (55 ± 5 N·m)

TURBOCHARGER
(Schwitzer EC283 Model)



Make reference to ANALYZING TURBOCHARGER FAILURE, Form No. FEG45138.

(1) End play for shaft (new) .... .0045 ± .0015 in. (0.114 ± 0.038 mm)

Maximum permissible end play (worn) .... .008 in. (0.20 mm)

(2) Thickness of thrust bearing .... .211 ± .001 in. (5.36 ± 0.03 mm)

(3) Diameter of surface on shaft (journal) for the bearing (new) .5612 to .5615 in. (14.254 to 14.262 mm)

Bore in the bearing (new) .... .5627 to .5630 in. (14.293 to 14.300 mm)

Maximum permissible clearance between bearing and shaft (worn) .... .003 in. (0.08 mm)

(4) Put 5P3931 Anti-Seize Compound on threads and tighten the bolt that holds band clamp to .... 120 lb. in. (13.6 N•m)

(5) Maximum permissible gap of oil seal ring, measured in bore of housing .... .009 in. (0.23 mm)

(6) Torque for nut .... 22 ± 2 lb. ft. (28 ± 3 N•m)

NOTE: Do not bend or add stress to the shaft when nut is tightened.

(7) Bore in housing (new) .... .8762 to .8767 in. (22.255 to 22.268 mm)

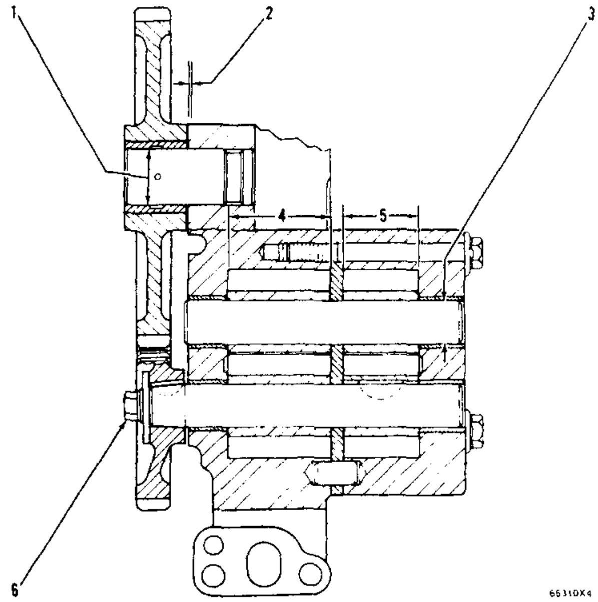
Outside diameter of the bearing (new) .... .8718 to .8722 in. (22.144 to 22.154 mm)

Maximum permissible clearance between bearing and bore in housing (worn) .... .006 in. (0.15 mm)

(8) Thickness of each thrust ring .... .1005 ± .0005 in. (2.553 ± 0.013 mm)

(9) Put 5P3931 Anti-Seize Compound on threads and tighten the bolts that hold turbocharger to manifold to .... 40 ± 4 lb. ft. (55 ± 5 N•m)

OIL PUMP



(1) Bore in bearing of idler gear . . . . 1.1260 ± .0019 in. (28.600 ± 0.048 mm)

Diameter of shaft for the idler gear . . . . 1.1225 ± .0005 in. (28.512 ± 0.013 mm)

Clearance between bearing and shaft . . . . .0011 to .0059 in. (0.028 to 0.150 mm)

(2) Clearance between gear and body of pump . . . . .002 to .026 in. (0.05 to 0.66 mm)

(3) Diameter of shafts for pump . . . . .8747 ± .0002 in. (22.217 ± 0.005 mm)

Bore in bearings for shafts . . . . .8763 ± .0003 in. (22.258 ± 0.008 mm)

Clearance between shafts and bearings . . . . .0011 to .0021 in. (0.028 to 0.053 mm)

(4) Length of gears . . . . 2.0003 ± .0010 in. (50.808 ± 0.025 mm)

Depth of bore in pump body for gears . . . . 2.0053 ± .0008 in. (50.935 ± 0.020 mm)

Clearance between end of gears and pump body . . . . .0032 to .0068 in. (0.081 to 0.173 mm)

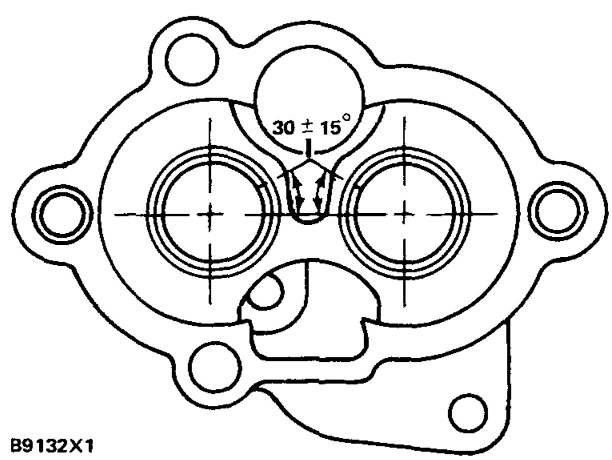
(5) Length of gears . . . . 1.4988 ± .0010 in. (38.070 ± 0.025 mm)

Depth of bore in pump body for gears . . . . 1.5038 ± .0008 in. (38.197 ± 0.020 mm)

Clearance between end of gears and pump body . . . . .0032 to .0068 in. (0.081 to 0.173 mm)

(6) Torque for bolt holding drive gear to drive shaft . . . . 32 ± 5 lb. ft. (43 ± 7 N•m)

NOTE: Install the bearings in the cover and body for the oil pump so the bearing junctions (joints) are in the position shown.



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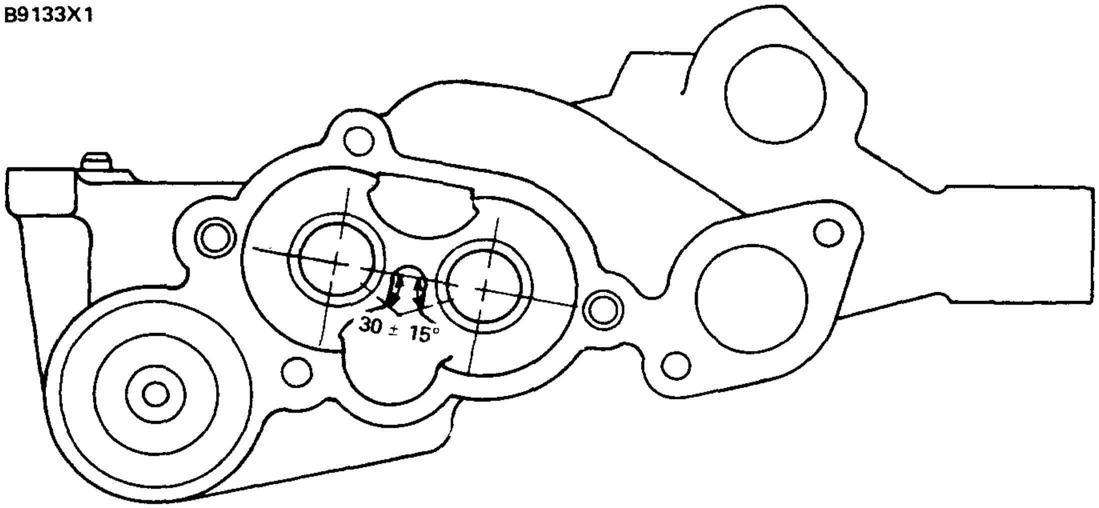
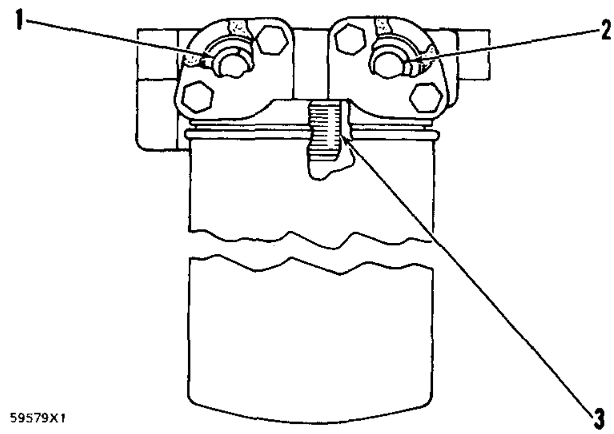
B9133X1



OIL FILTER



Oil cooler bypass valve and oil filter bypass valve must open at a pressure difference of .... 25 ± 3 psi (170 ± 20 kPa)

(1) (2) 8M3182 Spring for bypass valves:

Length under test force.................. 2.5 in. (63.5 mm)

Test force .... 8.92 lb. (40 N)

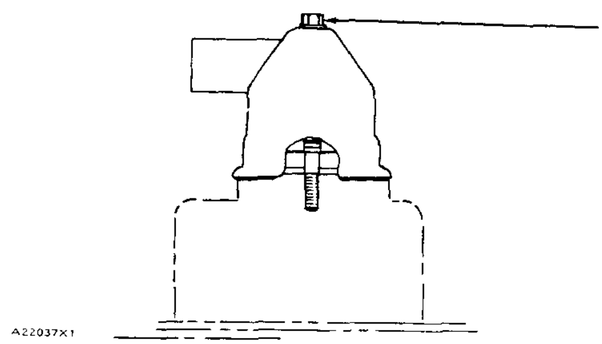
Free length after test .... 3.61 in. (91.7 mm)

Outside diameter.......................... .81 in. (20.6 mm)

(3) Torque for stud:

Put 9S3263 Thread Lock Compound on threads of the stud and tighten the stud to .... 50 ± 5 lb. ft. (70 ± 7 N•m)

OIL BREATHER CAP



(1) Torque for bolt holding breather cap .... 10 ± 2 lb. ft. (14 ± 3 N•m)

ENGINE OIL PRESSURE

All steps of this procedure must be followed for the pressure findings to be usable.

Step 1. Be sure that the engine is filled to the correct level with either SAE 10 or SAE 30 oil. If any other viscosity of oil is used, the information in the ENGINE OIL PRESSURE CHART does not apply.

Step 2. Find a location on the engine oil manifold to install a tee. The easiest method is to remove the sending unit for the present gauge and install a tee at this location. Install a probe from the 9S9102 Thermistor Thermometer Group in one side of the tee. Connect a 8M2744 Gauge from the 5P6225 Hydraulic Test Box to the other side of the tee.

Step 3. Run the engine to get the oil temperature at 210° F (90° C).

NOTE: A 5° F (3° C) increase in oil temperature gives approximately 1 psi (7 kPa) decrease in oil pressure.

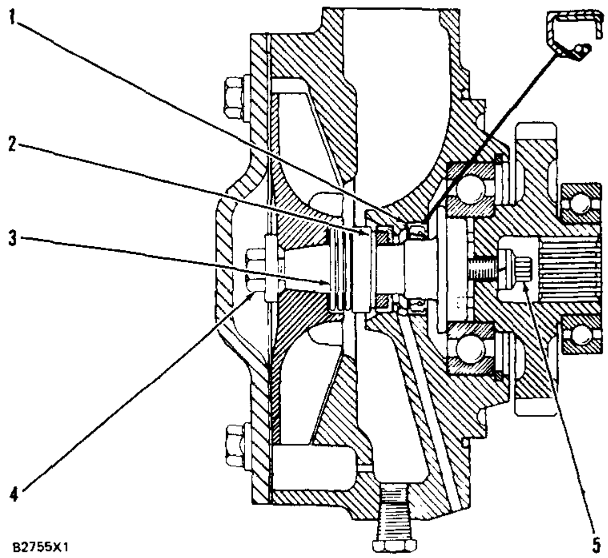
Step 4. Keep the engine oil temperature constant. With the engine at the rpm from the chart, read the pressure gauge.

Make a comparison between the pressure reading on the test gauge and the minimum permissible pressure from the ENGINE OIL PRESSURE CHART. If the pressure reading on the test gauge is below the minimum permissible pressure, find the cause and correct it. Operation of the engine with low oil pressure can be the cause of engine failure or of a reduction in engine life.

ENGINE OIL PRESSURE CHART

ENGINE	TEST rpm	SAE NO. OF TEST OIL	MINIMUM PERMISSIBLE PRESSURE	
			psi	kPa
3304	1500 rpm or above	10	20	140
		30	24	165
3306	600 to 800 rpm	10	6	40
		30	7	50

WATER PUMP



B2755X1

(1) Oil seal. Put engine oil on the seal lip. Assemble with the lip toward the bearings.

(2) Water seal and ring:

a. Put water on the seal.

b. Install the seal and ring together in the housing bore with the shiny face of the ring outside.

(3) Seal assembly:

a. Remove the spring from the seal.

b. Put water inside the seal assembly.

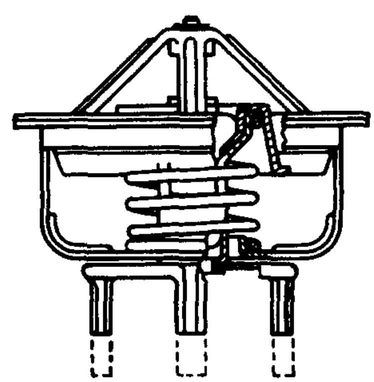
c. Install the seal assembly around the shaft, with the 7N7843 Installation Tool, (the tool is with the seal group) until the carbon face makes contact with the shiny face of the ring (2).

d. Install the spring.

(4) Torque for bolt that holds the impeller . . . . 28 ± 1 lb. ft. (38 ± 1 N•m)

(5) Torque for bolt that holds the gear . . . . 32 ± 5 lb. ft. (45 ± 7 N•m)

WATER TEMPERATURE REGULATOR



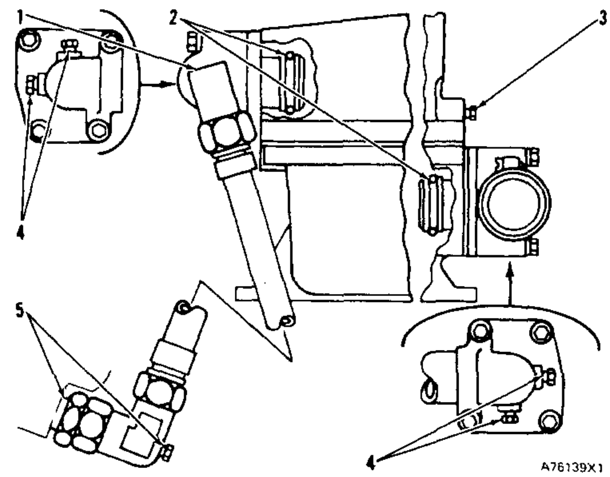
77719X1

6N1848 or 7N208 Regulator:

Temperature when completely open . . . . 195° F (90° C)

Minimum completely open distance . . . . .375 in. (9.53 mm)

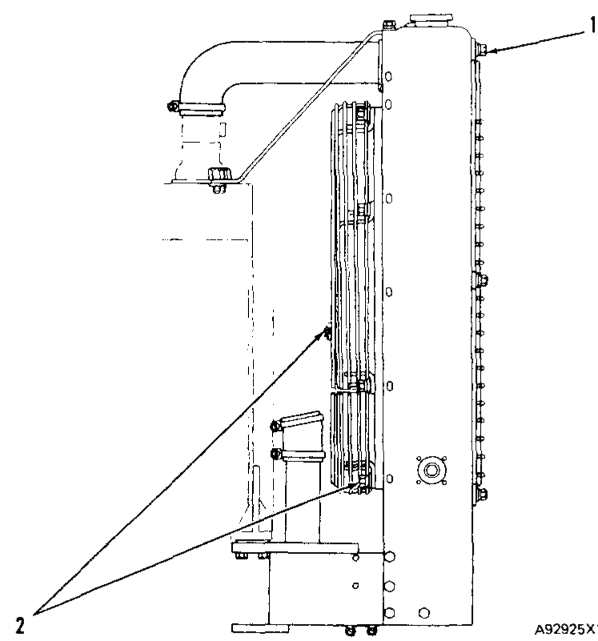
AUXILIARY WATER LINES



(1) (3), (4) and (5) Put 8M8058 Sealant on threads of fittings and plugs.

(2) Put a thin layer of engine oil in the bores before installation of seals.

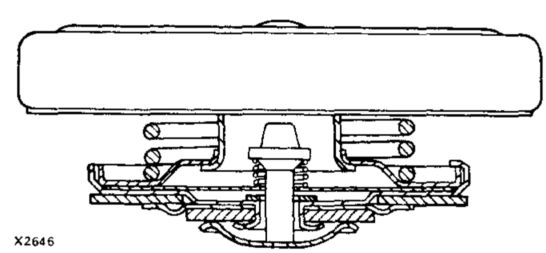
RADIATOR



(1) Torque for bolts that hold flange or guard to front of radiator .... 20 ± 5 lb. ft. (25 ± 7 N·m)

(2) Torque for bolts that hold guard to rear of radiator .... 15 ± 5 lb. ft. (20 ± 7 N·m)

COOLING SYSTEM PRESSURE CAP (6L8617)



Pressure that makes relief valve open .... 6.5 to 8.0 psi (45 to 55 kPa)

CYLINDER BLOCK

(1) Thickness of spacer plate .... .3925 ± .0010 in. (9.970 ± 0.025 mm)

Thickness of spacer plate gasket .... .0082 ± .0010 in. (0.208 ± 0.025 mm)

NOTE: For height of liner over top of block make reference to CYLINDER LINER PROJECTION.

(2) Camshaft bearing bore (installed) .... 2.3150 ± .0020 in. (58.801 ± 0.051 mm)

Bore in block for camshaft bearings............ 2.5630 ± .0010 in. (65.100 ± 0.025 mm)

Depth to install camshaft bearings at both ends of block.......................... .06 ± .02 in. (1.5 ± 0.5 mm)

NOTE: The camshaft bearing at the front of the block must be installed with oil holes in a horizontal position and joint at top within ± 15° from vertical.

(3) Bore in block for main bearings (standard size)................ 3.8160 ± .0005 in. (96.926 ± 0.013 mm)

Bore in block for main bearings .020 in. (0.51 mm oversize) .... 3.8360 ± .0005 in. (97.434 ± 0.013 mm)

(4) Dimension from center of main bearing bore to top of cylinder block (new)........... 15.099 ± .006 in. (383.51 ± 0.15 mm)

(5) Dimension from center of main bearing bore to bottom of cylinder block (new)............ 6.063 ± .004 in. (154.00 ± 0.10 mm)

(6) Torque for bolts that hold bearing caps for main bearings:

a. Put 2P2506 Thread Lubricant on threads and washer face.

b. Tighten all bolts to .... 30 ± 3 lb. ft. (40 ± 4 N•m)

c. Put a mark on each bolt and cap.

d. Tighten all bolts from mark .... 90°

NOTE: Install bearing caps with the part number toward the front of the engine. Be sure that the mark (number) on the bearing cap next to the bolt hole is in agreement with the mark in the cylinder block.

(7) Clearance between slot in block and bearing cap .... .0017 in. (0.04 mm) loose to .0013 in. (0.033 mm) tight

(8) Bore in bearing for balancer shaft (installed) .... 2.0886 ± .0024 in. (53.050 ± 0.061 mm)

Bore in block for bearings............ 2.2776 ± .0010 in. (57.851 ± 0.025 mm)

Depth to install bearings at both ends of block .... .03 ± .02 in. (0.8 ± 0.5 mm)

Depth from front face of block to install center bearings .... 11.44 ± .02 in. (290.6 ± 0.5 mm)

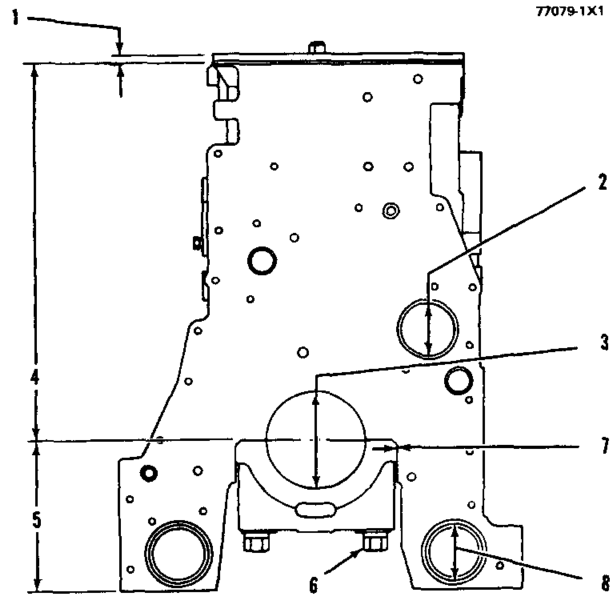
NOTE: Install balancer bearings so that the oil hole in the bearings is in alignment with the oil hole in the block.

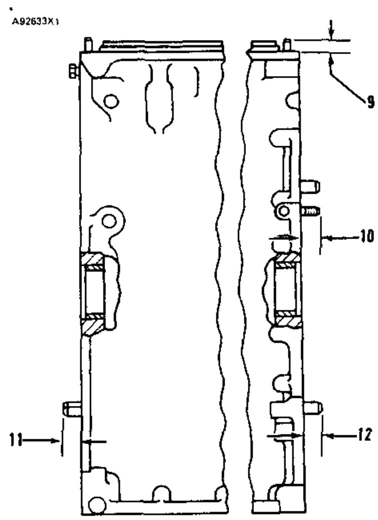
(9) Distance to install dowels from top of block .... .38 ± .02 in. (9.7 ± 0.5 mm)

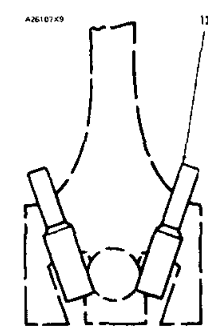
(10) Distance to install stud from face of block.................. .62 ± .02 in. (15.7 ± 0.5 mm)

(11) Distance to install dowels from rear face of block .... .50 in. (12.7 mm)

(12) Distance to install dowels from front face of block .... .88 ± .02 in. (22.4 ± 0.5 mm)







NOTICE

There are holes in the bores for the main bearings, between the cylinders for piston cooler orifices. These holes must have orifices (13) installed.

CYLINDER LINER PROJECTION

Make reference to CYLINDER LINER PROJECTION in Testing and Adjusting for the complete procedure.

1. Install gasket and spacer plate (2) with bolts (3) and two 1S379 Washers. Tighten bolts (3) evenly in four steps:

   1st step .... 10 lb. ft. (14 N•m)

   2nd step .... 25 lb. ft. (35 N•m)

   3rd step .... 50 lb. ft. (70 N•m)

   4th step .... 70 lb. ft. (95 N•m)

2. Install tools as shown. Tighten bolts (4) evenly in four steps:

   1st step .... 5 lb. ft. (7 N•m)

   2nd step .... 15 lb. ft. (20 N•m)

   3rd step .... 25 lb. ft. (35 N•m)

   4th step .... 50 lb. ft. (70 N•m)

3. Measure cylinder liner projection with dial indicator (6) in 1P2402 Gauge Body (8) as shown. Measure at four places around each cylinder liner near the clamped area.

   Cylinder liner projection measurements for any cylinder liner must be .... .0013 to .0069 in. (0.033 to 0.175 mm)

   Maximum permissible difference between all four measurements .... .002 in. (0.05 mm)

   Maximum permissible difference between average projection of any two cylinder liners next to each other .... .002 in. (0.05 mm)

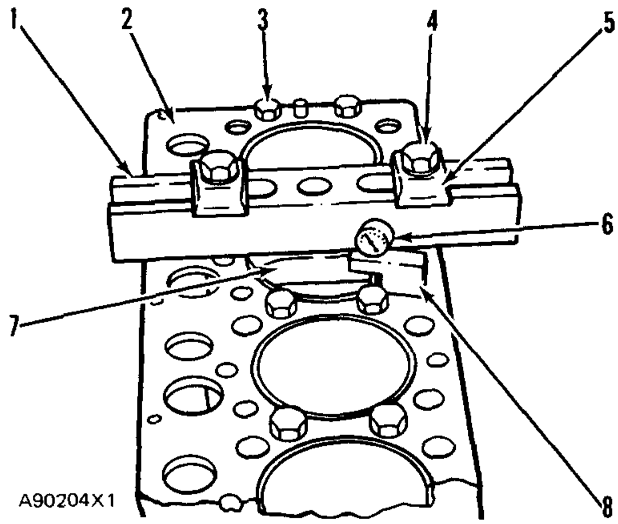
   Maximum permissible difference between average projection of all cylinder liners under one cylinder head:

   3304 .... .003 in. (0.08 mm)

   3306 .... .004 in. (0.10 mm)

NOTE: If liner projection is not correct, turn the liner to a new position within the bore. If projection can not be corrected this way, move the liner to a different bore. If the projection can not be corrected this way, make reference to Special Instruction, Form No. FM055228 for complete instructions on the use of 8S3140 Counterboring Tool Arrangement.

SHIM THICKNESS, COLOR CODE, AND PART NUMBER				
.007 in. (0.18 mm)	**.008 in. (0.20 mm)**	**.009 in. (0.23 mm)**	**.015 in. (0.38 mm)**	**.030 in. (0.76 mm)**
BLACK	**RED**	**GREEN**	**BROWN**	**BLUE**
8S6045	8S6046	8S6047	8S6048	8S6049



A90204X1

4. Minimum permissible depth to machine counterbore to adjust cylinder liner projection .... .030 in. (0.76 mm)

   Maximum permissible depth to machine counterbore to adjust cylinder liner projection .... .045 in. (1.14 mm)

   Install a .030 in. (0.76 mm) shim plus any added shims necessary to get the correct cylinder liner projection.

   NOTE: Be sure that the .030 in. (0.76 mm) shim is directly under the cylinder liner flange.

   Put 7M7260 Liquid Gasket on the top of the top shim and on the bottom of the bottom shim before installing.

(1) Crossbar (from 8B7548 Puller).

(2) Spacer plate.

(3) S1589 Bolt with two 1S379 Washers.

(4) 1D4595 Bolt.

(5) 3H465 Plate.

(6) 1P2403 Dial Indicator.

(7) 1P2394 Adapter Plate.

(8) 1P2402 Gauge Body.

CYLINDER LINER

NOTE: Make reference to GUIDELINE FOR REUSABLE PARTS; PISTONS AND CYLINDER LINERS, Form No. SEBF8001.

(1) Bore in liner
(new) .... 4.751 ± .001 in. (120.68 ± 0.03 mm)

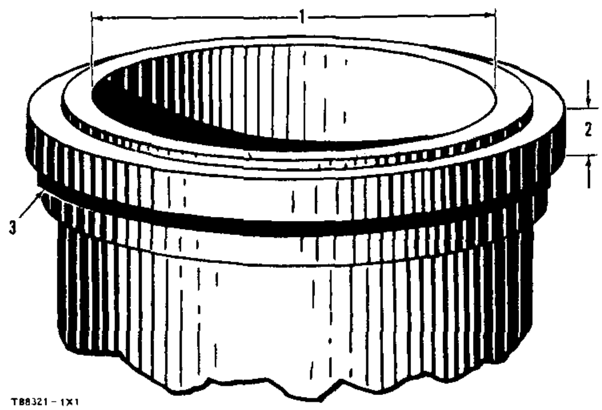
Use again maximum bore when measured near upper end of the wear surface of the cylinder liner .... 4.755 in. (120.78 mm)

(2) Thickness of flange on liner............... .4048 ± .0008 in. (10.282 ± 0.020 mm)

(3) Filler band.

Cylinder Liner Installation

Put liquid soap on bottom liner bore in block, on grooves in lower liner, and on O-rings. Install O-rings on liner. Put filler band (3) in engine oil for a moment and install on liner. Immediately install liner in cylinder block (before expansion of filler band).



T88321-1X1

CONNECTING ROD

(1) Bore in bearing for piston pin
(new) .... 1.5017 ± .0003 in. (38.143 ± 0.008 mm)

Maximum permissible clearance between bearing and piston pin (worn) .... .003 in. (0.08 mm)

(2) Bore in connecting rod for bearing .... 3.2500 ± .0005 in. (82.550 ± 0.013 mm)

NOTE: Connecting rod must be heated for installation of piston pin bearing. Do not use a torch.

Heat connecting rod to temperature of (maximum) .... 400° F (215° C)

NOTE: Piston pin bearing junction must be assembled within either area "A" (90 ± 10° from the centerline through the connecting rod bores) as shown.

(3) Distance between center of piston pin and center of crankshaft bearing
(new) .... 9.595 ± .001 in. (243.71 ± 0.03 mm)

(4) Diameter of piston pin
(new) .... 1.5003 ± .0002 in. (38.108 ± 0.005 mm)

(5) Clearance between connecting rod bearing and crankshaft bearing surface
(journal) .... .0030 to .0066 in. (0.076 to 0.168 mm)

Maximum permissible clearance between bearing and crankshaft (worn) .... .010 in. (0.25 mm)

(6) Torque on nut for connecting rod:

a. Put 2P2506 Thread Lubricant on threads and nut seat.

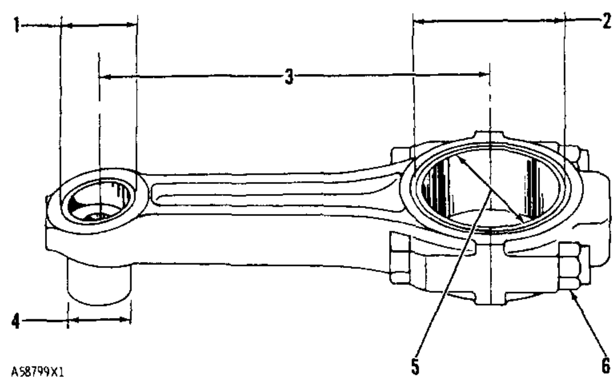
b. Tighten both nuts to .... 30 ± 3 lb. ft. (40 ± 4 N·m)

c. Put a mark on each nut and end of each bolt.

d. Again tighten both nuts (from mark) .... 90°

Install the connecting rod in the piston with the cylinder number on the rod on the same side as the V mark on the piston.

Make reference to Special Instructions, Form No. GMG02394 and SMHS7366 for information about checking and reconditioning connecting rods.



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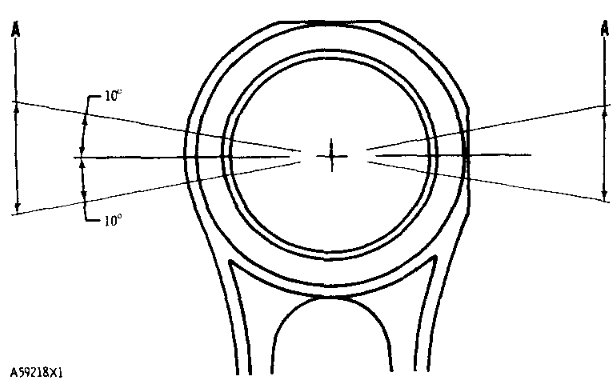

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PISTONS AND RINGS

Make reference to GUIDELINE FOR REUSABLE PARTS; PISTONS AND CYLINDER LINERS, Form No. SEBF8001.

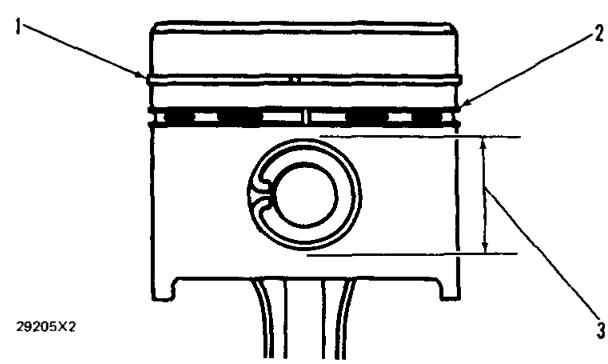
PISTONS AND PISTON RINGS		
	(1) TOP RING	(2) OIL CONTROL RING
	5S7570	**9S2412
Width of groove in piston for piston ring (new).	.1273 ± .0005 in. (3.233 ± 0.013 mm)	.1260 ± .0005 in. (3.200 ± 0.013 mm)
Thickness of piston ring (new).	.1240; +.0000 to −.0008 in. (3.150; +0.000 to −0.020 mm)	.1235 ± .0005 in. (3.137 ± 0.013 mm)
Clearance between groove and piston ring (new).	.0028 to .0046 in. (0.071 to 0.117 mm	.0015 to .0035 in. (0.038 to 0.089 mm)
Maximum permissible clearance (worn).	.006 in. (0.15 mm)	
Clearance between ends of piston ring when installed in a cylinder liner with a bore size of 4.7500 in. (120.650 mm)	.020 ± .003 in. (0.51 ± 0.08 mm)	.018 ± .005 in. (0.46 ± 0.13 mm)
Increase in clearance between ends of piston ring for each .001 in. (0.03 mm) increase in cylinder liner bore size.	.003 in. (0.08 mm)*	

*Install piston ring with "Up" side toward top of piston.

NOTE: 5S7570 Top Ring (1) has the mark "UP-1"

**Install 9S2412 Oil Control Ring (2) with the gap in the spring 180° away from the gap in the ring.

NOTE: Use 5P3519 PISTON RING GROOVE GAUGE to check top ring groove with straight sides. For instructions on the use of the gauge, see the GUIDELINE FOR REUSABLE PARTS; PISTONS AND CYLINDER LINERS, Form No. SEBF8001.

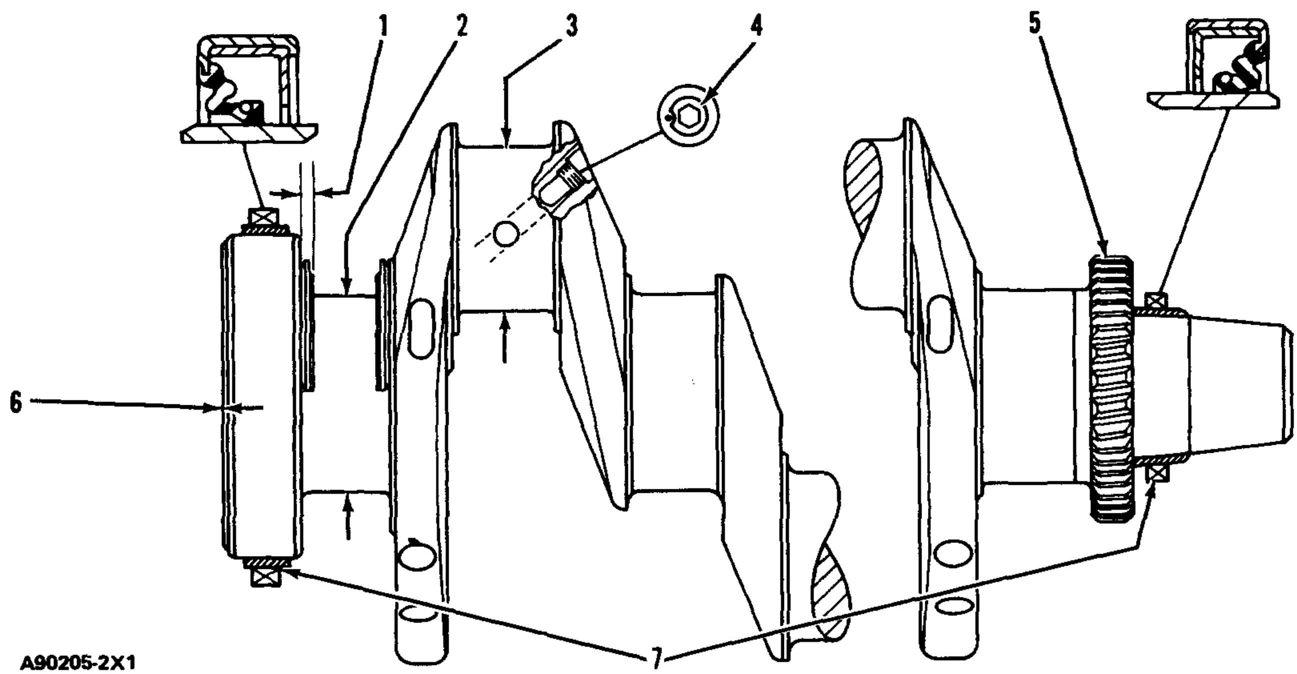


29205X2

(3) Bore in piston for pin ..... 1.5011 ± .0002 in. (38.128 ± 0.005 mm)

NOTE: When installed in the engine, the "V" mark on the top of the piston must be in alignment with the "V" mark on the cylinder block.

CRANKSHAFT



A90205-2X1

(1) Thickness of thrust plates with tabs (new):

7N9342 .... .2150 ± .0015 in. (5.461 ± 0.038 mm)

7N9343 .... .2620 ± .0015 in. (6.655 ± 0.038 mm)

NOTE: Make reference to THRUST PLATE USAGE CHART for the correct thrust plate to use.

(2) Make reference to MAIN BEARINGS and BEARING SURFACE (JOURNAL) FOR MAIN BEARINGS.

(3) Make reference to CONNECTING ROD BEARING and BEARING SURFACE (JOURNAL) FOR CONNECTING RODS.

(4) Tighten plugs to .... 17 ± 3 lb. ft. (23 ± 4 N•m)

Then "stake" the crankshaft to hold plugs in place. "STAKE" use a center punch and a hammer to change the shape of the holes as shown.

(5) Crankshaft gear:

Do not heat gear to more than 600° F (316° C).

(6) End play for crankshaft (new) .... .0025 to .0145 in. (0.064 to 0.368 mm)

Maximum permissible end play for crankshaft (worn)...................... .025 in. (0.64 mm)

(7) Front and rear wear sleeve and seal:

Remove wear sleeves with 5P7318 Distorter Group.

Install front and rear wear sleeves and seals as follows:

a. *Clean the inner surface of the sleeve and the outer surface* of the crankshaft with 8M8060 Quick Cure Primer.

b. Put 9S3265 Retaining Compound on the cleaned surfaces.

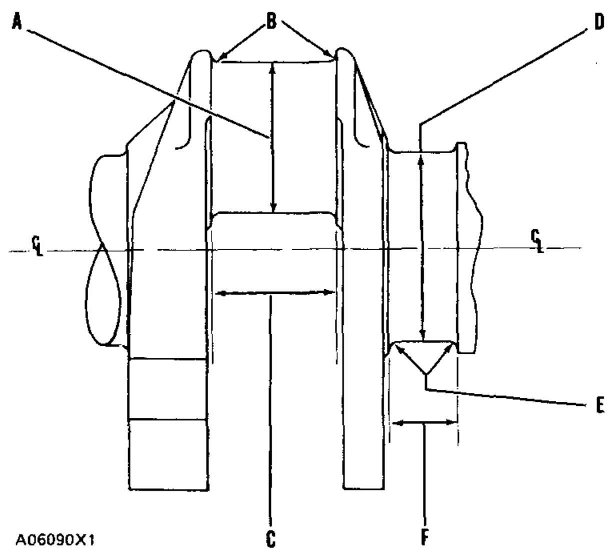
c. *Install the sleeve and seal at the same time on the crank*shaft as shown.

NOTE: See Special Instruction Form SMHS7100 for the necessary tools and complete procedure for installation of front wear sleeve and front seal.

THRUST PLATE USAGE CHART	
CRANKSHAFT JOURNAL WIDTH	THRUST PLATE PART NO.
*1.5935 +.0055 −.0025 in. (40.475 +0.140 −0.064 mm)	7N9342
**1.6875 ± .0025 in. (42.863 ± 0.064 mm)	7N9343

*Current Production Engines
**Engines with Wide Journal Crankshaft

BEARING SURFACE (JOURNAL) FOR MAIN BEARINGS

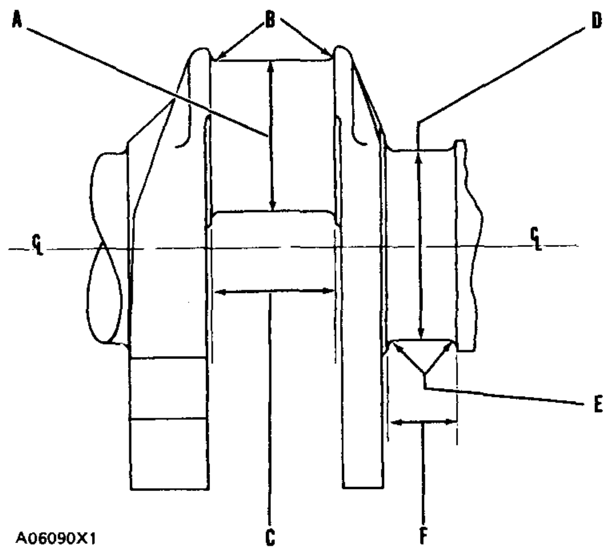


A06090X1

BEARING SURFACE (JOURNAL) FOR MAIN BEARINGS				
	ORIGINAL SIZE JOURNAL	.010 in. (0.25 mm) UNDERSIZE (SMALLER) JOURNAL	.020 in. (0.51 mm) UNDERSIZE (SMALLER) JOURNAL	.030 in. (0.76 mm) UNDERSIZE (SMALLER) JOURNAL
(D) Diameter of Journal	3.4992 ± .0008 in. (88.880 ± 0.020 mm)	3.4892 ± .0008 in. (88.626 ± 0.020 mm)	3.4792 ± .0008 in. (88.372 ± 0.020 mm)	3.4692 ± .0008 in. (88.118 ± 0.020 mm)
Surface finish on diameter of journal	10 micro inches or smoother (0.25 micrometre)			
*(E) Radius	.226 ± .008 in. (5.74 ± 0.20 mm)			
Surface finish in radius	63 micro inches or smoother (1.6 micrometres)			
(F) Maximum width of journals, except front and rear journal	1.712 in. (43.485 mm)			
Width of rear journal	1.5935 +.0055 −.0025 in. (40.475 +0.140 −0.064 mm)			
Surface finish on thrust faces of rear journal	18 micro inches or smoother (0.46 micrometre)			

*Radius must blend smoothly (have no sharp edges) with the machined surfaces of the journals.

BEARING SURFACE (JOURNAL) FOR CONNECTING RODS



BEARING SURFACE (JOURNAL) FOR CONNECTING RODS				
	ORIGINAL SIZE	.010 in. (0.25 mm) UNDERSIZE (SMALLER) JOURNAL	.020 in. (0.51 mm) UNDERSIZE (SMALLER) JOURNAL	.030 in. (0.76 mm) UNDERSIZE (SMALLER) JOURNAL
(A) Diameter of crankshaft journal (bearing surface) for connecting rod.	2.9992 ± .0008 in. (76.180 ± 0.020 mm)	2.9892 ± .0008 in. (75.926 ± 0.020 mm)	2.9792 ± .0008 in. (75.672 ± 0.020 mm)	2.9692 ± .0008 in. (75.418 ± 0.020 mm)
Surface finish on diameter of journal	10 micro inches or smoother (0.25 micrometre)			
*(B) Radius	.226 ± .008 in. (5.74 ± 0.20 mm)			
Surface finish in radius	63 micro inches or smoother (1.6 micrometres)			
(C) Width of journal	1.8775 ± .0055 in. (47.689 ± 0.140 mm)			

*Radius (B) must blend smoothly (have no sharp edges) with the machined surfaces of the journals.

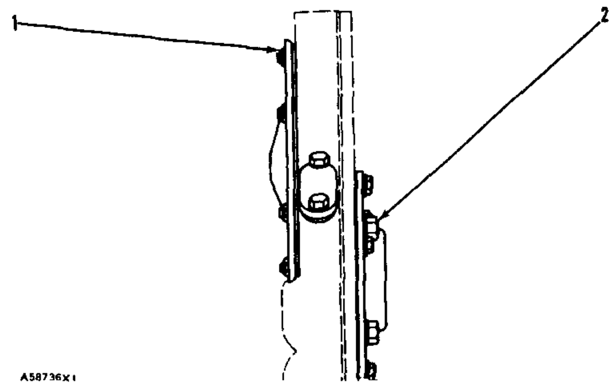
MAIN BEARINGS AND CONNECTING ROD BEARINGS

Make reference to GUIDELINE FOR REUSABLE PARTS; MAIN BEARINGS AND CONNECTING ROD BEARINGS, Form No. SEBF8009.

CONNECTING ROD BEARINGS				
	ORIGINAL SIZE	.010 in. (0.25 mm) UNDERSIZE (SMALLER) JOURNAL	.020 in. (0.51 mm) UNDERSIZE (SMALLER) JOURNAL	.030 in. (0.76 mm) UNDERSIZE (SMALLER) JOURNAL
Diameter of crankshaft journal (bearing surface) for connecting rod.	2.9992 ± .0008 in. (76.180 ± 0.020 mm)	2.9892 ± .0008 in. (75.926 ± 0.020 mm)	2.9792 ± .0008 in. (75.672 ± 0.020 mm)	2.9692 ± .0008 in. (75.418 ± 0.020 mm)
Clearance between bearing and journal (new)	.0030 to .0066 in. (0.076 to 0.168 mm)			
Maximum permissible clearance between bearing and journal.	.010 in. (0.25 mm)			

MAIN BEARINGS				
	ORIGINAL SIZE	.010 in. (0.25 mm) UNDERSIZE (SMALLER) JOURNAL	.020 in. (0.51 mm) UNDERSIZE (SMALLER) JOURNAL	.030 in. (0.76 mm) UNDERSIZE (SMALLER) JOURNAL
Diameter of crankshaft journal (bearing surface) for main bearings	3.4992 ± .0008 in. (88.880 ± 0.020 mm)	3.4892 ± .0008 in. (88.626 ± 0.020 mm)	3.4792 ± .0008 in. (88.372 ± 0.020 mm)	3.4692 ± .0008 in. (88.118 ± 0.020 mm)
Clearance between bearing and journal (new)	.0030 to .0065 in. (0.076 to 0.165 mm)			
Maximum permissible clearance between bearing and journal.	.010 in. (0.25 mm)			

TIMING GEAR COVER

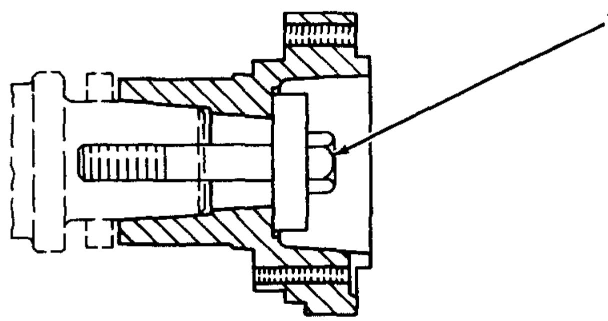


(1) Torque for nuts that hold cover for accessory drive gear .... 20 ± 5 lb. ft. (25 ± 7 N·m)

(2) Torque for two bolts that hold cover to plate .... 150 ± 20 lb. ft. (205 ± 25 N·m)

A58736X1

CRANKSHAFT HUB AND DAMPER



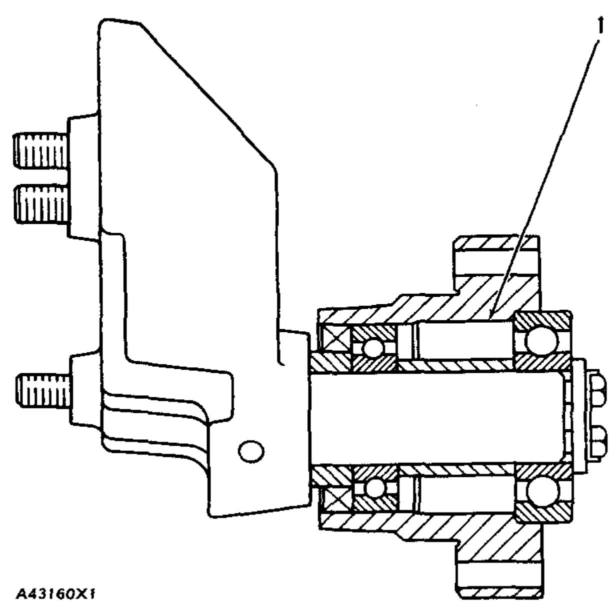
(1) *Tighten bolt that holds hub to crankshaft to* .... 210 to 250 lb. ft. (284 to 340 N·m)

Hit bolt with hammer and again tighten bolt to .... 210 to 250 lb. ft. (284 to 340 N·m)

A23401X1

NOTE: Install washer with the maximum flat area next to the hub.

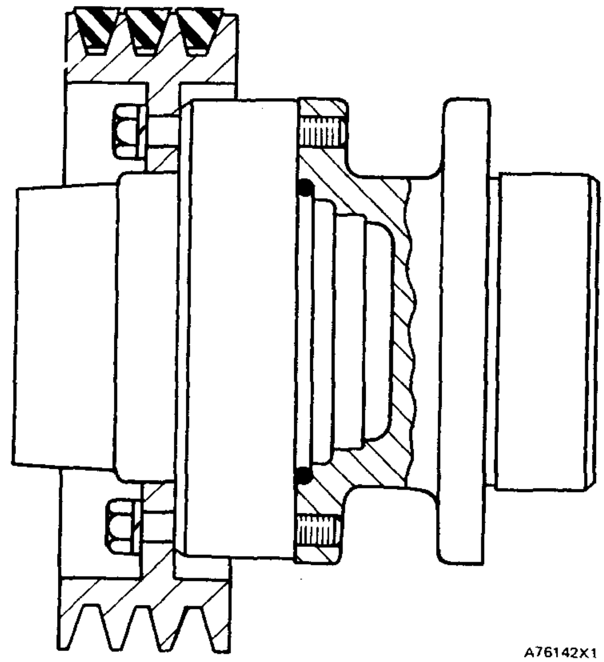
FAN DRIVE



(1) Fill chamber between bearings half full of 1P808 Grease before bolts are tightened.

A43160X1

FAN PULLEY

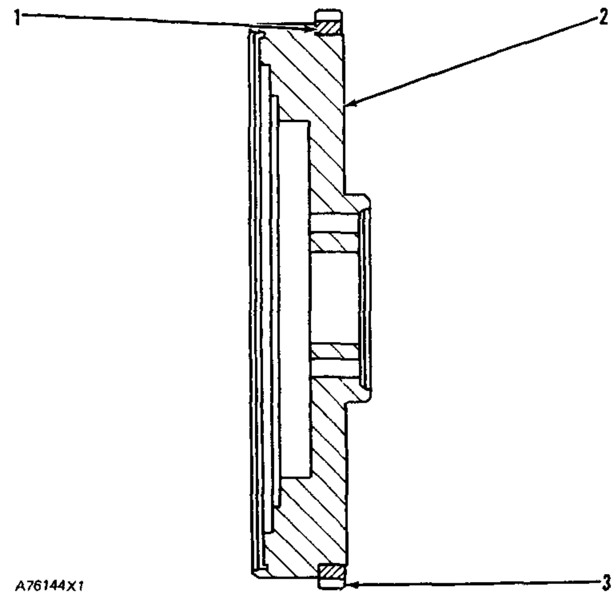

A76142X1

For tension of the V-belts, See the V-BELT TENSION CHART.

V-BELT TENSION CHART										
BELT SIZE	WIDTH BELT TOP		WIDTH TOP OF PULLEY GROOVE		BELT TENSION "INITIAL"* GAUGE READING		BELT TENSION "USED"** GAUGE READING		BORROUGHS GAUGE NUMBERS	
	in.	mm	in.	mm	lb.	N	lb.	N	OLD GAUGE NO.	NEW GAUGE NO.
3/8	.422	10.72	.380	9.65	100 ± 5	445 ± 22	90 ± 5	400 ± 22	BT-33-73F	BT-33-95
1/2	.547	13.89	.500	12.70	120 ± 5	534 ± 22	90 ± 10	400 ± 44	BT-33-96-4-16	BT-33-95
5V	.625	15.88	.600	15.24	120 ± 5	534 ± 22	90 ± 10	400 ± 44	BT-33-72-4-15	BT-33-72C
11/16	.688	17.48	.625	15.88	120 ± 5	534 ± 22	90 ± 10	400 ± 44	BT-33-72-4-15	BT-33-72C
3/4	.750	19.05	.690	17.53	120 ± 5	534 ± 22	90 ± 10	400 ± 44	BT-33-72-4-15	BT-33-72C
15/16	.938	23.83	.878	22.30	120 ± 5	534 ± 22	90 ± 10	400 ± 44	BT-33-72-4-15	BT-33-72C
MEASURE TENSION OF BELT FARTHEST FROM THE ENGINE										

*"INITIAL" BELT TENSION is for a new belt.
**"USED" BELT TENSION is for a belt which has more than 30 minutes of operation at rated speed of engine. A10232X5

FLYWHEEL RING GEAR



(1) Ring gear.

(2) Flywheel.

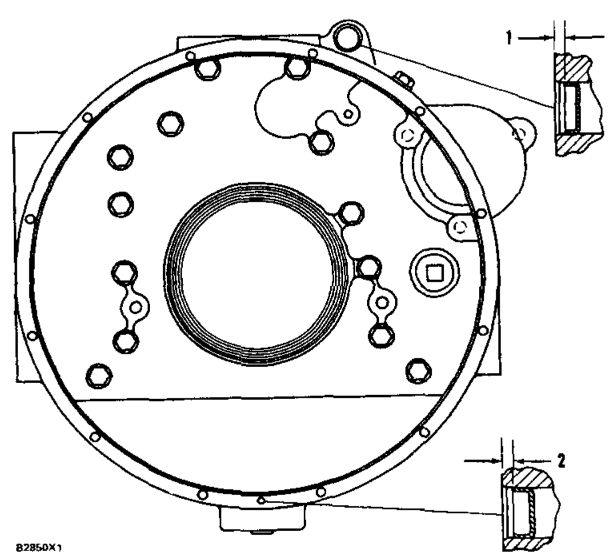
(3) Chamfer side of ring gear (1).

NOTE: Install ring gear (1) on flywheel (2) so that the chamfer side (3) of ring gear (1) is as shown.

NOTICE

Do not heat ring gear to more than 600°F (316°C) before installation on the flywheel.

FLYWHEEL HOUSING



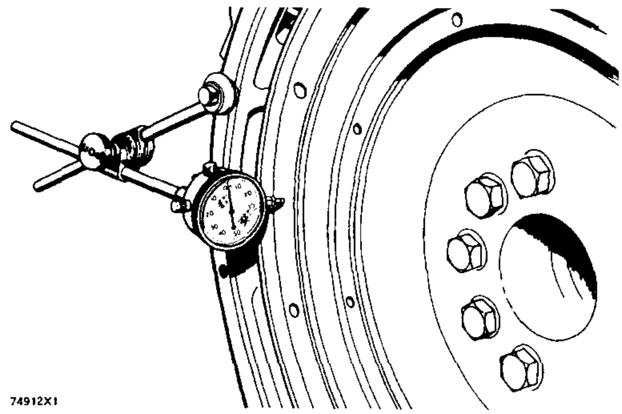
(1) Distance to install plug .... .197 in. (5.00 mm)

(2) Distance to install plug .... .045 ± .010 in. (1.14 ± 0.25 mm)

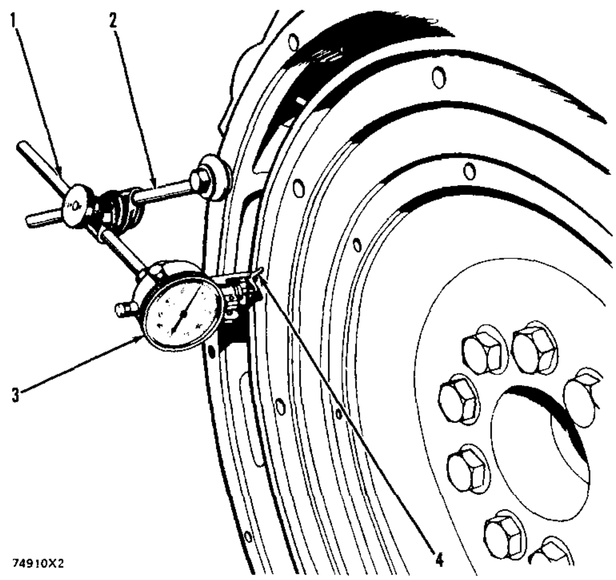
FLYWHEEL RUNOUT

Face Runout (axial eccentricity) of the Flywheel:

1. Install the dial indicator as shown. Put a force on the flywheel toward the rear.
2. Set the dial indicator to read .000 in. (0.00 mm)
3. Turn the flywheel and read the indicator every 90°. Put a force on the flywheel to the rear before the indicator is read at each point.
4. The difference between the lower and higher measurements taken at all four points must not be more than .006 in. (0.15 mm), which is the maximum permissible face runout (axial eccentrictiy) of the flywheel.



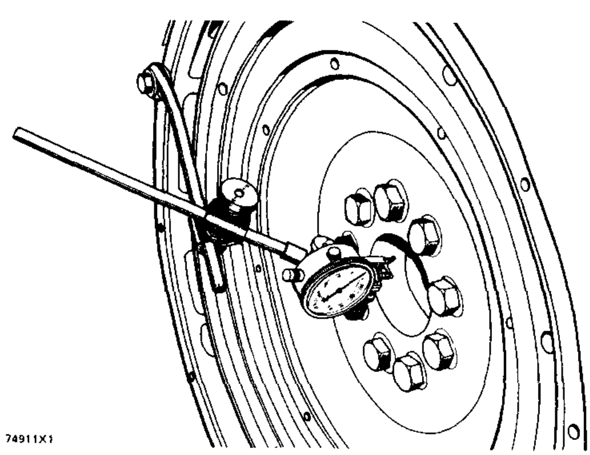
CHECKING FACE RUNOUT OF THE FLYWHEEL



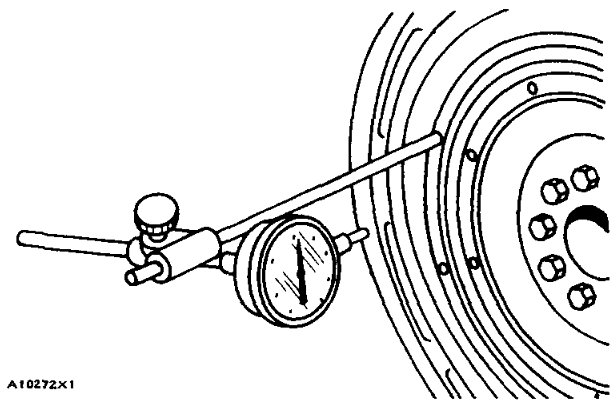
CHECKING FLYWHEEL BORE

Bore Runout (radial eccentricity) of the Flywheel:

1. Install the dial indicator (3) and make an adjustment of the universal attachment (4) so it makes contact as shown.
2. Set the dial indicator to read .000 in. (0.00 mm).
3. Turn the flywheel and read the indicator every 90°.
4. The difference between the lower and higher measurements taken at all four points must not be more than .006 in. (0.15 mm), which is the maximum permissible bore runout (radial eccentricity) of the flywheel.
5. Runout (eccentricity) of the bore for the pilot bearing for the flywheel clutch, must not exceed .005 in. (0.13 mm).

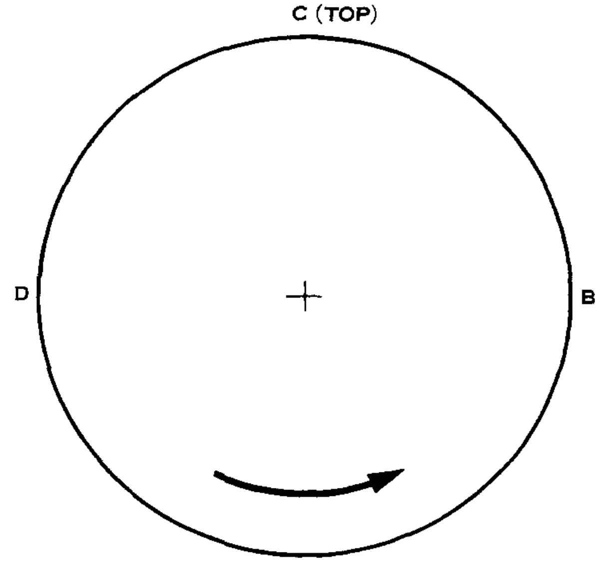


CHECKING FLYWHEEL CLUTCH PILOT BEARING BORE



8S2328 DIAL INDICATOR GROUP INSTALLED

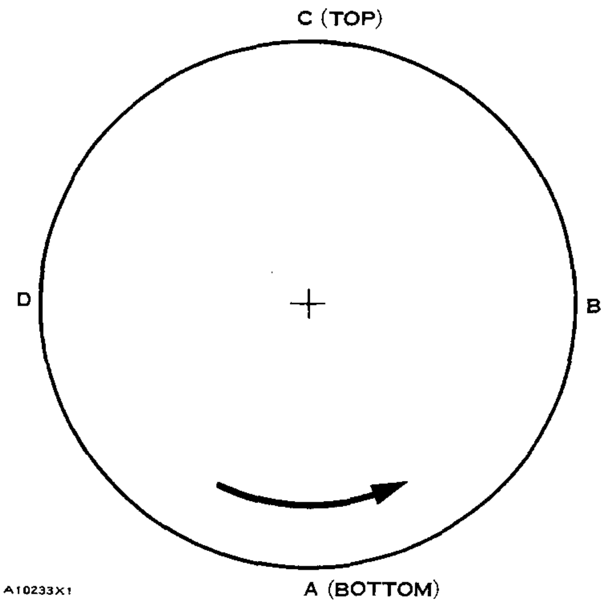
FLYWHEEL HOUSING RUNOUT



Face Runout (axial eccentricity) of the Flywheel Housing:

1. Fasten a dial indicator to the crankshaft flange so the anvil of the indicator will touch the face of the flywheel housing.
2. Put a force on the crankshaft toward the rear before the indicator is read at each point.
3. With dial indicator set at .000 in. (0.00 mm) at location (A), turn the crankshaft and read the indicator at locations (B), (C) and (D).
4. The difference between lower and higher measurements taken all four points must not be more than .012 in. (0.30 mm), which is the maximum permissible face runout (axial eccentricity) of the flywheel housing.

FLYWHEEL HOUSING BORE



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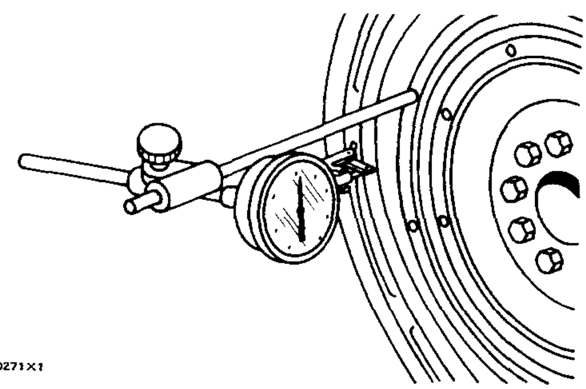


A10271X1

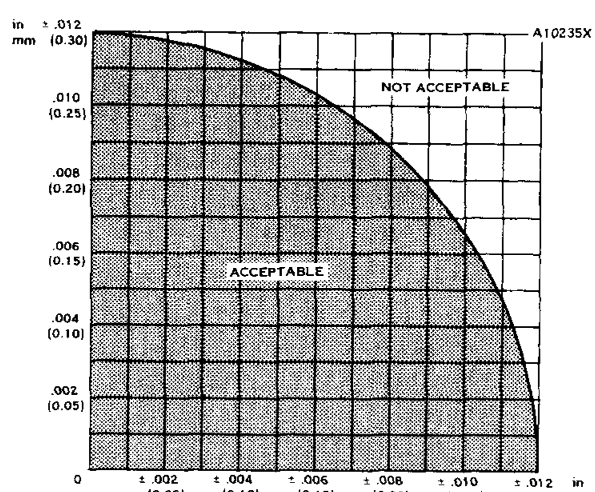
NOTE: Write the dial indicator measurements with their positive (+) and negative (−) notation (signs). This notation is necessary for making the calculations in the chart correctly.

1. With the dial indicator in position at (C), adjust the dial indicator to "0" (zero). Push the crankshaft up against the top bearing. Write the measurement for bearing clearance on line 1 in column (C).
2. Divide the measurement from Step 1 by 2. Write this number on line 1 in columns (B) & (D).
3. Turn the crankshaft to put the dial indicator at (A). Adjust the dial indicator to "0" (zero).
4. Turn the crankshaft counterclockwise to put the dial indicator at (B). Write the measurement in the chart.
5. Turn the crankshaft counterclockwise to put the dial indicator at (C). Write the measurement in the chart.
6. Turn the crankshaft counterclockwise to put the dial indicator at (D). Write the measurement in the chart.
7. Add lines I & II by columns.
8. Subtract the smaller number from the larger number in line III in columns (B) & (D). The result is the horizontal "eccentricity" (out of round). Line III, column (C) is the vertical eccentricity.

CHART FOR DIAL INDICATOR MEASUREMENTS					
	Position of dial indicator				
	Line No.	A	B	C	D
Correction for bearing clearance	I	0			
Dial Indicator Reading	II	0			
Total of Line 1 & 2	III	0	**	*	**

*Total Vertical eccentricity (out of round).
**Subtract the smaller No. from the larger No. The difference is the total horizontal eccentricity.

A10234X1



A10235X1

9. On the graph for total eccentricity find the point of intersection of the lines for vertical eccentricity and horizontal eccentricity.
10. If the point of intersection is in the range marked "Acceptable" the bore is in alignment. If the point of intersection is in the range marked "Not Acceptable" the flywheel housing must be changed.

ALTERNATORS

2N7759 12V (Motorola Number 8MH-2003K)

Rotation is either direction.

Output at 5000 rpm and 14V, cold (connect a carbon pile to the battery to get maximum output) .... 50 A

Rated output (hot) .... 50 A

Field Current at 12V and 75° F (24° C) .... Maximum 3 A

(1) Torque for nut .... 45 ± 5 lb. ft. (60 ± 7 N•m)

(2) Tension of brush spring .... 5.5 to 7 oz. (1.5 to 1.9 N)

Torque for electrical connections on alternator .... 20 ± 2 lb. in. (2.3 ± 0.2 N•m)

2N6398 24V (Motorola Number MH24-902A or 8MH3005F)

Rotation is clockwise when seen from drive end.

Output at 1800 rpm and 28 V (cold) .... *21.5 A

Output at 2500 rpm and 28 V (cold) .... *31 A

*6.5 to 9.3% higher with no regulator.

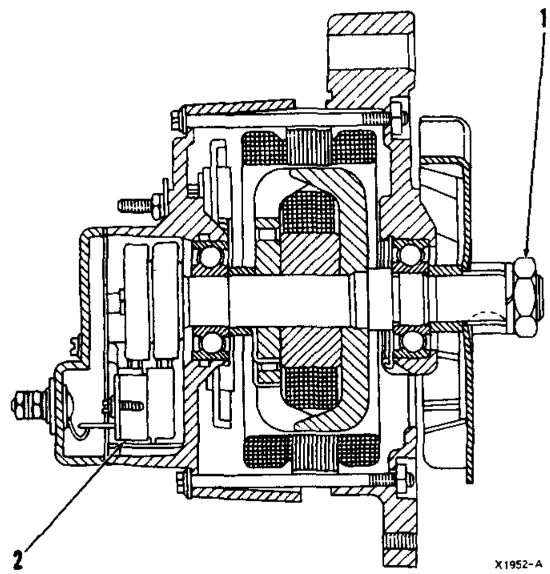
Rated output (hot) in air temperature of 77° F (25° C) .... 35 A

Field current at 24 V and 80° F (27° C) .... 1.7 A

(1) Torque for nut .... 45 ± 5 lb. ft. (60 ± 7 N•m)

(2) Tension of brush spring .... 6 to 8 oz. (1.67 to 2.22 N)

Torque for electrical connections on alternator .... 20 ± 2 lb. in. (2.3 ± 0.2 N•m)



X1952-A

ALTERNATOR REGULATORS

6N3161 12V (Motorola Number 8RD3018)

Polarity is negative ground or insulated.

SWITCH POSITION	1	2	3	4	5
VOLTAGE SETTING	14.4 + .3 − .2	14.1 ± .2	13.8 ± .2	13.5 ± .2	13.2 ± .2

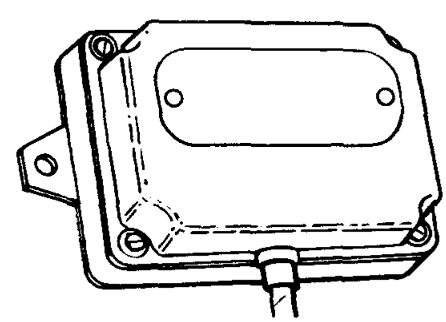
Original setting is .... 13.8 ± .2 Volt

Clockwise rotation of adjusting screw gives increase in voltage.

6N3160 24V (Motorola Number 8RD3019)

Polarity is negative ground or insulated.

SWITCH POSITION	1	2	3	4	5
VOLTAGE SETTING	29.2 + .4 − .3	28.6 ± .3	28.0 ± .3	27.4 ± .3	26.8 ± .3

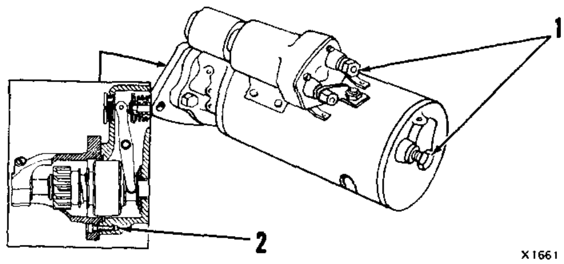


48739X1

Original setting is .... 28.0 ± .3 Volt

Clockwise rotation of adjusting screw gives increase in voltage.

STARTER MOTORS

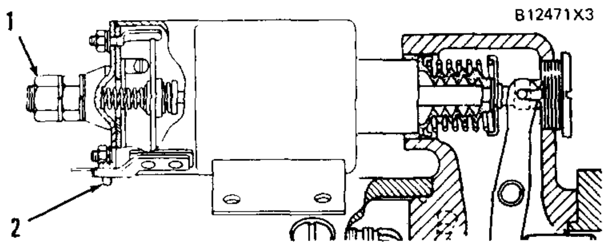


X1661

12 Volt Starting Motor (Delco-Remy — Enclosed Lever — Heavy Duty)									
			No Load				(1)	(2) Torque for screws holding nose housing to lever housing lb. ft. (N·m)	Clearance between pinion & housing (pinion clearance) in. (mm)
		Rotation as seen from drive end	Speed RPM		Current Consumption (Draw) with solenoid at 9V		Torque of terminal nuts lb. ft. (N·m)		
Caterpillar Number	Delco-Remy Number		Min	Max	Min	Max			
3T2655	1114885	CW	4000	7000	140 A	215 A	20 to 25 (27.0 to 33.8)	13 to 17 (17.6 to 23.0)	.33 to .39 (8.3 to 9.9)

24 Volt Starting Motor (Delco-Remy — Enclosed Lever — Heavy Duty)									
			No Load				(1)	(2) Torque for screws holding nose housing to lever housing lb. ft. (N·m)	Clearance between pinion & housing (pinion clearance) in. (mm)
		Rotation as seen from drive end	Speed (rpm)		Current Consumption (Draw) with solenoid at 20V		Torque of terminal nuts lb. ft. (N·m)		
Caterpillar Number	Delco-Remy Number		Min	Max	Min	Max			
3T2652	1114905	CW	5500	9000	70 A	110 A	20 to 25 (27.0 to 33.8)	13 to 17 (17.6 to 23.0)	.33 to .39 (8.3 to 9.9)

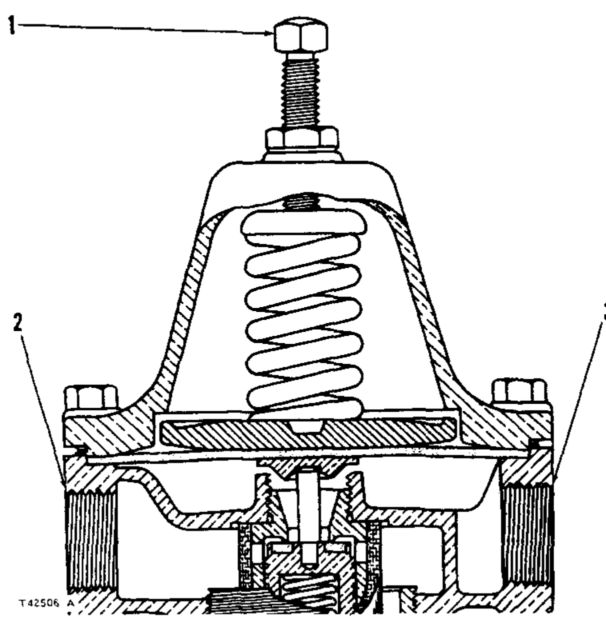
STARTER SOLENOID



Starter Solenoids (Delco-Remy)						
Caterpillar Number	Delco-Remy Number	Voltage Rating	Current Consumption (Draw)		(1) Torque Terminal Nuts lb. ft. (N·m)	(2) Torque Terminal Screws lb. in. (N·m)
			Pull-in Windings	Hold-in Windings		
3T5045	1115556	12V	28 to 35.7 A at 5V	13 to 15.4 A at 10V	20 to 25 (27.1 to 33.7)	16 to 30 (1.8 to 3.4)
3T4704	1115557	24V	9 to 11.5 A at 5V	6.8 max. at 20V		

PRESSURE REGULATING VALVE FOR AIR STARTING MOTOR

(1L5011)



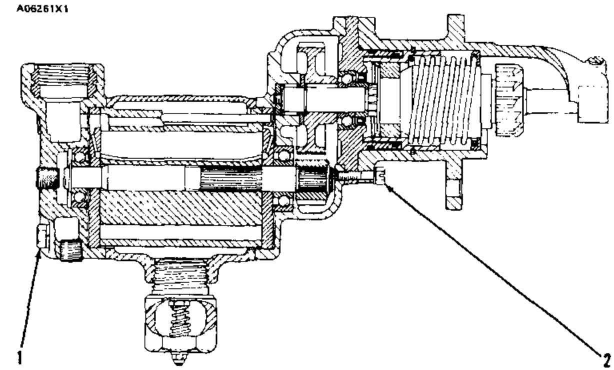
(1) Adjustment screw.

(2) Maximum permissible inlet pressure .... 250 psi (1720 kPa)

(3) Maximum permissible outlet pressure .... 150 psi (1030 kPa)

Minimum outlet pressure .... 90 to 110 psi (620 to 760 kPa)

AIR STARTING MOTOR



4N4370 (Ingersoll-Rand Number 150 BMP-C78RH-53)

Output torque .... 50 lb. ft. (70 N·m)

with pinion speed of .... 2240 rpm

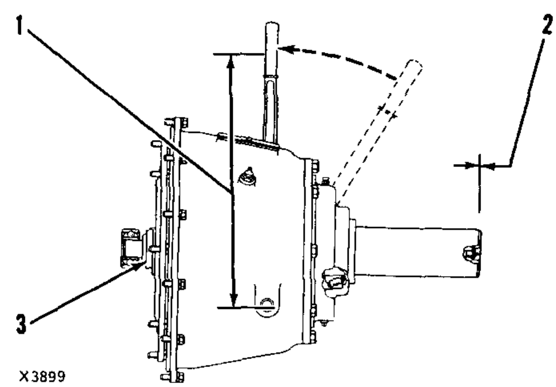
at air pressure to motor of .... 120 psi (830 kPa)

Rotation is clockwise when seen from drive end.

(1) Torque for bolts of rear cover (tighten bolts evenly) .... 20 to 25 lb. ft. (25 to 35 N·m)

(2) Torque for bolts of pinion housing (tighten bolts evenly) .... 100 lb. in. (11.3 N·m)

ENCLOSED CLUTCH
(2N7078)



After clutch installation check crankshaft end play.

Total thickness of one new drive plate and two drive plates .... .620 to .630 in. (15.75 to 16.00 mm)

(1) Adjustment of clutch lever pull:

Force at 21.3 in. (641 mm) distance from center of shaft .... 123 to 163 lb. (545 to 725 N)

(2) End clearance .... .006 to .010 in. (0.15 to 0.25 mm)

(3) Torque for nut .... 30 lb. ft. (40 N•m)

Then tighten additional .... 60° to 90°

ELECTRONIC SPEED SWITCH

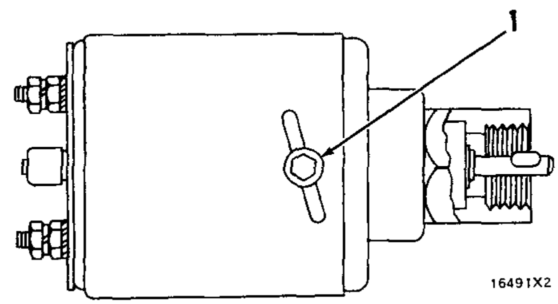
The normal overspeed setting for the electronic speed switch is ± 25 RPM above full load speed.

For setting and checking, install a temporary jumper wire between terminal 1 (VERIFY) and terminal 2 (SHLD). This makes the electronic overspeed switch activate at 25% of its normal setting.

OVERSPEED ADJUSTMENT		
FULL LOAD RPM	OVERSPEED SETTING ± 25 RPM	CONTACTOR TRIP SPEED
1500	1770	885
1600	1888	944
1700	2006	1003
1800	2124	1062
1900	2242	1121
2000	2360	1180
2100	2478	1239
2200	2596	1298
2300	2714	1357
2400	2832	1416

CONTACTOR SWITCH FOR OVERSPEED

(3N4026 Contactor Switch)



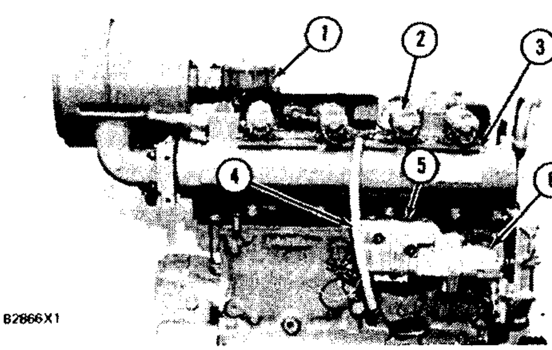
(1) Adjustment screw.

Maximum percent above full load rpm that normally open (NO) contacts close 18%

Speed which causes normally closed (NC) contacts to open (if used) is approximately....................... 600 rpm

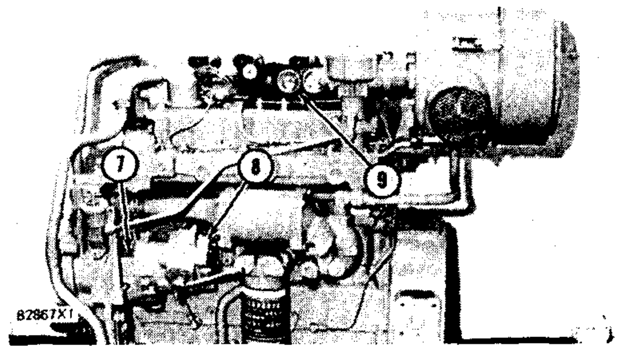
SYSTEMS OPERATION (Section 2)

GENERAL INFORMATION



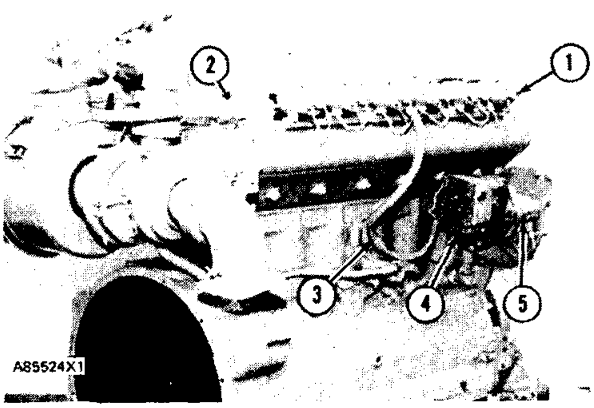
COMPONENT LOCATION
(3304 Engine)

1. Carburetor. 2. Ignition transformer. 3. Spark plug. 4. Wiring harness. 5. Magneto. 6. Magneto drive housing.



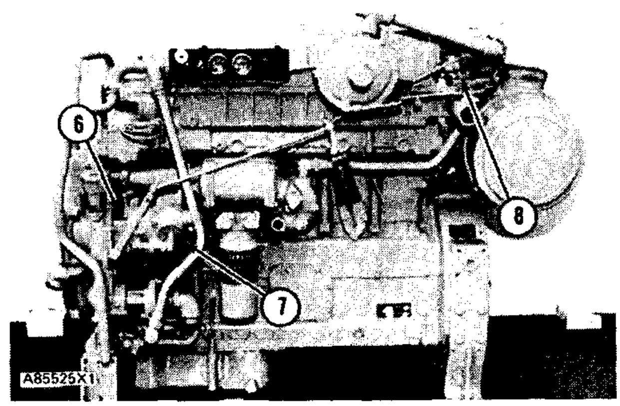
COMPONENT LOCATION
(3304 Engine)

7. Governor drive. 8. Governor. 9. Instrument panel.



COMPONENT LOCATION
(3306 Engine)

1. Ignition transformer. 2. Spark plug. 3. Wiring harness. 4. Magneto. 5. Magneto drive housing.



COMPONENT LOCATION
(3306 Engine)

6. Governor drive. 7. Governor. 8. Boost limit control.

The 3304 and 3306 Natural Gas engines are part of a series of 4.75 in. (120.7 mm) bore, 6.00 in. (152.4 mm) stroke in-line engines.

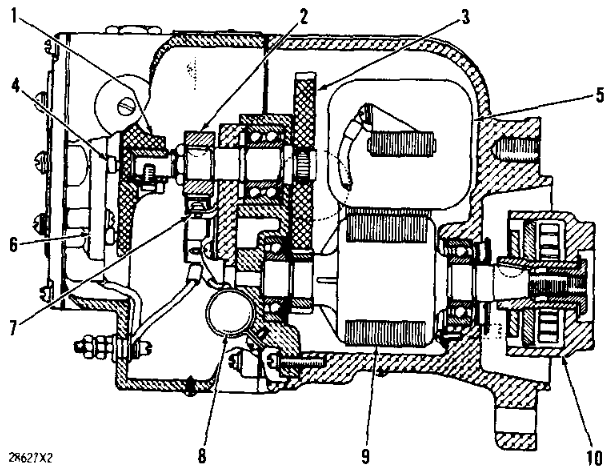
The starting system can be either direct electric with a 12 volt starter motor or air start with an air starting motor.

IGNITION SYSTEM

The ignition system has five basic components: A magneto, ignition transformers for each cylinder, a wiring harness, spark plugs and an instrument panel.

SPARK GAP MAGNETO

The magneto is an alternating current generator that produces the electric source (and stops it at the right time) necessary for spark ignition engines. The basic components of the spark gap magneto are the transformer, rotor, contact breaker, distributor, and condenser.



CROSS SECTION OF SPARK GAP MAGNETO

1. Distributor disc. 2. Cam. 3. Distributor gear and shaft assembly. 4. Brush and spring assembly. 5. Transformer. 6. Distributor block. 7. Contact points. 8. Condenser. 9. Rotor. 10. Impulse coupling.

Transformer (5) has a primary coil made of heavy wire. One end of the primary coil is connected to ground on the transformer core. The other end of the primary coil is connected to contact points (7).

Rotor (9) is a permanent magnet. When the rotor turns, one pole of the magnet in the rotor moves under the core of transformer (5). A flow having the characteristics of the magnet (flux) moves from this pole of the magnet to the opposite pole of the magnet through the layers of the metal core. There is an increase in the flux in the core until the pole is exactly under the core. The flux is then at its largest strength. As the rotor turns more it moves out from under the core and there is a decrease in the flux. The rotor turns so that the opposite pole is under the transformer core. Now the flux must change its direction of flow through the transformer coil. The flux gets larger and then smaller in the opposite direction. The flux direction changes each time the rotor makes a revolution. This flux in the core is all around the wires in the coil of the transformer and causes electricity in the wires.

Cam (2) opens contact points (7) at the point in the alternating current cycle when the voltage in the primary coil is large.

When the points open the circuit is broken and the flux around the primary coil wires suddenly falls (collapses) through the primary coil. This sudden collapse of flux causes the largest voltage (peak voltage) in the primary coil.

At peak voltage the contact on distributor disc (1) is in a position to make a complete circuit through brush and spring assembly (4) in the distributor block and through the low tension leads to the ignition transformers.

Condenser (8) prevents a spark that can cause damage to contact points (7). The electrical energy which normally makes a spark across the gap in the contact points goes into the condenser. When the contact points open wider, the electrical energy in the condenser moves back into the primary coil and adds to the voltage.

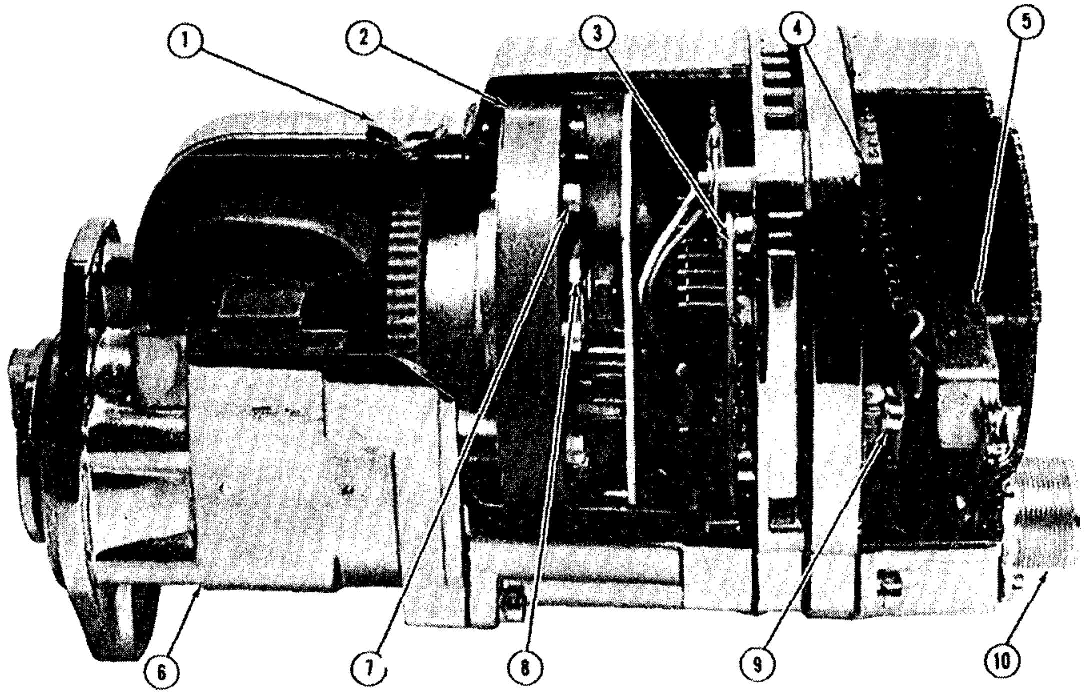
When there is an increase of rpm of the rotor, there is an increase in strength of spark at the spark plug electrodes. An impulse coupling (10) is used to cause an increase in rotor rpm as the engine is started. The impulse coupling is not engaged when the engine is in operation.

SOLID STATE MAGNETO (FAIRBANKS MORSE)

The solid state type magneto makes (generates) current in the alternator section of the magneto. Low tension current is held in the capacitor and then released. Distribution is then made through the distribution board (4). This system has no contact points, contactors, or brushes. There is no spark inside the magneto and only minimum wear. An ignition spark of high tension is made by the transformer to start the air fuel mixture burning under all operating conditions.

The alternator makes a voltage as the magnet rotor is turned by the engine through a drive coupling. The alternating current is sent through a rectifier and held in a capacitor (5). A zener diode, on the power board is the regulator of the capacitor voltage for proper ignition.

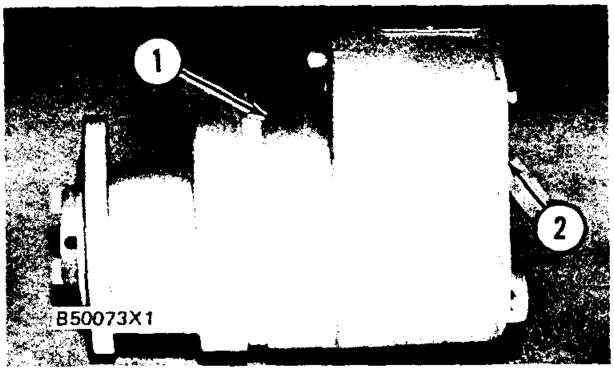
As the pulser rotor (8) moves by each pulser coil (trigger circuit) (7), a voltage is made and sent to the electronic switch (silicon controlled rectifier) (9) for the cylinder ready for ignition. The switch is then turned on and permits the capacitor (5) to release the voltage (discharge). Then the voltage goes through the distribution board (4) and to the transformer. The transformer causes a spark (impulse) of high voltage and low current. This is sent across the electrodes of the spark plug. As the pulser rotor moves by each pulser coil, the same development of spark (impulse) is made.



CUTAWAY VIEW OF SOLID STATE MAGNETO (FAIRBANKS MORSE)
(Typical Illustration)

1. Timing bolt. 2. Pulser coil assembly. 3. Plate and power board assembly. 4. Distribution board. 5. Capacitor. 6. Alternator housing. 7. Pulser coil (trigger circuit). 8. Pulser rotor. 9. Electronic switch (*silicon* controlled rectifier). 10. Plug connector.

SOLID STATE MAGNETO (ALTRONIC)



SOLID STATE MAGNETO (ALTRONIC)

1. Alternator section. 2. Electronic firing section.

The Altronic magneto is made of a permanent magneto alternator section (1) and brakerless electronic firing circuit (2). There are no brushes or distributor contacts.

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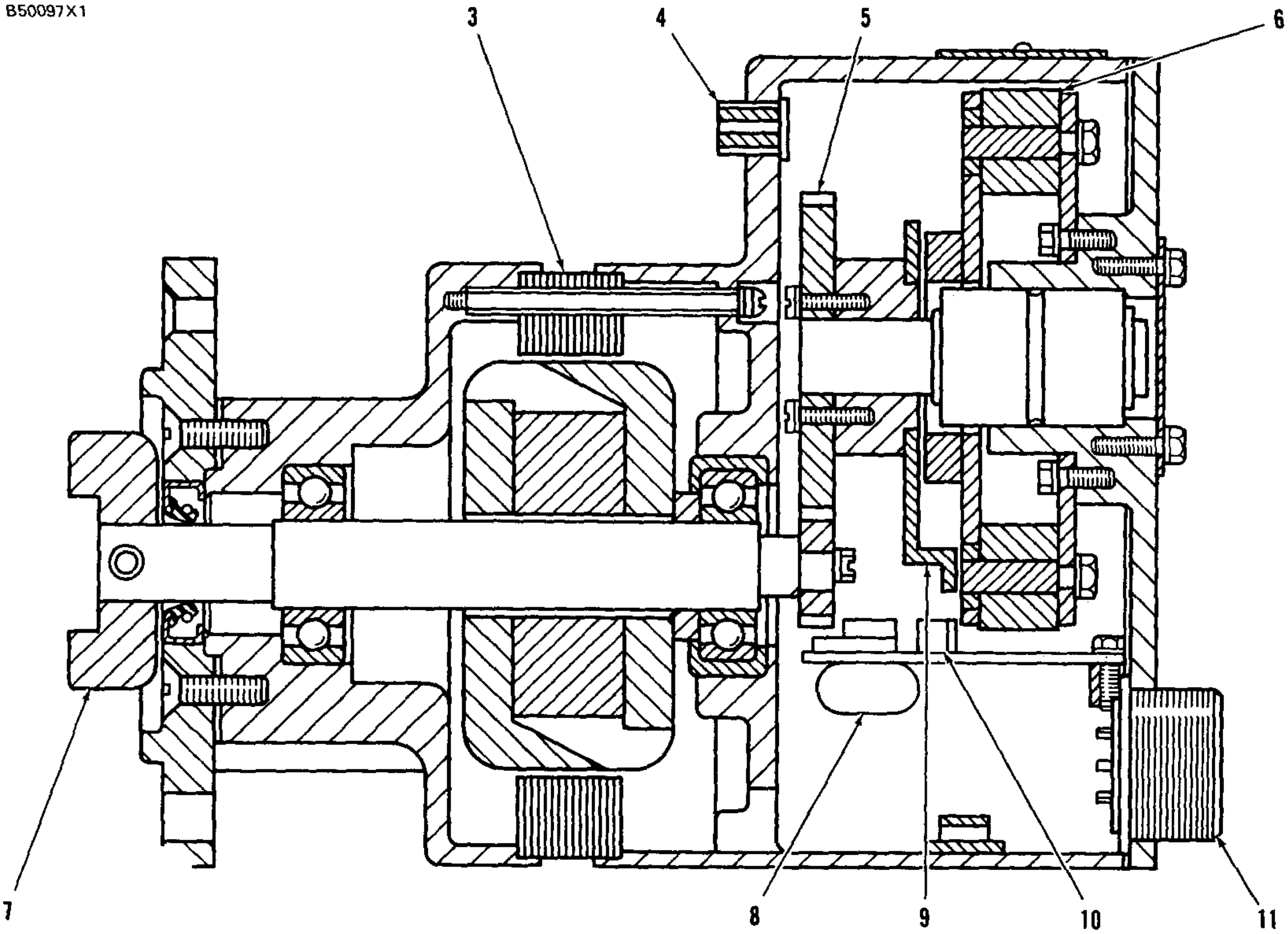
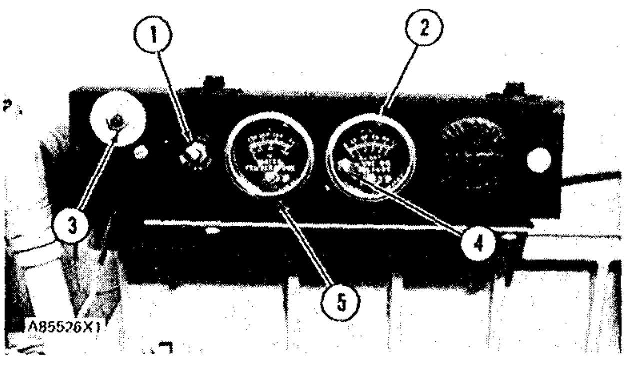


CROSS SECTION OF SOLID STATE MAGNETO (ALTRONIC)

3. Alternator. 4. Vent. 5. Speed reduction gears. 6. Pick-up coil. 7. Drive tang. 8. Energy storage capacitor. 9. Rotating timer arm. 10. SCR solid state switch. 11. Output connector.

The engine turns magneto drive tang (7). The drive tang turns alternator (3), speed reduction gears (5) and rotating timer arm (9). As the alternator is turned it provides power to charge energy storage capacitor (8). There are separate pick-up coils (6) and SCR (silicon controlled rectifier) solid state switches (10) for each engine cylinder. The timer arm passes over pick-up coils (6) in sequence. The pick-up coils turn on solid state switches (10) which release the energy stored in capacitor (8). This energy leaves the magneto thru output connector (11). The energy travels thru the wiring harness to the ignition coils where it is transformed to the high voltage needed to fire the spark plugs.

INSTRUMENT PANEL



INSTRUMENT PANEL

1. Stop switch. 2. Gauge for the oil pressure. 3. Reset button for the magnetic switch. 4. Reset button for the gauge for oil pressure. 5. Gauge for the water temperature.

The instrument panel has a magnetic switch, manual stop switch (1), oil pressure gauge (2), and a water temperature gauge (5) which are connected to the magneto. The protection shut-off valve for the gas supply line is also operated by the instrument panel.

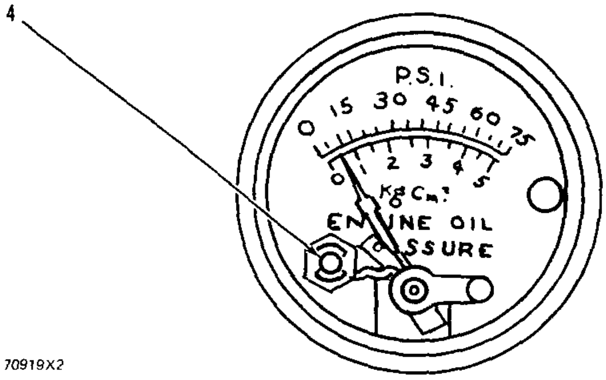
When the magnetic switch is activated it connects the magneto to ground and stops the engine. This is the normal way to stop the engine. If the water temperature gets too high or if the oil pressure gets too low the magnetic switch is activated.

Before a cold engine is started, push in reset button (3) for the magnetic switch and reset button (4) for the gauge for the oil pressure. This prevents the connection of the magneto to ground because of low oil pressure. When the engine starts, normal oil pressure releases the switch from reset position. The gauge switch is then ready to stop the engine when the oil pressure is low.

When the gauge switch for the water temperature has correct operation, a hot engine can not be started.

When the reset button for the magnetic switch is held in, the gauge switches for the oil pressure and water temperature can not make connection of the magneto to ground.

The protection shut-off valve for the gas line needs manual setting to open it after the engine has stopped.

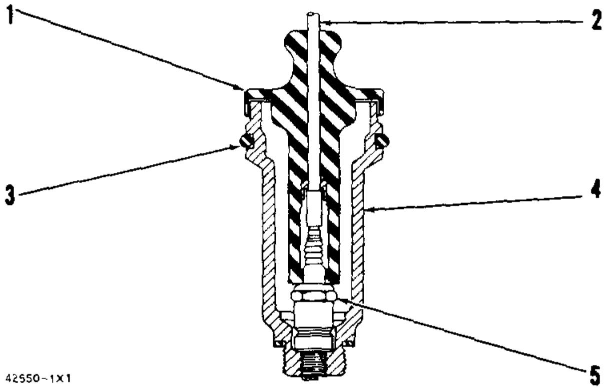


OIL PRESSURE GAUGE

4. Reset button for the gauge for oil pressure.

SPARK PLUGS AND ADAPTERS

Spark plugs for this natural gas engine use two ground electrodes. This permits the spark plug to operate longer before adjustment or replacement is needed.



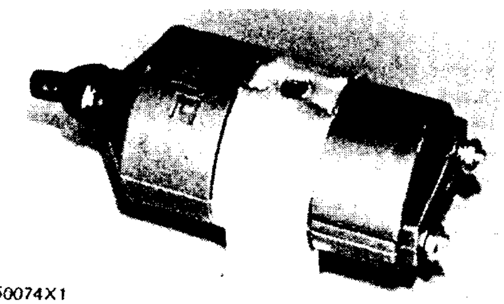
SPARK PLUG AND ADAPTER

1. Cover. 2. High tension wire. 3. Seal. 4. Spark plug adapter. 5. Spark plug.

A cover (1) is used over the spark plug adapter. High tension wire (2) goes through cover (1) to the connection (terminal) portion of spark plug (5). This keeps water, dirt and other foreign material out of spark plug adapter (4).

IGNITION TRANSFORMER

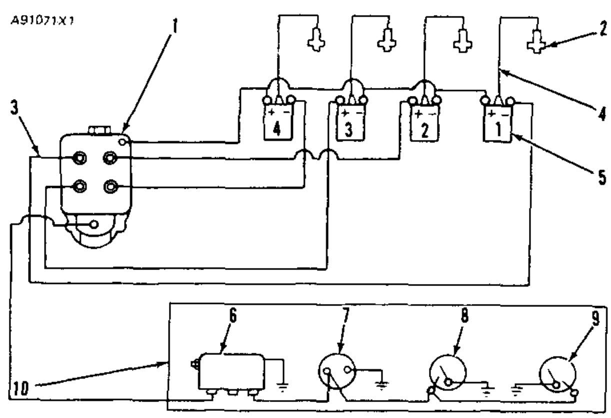
The ignition transformer causes an increase of the magneto voltage. This is needed to send a spark (im-



IGNITION TRANSFORMER
(Typical Example)

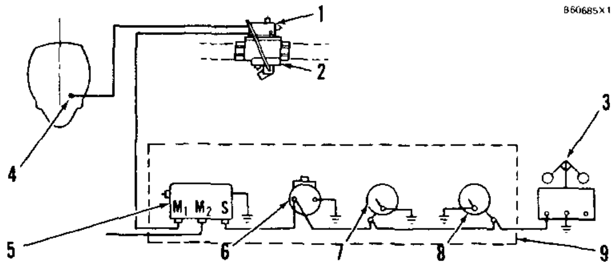
pulse) across the electrodes of the spark plugs. For good operation, the connections (terminals) must be clean and tight. The wiring diagram shows how all wires are to be connected to the plug connection at the magneto.

WIRING DIAGRAMS



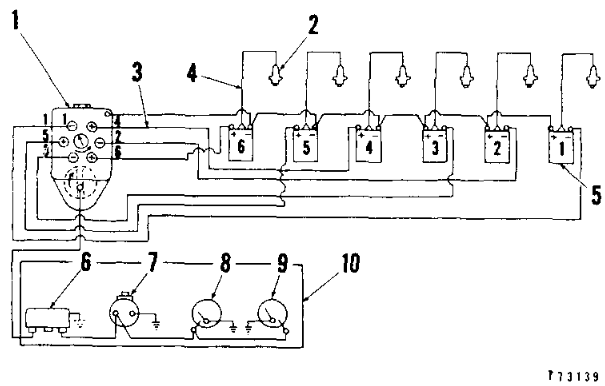
IGNITION SYSTEM DIAGRAM FOR SPARK GAP MAGNETO
(3304 Engine)

1. Magneto. **2.** Spark plugs. **3.** Low tension leads. **4.** High tension leads. **5.** Transformers. **6.** Magnetic switch. **7.** Manual stop switch. **8.** Switch of the gauge for the oil pressure. **9.** Switch of the gauge for the water temperature. **10.** Instrument panel.



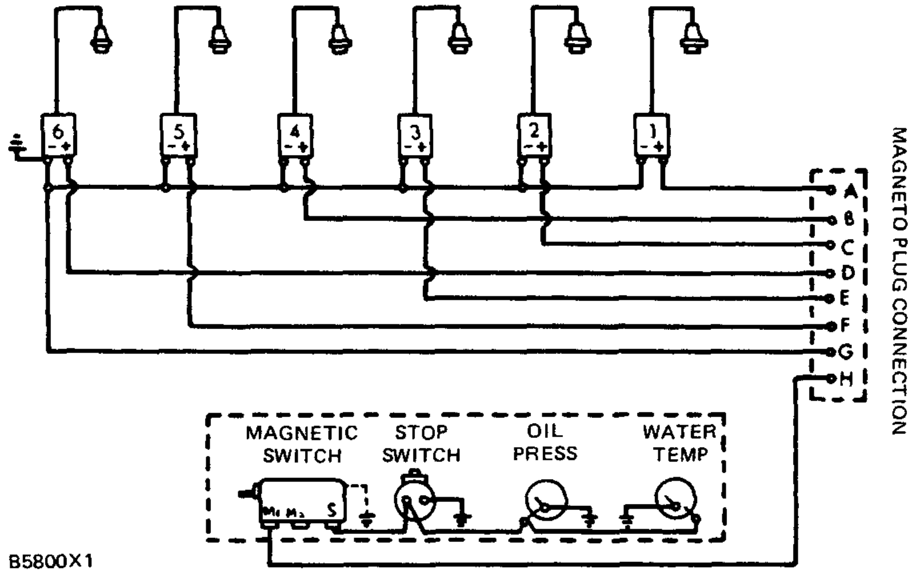
WIRING DIAGRAM WITH OVERSPEED CONTACTOR AND GAS VALVE

1. Solenoid. **2.** Gas valve. **3.** Overspeed contactor. **4.** Shut-off stud for breaker point magneto or H pin for Fairbanks Morse Solid State Magneto or G pin for Altronic Magneto. **5.** Magnetic switch. **6.** Stop switch. **7.** Switch of the gauge for the oil pressure. **8.** Switch of the gauge for the water temperature. **9.** Engine instrument panel.

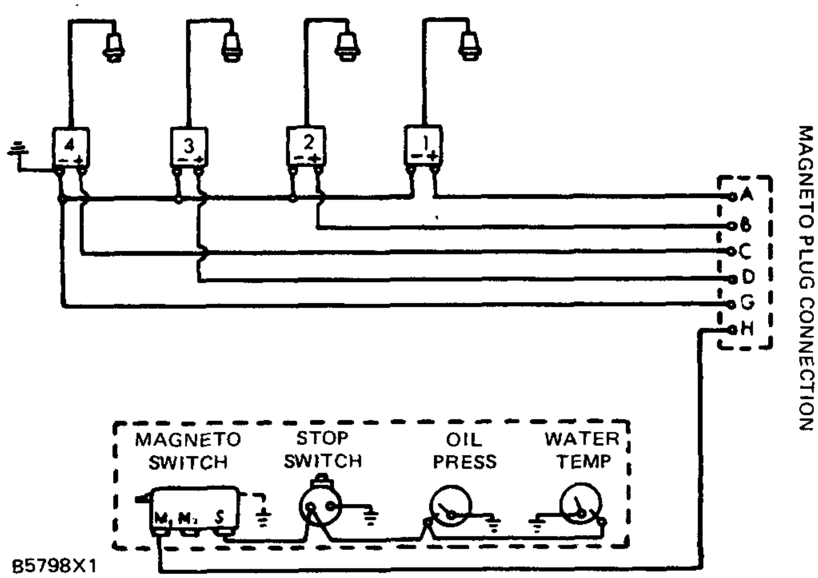


IGNITION SYSTEM DIAGRAM FOR SPARK GAP MAGNETO
(3306 Engine)

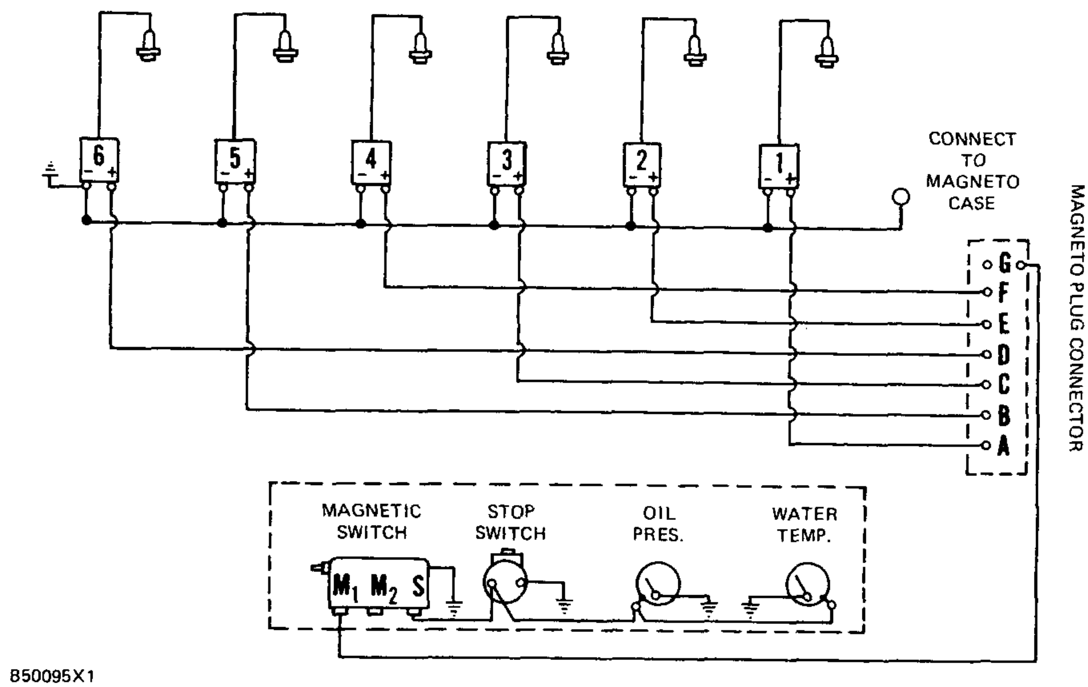
1. Magneto. **2.** Spark plugs. **3.** Low tension leads. **4.** High tension leads. **5.** Transformers. **6.** Magnetic switch. **7.** Manual stop switch. **8.** Switch of the gauge for the oil pressure. **9.** Switch of the gauge for the water temperature. **10.** Instrument panel.



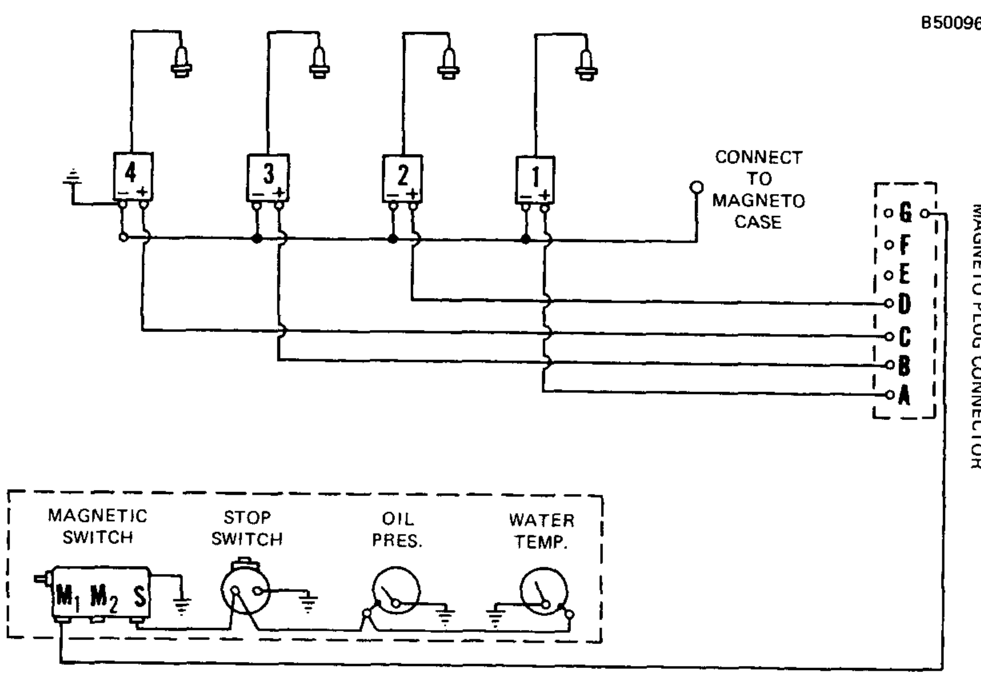
IGNITION SYSTEM DIAGRAM FOR SOLID STATE MAGNETO (FAIRBANKS MORSE)
(3306 Engine)



IGNITION SYSTEM DIAGRAM FOR SOLID STATE MAGNETO (FAIRBANKS MORSE)
(3304 Engine)

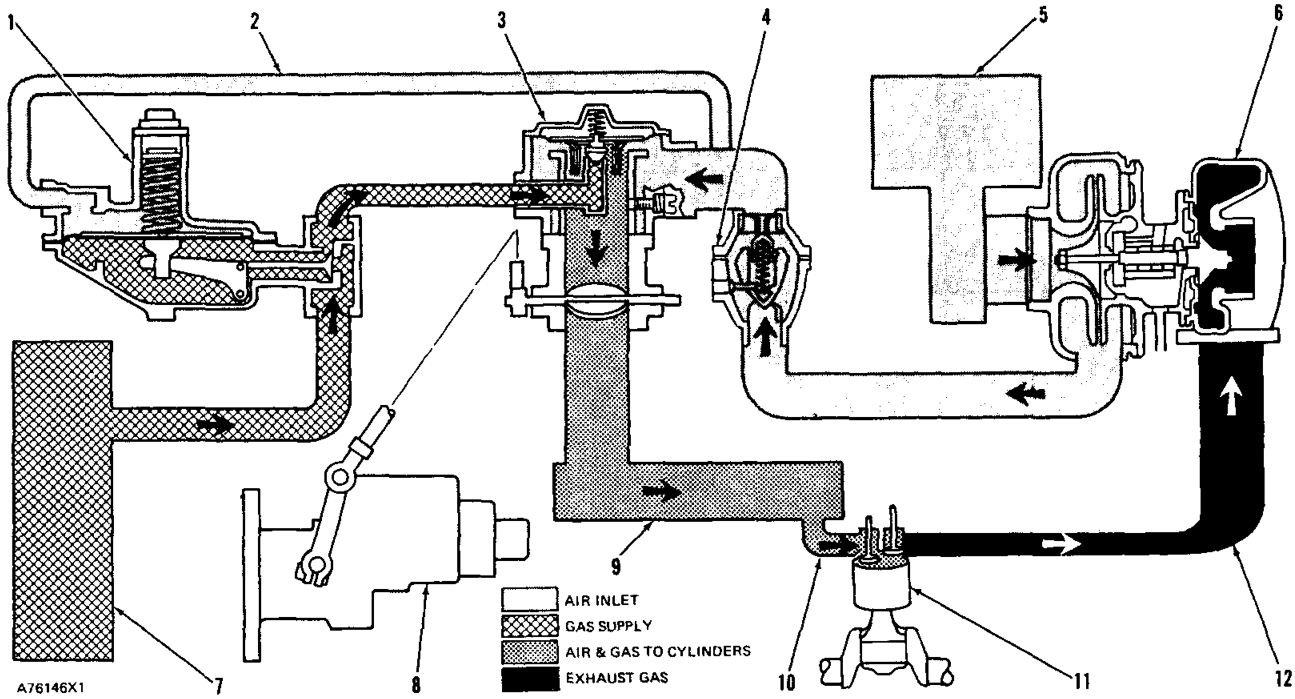


IGNITION SYSTEM DIAGRAM FOR SOLID STATE MAGNETO (ALTRONIC)
(3306 Engine)



IGNITION SYSTEM DIAGRAM FOR SOLID STATE MAGNETO (ALTRONIC)
(3304 Engine)

GAS, AIR INLET AND EXHAUST SYSTEM



GAS, AIR INLET AND EXHAUST SYSTEM WITH TURBOCHARGER (3306 ENGINE)

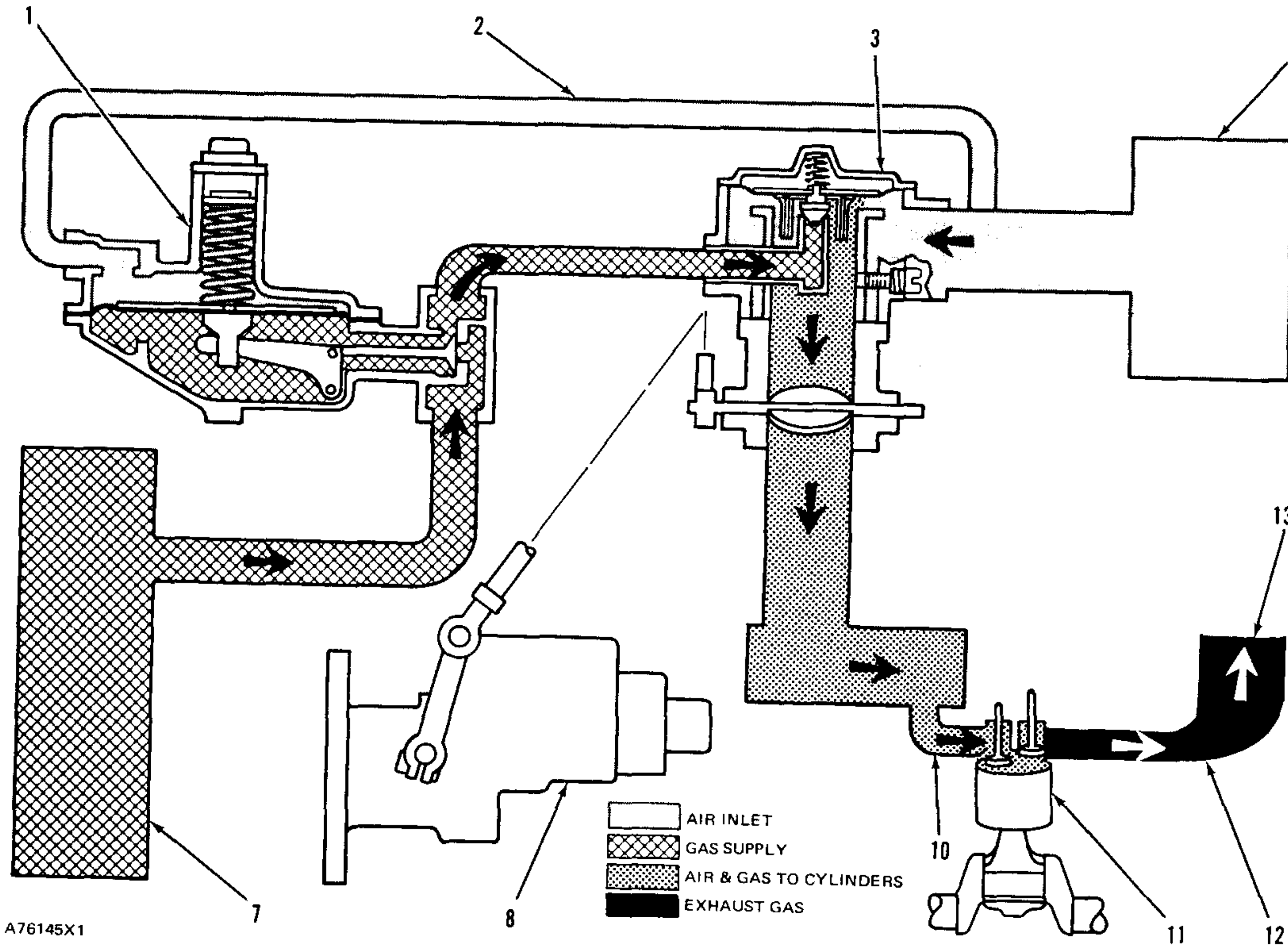
1. Gas pressure regulator. 2. Balance line. 3. Carburetor. 4. Boost limit control. 5. Air cleaner. 6. Turbocharger. 7. Gas supply. 8. Governor. 9. Aftercooler. 10. Air inlet manifold. 11. Cylinder. 12. Exhaust manifold.

In addition to components shown in the diagram, some installations have a shut-off valve attachment in the supply line for the gas. The valve is electrically operated from the ignition system and can also be manually operated to stop the engine. After the engine is stopped, manual setting is needed to start the engine.

Engine installations using propane gas have system components the same as illustrated above. In addition, on some engines, a thermac valve for reduction of pressure, and a load adjusting valve, between the gas pressure regulator and carburetor, are used. Engines with a propane or dual fuel system have a vacuum regulator in place of the gas pressure regulator and thermac valve. This vacuum regulator permits an adjustment to be made for differences in BTU content of the gas being used.

Changes in engine load and fuel burnt cause changes in rpm of the turbine wheels and impellers of the turbocharger (6).

When the turbocharger gives a pressure boost to the inlet air, the temperature of the air goes up. A water cooled aftercooler (9), is installed between the carburetor (3) and the air inlet manifold (10) to cylinders. The aftercooler causes a reduction of air temperature from the turbocharger. Engines that do not have a turbocharger, do not have an aftercooler (9) or a boost limit control (4).



GAS, AIR INLET AND EXHAUST SYSTEM WITHOUT TURBOCHARGER (3304 and 3306 ENGINES)

1. Gas pressure regulator. 2. Balance line. 3. Carburetor. 5. Air cleaner. 7. Gas supply. 8. Governor. 10. Air inlet manifold. 11. Cylinder. 12. Exhaust manifold. 13. Exhaust pipe.

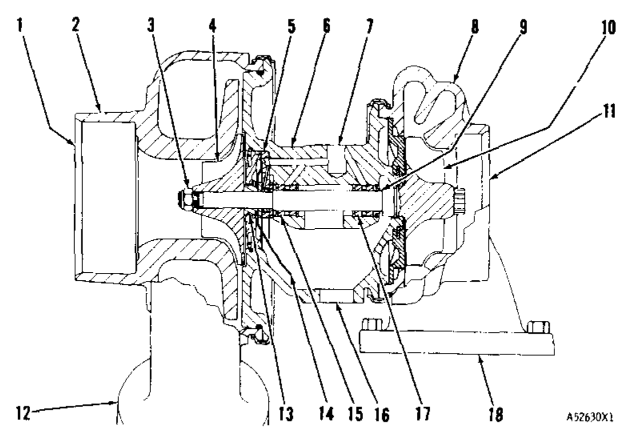
TURBOCHARGER (Engines so Equipped)

The turbocharger is on the exhaust outlet of the engine exhaust manifold. The energy that normally would be lost from the exhaust gases is used to turn the turbocharger.

As the engine starts, the flow of exhaust gases from the exhaust manifold goes through exhaust inlet (18) to the turbine wheel (10). The turbine wheel and compressor impeller (4) are on a common shaft. The exhaust gases flow over the turbine wheel making it and the impeller turn.

Air from the air cleaner flows through air inlet (1) to the center of the impeller. The rotating impeller puts a compression force on the air. The air then goes into the carburetor.

The bearings of the turbocharger get pressure lubrication from engine oil. The oil goes in through port (7) and is sent through passages to give lubrication to the sleeves (9) and (13), and the bearings (15) and (17).



TURBOCHARGER

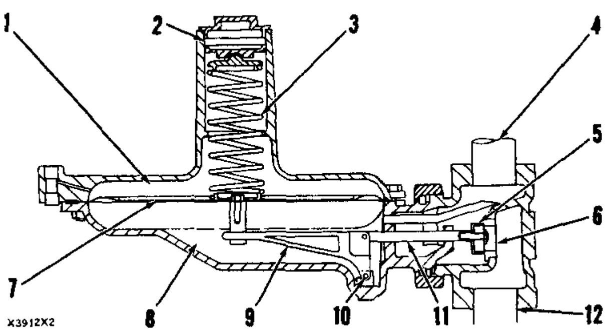
1. Air inlet. 2. Compressor housing. 3. Nut. 4. Compressor impeller. 5. Thrust bearing. 6. Center housing. 7. Lubrication inlet port. 8. Turbine housing. 9. Sleeve. 10. Turbine wheel. 11. Exhaust outlet. 12. Air outlet. 13. Sleeve. 14. Oil deflector. 15. Bearing. 16. Oil outlet port. 17. Bearing. 18. Exhaust inlet.

AFTERCOOLER

The aftercooler is installed between the carburetor and the inlet manifold. There is a flow of water through the aftercooler. This cools the hot air which is under compression from the turbocharger. The cooler air makes more oxygen available for combustion. More oxygen permits more fuel to be burned. This gives more power.

GAS PRESSURE REGULATOR

The gas pressure regulator is needed on engines equipped with turbochargers. Engines without turbochargers need a gas pressure regulator if the pressure of the gas supply is more than the desired inlet pressure difference between the gas and air.



GAS PRESSURE REGULATOR

1. Spring side chamber. 2. Adjustment screw. 3. Spring. 4. Outlet. 5. Valve disc. 6. Orifice. 7. Main diaphragm. 8. Lever side chamber. 9. Lever. 10. Pivot pin. 11. Valve stem. 12. Inlet.

To make an adjustment to the regulator turn screw (2).

Gas goes through inlet (12), orifice (6), by valve disc (5), and through outlet (4). The outlet pressure is in chamber (8) on the lever side of diaphragm (7).

As the gas pressure in chamber (8) becomes higher than the force of spring (3) and the air pressure in the spring side chamber (1) (atmosphere on naturally aspirated engines; turbocharger boost on turbocharged engines), the diaphragm is pushed against the spring. This turns lever (9) at pivot pin (10) and causes valve stem (11) to move to valve disc (5) and close orifice (6).

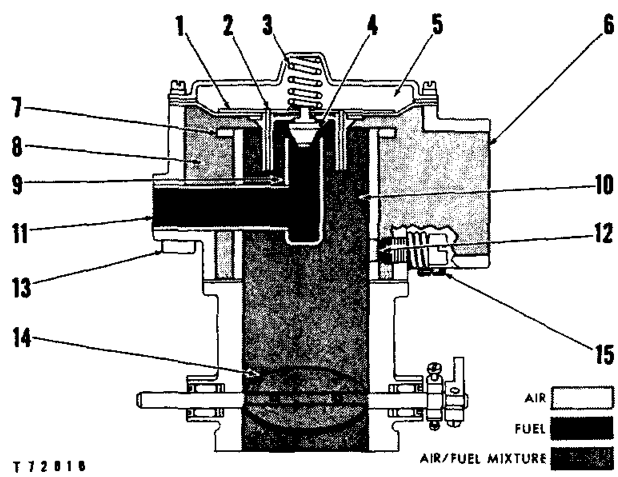
When orifice (6) is closed, gas is pulled from chamber (8). This causes a reduction in pressure in chamber (8) to a pressure less than that on the spring side of the diaphragm. The force of the spring and air pressure in chamber (1) moves the diaphragm toward the lever. This turns the lever and opens valve disc (5). This permits additional gas to fill chamber (8) and go to the carburetor.

When the pressure on either side of the diaphragm is the same, the regulator permits a set amount of gas flow to the carburetor.

CARBURETOR

Air goes into the carburetor through air horn (6) and fills outer chamber (8). Air moves diaphragm (1) away from ring (7) and goes into inner chamber (10) (mixing chamber).

Fuel goes into the carburetor through fuel inlet (11), and goes by power mixture adjustment (13) to the center of the carburetor and into tube (9) for the fuel outlet. Fuel valve (4) is fastened to diaphragm (1). With the diaphragm moved away from ring (7), fuel goes through fuel valve (4) and into chamber (10). The fuel and air mixture in inner chamber (10) goes down by throttle plate (14) and into the inlet manifold.



CARBURETOR OPERATION-SCHEMATIC

1. Diaphragm. 2. Sensing holes. 3. Spring. 4. Fuel valve. 5. Chamber. 6. Air horn. 7. Ring. 8. Outer chamber. 9. Fuel outlet tube. 10. Inner chamber. 11. Fuel inlet. 12. Idle adjustment opening. 13. Power mixture adjustment. 14. Throttle plate. 15. Balance line connection.

With the engine stopped, spring (3) holds diaphragm (1) against ring (7) and holds fuel valve (4) closed. No air or fuel can go to inner chamber (10). As the engine is started, the vacuum in the cylinders, caused by the intake strokes of the pistons, make a low pressure condition in inner chamber (10). This low pressure is felt by chamber (5), behind the diaphragm, through holes (2). This permits the pressure in chamber (5) to balance with the low pressure condition in the inner chamber. As soon as the inlet pressure on the diaphragm (1) is higher than the spring force, the diaphragm moves out.

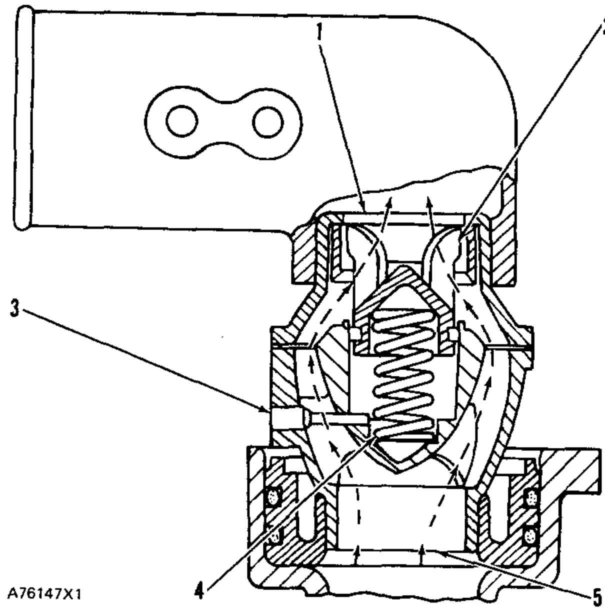
This also moves fuel valve (4) out and permits air and fuel to go into the inner chamber. A small volume of air is also measured into the inner chamber (10) through idle adjustment opening (12).

When the engine is in operation at a constant rpm, the diaphragm does not move from one position. This position is caused by the difference in pressure between the gas and the air. An adjustment can be made to this pressure difference by adjustment to the gas pressure regulator.

BALANCE LINE

The balance line controls the correct pressure difference between the line pressure regulator and the carburetor inlet.

When the load on the engine changes, the boost pressure from the turbocharger changes in the inlet manifold. The balance line sends a signal of this change through the vent valve to the spring side chamber of the line pressure regulator. This pressure change causes the regulator diaphragm to move the line regulator valve to correct the gas pressure to the carburetor.



BOOST LIMIT VALVE
(Open position)

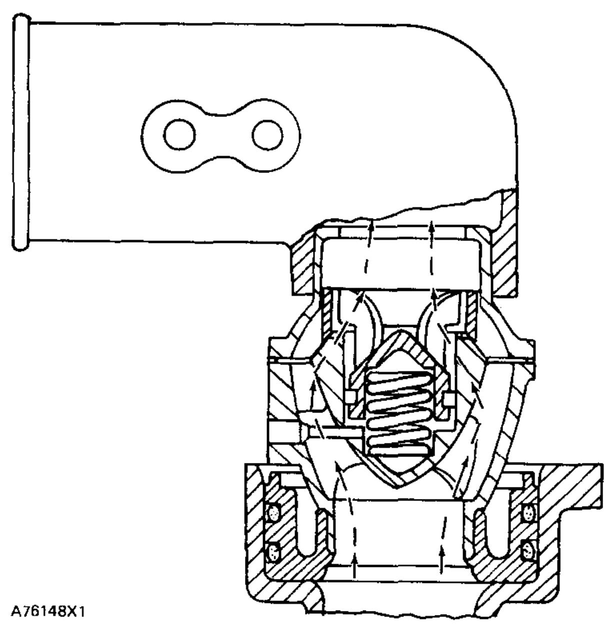
1. Opening to carburetor. 2. Piston sleeve valve. 3. Vent hole. 4. Spring. 5. Opening from turbocharger.

BOOST LIMIT CONTROL
(Engines Equipped with Turbocharger)

The boost limit control valve is located in the air supply line to the carburetor. It has a spring-loaded piston sleeve valve inside a housing. The pressure of the spring keeps the piston sleeve valve in an open position to let full air pressure from the turbocharger go through. As pressure from the turbocharger increases, the pressure pushes against the cone-shaped face of piston (2). When the pressure reaches its maximum spring (4) will have compressed and the piston sleeve valve will have moved to the point where the passage in the valve is almost closed.

NOTE: Vent hole (3) must be open, (never plugged).

If the boost limit valve does not work correctly, disassemble the valve and inspect for worn parts. If there are no worn parts, make replacement of spring (4). If there are worn parts, install a new boost limit valve.

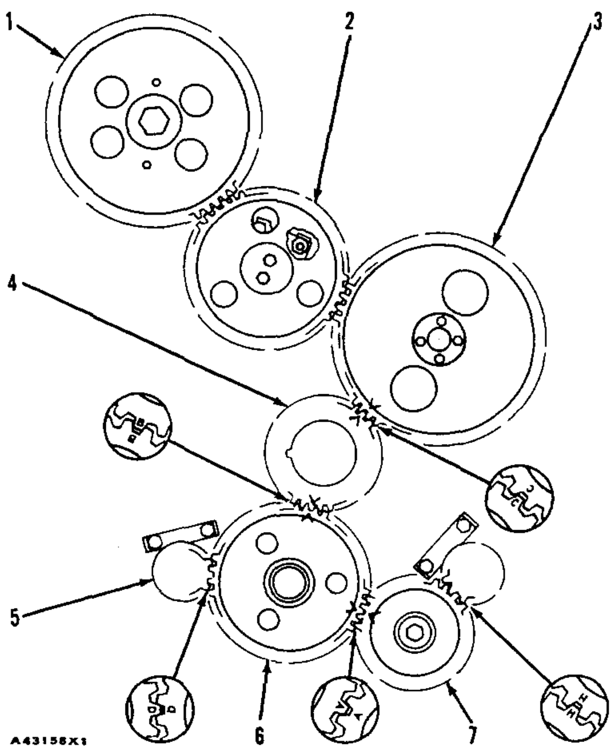


BOOST LIMIT VALVE
(Closed Position

TIMING GEARS

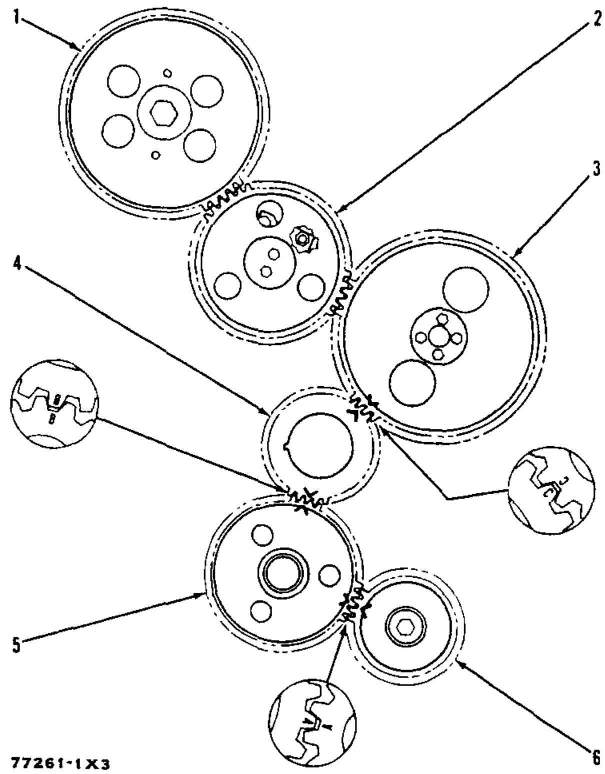
The timing gears are at the front of the cylinder block. Their cover is the housing for the timing gears. The timing gears keep the rotation of the crankshaft, camshaft, and magneto in the correct relation to each other. The timing gears are driven by the crankshaft gear.

The 3304 engine has balancer shafts. The balancer for the right side of the engine is driven by the idler gear for the oil pump. The balancer for the left side of the engine is driven by the drive gear for the oil pump.



TIMING GEARS (3304 ENGINE)

1. Drive gear for magneto. 2. Idler gear for magneto drive gear. 3. Camshaft gear. 4. Crankshaft gear. 5. Balancer shafts. 6. Idler gear for oil pump. 7. Drive gear for oil pump.



TIMING GEARS (3306 ENGINE)

1. Drive gear for magneto. 2. Idler gear for magneto drive gear. 3. Camshaft gear. 4. Crankshaft gear. 5. Idler gear for oil pump. 6. Drive gear for oil pump.

VALVES AND VALVE MECHANISM

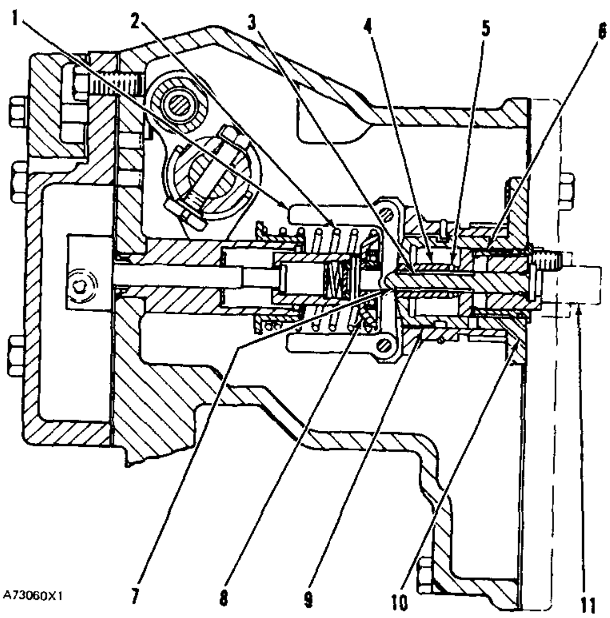
The valves and valve mechanism control the flow of air and exhaust gases in the cylinder during engine operation.

The intake and exhaust valves are opened and closed by movement of these components; crankshaft, camshaft, valve lifters (cam followers), push rods, rocker arms, and valve springs. Rotation of the crankshaft causes rotation of the camshaft. The camshaft gear is driven by, and timed to, a gear on the front of the crankshaft. When the camshaft turns, the cams on the camshaft also turn and cause the valve lifters (cam followers) to go up and down. This movement makes the push rods move the rocker arms. The movement of the rocker arms will make the intake and exhaust valves in the cylinder head open according to the firing order (ignition sequence) of the engine. A valve spring for each valve pushes the valve back to the closed position.

Valve rotators cause the valves to have rotation while the engine is in operation. This rotation of the valves keeps the deposit of carbon on the valves to a minimum and gives the valves longer service life.

GOVERNORS

Mechanical Governor



GOVERNOR

1. Governor weights. 2. Governor spring. 3. Valve. 4. Piston. 5. Oil passage. 6. Sleeve. 7. Oil outlet passage. 8. Spring seat. 9. Cylinder. 10. Oil inlet passage. 11. Governor shaft.

When the engine is running, the balance between (centrifugal force) of the governor weights (1) and the force of governor spring (2) controls the movement of valve (3). The valve directs oil under pressure to either side of piston (4). The position of valve (3), will cause piston (4) to move the governor shaft (11) to increase or decrease fuel to the engine when the load on the engine changes.

Lubrication oil under pressure goes into passage (10) and in the governor cylinder (9). The oil goes around sleeve (6) inside of cylinder (9). Oil then goes through a passage in piston (4) where it comes in contact with valve (3).

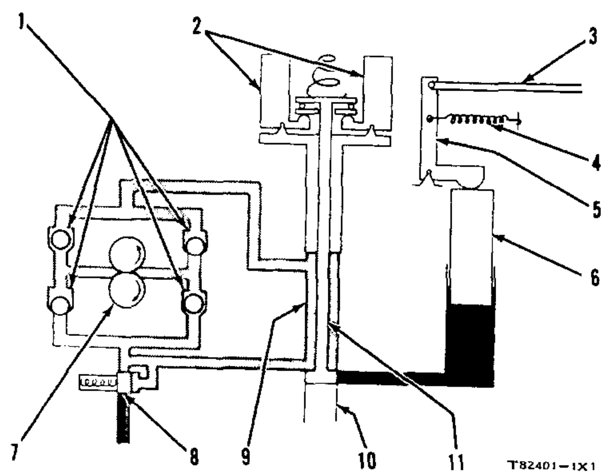
When the engine load is increased, engine rpm is decreased and the rotation of governor weights (1) will slow down. The governor weights (1) move toward each other and let governor spring (2) move valve (3) forward. As valve (3) moves, the oil passage around valve (3) is open to pressure oil. Oil then goes through oil passage (5) to fill the chamber behind piston (4). The pressure of the oil forces the piston and the shaft forward. This will increase the amount of fuel to the engine. Engine rpm is increased until the rotation (centrifugal force) of the governor weights (1) turn fast enough to make a balance of force with governor spring (2).

When the engine load is decreased, engine rpm is increased, the rotation of the governor weights (1) will get faster. The toes of the weights move valve (3) backward, to let the oil behind piston (4) go through a drain passage which is opened at the rear of the piston (4). At the same time, the oil is under pressure between the sleeve (6) and piston (4). It forces the piston (4) and governor shaft (11) back to decrease the amount of fuel to the engine. Engine rpm is decreased until the rotation of governor weights (1) is in balance with the force of governor spring (2).

Oil from the engine lubrication system is the lubricant for the bearing for the governor weights. The other parts of the governor get lubricant from oil (splash lubrication). Oil from the governor drains into the governor housing and timing gear housing.

Woodward PSG Governor

The Woodward PSG Governor is a hydraulic speed governor with a system for compensation of the small movements of the governor weights and spring which would normally cause a change in the engine rpm. The governor will cause the engine to keep the same speed when there is a change in the load on the engine.



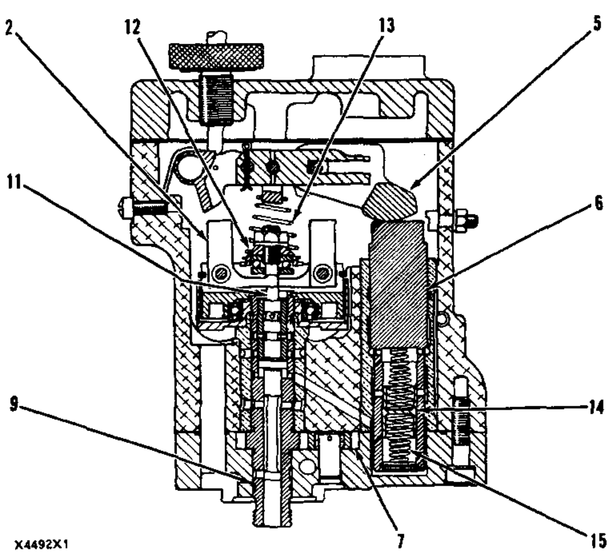
SCHEMATIC OF OIL FLOW IN GOVERNOR

1. Check valves. 2. Governor weights. 3. Linkage to carburetor throttle. 4. Return spring. 5. Terminal lever. 6. Power piston. 7. Pump. 8. Supply valve (pressure controlled). 9. Hydraulic valve bushing and governor drive shaft. 10. Drain. 11. Pilot valve plunger.

The oil supply is from the engine lubrication system. This oil goes to the governor oil pump (7) which increases pressure to 175 psi (1200 kPa). Four check valves permit rotation of the governor in either direction. Oil from the relief valve goes back to the supply, so oil which is not used is pumped to the components inside the governor.

The governor drive shaft is the hydraulic valve bushing (9). Pilot valve plunger (11) in the center of the bushing is installed in the thrust bearing and spring seat (12). The rotation of the bushing causes governor weights (2) to turn. The toes of the weights are against the thrust bearing and the spring seat. One of the hydraulic pump gears is made as part of bushing (9).

When there is an increase in the load on the engine, the rpm of the engine goes down and there is a reduction to the speed of the governor weights (2). The force of rotation (centrifugal force) of the governor weights (2) is less and the spring (13) pushes seat (12) and pilot valve plunger (11) to a position in bushing (9) where an oil passage is opened and oil is sent to power piston (6). The pressure of the oil moves the power piston which moves lever (5). The lever is part of the governor terminal shaft which is connected to the carburetor throttle. The throttle is moved to a more fuel position and there is an increase in engine rpm. As the engine rpm goes up, the governor weights turn faster. The force of rotation (centrifugal force) is larger and the toes of the weights move the thrust bearing and spring seat (12) and pilot valve plunger (11). When the rpm of the engine is again the same as it was before there was an increase in the load, the governor weights have moved the pilot valve plunger to its original position. This closes the oil passage to the power piston (6) to stop the movement of the power piston and linkage to the throttle.



CROSS SECTION OF HYDRAULIC GOVERNOR

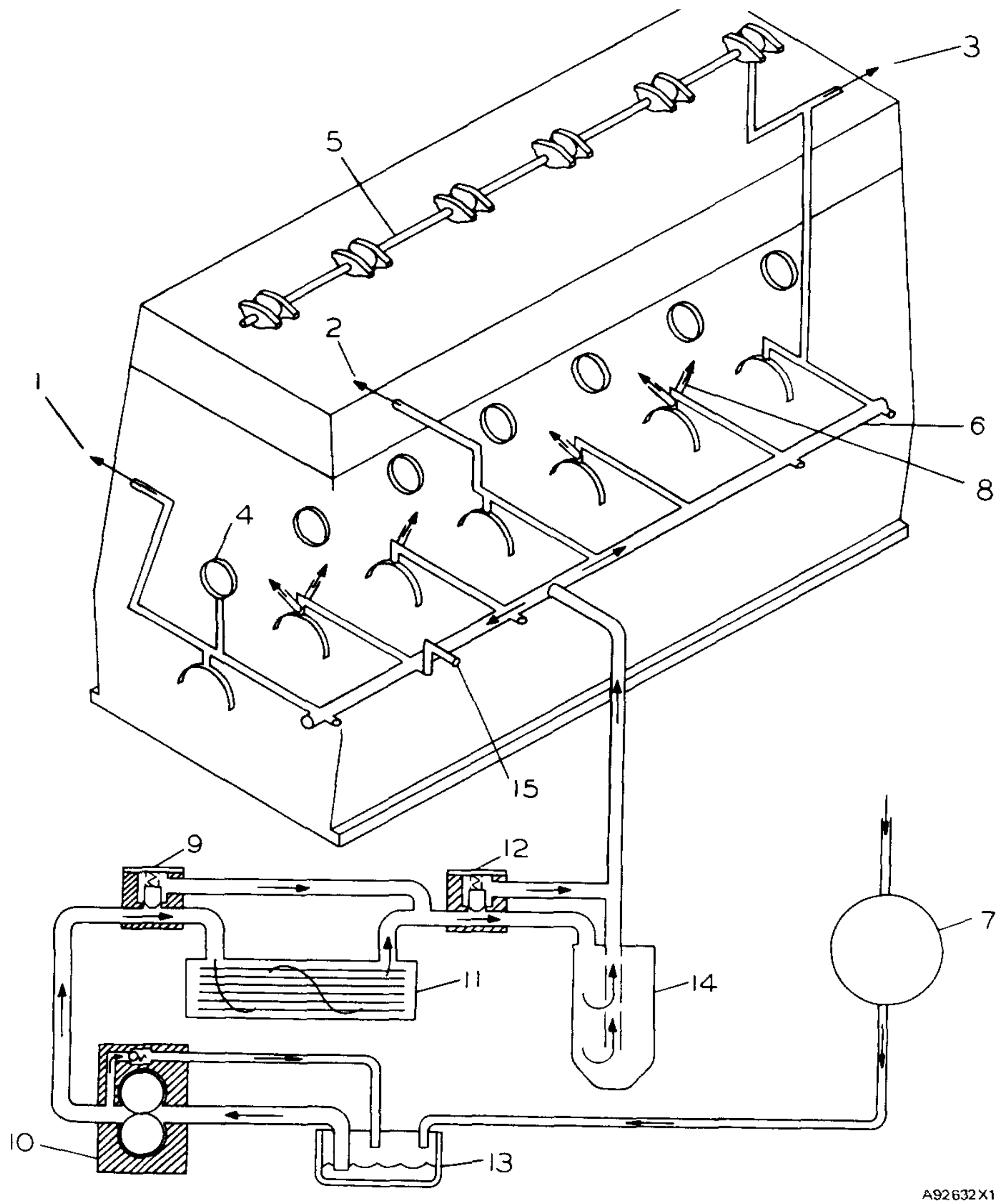
2. Governor weights. 5. Terminal lever. 6. Power piston. 7. Pump. 9. Hydraulic valve bushing and governor drive shaft. 11. Pilot valve plunger. 12. Thrust bearing and spring seat. 13. Governor spring. 14. Buffer piston. 15. Buffer springs (two).

When there is a decrease in the load on the engine there is an increase in the rpm of the engine and the speed of the governor weights is faster. The toes on the governor weights move the thrust bearing, spring seat (12), and pilot valve plunger (11) to a position in bushing (9) that permits the oil under power piston (6) to flow through drain (10). When the oil under the power piston can flow through the drain, a return spring (4) in the governor linkage moves the linkage to the carburetor throttle to a less fuel position and there is a decrease in the rpm of the engine. The governor weights have slower rotation and the governor spring (13) pushes on the spring seat (12) and pilot valve plunger (11). When the rpm of the engine is again the same as it was before there was a decrease in the load, the governor spring pushes the pilot valve plunger (11) to a position where no oil can flow to drain (10) from under the power piston (6). The movement of power piston and linkage to the carburetor throttle is now stopped.

Small movements in the governor weights and springs during rotation of the governor do not cause a change in engine rpm. This is because of compensation by buffer piston (14) and buffer springs (15). The buffer springs keep the buffer piston in the center of power piston (6). The oil which is sent to the power piston must first go through an opening in the bottom of the power piston and push on the buffer piston to move the power piston.

LUBRICATION SYSTEM

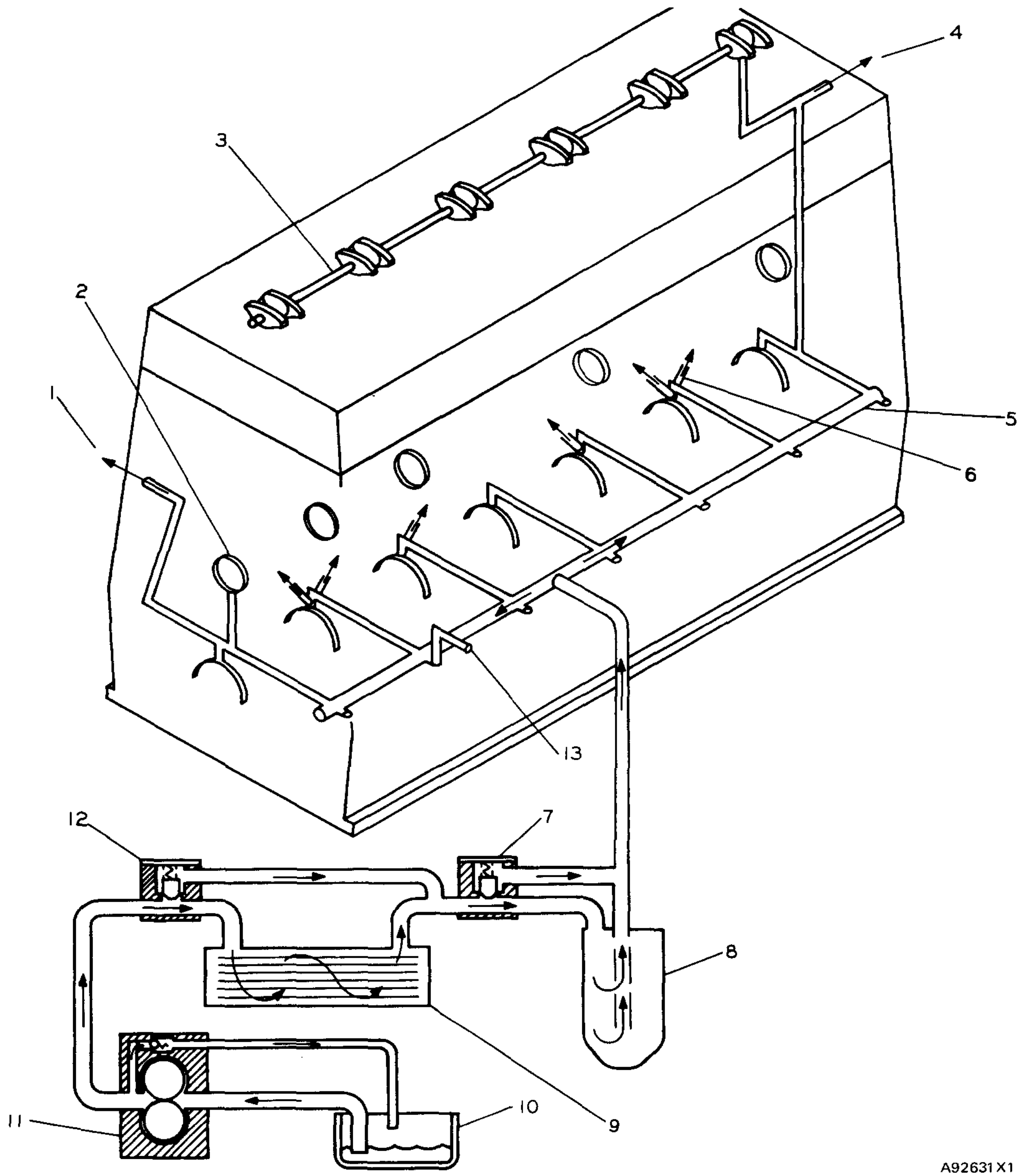
LUBRICATION SYSTEM SCHEMATIC
(3306 Engines With Turbocharger)



LUBRICATION SYSTEM SCHEMATIC

1. Oil supply to magneto drive. 2. Oil supply for turbocharger. 3. Oil pressure connection. 4. Camshaft bores. 5. Oil passage through rocker shaft to rocker arm. 6. Oil manifold. 7. Turbocharger. 8. Piston cooling orifices. 9. Oil cooler bypass. 10. Oil pump. 11. Oil cooler. 12. Oil filter bypass. 13. Oil sump. 14. Oil filter. 15. Oil supply to governor drive.

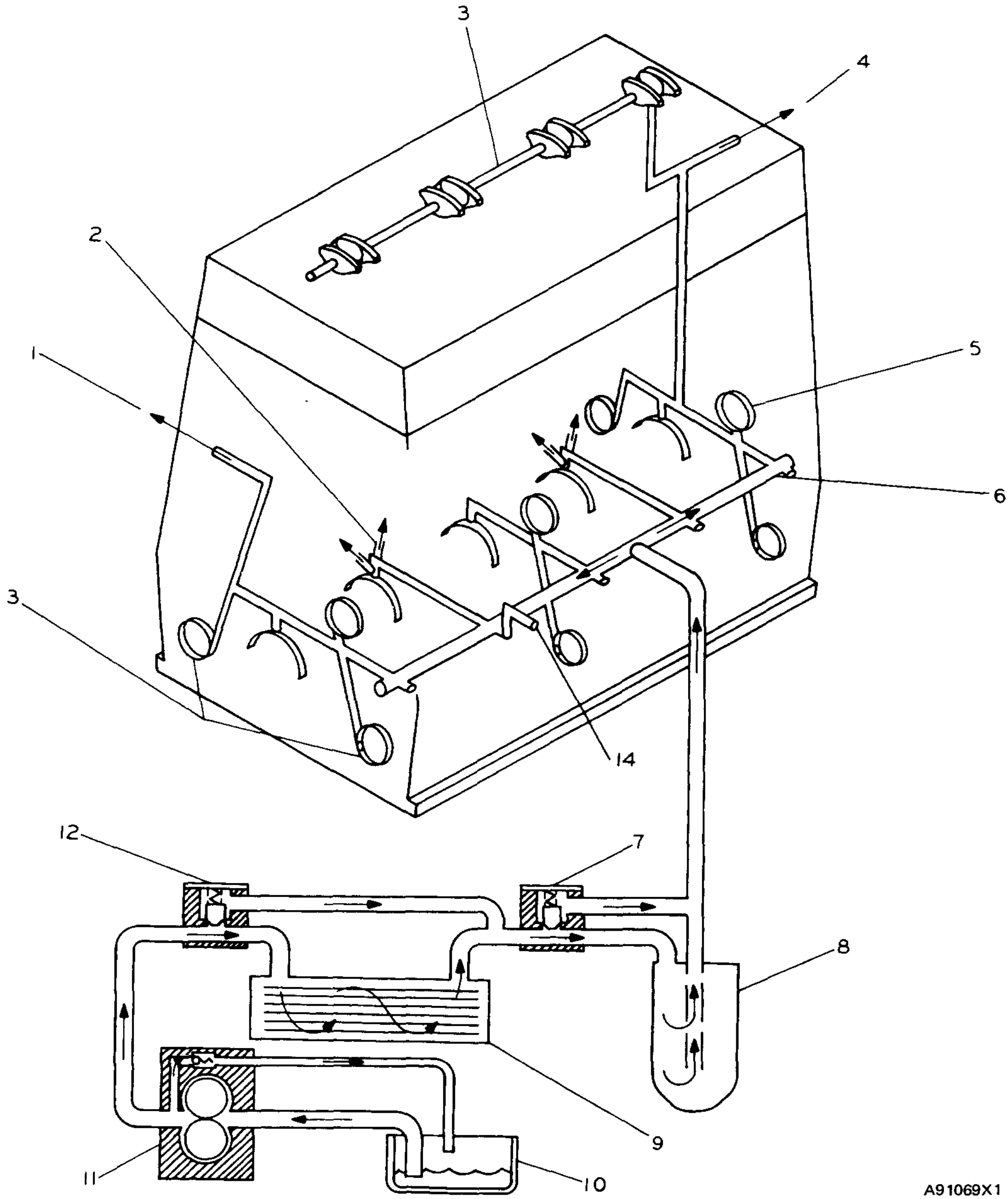
LUBRICATION SYSTEM SCHEMATIC
(3306 Engines Without Turbocharger)



LUBRICATION SYSTEM SCHEMATIC

1. Oil supply to magneto drive. 2. Camshaft bore. 3. Oil passage through rocker shaft to rocker arm. 4. Oil pressure connection. 5. Oil manifold. 6. Piston cooling orifices. 7. Filter bypass. 8. Oil filter. 9. Oil cooler. 10. Oil sump. 11. Oil pump. 12. Oil cooler bypass. 13. Supply to governor drive.

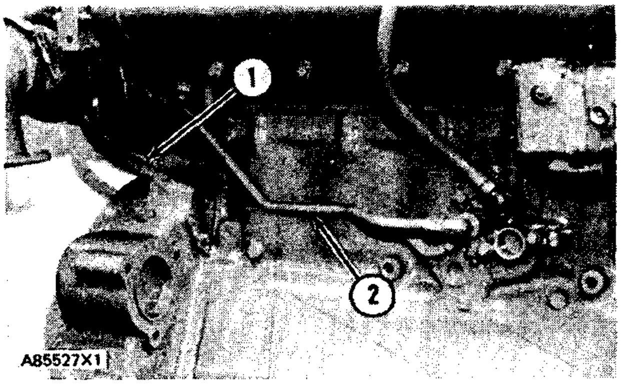
LUBRICATION SYSTEM SCHEMATIC (3304 Engine)



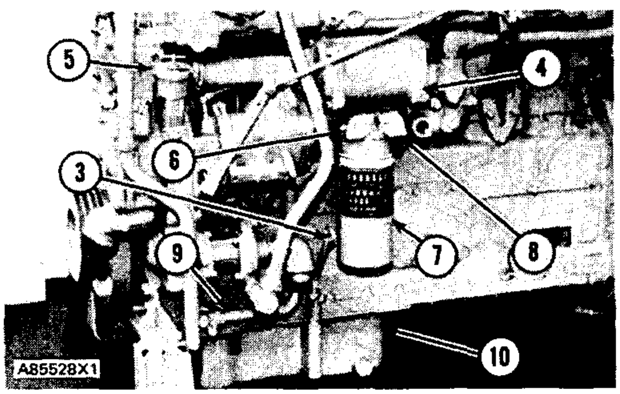
LUBRICATION SYSTEM SCHEMATIC

1. Oil supply to magneto drive. 2. Piston cooling orifices. 3. Oil passage through rocker shaft to rocker arm. 4. Oil pressure connection. 5. Camshaft bores. 6. Oil manifold. 7. Filter bypass. 8. Oil filter. 9. Oil cooler. 10. Oil sump. 11. Oil pump. 12. Oil cooler bypass. 13. Balancer shaft bores. 14. Oil supply to governor drive.

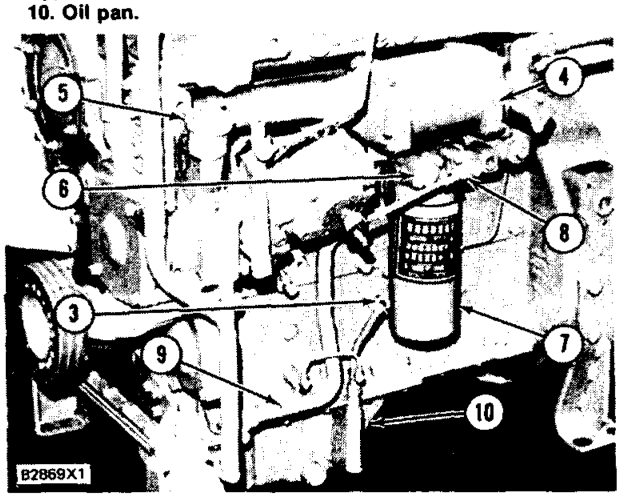
LUBRICATION SYSTEM COMPONENTS



LUBRICATION SYSTEM COMPONENTS
(3306 Engines With Turbocharger)
1. Return line for turbocharger. 2. Supply line for turbocharger.



LUBRICATION SYSTEM COMPONENTS
(3306 Engine)
3. Oil level gauge. 4. Engine oil cooler. 5. Oil filler cap. 6. Bypass valve for engine oil cooler. 7. Oil filter. 8. Bypass valve for oil filter. 9. Oil line to cooler and filter. 10. Oil pan.

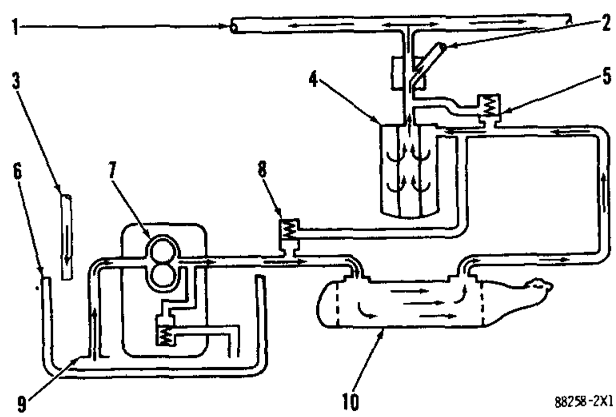


LUBRICATION SYSTEM COMPONENTS
(3304 Engine)
3. Oil level gauge. 4. Engine oil cooler. 5. Oil filler cap. 6. Bypass valve for engine oil cooler. 7. Oil filter. 8. Bypass valve for oil filter. 9. Oil line to cooler and filter. 10. Oil pan.

The lubrication system has the components that follow: oil pan, oil pump, oil cooler, oil filter, oil passages in the cylinder block, and lines to engine components and attachments such as turbocharger.

OIL FLOW THROUGH THE OIL FILTER AND OIL COOLER

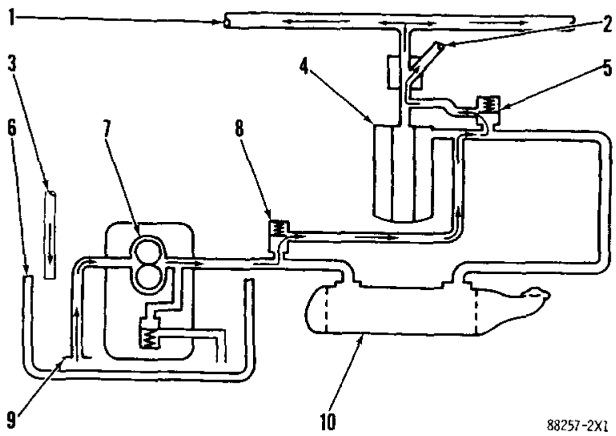
With the engine warm (normal operation), oil comes from oil pan (6) through suction bell (9) to oil pump (7). The oil pump sends warm oil to oil cooler (10) and then to oil filter (4). From the oil filter, oil is sent to oil manifold (1) in the cylinder block and to oil supply line (2) for the turbocharger. Oil from the turbocharger goes back through oil return line (3) to the oil pan.



FLOW OF OIL (ENGINE WARM)
1. Oil manifold in cylinder block. 2. Oil supply line to turbocharger. 3. Oil return line from turbocharger. 4. Oil filter. 5. Bypass valve for the oil filter. 6. Oil pan. 7. Oil pump. 8. Bypass valve for the oil cooler. 9. Suction bell. 10. Oil cooler.

With the engine cold (starting conditions), oil comes from oil pan (6) through suction bell (9) to oil pump (7). When the oil is cold, an oil pressure difference in the bypass valve (installed in the oil filter housing) causes the valves to open. These bypass valves give immediate lubrication to all components when cold oil with high viscosity causes a restriction to the oil flow through oil cooler (10) and oil filter (4). The oil pump then sends the cold oil through the bypass valve for oil cooler (8) and through the bypass valve for oil filter (5) to oil manifold (1) in the cylinder block and to supply line (2) for the turbocharger. Oil from the turbocharger goes back through oil return line (3) to the oil pan.

When the oil gets warm, the pressure difference in the bypass valves decreases and the bypass valve close. Now there is a normal flow of oil through the oil cooler and oil filter.



FLOW OF OIL (ENGINE COLD)

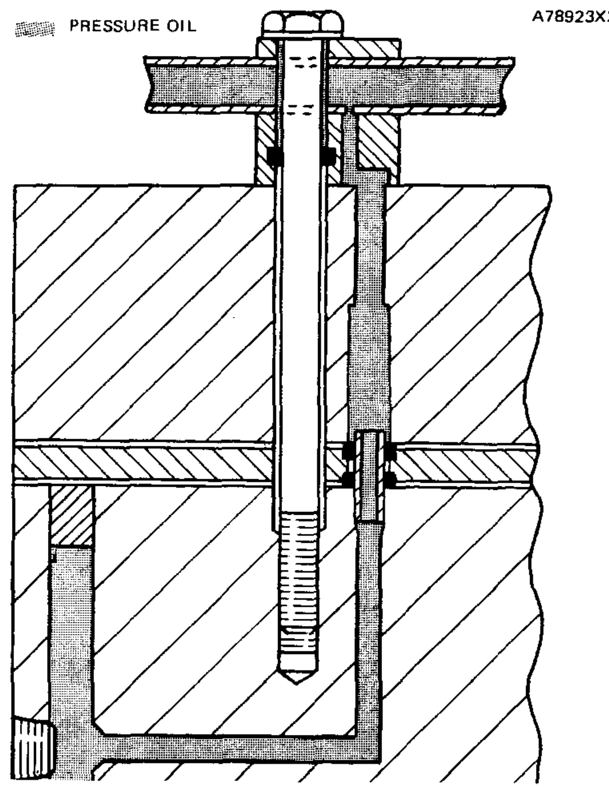
1. Oil manifold in cylinder block. 2. Oil supply line to turbocharger. 3. Oil return line from turbocharger. 4. Oil filter. 5. Bypass valve for the oil filter. 6. Oil pan. 7. Oil pump. 8. Bypass valve for the oil cooler. 9. Suction bell. 10. Oil cooler.

The bypass valves will also open when there is a restriction in the oil cooler or oil filter. This action does not let an oil cooler or oil filter with a restriction prevent lubrication of the engine.

OIL FLOW IN THE ENGINE

There is a bypass valve in the oil pump. This bypass valve controls the pressure of the oil that comes from the oil pump. The oil pump can put more oil into the system than needed. When there is more than needed, the oil pressure goes up and the bypass valve opens. This lets the oil that is not needed go back to the oil pan.

The output of the oil pump goes to the oil manifold in the cylinder block. The oil manifold is the source for oil under pressure and for the engine and its attachments. From the oil manifold the oil gets to the main bearings, timing gear bearings, and the bearings for the rocker arm shaft through oil passages.



ROCKER ARM OIL SUPPLY

The flow of oil which goes to the main bearings is divided. Some of the oil is the lubricant between the main bearings and the bearing surfaces (journals) of the crankshaft. Some of the oil goes through passages drilled in the crankshaft. This oil is the lubricant between the connecting rod bearings and the bearing surfaces (journals) of the crankshaft. The rest of the oil goes out through orifices in the block near the main bearings. This oil is both a coolant and a lubricant for the pistons, piston pins, cylinder walls and the piston rings.

An oil passage from the rear of the cylinder block goes below the head bolt hole and connects with a drilled passage that goes up next to the head bolt hole. A hollow dowel connects the vertical oil passage in the cylinder block to the oil passage in the head. The spacer plate has a hole with a counterbore on each side that the hollow dowel goes through. An O-ring is in each counterbore to prevent oil leakage around the hollow dowel. Oil flows through the hollow dowel into a vertical passage in the cylinder head to the rocker arm shaft bracket. The rocker arm shaft has an orifice to restrict the oil flow to the rocker arms. The rear rocker arm bracket also has an O-ring that seals against the head bolt. This seal prevents oil from going down around the head bolt and leaking past the head gasket or spacer plate gasket. The O-ring must be replaced each time the head bolt is removed from the rear rocker arm bracket.

Some of the oil is the lubricant for the valve stems. The rest of the oil drains on the cylinder head where it is the lubricant for the push rods and valve lifters and the cams for the camshaft. This oil is the lubricant for the intermediate and rear camshaft bearings.

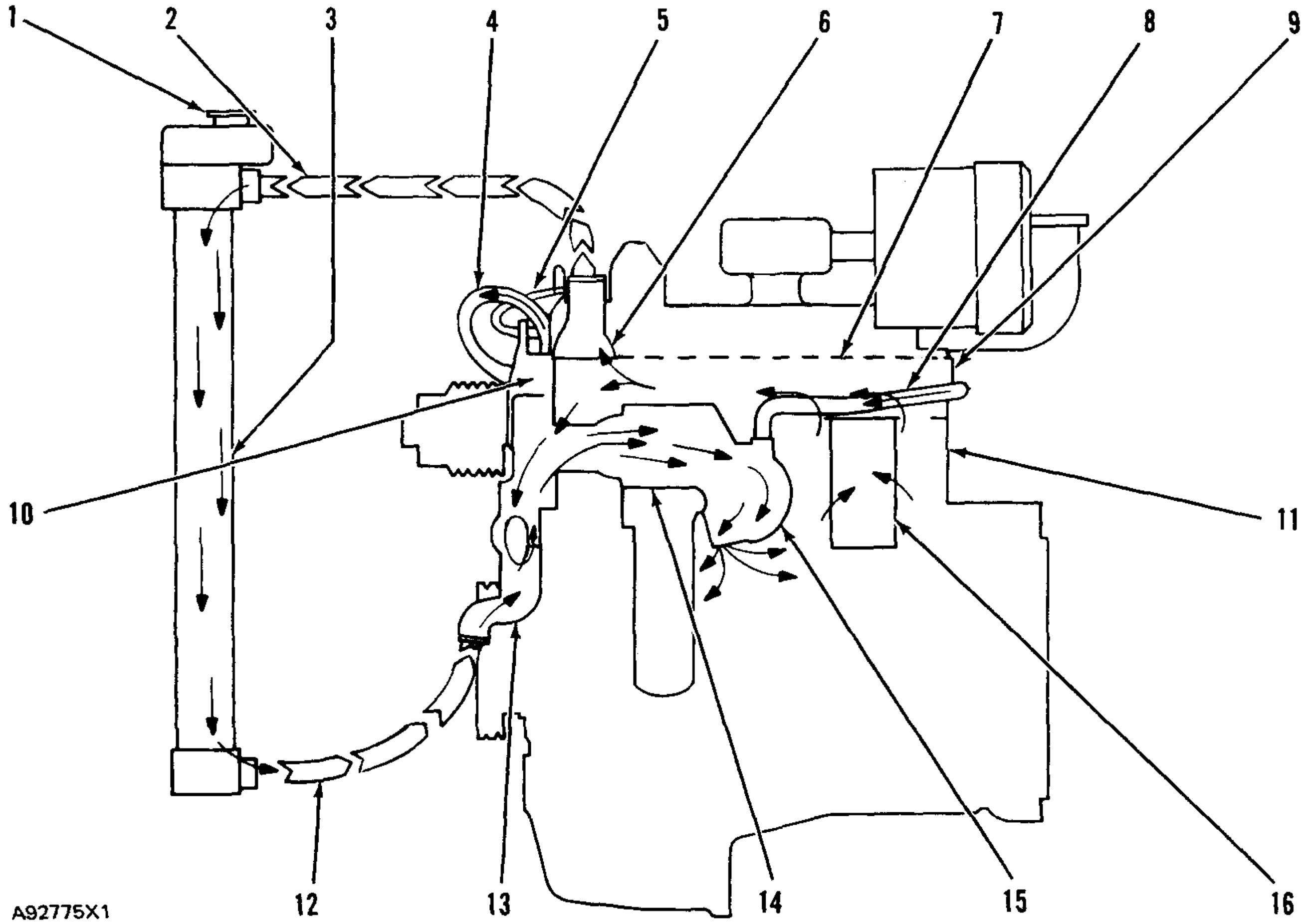
All timing gear bearings get lubricant under pressure from the oil manifold through drilled passages.

Oil goes to the components and attachments on the outside of the engine through supply lines which connect to the oil manifold. One of the supply lines goes to the turbocharger (engines so equipped).

After the lubrication oil has done its work, it goes back to the engine oil pan.

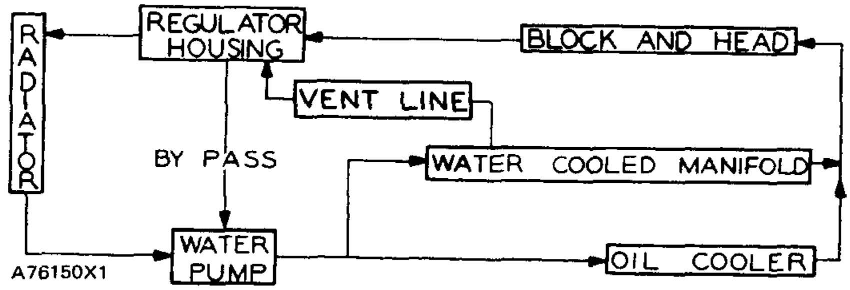
COOLING SYSTEM

COOLING SYSTEM SCHEMATIC (3304 Engines)



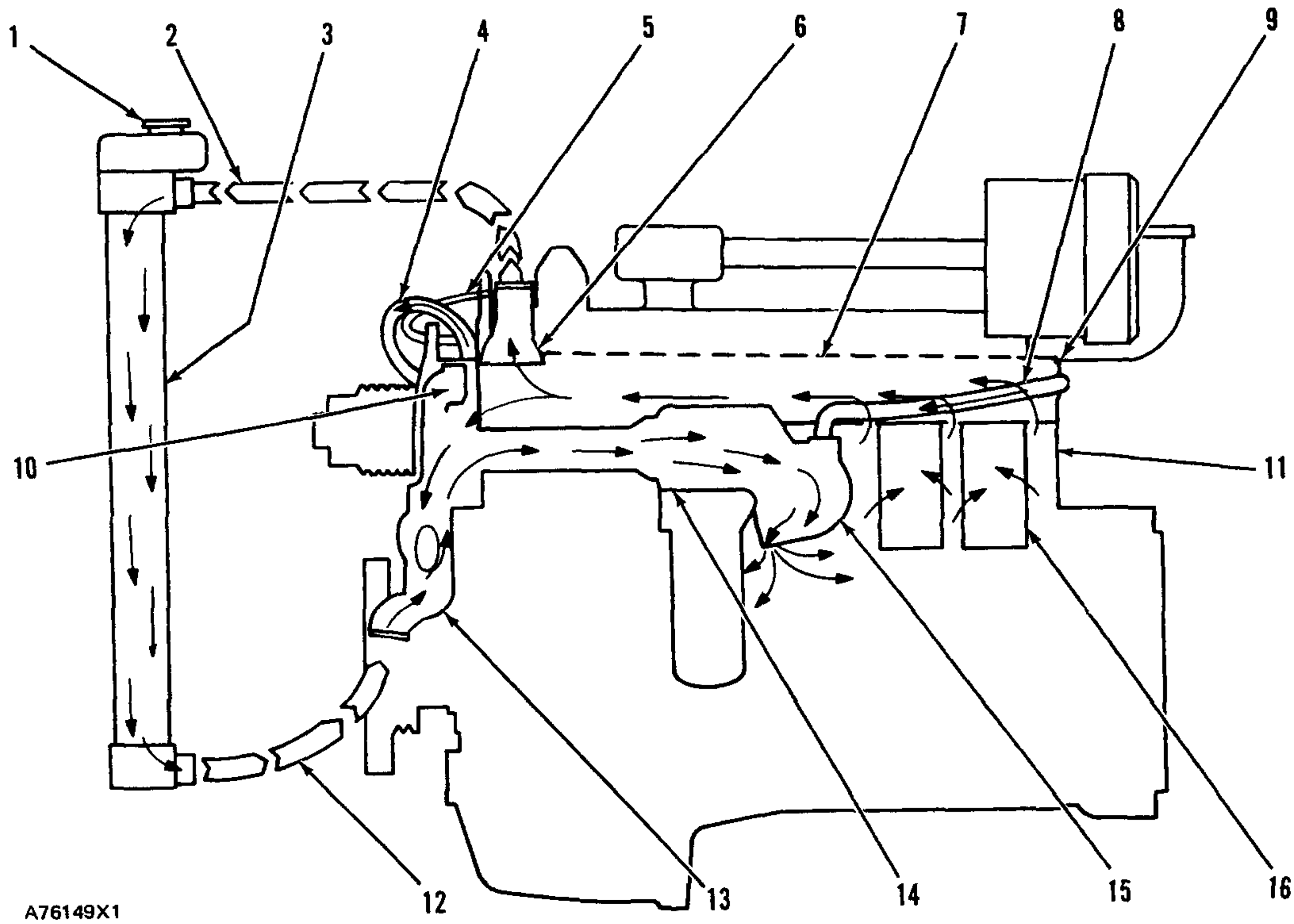
COOLANT FLOW SCHEMATIC

1. Pressure relief cap. 2. Inlet line for radiator. 3. Radiator. 4. Water cooled exhaust manifold inlet. 5. Vent line. 6. Temperature regulator. 7. Water cooled exhaust manifold. 8. Water cooled exhaust manifold outlet. 9. Cylinder head. 10. Internal passage. 11. Cylinder block. 12. Inlet line for water pump. 13. Water pump. 14. Oil cooler. 15. Oil cooler bonnet. 16. Cylinder liner.



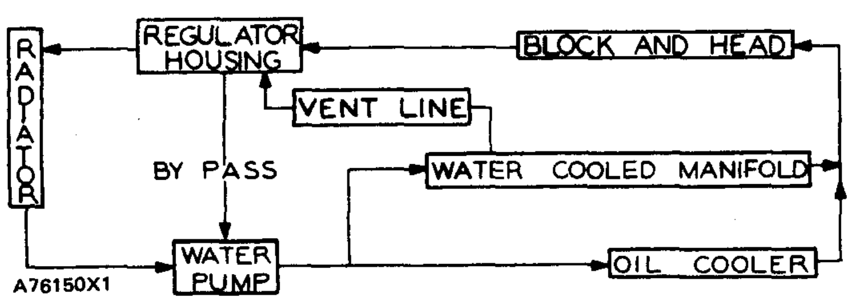
SCHEMATIC OF COOLING SYSTEM

COOLING SYSTEM SCHEMATIC (3306 Engines Without Turbocharger)



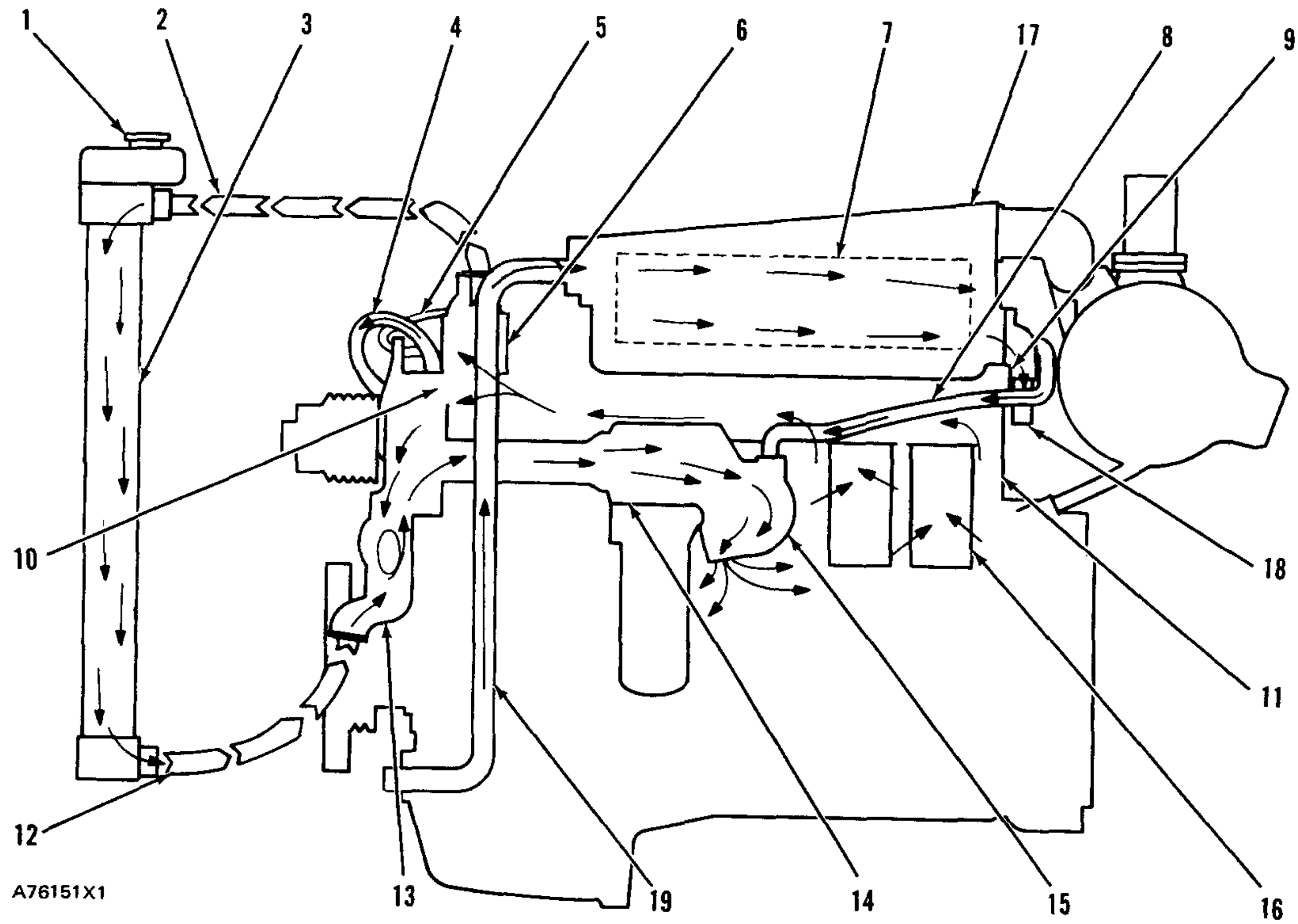
COOLANT FLOW SCHEMATIC

1. Pressure relief cap. 2. Inlet line for radiator. 3. Radiator. 4. Water cooled exhaust manifold inlet. 5. Vent line. 6. Temperature regulator. 7. Water cooled exhaust manifold. 8. Water cooled exhaust manifold outlet. 9. Cylinder head. 10. Internal passage. 11. Cylinder block. 12. Inlet line for water pump. 13. Water pump. 14. Oil cooler. 15. Oil cooler bonnet. 16. Cylinder liner.



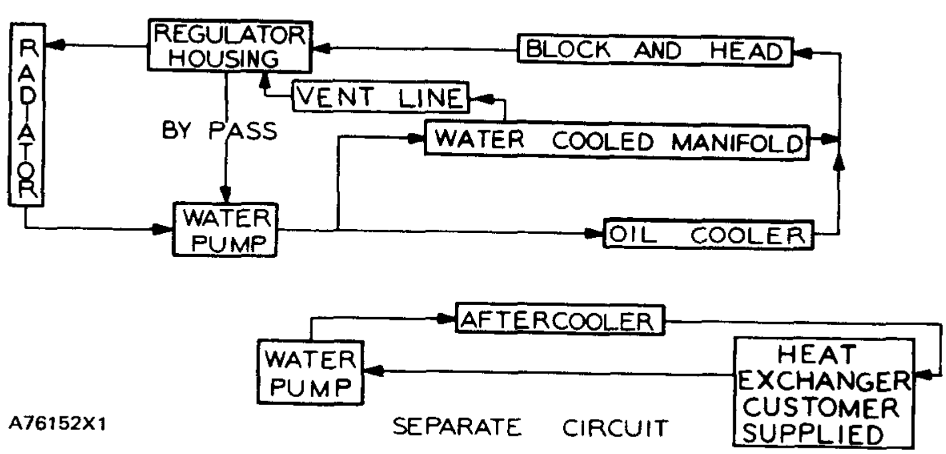
SCHEMATIC OF COOLING SYSTEM

COOLING SYSTEM SCHEMATIC (3306 Engines With Turbocharger)



COOLANT FLOW SCHEMATIC

1. Pressure relief cap. 2. Inlet line for radiator. 3. Radiator. 4. Water cooled exhaust manifold inlet. 5. Vent line. 6. Temperature regulator. 7. Water cooled exhaust manifold. 8. Water cooled exhaust manifold outlet. 9. Cylinder head. 10. Internal passage. 11. Cylinder block. 12. Inlet line for water pump. 13. Water pump. 14. Oil cooler. 15. Oil cooler bonnet. 16. Cylinder liner. 17. Aftercooler. 18. Aftercooler outlet. 19. Inlet line from auxiliary water pump to aftercooler.



SCHEMATIC OF COOLING SYSTEM

Water pump (13) is on the left front side of the engine. It is gear driven by the timing gears. Coolant from the bottom of radiator (3) goes to water pump inlet (12). The rotation of the impeller in the water pump pushes the coolant through the system.

Some of the coolant from water pump (13) goes through inlet line (4) to water cooled exhaust manifold (7). The remainder of the coolant goes through engine oil cooler (14) to bonnet (15). Bonnet (15) on the outlet side of engine oil cooler (14) connects to the side of cylinder block (11). The bonnet sends the coolant into the cylinder block.

Inlet line (4) for water cooled exhaust manifold (7) directs the coolant from water pump (13) to the front of water cooled exhaust manifold (7). The coolant goes through the manifold to the rear of the engine. It comes out through oulet line (8) and goes into bonnet (15) where it mixes with the rest of the coolant for the engine.

NOTICE

Vent line (5) must be connected to water cooled exhaust manifold (7) and to some higher point in the cooling system. This will prevent the possibility of cracking water cooled exhaust manifold (7) or cylinder head (9) due to trapped air in the cooling system. Trapped air will cause high cooling system temperatures and hot spots in the water cooled exhaust manifold and cylinder head.

Inside cylinder block (11) the coolant goes around cylinder liners (16) and up through the water directors into cylinder head (9). The water directors send the flow of coolant around the valves and the passages for exhaust gases in the cylinder head. The coolant goes to the front of the cylinder head. Here water temperature regulator (6) controls the direction of the flow. If the coolant temperature is less than normal for engine operation, water temperature regulator (6) is closed. The only way for the coolant to get out of cylinder head (9) is through internal bypass (10). The coolant from this line goes to water pump (13) which pushes it through the system again. The coolant from internal bypass (10) also works to prevent cavitation (air bubbles) in the coolant. When the coolant gets to the correct temperature, water temperature regulator (6) opens and coolant flow is divided. Most of the coolant goes through radiator (3) where it is made cooler. The remainder goes through the internal bypass (10) to water pump (13). The amount of the two flows is controlled by water temperature regulator (6).

NOTE: Water temperature regulator (6) is an important part of the cooling system. It divides coolant flow between radiator (3) and internal bypass (10) as necessary to maintain the correct temperature. If the water temperature regulator is not installed in the system, there is no mechanical control, and most of the coolant will take the path of least resistance thru internal bypass (10). This will cause the engine to overheat in hot weather. In cold weather, even the small amount of coolant that goes thru the radiator is too much, and the engine will not get to normal operating temperatures.

Internal bypass (10) has another function when the cooling system is being filled. It lets the coolant go into cylinder head (9) and cylinder block (11) without going through water pump (13).

Radiator (3) has a pressure relief cap (1). Pressure relief cap (1) keeps the pressure in the cooling system from getting too high when the engine is running. It also lets air come into the system when the pressure in the system is less than atmospheric.

Engines that have a turbocharger, have two completely seperate cooling circuits. One of these circuits is the engine coolant circuit. Normally this circuit cools the engine and all the attachments. The other circuit is the aftercooler circuit. It cools the aftercooler only. This type of cooling system keeps the temperatures of the coolant in the two circuits in the correct ranges for the maximum horsepower output.

The aftercooler circuit uses an auxiliary water pump. It is on the left front side of the engine and is driven by the timing gears.

The coolant for aftercooler (17) goes from the auxiliary water pump through aftercooler inlet line (19) into the core of the aftercooler (17). Aftercooler (17) is a group of plates and fins. The coolant goes through the plates. The inlet air for the engine goes around the fins. This cools the inlet air. The coolant comes out of the aftercooler at the rear of the engine and goes through outlet line (18) to the heat exchanger and back to the auxiliary water pump.

COOLING SYSTEM COMPONENTS

Water Pump

The centrifugal-type water pump has two seals. One prevents leakage of water, and the other prevents leakage of lubricant.

An opening in the bottom of the pump housing allows any leakage at the water seal or the rear bearing oil seal to escape.

Auxiliary Water Pump

The centrifugal-type auxiliary water pump has two seals.

One prevents leakage of water, and the other prevents leakage of lubricant.

An opening in the bottom of the pump housing allows any leakage at the water seal or the rear bearing oil seal to drain.

Fan

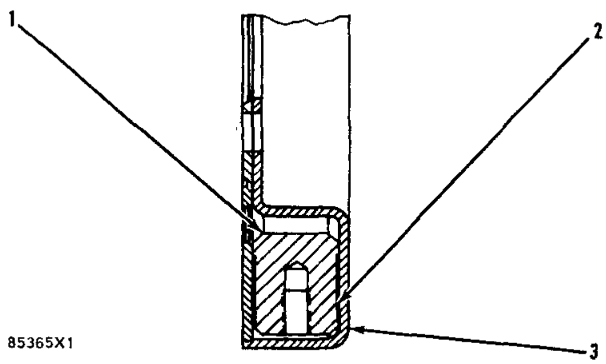
The fan is driven by V-belts, from a pulley on the crankshaft. To adjust the belt tension, move the clamp assembly.

BASIC BLOCK

VIBRATION DAMPER (3306 Engine)

The twisting of the crankshaft, due to the regular power impacts along its length, is called twisting (torsional) vibration. The vibration damper is installed on the front end of the crankshaft. It is used for reduction of torsional vibrations and stops the vibration from building up to amounts that could cause damage.

The damper is made of a weight (1) in a metal case (3). The small space (2) between the case and weight is filled with a thick fluid. The fluid permits the weight to move in the case to cause a reduction of vibrations of the crankshaft.



CROSS SECTION OF A TYPICAL VIBRATION DAMPER

1. Solid cast iron weight. 2. Space between weight and case. 3. Case.

ELECTRICAL SYSTEM

The electrical system can have three separate circuits: the charging circuit, the starting circuit and the low amperage circuit. Some of the electrical system components are used in more than one circuit. The battery (batteries), circuit breaker, ammeter, cables and wires from the battery are all common in each of the circuits.

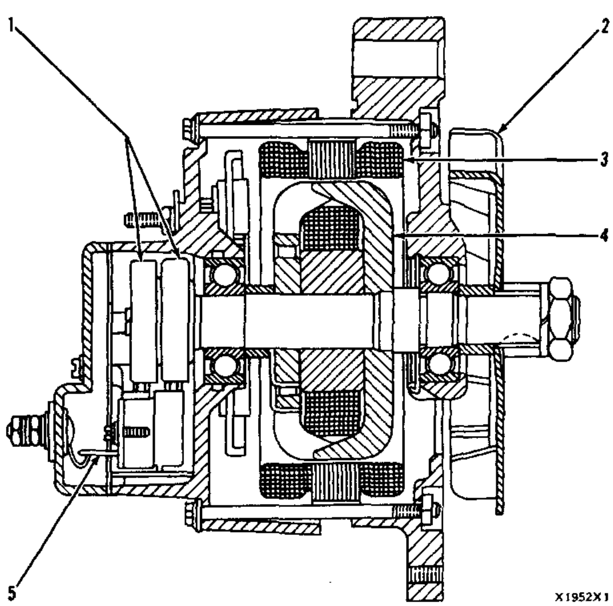
The charging circuit is in operation when the engine is running. An alternator makes electricity for the charging circuit. A voltage regulator in the circuit controls the electrical output to keep the battery at full charge.

The starting circuit is in operation only when the start switch is activated.

The low amperage circuit and the charging circuit are both connected to the same side of the ammeter. The starting circuit connects to the opposite side of the ammeter.

CHARGING SYSTEM COMPONENTS

Alternator (Motorola)



ALTERNATOR

1. Slip rings. 2. Fan. 3. Stator. 4. Rotor. 5. Brush assembly.

The alternator is a three phase, self rectifying charging unit. The alternator is driven from an auxiliary drive by a V-type belt.

The alternator has three main parts: a "rotating" (turning, radial motion) rotor (4) which makes magnetic lines of force; a stationary stator (3) in which alternating current (AC) is made; and stationary rectifying diodes that change alternating current (AC) to direct current (DC).

The alternator field current goes through the brushes. The field current is 2 to 3 amperes. The rectifying diodes will send current from the alternator to the battery or load, but will not send current from the battery to the alternator.

Regulator (Motorola)

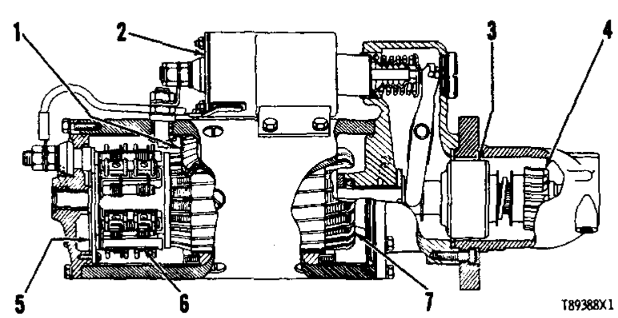
The voltage regulator is a transistorized electronic switch. It feels the voltage in the system at the switch for oil pressure and gives the necessary field current to keep the needed system voltage. The voltage regulator has two basic circuits, the load circuit and the control circuit.

The load circuit has a positive potential from the input lead of the regulator to the rotor (field) winding. The control circuit makes the load circuit go off and on at a rate that will give the needed charging voltage.

STARTING SYSTEM COMPONENTS

Starter Motor

The starter motor is used to turn the engine flywheel fast enough to get the engine running.

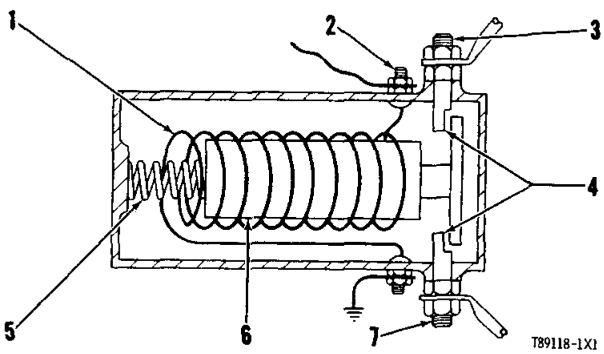


STARTER MOTOR

1. Field. 2. Solenoid. 3. Clutch. 4. Pinion. 5. Commutator. 6. Brush assembly. 7. Armature.

The starter motor has a solenoid. When the start switch is activated, electricity from the electrical system will cause the solenoid to move the starter pinion to engage with the ring gear on the flywheel of the engine. The starter pinion will engage with the ring gear before the electric contacts in the solenoid close the circuit between the battery and the starter motor. When the start switch is released, the starter pinion will move away from the ring gear of the flywheel.

Solenoid



SCHEMATIC OF A SOLENOID

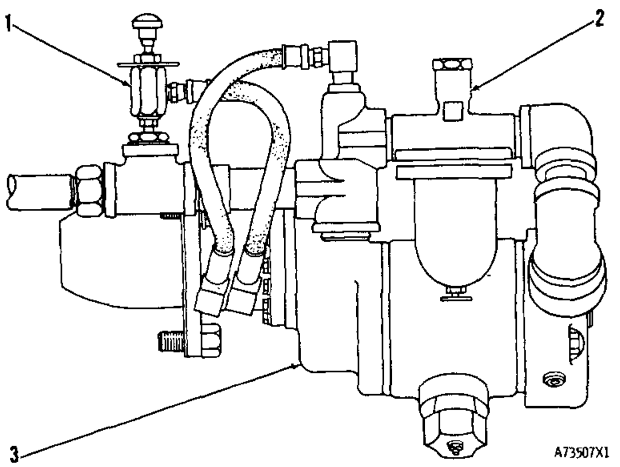
1. Coil. 2. Switch terminal. 3. Battery terminal. 4. Contacts. 5. Spring. 6. Core. 7. Component terminal.

A solenoid is a magnetic switch that uses low current to close a high current circuit. The solenoid has an electromagnet with a core (6) which moves.

AIR STARTING SYSTEM

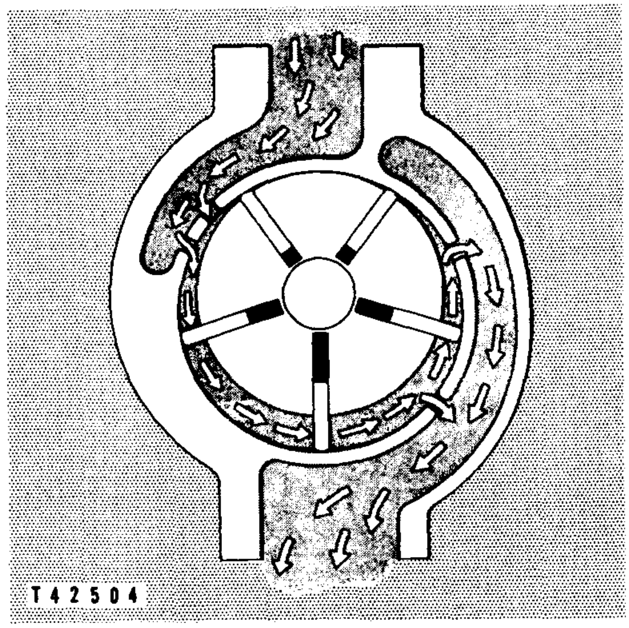
The air starting system is installed on the flywheel housing. Air for the starting system comes from an accessory air compressor. Air is sent through a tank to a remotely installed pressure regulator valve where the pressure is changed to a correct starting pressure.

To start the engine push on knob of starter control valve (1).



AIR STARTING SYSTEM
1. Starter control valve. 2. Oiler. 3. Air motor.

The starter control valve (1) controls the air passage to the air motor (3). As the air goes through the oiler (2) it gets an oil spray which gives lubrication to the rotor and vanes of the air motor.



FLOW OF AIR THROUGH STARTING MOTOR (VIEWED FROM DRIVE END OF MOTOR)

OILER

An air tube in the air passage through the body of the oiler causes pressure above the oil in the bowl. Oil is sent from the bowl through a tube and passage to a chamber under the top plug on the body. From the chamber a flow of oil goes through the oil drip orifice which permits a flow of oil of about four drops per minute.

TESTING AND ADJUSTING (Section 3)

TROUBLESHOOTING

Troubleshooting can be difficult. The TROUBLESHOOTING INDEX gives a list of possible problems. To make a repair to a problem, make reference to the cause and corrections on the pages that follow.

This list of problems, causes, and corrections, will only give an indication of where a possible problem can be, and what repairs are needed. Normally, more or other repair work is needed beyond the recommendations in the list. Remember that a problem is not normally caused only by one part, but by the relation of one part with other parts. This list is only a guide and can not give all possible problems and corrections. The serviceman must find the problem and its source, then make the necessary repairs.

TROUBLESHOOTING INDEX

1. ENGINE CRANKSHAFT WILL NOT TURN WHEN START SWITCH IS ON.

Cause	Correction
Battery Has Low Output	Make Reference to Item 26.
Wiring or Switches Have Defect	Make Reference to Item 26.
Starting Motor Solenoid Has A Defect	Make Reference to Item 25.
Starting Motor Has A Defect	Make Reference to Item 25.
Inside Problem Prevents Engine Crankshaft From Turning	If the crankshaft can not be turned after the driven equipment is disconnected, remove the spark plugs and check for fluid in the cylinders while the crankshaft is turned. If fluid in the cylinders is not the problem, the engine must be disassembled to check for other inside problems. Some of these inside problems are bearing seizure, piston seizure, or wrong pistons installed in the engine and valves making contact with pistons.

2. ENGINE WILL NOT START

Cause	Correction
Slow Cranking Speed	Make Reference to Item 26.
No Gas to Engine	Check gas supply and pressure regulator. Reset shutoff valve in the supply line. Check carburetor throttle and linkage between carburetor and governor.
Wrong Ignition Timing	Make adjustment to magneto timing.
Ignition System Failure	Check the ignition transformers for loose connection, moisture, short or open circuits. Check the low and high tension wires. Check the spark plugs for correct type and spark plug adapters. Check the magneto. Repair or replace any component that shows signs of failure.
Gas Line Pressure Regulator Not Working	Clean balance line. Check inlet and outlet regulator pressures.
Carburetor Not Working	Check all carburetor adjustments. Be sure that throttle plate is open and that governor permits it to open fully. Check the BTU content of the fuel based on lower heat value (LHV). If it is too low, a higher fuel pressure (correct spring in the regulator), or a special carburetor may be needed. Inspect the fuel-air diaphragm for leaks, dirt or wet fuel. Check the governor high idle and carburetor stop screw for low idle adjustments.
Slow Cranking Speed	Cranking speed must be at least 100 rpm. Check condition of starting system. Make reference to Item 25.
Switch of the Gauge Panel Broken	Hold in reset button of the magnetic switch while cranking to cut out (override) gauge switches.

3. MISFIRING OR RUNNING ROUGH

Cause	Correction
Ignition System Failure	Make Reference to Item 2.
Low Gas Pressure	Check for leaks in gas supply. Check the line pressure regulator, shutoff valve and solenoid. If two or more engines are used, be sure the common supply line is large enough. Regulator pressure should not change over the normal load range. Inspect the regulator diaphragm for leaks and valve for correct seat contact. Check gas pressure before and after the line pressure regulator. Check for restriction in balance line for carburetor to regulator. Set valve clearances.
Wrong Valve Clearance	Make adjustment according to Specifications.
Bent or Broken Push Rod	Replacement of push rod is necessary.

4. STALL AT LOW RPM

Cause	Correction
Idle rpm Too Low	Make adjustment to the throttle stop screw at the carburetor.
Too Much Load	Be sure the attachments do not put too much load on the engine. Make a reduction in load and/or make adjustment to throttle stop. If necessary, disconnect attachments and test engine.

5. SUDDEN CHANGES IN ENGINE SPEED

Cause	Correction
Governor Failure	Look for damaged or broken springs, linkage or other components. Check governor-to-carburetor linkage or other components. Check for correct spring.
Wrong Adjustment or Valve Leakage	Make adjustment to the valves. If necessary, make replacement of the valves.
Governor Springs Not Fully On Spring Seat	Put springs fully on spring seat.
Governor or Linkage Adjustment Incorrect	Check to see if linkage between governor and carburetor operates smoothly and has no free play. Make adjustment to the governor and linkage as necessary.
Low Gas Pressure	Make reference to Item 3.

6. NOT ENOUGH POWER

Cause	Correction
Low Gas Pressure or Gas Line Pressure Regulator Failure	Make reference to Item 3.
Carburetor Adjustment or Carburetor Not Working	Make reference to Item 2.
Leaks in Air Induction System	Check air cleaner for restriction. Check inlet manifold pressure on turbocharged engines.
Too Much Valve Clearance	Set to correct clearance.
Failure of Ignition Wires	Check for damage to wires arcing, or bare wire. Check rubber boot over spark plugs for cracks or moisture.
Transformer Failure	Check for loose connections, moisture, short or open circuits.
Bad Spark Plugs	Check type of plug used. Install correct type. Inspect for gas leaks and/or cracked porcelain. Clean and set gap of the plugs. Install new plugs if badly worn.
Wrong Ignition Timing	Make adjustment to magneto timing. Tighten any loose wires.
Spark Plug Adapters Leak	Check for water leakage into cylinder, or combustion gases in coolant. Install new adapters.
Boost Limit Control Failure	Check the valve movement.
Too Much Carbon In Turbocharger or Turbocharger Turns Too Slow	Inspect and install a new turbocharger as necessary.
Deposits in the Combustion Chamber	Make a compression test on all cylinders. Any cylinder which has great difference from the others should be inspected and cleaned.
Governor Linkage	Make adjustment to get full travel of linkage. Install new parts for those that have damage or defects.
Wrong Valve Clearance	Make adjustment according to Specifications.

7. TOO MUCH VIBRATION

Cause	Correction
Loose Bolt or Nut Holding Pulley or Damper	Tighten bolt or nut.
Pulley or Damper Has A Defect	Install a new pulley or damper.
Fan Blade Not in Balance	Loosen or remove fan belts and operate engine for a short time at the rpm that the vibration was present. If vibration is not still present, make a replacement of the fan assembly.
Engine Supports Are Loose, Worn, or Have a Defect	Tighten all mounting bolts. Install new components if necessary.
Misfiring or Running Rough	Make Reference to Item 3.
Balancer Shafts Not Correctly Timed	Put the balancer shafts in correct timing.

8. LOUD COMBUSTION NOISE (KNOCK)

Cause	Correction
Gas Octane Rating Too Low	Use recommended gas.
Detonation	Make reference to Item 33.
Preignition	Make reference to Item 32.

9. LOUD NOISE (CLICKING) FROM VALVE COMPARTMENT

Cause	Correction
Damage to Valve Spring(s) or Locks	Install new parts where necessary. Locks with defects can cause the valve to slide into the cylinder. This will cause much damage.
Not Enough Lubrication	Check lubrication in valve compartment. There must be a strong flow of oil at engine high rpm, but only a small flow of oil at low rpm. Oil passages must be clean, especially those that send oil to the cylinder head.
Too Much Valve Clearance	Make adjustment according to Specifications.
Damage to Valves	Make a replacement of the valve(s) and make an adjustment as necessary.

10. OIL IN COOLING SYSTEM

Cause	Correction
Defect In Core of Oil Cooler	Install a new oil cooler.
Defect of Head Gasket or Water Seals	Install a new head gasket and new water seals in spacer plate.

11. MECHANICAL NOISE (KNOCK) IN ENGINE

Cause	Correction
Failure of Bearing For Connecting Rod	Inspect the bearing for the connecting rod and the bearing surface on the crankshaft. Install new parts where necessary.
Damaged Timing Gears	Install new parts where necessary.
Defect in Attachment	Repair or install new components.
Broken Crankshaft	Install a new crankshaft. Check other components for damage.

12. GAS CONSUMPTION TOO HIGH

Cause	Correction
Gas System Leaks	Replacement of parts is needed at points of leakage.
Spark Plugs Not Firing	Check spark and install new plugs if necessary.
Wrong Ignition Timing	Make adjustment to magneto timing.

13. LOUD NOISE FROM VALVES OR VALVE DRIVE COMPONENTS

Cause	Correction
Damage to Valve Spring(s)	Make replacement of parts with damage.
Damage to Camshaft	Make replacement of parts with damage. Clean engine thoroughly.
Damage to Valve Lifter	Clean engine thoroughly. Make a replacement of the camshaft and valve lifters. Look for valves that do not move freely. Make an adjustment to valve clearance according to Specifications.
Damage to Valve(s)	Make a replacement of the valve(s) and make an adjustment as necessary.

14. LITTLE MOVEMENT OF ROCKER ARM AND TOO MUCH VALVE CLEARANCE

Cause	Correction
Too Much Clearance	Make adjustment according to Specifications.
Not Enough Lubrication	Check lubrication in valve compartment. There must be a strong flow of oil at engine high rpm, but only a small flow at low rpm. Oil passages must be clean, especially those that send oil to the cylinder head.
Rocker Arm Worn at Face That Makes Contact With Valve	If there is too much wear, install new rocker arms. Make adjustment of valve clearance according to the Specifications.
End of Valve Stem Worn	If there is too much wear, install new valves. Make adjustment of valve clearance according to Specifications.
Worn Push Rods	If there is too much wear, install new push rods. Make adjustment of valve clearance according to the Specifications.
Valve Lifters Worn	If there is too much wear, install new valve lifters. Make adjustment of valve clearance according to the Specifications.
Damage to Valve Lifters	Install new valve lifters. Check camshaft for wear. Check for free movement of valves or bent valve stem. Clean engine thoroughly. Make adjustment of valve clearance according to Specifications.
Worn Cams on Camshaft	Check valve clearance. Check for free movement of valves or bent valve stems. Check for valve lifter wear. Install a new camshaft. Make adjustment of valve clearance according to Specifications.

15. VALVE ROTOCOIL OR SPRING LOCK IS FREE

Cause	Correction
Damage to Locks	Locks with damage can cause the valve to fall into the cylinder. This will cause much damage.
Damage to Valve Spring(s)	Install new valve spring(s).

16. OIL AT THE EXHAUST

Cause	Correction
Too Much Oil in the Valve Compartment	Look at both ends of the rocker arm shaft. Be sure that there is a plug in each end.
Worn Valve Guides	Reconditioning of the cylinder head is needed.
Worn Piston Rings	Inspect and install new parts as needed.
Running Engine Too Long at Low Idle	Do not let the engine run for long periods of time at low idle.
Turbocharger Leak	Check turbocharger oil seals.

17. LITTLE OR NO VALVE CLEARANCE

Cause	Correction
Worn Valve Seat or Face of Valve	Reconditioning of cylinder head is needed. Make adjustment of valve clearance according to Specifications.

18. ENGINE HAS EARLY WEAR

Cause	Correction
Dirt in Lubrication Oil	Remove dirty lubrication oil. Install a new oil filter element. Put clean oil in the engine.
Air Inlet Leaks	Inspect all gaskets and connections. Make repairs if leaks are present.

19. COOLANT IN LUBRICATION OIL

Cause	Correction
Failure of Oil Cooler Core	Install a new oil cooler.
Failure of Cylinder Head Gasket or Water Seals	Install a new cylinder head gasket and new water seals in the spacer plate. Tighten the bolts that hold the cylinder head according to the Specifications.
Crack or Defect in Cylinder Head	Install a new cylinder head.
Crack or Defect in Cylinder Block	Install a new cylinder block.
Failure of Seals for Cylinder Liners	Make a replacement of the seals.

20. EXHAUST TEMPERATURE IS TOO HIGH

Cause	Correction
Air Inlet System Has A Leak	Check pressure in the air inlet manifold. Look for restrictions at the air cleaner. Correct any leaks.
Exhaust System Has A Leak	Find cause of exhaust leak. Make repairs as necessary.
Air Inlet or Exhaust System Has A Restriction	Remove restriction.
Wrong Ignition Timing	Make adjustment to magneto timing.

21. TOO MUCH WHITE OR BLUE SMOKE

Cause	Correction
Too Much Lubrication Oil in Engine	Remove extra oil. Find where extra oil comes from. Put correct amount of oil in engine.
Misfiring or Running Rough	Make reference to Item 3.
Wrong Timing	Make adjustment to magneto timing.
Worn Valve Guides	Reconditioning of cylinder head is needed.
Worn Piston Rings	Install new piston rings.
Failure of Turbocharger Oil Seal	Check inlet manifold for oil and make repair to turbocharger if necessary.

22. ENGINE HAS LOW OIL PRESSURE

Cause	Correction
Defect in Oil Pressure Gauge	Install new gauge.
Dirty Oil Filter or Oil Cooler	Check the operation of bypass valve for the filter. Install new oil filter elements if needed. Clean or install a new oil cooler. Remove dirty oil from engine. Put clean oil in engine.
Too Much Clearance Between Rocker Arm Shaft and Rocker Arms	Check lubrication in valve compartment. Install new parts as necessary.
Oil Pump Suction Pipe Has A Defect	Replacement of pipe is needed.
Relief valve for Oil Pump Does Not Operate Correctly	Clean valve and housing. Install new parts as necessary.
Oil Pump Has A Defect	Make repair or replacement of oil pump if necessary.
Too Much Clearance Between Camshaft and Camshaft Bearings	Install new camshaft and camshaft bearings if necessary.
Too Much Clearance Between Crankshaft and Crankshaft Bearings	Check the oil filter for correct operation. Install new parts if necessary.
Too Much Bearing Clearance for Idler Gear	Inspect bearings and make replacement as necessary.
Orifices For Piston Cooling Not Installed	Be sure orifices are installed in the cylinder block.

23. ENGINE USES TOO MUCH LUBRICATION OIL

Cause	Correction
Too Much Lubrication Oil in Engine	Remove extra oil. Find where extra oil comes from. Put correct amount of oil in engine.
Oil Leaks	Find all oil leaks. Make repairs as needed.
Oil Temperature is Too High	Check operation of oil cooler. Install new parts if necessary. Clean or install a new oil cooler.
Too Much Oil in Valve Compartment	Make Reference to Item 16.
Worn Valve Guides	Make Reference to Item 16.
Worn Piston Rings and Cylinder Liners	Install new parts if necessary.
Failure of Seal Rings in Turbocharger	Check inlet manifold for oil and make repair to turbocharger if necessary.

24. ENGINE COOLANT IS TOO HOT

Cause	Correction
Restriction To Air Flow Through Radiator or Restriction To Flow of Coolant Through the Heat Exchanger	Remove all restrictions to flow.
Not Enough Coolant in System	Add coolant to cooling system.
Pressure Cap Has Defect	Check operation of pressure cap. Install a new pressure cap if necessary.
Combustion Gases in Coolant	Find out where gases get into the cooling system. Make repairs as needed.
Water Temperature Regulator (Thermostat) or Temperature Gauge Has A Defect	Check water temperature regulator for correct operation. Check temperature gauge operation. Install new parts as necessary.
Water Pump Has A Defect	Make repairs to the water pump as necessary.
Too Much Load on The System	Make a reduction in the load.
Wrong Ignition Timing	Make adjustment to timing.

25. STARTER MOTOR DOES NOT TURN

Cause	Correction
Battery Has Low Output	Check condition of battery. Charge battery or make replacement as necessary.
Wires or Switch Has Defect	Make repairs or replacement as necessary.
Starter Motor Solenoid Has A Defect	Install a new solenoid.
Starter Motor Has A Defect	Make repair or replacement of starter motor.
Inside of Engine Problem	Make reference to Item 1.

26. ALTERNATOR GIVES NO CHARGE

Cause	Correction
Loose Drive Belt For Alternator	Make an adjustment to put the correct tension on the drive belt.
Charging or Ground Return Circuit or Battery Connections Have A Defect	Inspect all cables and connections. Clean and tighten all connections. Make replacement of parts with defect.
Brushes Have A Defect	Install new brushes.
Rotor (Field Coil) Has A Defect	Install a new rotor.

27. ALTERNATOR CHARGE RATE IS LOW OR NOT REGULAR

Cause	Correction
Loose Drive Belt For Alternator	Make an adjustment to put the correct tension on the drive belt.
Charging, Ground Return Circuit or Battery Connections Have A Defect	Inspect all cables and connections. Clean and tighten all connections. Make replacement of parts with defects.
Alternator Regulator Has A Defect	Make an adjustment or replacement of alternator regulator.
Alternator Brushes Have A Defect	Install new brushes.
Rectifier Diodes Have A Defect	Make replacement of rectifier diode that has a defect.
Rotor (Field Coil) Has A Defect	Install a new rotor.

28. ALTERNATOR CHARGE TOO HIGH (AS SHOWN BY BATTERY NEEDS TOO MUCH WATER)

Cause	Correction
Alternator or Alternator Regulator Has Loose Connections	Tighten all connections to alternator or alternator regulator.
Alternator Regulator Has A Defect	Make an adjustment or replacement of alternator regulator.

29. ALTERNATOR HAS NOISE

Cause	Correction
Drive Belt for Alternator is Worn or Has A Defect	Install a new drive belt for the alternator.
Loose Alternator Drive Pulley	Check groove in pulley for key that holds pulley in place. If groove is worn, install a new pulley. Tighten pulley nut according to Specifications.
Drive Belt and Drive Pulley For Alternator Are Not in Alignment	Make an adjustment to put drive belt and drive pulley in correct alignment.
Worn Alternator Bearings	Install new bearings in the alternator.
Armature or Rotor Shaft is Bent	Make a replacement of the component.
Rectifiers in the Alternator Are Shorted	Make a replacement of the diode assembly.

30. SOLENOID DOES NOT STOP ENGINE

Cause	Correction
Not Enough Plunger Travel	Make an adjustment to the plunger shaft or make a replacement of the solenoid if necessary.
Defect in Solenoid Wiring	Make a replacement of the solenoid.
Electrical Connections Are Not Correct	Correct electrical connections and wiring.
Adjustment for Plunger Shaft is Not Correct	Make an adjustment to the plunger shaft.
Wrong Plunger in Solenoid	Install the correct plunger in the solenoid.

31. SHORT SPARK PLUG LIFE

Cause	Correction
Wrong Polarity of Connections at Transformers	Check wiring diagrams in SYSTEMS OPERATION. Make change to the connection of wires to the primary coil of transformers.
Wrong Magneto Timing (Ignition Sequence)	Make adjustment to magneto timing.
Wrong Spark Plugs	Install correct spark plugs.

32. PREIGNITION

Cause	Correction
Worn Spark Plugs	Clean and make adjustment to the plug gap. If worn install new plugs.
Water Leakage in Cylinder or Combustion Gas	Inspect spark plug adapter gasket. Check spotface for adapter in head for roughness. Install a new adapter to correct torque.

33. DETONATION

Cause	Correction
Wrong Magneto Timing	Make adjustment to magneto timing.
Deposits in Combustion Chamber	Remove deposits from combustion chambers.
High Ambient Air Temperature	Check for high engine room temperature or high temperature of water to aftercooler.
Too Much Load	Make a reduction in the load.
Restrictions in Aftercooler	Inspect, clean or install new aftercooler as necessary.
Fuel to Air Ratio Too "Rich"	Check and make adjustment to gas regulator setting.

34. GAS SUPPLY LINE SHUTOFF VALVE FAILURE

Cause	Correction
Defect in Solenoid	Install new solenoid.
Wrong Electrical Rated Solenoid	Install new solenoid valve with correct valve.
Defect in Wiring and/or Connections	Correct the defect in wiring and connections.

35. INSTRUMENT PANEL GAUGE SWITCHES DO NOT STOP ENGINE

Cause	Correction
Loose Connection or Defect In Wiring	Check the wiring and tighten the connections at overspeed shutoff, water temperature gauge, oil pressure gauge, magnetic switch, stop switch, valve solenoid in gas supply line and magneto.
Defect in Magnetic Switch	Install a new magnetic switch.
Defect in Gauge Switches or Overspeed Shutoff	Make adjustment to or install new gauge or overspeed shutoff.
Defect in Valve Solenoid In The Gas Supply Line	Install a new solenoid valve.

36. INSTRUMENT PANEL GAUGE SWITCHES PREVENT ENGINE START

Cause	Correction
Defective Wiring	Check for wiring contact to ground.
Magnetic Switch Failure	Check wiring in panel for ground and gauge switches for failure.
High Water Temperature or Oil Pressure Gauge Switches not Reset or Failure of Switches	Permit engine to cool. Engage switches. Make adjustment or install new switches.

37. FAILURE OF OVERSPEED CONTACTOR SWITCH TO SHUTOFF ENGINE

Cause	Correction
Wrong Electrical Connections	Check connection, wiring and correct where necessary.
Wrong Adjustment	*Make adjustment or install new contactor switch.*

38. OVERSPEED CONTACTOR STOPS ENGINE AT LOW SPEED

Cause	Correction
Wrong Adjustment	Make adjustment or install new contactor switch if necessary.

39. AIR STARTING MOTOR TURNS SLOWLY

Cause	Correction
Low Supply Air Pressure	Make an increase to the air supply pressure.
Pressure Regulator Adjustment Not Correct	Make an adjustment to the air pressure regulator.
Oiler Not Working Correctly	Clean, make an adjustment to, and fill oiler.

40. TROUBLESHOOTING SOLID STATE MAGNETO (FAIRBANKS MORSE)

40A. Missing on One or More Cylinders

1. Use a 1P1790 Firing Indicator to find which cylinder(s) is missing.

   Note: The brightness of the neon bulb used in this tool indicates the required voltage of the spark plug only. It does not reflect the output of the magneto.

2. Find which wire, in the primary magneto harness, (wire from magneto to transformer), is connected to the problem cylinder. See Wiring Diagrams in SYSTEMS OPERATION.
3. Stop the engine and disconnect the magneto harness connector from the magneto.

   Note: All ohmmeters must be "zeroed" (adjusted to read zero when the leads are connected together) before using. Follow instructions with your meter.

   All meters have a percentage of error because of the type of meter movement used. This error can be from 3 to 5%. A variation between meters is normal.

4. Using an ohmmeter having a scale of RX1, connect the probes between the pin of the problem cylinder, (pin in wiring harness), and a good ground. Read the resistance. The resistance should be between .3 and .6 ohms. If reading is within specification the primary circuit is not defective. Proceed to Step 7.

   A reading of less than .3 ohms indicates grounded primary wire or shorted primary in the transformer.

   A reading of more than .6 ohms indicates poor connections, defective primary in transformer, or poor ground connection.

5. To locate the defect, disconnect the primary wire from the transformer, (wire from magneto). Connect the ohmmeter to the primary stud of the transformer and ground. Check resistance again. Correct reading is .3 to .6 ohms.

   Correct reading: defect in primary harness wire or connector in harness.

   Incorrect reading: defective transformer or poor ground.

6. Connect the ohmmeter across the primary terminals of the transformer. Read the resistance. Correct reading is .3 to .6 ohms.

   Correct reading: poor ground.

   Incorrect reading: defective transformer.

7. With the magneto harness still disconnected, remove the spark plug high tension lead from the spark plug. Do not remove the transformer.

8. Using a scale of RX 100 or RX1000, connect the ohmmeter between the spark plug connector and ground. The resistance should be between 11,000 to 13,000 ohms.

   Correct reading: defective spark plug or magneto.

   Incorrect reading: defective spark plug high tension lead, transformer or ground.

9. Remove the spark plug high tension lead from the transformer. Read resistance between high tension outlet of the transformer to ground. The resistance should be between 11,000 to 13,000 ohms.

   Correct reading: defective spark plug high tension lead and/or connections.

   Incorrect reading: defective transformer or ground.

10. Connect ohmmeter between the high tension outlet of the transformer and ground terminal of the transformer. The correct reading is 11,000 to 13,000 ohms.

    Correct reading: defective ground.

    Incorrect reading: defective transformer.

40B. Engine Dead and Has No Spark

1. At a convenient place, break the connection between the "H" wire of the magneto harness and the shutdown circuit. Try to start the engine.

   Engine Starts: Defect in shutdown circuit.
   Repair as required.

   Engine Does Not Start: Proceed to Step 2.

2. Connect an ohmmeter, using high scale, between the "H" wire, at the place you made the break, and ground.

   A reading of "Infinite": "H" lead not grounded.

   Any resistance: Grounded "H" lead or defective magneto.

   Note: For this test, any reading over 500,000 ohms is to be considered infinite.

3. Remove harness connector from magneto. Connect an ohmmeter, using high scale, between "H" pin in the harness connector and ground. Be sure to touch only the "H" pin when making this test.

   A reading of "Infinite": "H" lead not grounded. Defective magneto. Replace the magneto.

   Any resistance: "H" lead grounded. Repair as required.

NOTICE

Be sure to reconnect "H" lead to shutdown circuit after repairs are made. Failure to do so will leave the engine unprotected and damage could result.

41. TROUBLESHOOTING SOLID STATE MAGNETO (ALTRONIC)

41A. Missing on One or More Cylinders

1. Use a 1P1790 Firing Indicator to find which cylinder(s) is missing.

   Note: The brightness of the neon bulb used in this tool indicates the required voltage of the spark plug only. It does not reflect the output of the magneto.

2. Find which wire, in the primary magneto harness, (wire from magneto to transformer), is connected to the problem cylinder. See Wiring Diagrams in SYSTEMS OPERATION.

3. Stop the engine and disconnect the magneto harness connector from the magneto.

   Note: All ohmmeters must be "zeroed" (adjusted to read zero when the leads are connected together) before using. Follow instructions with your meter.

   All meters have a percentage of error because of the type of meter movement used. This error can be from 3 to 5%. A variation between meters is normal.

4. Using an ohmmeter having a scale of RX1, connect the probes between the pin of the problem cylinder, (pin in wiring harness), and a good ground. Read the resistance. The resistance should be between .1 and .2 ohms. If reading is within specification the primary circuit is not defective. Proceed to Step 7.

   A reading of less than .1 ohm indicates grounded primary wire or shorted primary in the transformer.

   A reading of more than .2 ohms indicates poor connections, defective primary in transformer, or poor ground connection.

5. To locate the defect, disconnect the primary wire from the transformer, (wire from magneto). Connect the ohmmeter to the primary stud of the transformer and ground. Check resistance again. Correct reading is .1 to .2 ohms.

   Correct reading: defect in primary harness wire or connector in harness.

   Incorrect reading: defective transformer or poor ground.

6. Connect the ohmmeter across the primary terminals of the transformer. Read the resistance. Correct reading is .1 to .2 ohms.

   Correct reading: poor ground.

   Incorrect reading: defective transformer.

7. With the magneto harness still disconnected, remove the spark plug high tension lead from the spark plug. Do not remove the transformer.

8. Using a scale of RX 100 or RX1000, connect the ohmmeter between the spark plug connector and ground. The resistance should be between 5,000 to 8,000 ohms.

   Correct reading: defective spark plug or magneto.

   Incorrect reading: defective spark plug high tension lead, transformer or ground.

9. Remove the spark plug high tension lead from the transformer. Read resistance between high tension outlet of the transformer to ground. The resistance should be between 5,000 to 8,000 ohms.

   Correct reading: defective spark plug high tension lead and/or connections.

   Incorrect reading: defective transformer or ground.

10. Connect ohmmeter between the high tension outlet of the transformer and ground terminal of the transformer. The correct reading is 5,000 to 8,000 ohms.

    Correct reading: defective ground.

    Incorrect reading: defective transformer.

41B. Engine Dead and Has No Spark

1. Disconnect the M_1 terminal of the magnetic switch on the engine instrument panel. Try to start the engine.

   Engine Starts: Defect in shutdown circuit. Repair as required.

   Engine Does Not Start: Proceed to Step 2.

2. Connect an ohmmeter between the wire that was removed from the magnetic switch M_1 terminal and ground.

   An ohmmeter reading of infinite (500,000 ohms or greater).

   a. The wire is not grounded.

   b. Possible defective magneto.

   A resistance indication on the ohmmeter.

   a. Grounded wire between instrument panel and magneto.

   b. Defective magneto.

3. Remove the wiring harness connector from the magneto. Connect an ohmmeter between the G pin in the wiring harness connector and ground.

   a. Any resistance indication means that the wire is grounded. Replace or repair as required.

   b. A reading of infinite indicates that the wire is not grounded. Defective magneto. Repair or replace the magneto.

NOTICE

Be sure to reconnect the wire to the magnetic switch and the connector to the magneto after the repairs are made.

IGNITION SYSTEM

To make a test of the magneto on the engine, check the condition (intensity) of the spark at the spark plug. Remember that the condition of the instrument panel components: magnetic switch, stop switch, oil pressure gauge and water temperature gauge have an effect on the output of the magneto. A defect in, or an activated overspeed shutoff contact or gas line solenoid valve can cause an indication of a defect in the magneto.

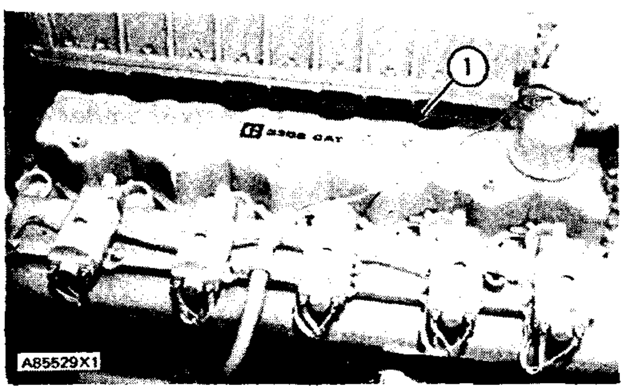
A test of the magneto off the engine can be used to find a defect in the electrical components. The 2P2340 Magneto Test Bench is used to make the tests. Special Instruction Form No. GEG02059 gives the complete test procedure.

FINDING TOP CENTER COMPRESSION POSITION FOR NO. 1 PISTON

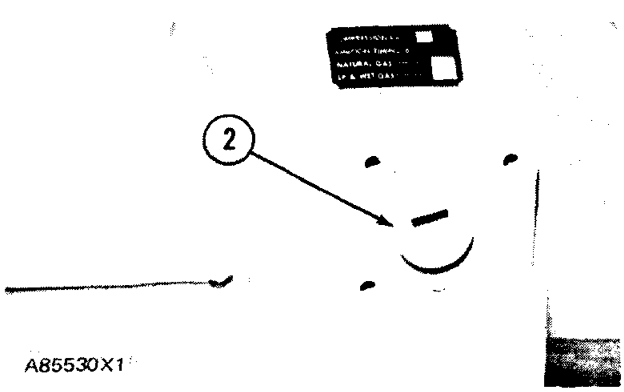
Tools Needed: 5P7307 Engine Turning Tool Group.

No. 1 piston at top center (TC) on the compression stroke is the starting point for all timing procedures.

1. Remove valve cover (1).

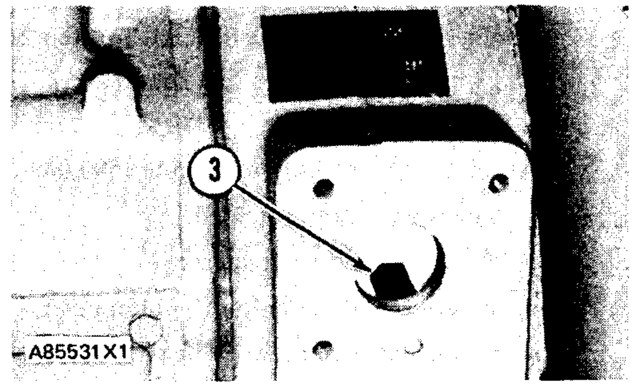


LOCATION OF VALVE COVER
(3306 Engine Shown)
1. Valve cover.



TIMING MARK PLUG
2. Plug.

2. Remove plug (2) from the housing for the flywheel.

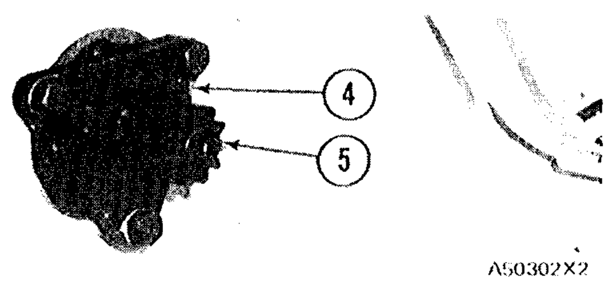


TIMING MARKS ON FLYWHEEL
3. Pointer.

3. Turn the flywheel in the direction of engine rotation until No. 1 piston is at top center (TC) on the compression stroke. An indication is by pointer (3).

4. Look at the valves for No. 1 cylinder (the two valves at the front of the engine). The intake valve and exhaust valve for No. 1 cylinder must be closed.

5. If the intake and exhaust valves for No. 1 cylinder are not closed, turn the flywheel in the direction of engine rotation 360°. If both valves are now closed, this is top center (TC) compression position for No. 1 piston.



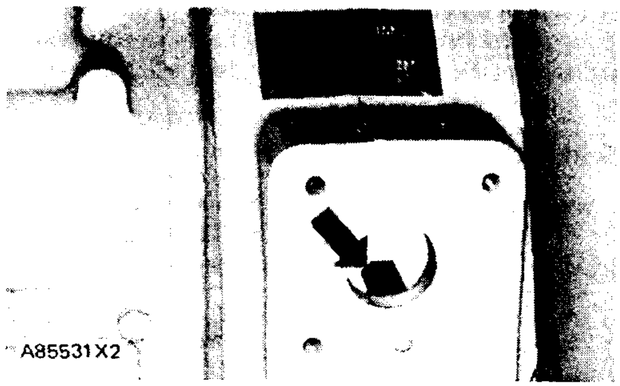
ENGINE TURNING TOOLS
(Typical Example)
4. 5P7306 Housing. 5. 5P7305 Gear.

NOTE: If the flywheel is turned too far, turn it in the other direction a minimum of 60°, then turn the flywheel in the direction of engine rotation until No. 1 piston is at top center (TC) on compression stroke.

TIMING OF MAGNETO TO ENGINE (SPARK GAP)

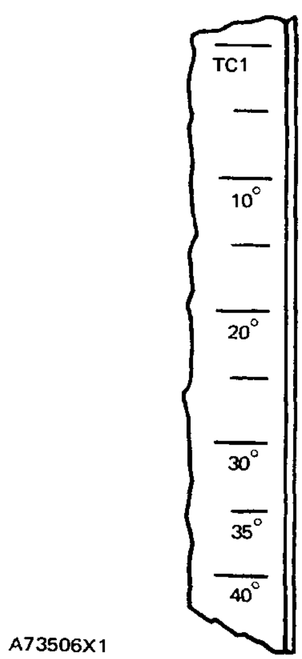
Tools Needed: 5P7307 Engine Turning Tool Group.

1. Turn the flywheel in direction of engine rotation until the No. 1 piston is coming up on the compression stroke. See subject Finding Top Center Compression Position for No. 1 Piston.



FLYWHEEL POINTER

2. Turn the flywheel until the desired timing mark is directly under the flywheel pointer. See the Chart INSTRUCTIONS FOR TIMING MAGNETO TO NO. 1 CYLINDER.



FLYWHEEL TIMING MARKS

3. With the magneto off the engine, remove the timing nut (2) and turn the magneto drive until the yellow mark on distributor disc is in the center of the hole.

4. Put the magneto drive slot (1) in vertical position as shown in illustration. The drive coupling can be pulled out, put in the correct position, and then pushed in to engage with the gear teeth.

INSTRUCTIONS FOR TIMING MAGNETO TO NO. 1 CYLINDER (3306 Engine)

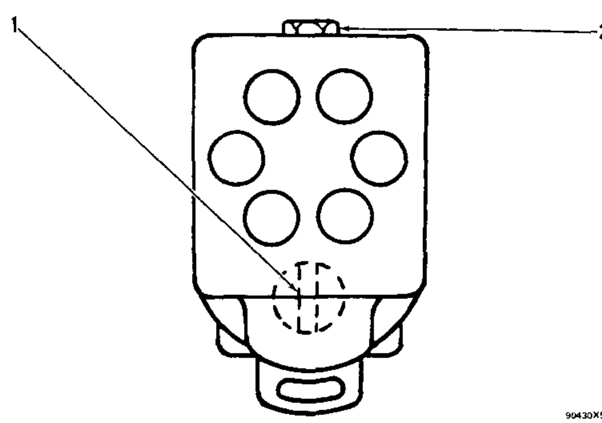
Compression Ratio	Other Conditions	Flywheel Mark Engine Stopped or Running
10.5:1	N.A. (Natural Gas)	35° BTC
10.5:1	T.A. (Natural Gas)	25° BTC
10.5:1	N.A. (Propane)	17.5° BTC
10.5:1	T.A. (Propane)	15° BTC
8:1	N.A. (Natural Gas)	40° BTC
8:1	T.A. (Natural Gas)	35° BTC
8:1	N.A. (Propane)	30° BTC
8:1	T.A. (Propane)	20° BTC

BTC = Before top center.

INSTRUCTIONS FOR TIMING MAGNETO TO NO. 1 CYLINDER (3304 Engine)

Compression Ratio	Other Conditions	Flywheel Mark Engine Stopped or Running
10.5:1	N.A. (Natural Gas)	35° BTC
10.5:1	N.A. (Propane)	17.5° BTC
8:1	N.A. (Natural Gas)	40° BTC
8:1	N.A. (Propane)	30° BTC

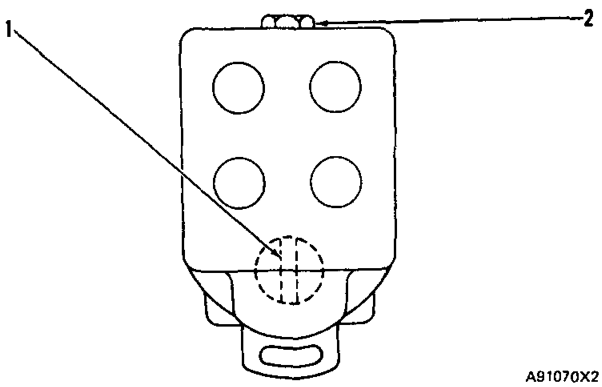
BTC = Before top center.



DRIVE TANG AND SLOT POSITION FOR 3306 ENGINE
(Seen from Rear of Engine)
1. Drive tang and slot. 2. Timing nut.

5. Install the magneto. The drive tang and slot will engage.

6. Make the final timing adjustment by turning the magneto at the drive housing mounting. Use a timing light with the engine running to check the alignment of the correct mark on the flywheel with the pointer.



DRIVE TANG AND SLOT POSITION FOR 3304 ENGINE
(Seen from Rear of Engine)
1. Drive tang and slot. 2. Timing nut.

Firing Order

The firing order (ignition sequence) is 1, 3, 4, 2 for 3304 Engine and 1, 5, 3, 6, 2, 4 for 3306 Engine. The direction of the arrows in the illustrations show the rotation of the magneto distributor disc (A) and the drive tang (B) as seen from the end cap cover (rear of engine).

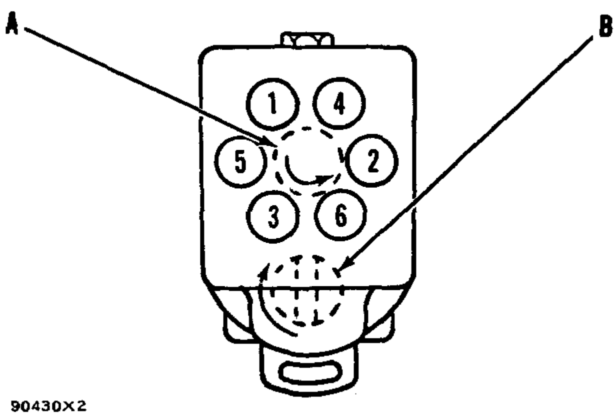


DIAGRAM OF MAGNETO NUMBERING
(Seen from rear of engine)
A. Magneto distributor disc. B. Drive tang.

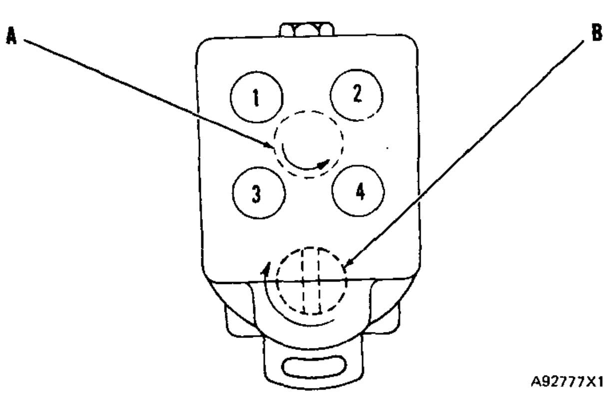


DIAGRAM OF MAGNETO NUMBERING
(Seen from rear of engine)
A. Magneto distributor disc. B. Drive tang.

Magneto Point Gap

Make the magneto point gap setting to .017 in. (0.43 mm).

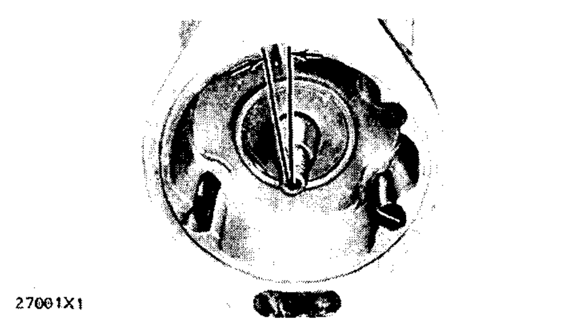
Magneto Edge Gap

The maximum ignition discharge is a result of breaking the primary circuit at the exact point in time that the voltage in the primary circuit is at the maximum value. At this point the contact points are just starting to open.

Field Method

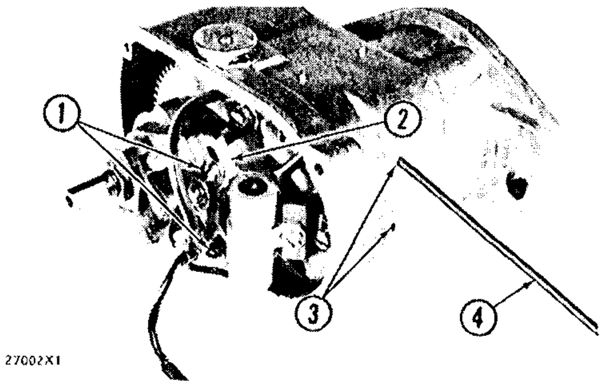
When the setting of the edge gap is needed and can not be made with the use of 2P2340 Magneto Test Bench, a temporary setting can be made.

1. Check the contact points and make an adjustment to the proper gap, if needed.
2. Remove the impulse coupling.
3. Turn the rotor shaft so the keyway is up. Then turn the shaft approximately 15° in the direction of rotation.



POSITION OF SHAFT
(Counterclockwise Magneto)

4. Look at magneto from the drive end. Remove the setscrew and put a .094 in. (2.39 mm) diameter rod (4) in the right timing hole (3). The left hole is used for clockwise rotation magnetos. Do not use it.
5. Loosen screws (1) for the support plate (2).
6. Push rod (4) in until it is in contact with the rotor. Turn the rotor shaft in the direction opposite the normal rotation until the rod is tight between the rotor pole shoe and housing field.
7. With the rotor in this position, move the plate (2) either left or right until the contact points start to open. Tighten the screws (1) for the support plate.
8. Install the impulse coupling.



EDGE GAP ADJUSTMENT
(Counterclockwise Magneto)

1. Screws for the support plate. 2. Support plate. 3. Timing holes. 4. Rod.

Shop Method

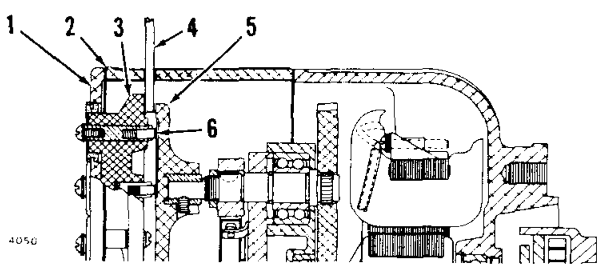
Tools Needed: 2P2340 Magneto Test Bench.

The method of making the edge gap setting with the most accuracy is with the 2P2340 Magneto Test Bench. The complete instructions for making the setting are in Special Instruction Form No. GEG02059. The correct speed for rotation of the magneto is 1800 rpm.

Brush Spring Adjustment

Each time service is done on a magneto, a check must be made of the distance between the distributor block (3) and the face of the distributor disc (5). The correct gap gives the correct pressure on the brush and spring assembly (6). Remove the timing bolt and put a drill rod (4) between distributor block (3) and distributor disc (5). The clearance is .156 to .219 in. (3.96 to 5.56 mm).

To make an increase in clearance use additional gaskets (2) for the end cap cover. To make a decrease in clearance use number 10 washers between the distributor block (3) and end cap cover (1).



MAKING A CHECK OF THE BRUSH SPRING ADJUSTMENT

1. End cap cover. 2. Gasket for the end cap cover. 3. Distributor block. 4. Drill rod. 5. Distributor disc. 6. Brush and spring assembly.

TIMING OF MAGNETO TO ENGINE (SOLID STATE FAIRBANKS MORSE)

1. Turn the crankshaft in the direction of engine rotation until the No. 1 piston is coming up on the compression stroke. See the subject Finding Top Center Compression Position for the No. 1 Piston.
2. Turn the crankshaft until the desired timing mark is directly under the flywheel pointer. See the charts No. 1 Cylinder Timing Angles (Fairbanks Morse Solid State Magneto) for the correct operating conditions.

NOTE: After top center (ATC) timing with the engine stopped is needed under some conditions. When flywheels with no ATC marks are found, put marks on the outside diameter of the flywheel by using the same dimensions from the marks now on the flywheel.

No. 1 CYLINDER TIMING ANGLES (3306 Engines)
(FAIRBANKS MORSE SOLID STATE MAGNETO)

Compression Ratio	Conditions	Engine Stopped	Engine at Rated Speed
10.5:1	NA	15° BTC	35° BTC
10.5:1	TA (90° Water)	5° BTC	25° BTC
10.5:1	NA (Propane)	2.5° ATC	17.5° BTC
10.5:1	TA (Propane)	5° ATC	15° BTC
8:1	NA	20° BTC	40° BTC
8:1	TA (130° Water)	15° BTC	35° BTC
8:1	NA (Propane)	10° BTC	30° BTC
8:1	TA (Propane or Well Scrubbed Field Gas)	0° TC	20° BTC

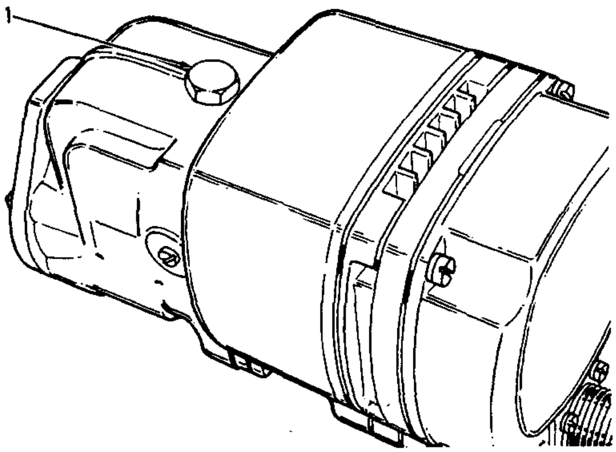
TC = Top center. BTC = Before top center.
ATC = After top center.

No. 1 CYLINDER TIMING ANGLES (3304 Engines)
(FAIRBANKS MORSE SOLID STATE MAGNETO)

Compression Ratio	Conditions	Engine Stopped	Engine at Rated Speed
10.5:1	NA	15° BTC	35° BTC
10.5:1	NA (Propane)	2.5° ATC	17.5° BTC
8:1	NA	20° BTC	40° BTC
8:1	NA (Propane)	10° BTC	30° BTC
	(Well Scrubbed field Gas)	0° TC	20° BTC

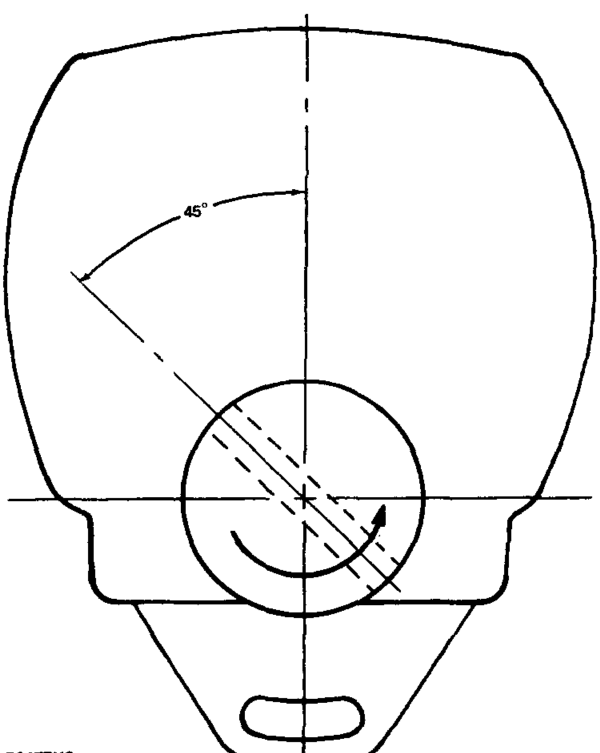
TC = Top center. BTC = Before top center.
ATC = After top center.

3. With magneto off the engine, remove timing bolt (1) and rotate magneto drive until yellow mark on the gear is in the center of hole.

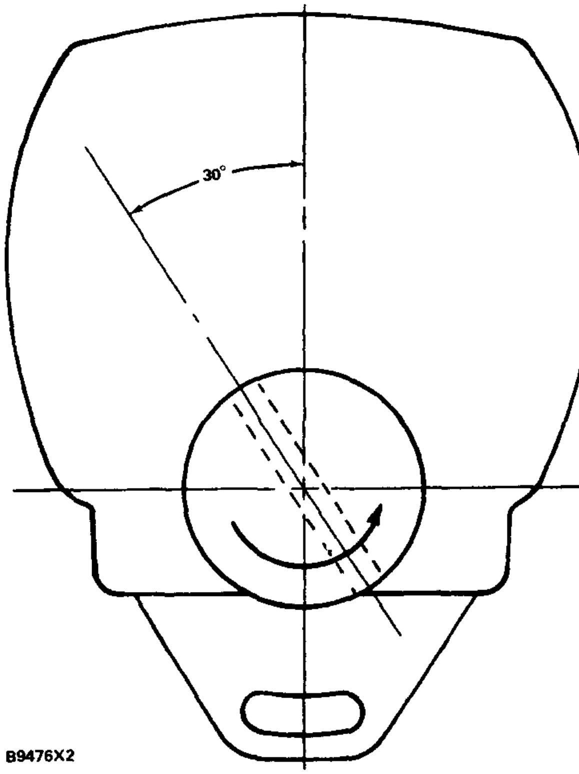


SOLID STATE MAGNETO
1. Timing bolt.

4. Position the magneto drive slots in proper position for timing. The drive coupling can be pulled out, then positioned and pushed in for engagement.
5. Install the magneto. The drive tang and slot will engage.



DRIVE TANG AND SLOT POSITION (3306 Engine)
(Viewed from the rear of the engine)



DRIVE TANG AND SLOT POSITION (3304 Engine)
(Viewed from the rear of the engine)

6. Make final timing adjustment by rotating the magneto at the drive housing mounting and with the use of a timing light when the engine is running at rated speed.

NOTE: Timing must NOT be made at low idle because of the timing advance in the magneto.

TIMING OF MAGNETO TO ENGINE (SOLID STATE ALTRONIC)

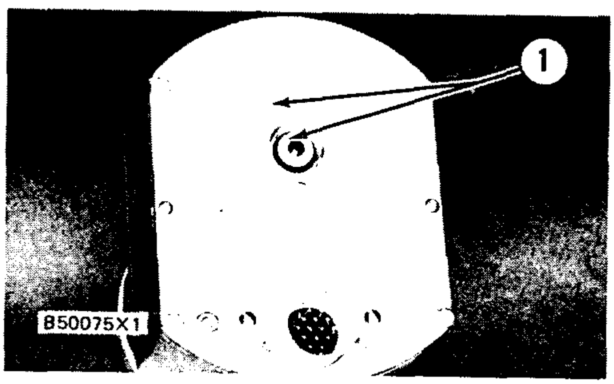
1. Turn the crankshaft in the direction of engine rotation until the No. 1 piston is coming up on the compression stroke. See the subject Finding Top Center Compression Position for the No. 1 Piston.
2. Turn the crankshaft until the desired timing mark is directly under the flywheel pointer. See the charts No. 1 Cylinder Timing Angles (Altronic Solid State Magneto) for the correct operating conditions.

No. 1 CYLINDER TIMING ANGLES (3304 ENGINE) (ALTRONIC SOLID STATE MAGNETO)		
Compression Ratio	Other Conditions	Flywheel Mark — Engine Stopped or Running
10.5:1	N.A. (Natural Gas)	35° BTC
10.5:1	N.A. (Propane)	17.5° BTC
8:1	N.A. (Natural Gas)	40° BTC
8:1	N.A. (Propane)	30° BTC

BTC = Before top center.

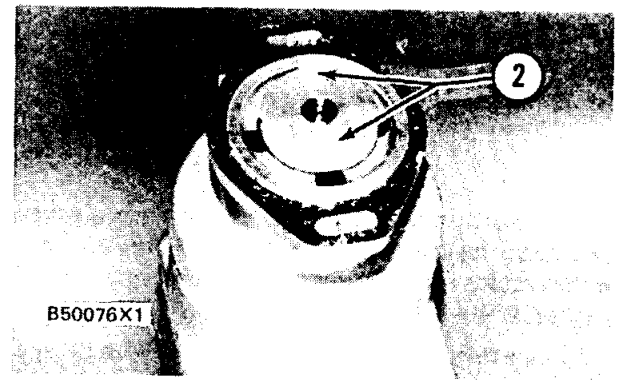
No. 1 CYLINDER TIMING ANGLES (3306 ENGINE) (ALTRONIC SOLID STATE MAGNETO)		
Compression Ratio	Other Conditions	Flywheel Mark — Engine Stopped or Running
10.5:1	N.A. (Natural Gas)	35° BTC
10.5:1	T.A. (Natural Gas)	25° BTC
10.5:1	N.A. (Propane)	17.5° BTC
10.5:1	T.A. (Propane)	15° BTC
8:1	N.A. (Natural Gas)	40° BTC
8:1	T.A. (Natural Gas)	35° BTC
8:1	N.A. (Propane)	30° BTC
8:1	T.A. (Propane)	20° BTC

BTC = Before top center.



MAGNETO TIMING MARKS
(Typical Example)
1. Timing marks.

3. The magneto timing marks (1) must be in alignment when the No. 1 piston is at the correct BTC position.
4. If not correct, remove the magneto from the engine.



MAGNETO DRIVE TANG
2. Drive tang.

5. Put timing marks (1) in the correct position with drive tang (2) positioned as shown.
6. Position the magneto drive slots in proper position for timing. The drive coupling can be pulled out, then positioned and pushed in for engagement.
7. Install the magneto. The drive tang and slot will engage.
8. Make final timing adjustment by rotating the magneto at the drive housing mounting and with the use of a timing light when the engine is running at rated speed.

IGNITION TRANSFORMERS

See the subject WIRING DIAGRAM in the SYSTEMS OPERATION section for the way the transformers are connected to the magneto.

SPARK PLUGS AND ADAPTERS

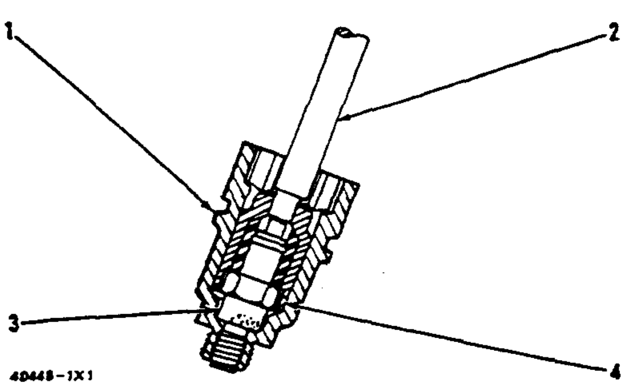
Tools Needed: 1F0479 Wrench.
1P1790 Firing Indicator
2P5481 Spark Plug Socket

If the spark plug adapter does not have a covered seat, water leakage or detonation and preignition can be the result. Adapters are installed and removed with a 1F0479 Wrench.

Voltage to cause the spark will change with the spark plug condition and engine load. A new spark plug in an engine at low idle will take 3,000 to 6,000 volts. At full load, this voltage will be 8,000 to 10,000 volts. When the gap of the spark plug needs adjustment the voltage needed will be over 10,000 volts. Voltage needed will go higher if plug gap adjustment is not made. Spark plugs start to cause the engine to run rough (fire erratically) when the spark plug voltage needs go higher than 10,000 volts.

Spark plug gap must be kept at .014 ± .001 in. (0.36 ± 0.03 mm). The use of 1P1790 Firing Indicator is an aid for finding ignition problems. Follow the instructions that come with the tool.

Put liquid soap on the seat groove of adapter (1) and seal. Install the adapter into cylinder head and tighten to a torque of 70 ± 5 lb.ft. (95 ± 7 N.m). Spark plugs (3) must be installed to a torque of 26 ± 4 lb.ft. (36 ± 5 N.m) with 2P5481 Spark Plug Socket (4).



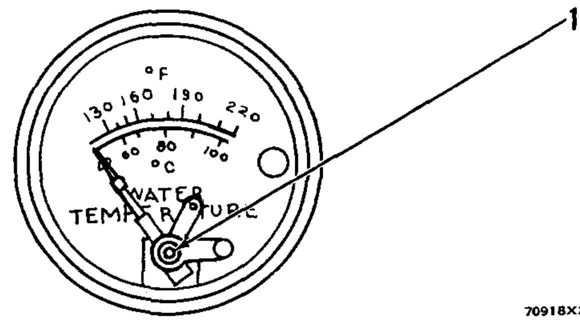
SPARK PLUG INSTALLATION

1. Adapter. 2. 3/8 in. Drive extension. 3. Spark plug. 4. 2P5481 Spark Plug Socket.

ADJUSTMENT OF GAUGE CONTACT POINT

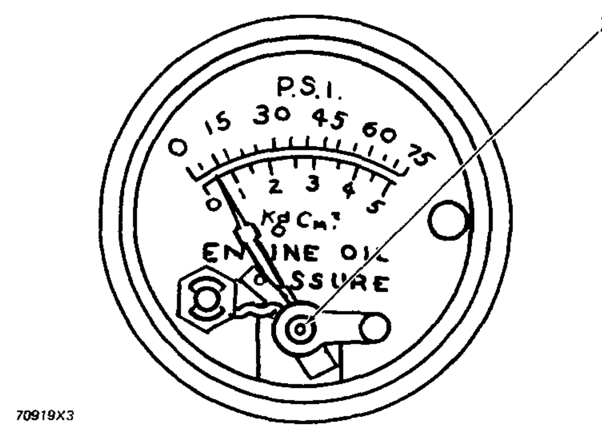
The adjustment of the contact for the pressure gauge for oil is correct when the engine is stopped at 8 psi (55 kPa) oil pressure. The correct adjustment of the gauge for water temperature is when the engine is stopped at 210°F (99°C).

Adjustment of the gauges is made with a small hollow head screw wrench.



WATER TEMPERATURE GAUGE

1. Adjustment screw.



OIL PRESSURE GAUGE

2. Adjustment screw.

GAS, AIR INLET AND EXHAUST SYSTEM

RESTRICTION OF AIR INLET AND EXHAUST

There will be a reduction of horsepower and efficiency of the engine if there is a restriction of the air inlet or exhaust system.

Air flow through the air cleaner must not have a restriction of more than 15 in. (381 mm) of water difference in pressure.

Back pressure from the exhaust (pressure difference measurement between exhaust outlet elbow and atmosphere) must not be more than 34 in. (864 mm) for naturally aspirated and 27 in. (686 mm) for turbocharged engines measured between the turbocharger outlet and atmosphere.

CRANKCASE (CRANKSHAFT COMPARTMENT) PRESSURE

Pistons or piston rings that have damage can be the cause of too much pressure in the crankcase. This condition will cause the engine to run rough. There will also be more than the normal amount of fumes coming from the crankcase breather. This crankcase pressure can also cause the element for the crankcase breather to have a restriction in a very short time. It can also be the cause of oil leakage at gaskets and seals that would not normally have leakage.

Normal crankcase pressure with a clean crankcase breather is 2 in. (50.8 mm) of water or less.

COMPRESSION

Tools Needed: 5P7307 Engine Turning Tool Group.

An engine that runs rough can have a leak at the valves, or valves that need adjustment. Run the engine at the speed that gives rough running. To find a cylinder that has low compression or does not have good ignition, remove spark plug wires one at a time. This will stop the flow of current to that cylinder. Do this for each cylinder until a removed wire is found that makes no difference in engine rough running. Be sure to install the wire for the spark plug after each cylinder test before the next wire is removed. This test can also be an indication that the spark plug is bad, so more checking of the cylinder will be needed.

Condition of the valves, valve seats, pistons, piston rings and cylinder liners can be tested by putting air pressure in the cylinder. Special Instruction Form No. GMG00694 gives instructions for the test procedure. It also gives the list of parts needed from Parts Department to make the test.

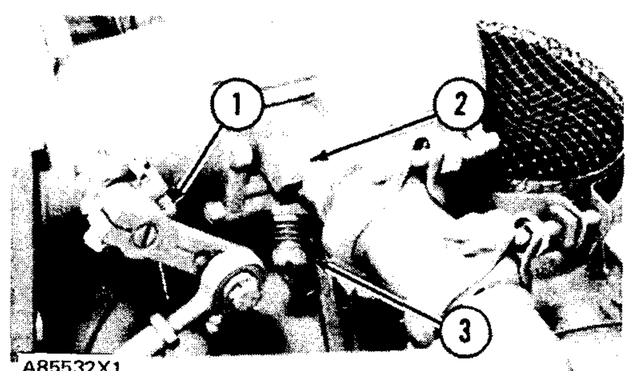
This test is a fast method of finding the cause of compression loss in a cylinder. Removal of the head and inspection of the valves and valve seats is necessary to find those small defects that do not normally cause a problem. Repair of these problems is normally done when reconditioning is done on the engine.

CARBURETOR

The carburetor and governor linkage adjustment is given in the subject GOVERNOR.

Turn the power mixture adjustment (2) to center between "R" (rich) and "L" (lean). Make fuel mixture adjustments by changing the gas pressure from the line pressure regulator. See the subject GAS PRESSURE REGULATOR ADJUSTMENTS.

Turn idle adjustment screw (3) four full turns open (from the closed position).



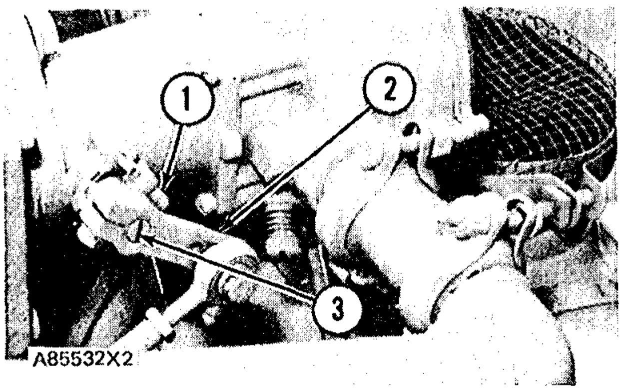
CARBURETOR ADJUSTMENTS

1. Throttle stop screw. 2. Power mixture adjustment. 3. Idle adjustment screw.

Turn throttle stop screw (1), to obtain desired idle speed. See FUEL SETTING INFORMATION for low idle rpm.

Adjustment to the Low Idle (Engine Not Operating)

1. Disconnect governor linkage at throttle shaft lever (2).
2. Turn screw (1) out until the throttle will close before the screw makes contact with the stop. Slot (3) in the end of the throttle shaft shows the position of the throttle plate.
3. Turn stop screw (1) so it will just make contact with the stop while the throttle plate is closed.



THROTTLE VALVE SYNCHRONIZATION

1. Throttle stop screw for low idle. 2. Throttle shaft lever. 3. Slot.

4. Move the control lever for the governor to the OFF position.

5. Make adjustments to the length of the linkage between governor and carburetor until both connections can be made while the throttle plate is completely closed, and the governor weight fully closed.

6. Connect the linkage to throttle shaft lever (2).

7. Start the engine and make a setting to throttle stop screw (1) for the low idle.

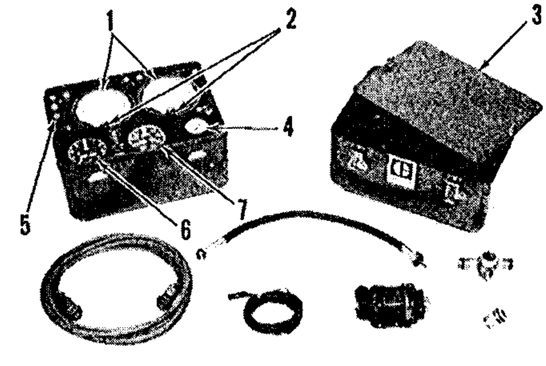
PERFORMANCE EVALUATION

When an engine has no power, it is desirable to make a quick check with an instrument to find the approximate horsepower.

Use the 4S6553 Instrument Group to check engine rpm and the pressure in the inlet manifold. This instrument group has a tachometer for reading the engine rpm and a gauge for reading the pressure in the inlet manifold. Differential pressure gauges are used to make measurements of the gas pressure and air inlet pressure. Special Instruction Form No. SEHS7341 is with the tool group and gives instructions for the test procedures.

Correct engine operating adjustments must be made to get the correct results from the instruments and tests.

Correct analysis can be made of the engine operating efficiency by a check of the pressure of the inlet manifold and a comparison of that pressure with the information in the FUEL SETTING INFORMATION. This test is used if the engine horsepower is too low, but with no other condition of engine problem.



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4S6553 INSTRUMENT GROUP

1. 4S6992 Differential Pressure Gauges. 2. Zero adjustment screw. 3. Lid. 4. 8M2743 Gauge. 5. Pressure tap fitting. 6. 1P7443 Tachometer. 7. 4S6997 Manifold Pressure Gauge.

GAS LINE PRESSURE

Gas engines burn a wide range of gaseous fuels. BTU rating of a fuel is a measure of the power content of the fuel. The higher BTU rated fuels need less gas pressure to have the correct gas volume for a specific horsepower.

The BTU HHV (high heat value) of gaseous fuels is the unit of measurement of the total fuel heat content. The BTU LHV (low heat value) content is more important. The combustion procedure in a cylinder causes carbon dioxide and water, but the heat needed for the conversion of water into vapor is lost and can not be used in the engine. The remainder of the heat that can be used from the fuel is the LHV, and, as a rule, is 10% less than the HHV of natural gas. When BTU HHV is given, remember to make a conversion to LHV so the correct settings can be made.

Low octane fuels burn so fast that an adjustment to the timing must be made to move it back (retard). With early timing and low octane fuel, the fast burning fuel burns too much before the piston goes over top center. The result of this is "knocking" (detonation).

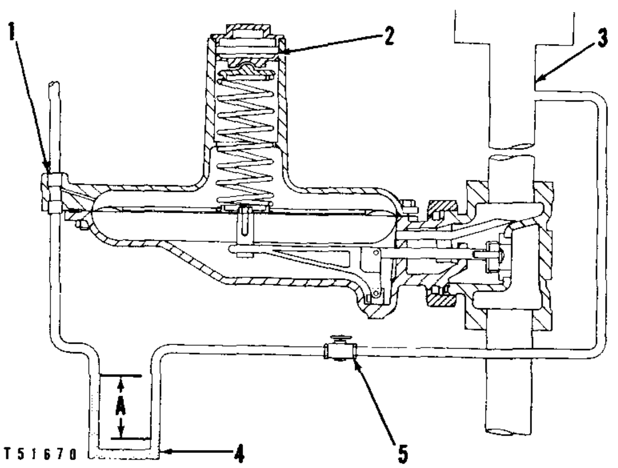
A change to the fuel to air ratio is made by changing the gas pressure in relation to the air pressure. Too much gas makes a "rich mixture" and not enough gas makes a "lean mixture". Either will cause a loss of power. If the compression is too high and the fuel to air mixture is too rich, fuel ignition will be without the aid of the spark and at a time different than the timing setting. When Propane gas is used, the adjustment of the fuel to air setting must be made with much more precision than when natural gas is used.

Make an adjustment to (regulate) the pressure in main gas supply to the engine. Naturally aspirated engines need main gas supply line pressure of 3 to 20 psi (20 to 140 kPa). Turbocharged engines need more pressure, 12 to 20 psi (85 to 140 kPa); 20 psi (140 kPa) is the maximum pressure that can be used in this engine. If the main line pressure of the gas supply is more than 20 psi (140 kPa), another regulator is needed.

ADJUSTMENT TO GAS PRESSURE REGULATOR

Tools Needed: 4S6553 Instrument Group.

A line pressure regulator is needed if the engine is turbocharged, or if the fuel supply pressure is higher than normal.



CHECKING LINE PRESSURE REGULATOR ADJUSTMENT (Schematic Diagram for Turbocharged Engine)

1. Bottom port. 2. Adjustment screw. 3. Gas supply at carburetor. 4. Water manometer. 5. Valve. A. Positive pressure differential.

1. Line pressure regulator adjustment can be checked with either the 4S6553 Instrument Group or a water manometer while engine is running.
2. Connect one end of a water manometer (4) to the gas supply at carburetor (3). On turbocharged engines, attach the other end of the manometer to the bottom port (1) of the line pressure regulator as shown, to measure the pressure differential (A). On naturally aspirated engines, connect the manometer only at (3) and leave the other end open to the atmosphere.
3. Remove the cap and turn screw (2) until the value (A) is within the given range. Natural Gas: 5.5 in. (139.7 mm); Propane: 1 in. negative (25.4 mm).

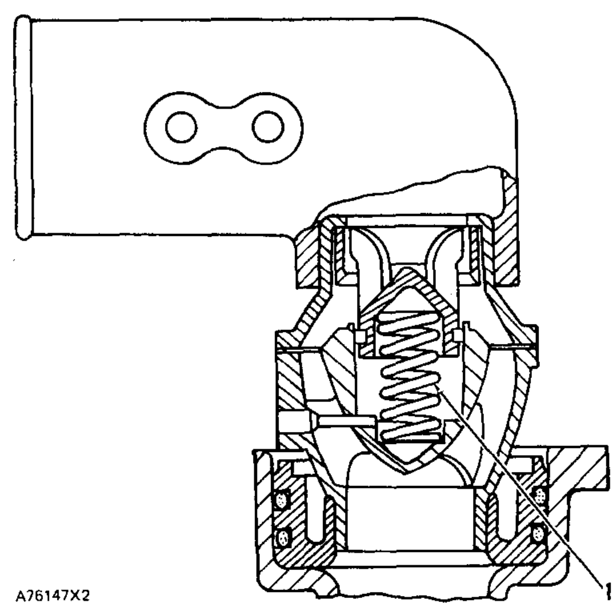
NOTE: Close valve (5) before the engine is stopped. This will prevent the manometer fluid from being drawn into the inlet of the carburetor (3).

BOOST LIMIT CONTROL

When an engine has low power, it is desirable to make a quick check with an instrument to find the approximate horsepower.

Use the 4S6553 Instrument Group to check engine rpm and the pressure in the inlet manifold. See the subject Performance Evaluation.

1. See the subject Adjustment to the Gas Pressure Regulator for the correct procedure to get the engine started.
2. If the boost limit control does not work correctly, make replacement of spring (1). Inspect for worn or damaged parts. If needed, make replacement of the control.



BOOST LIMIT CONTROL

1. Spring.

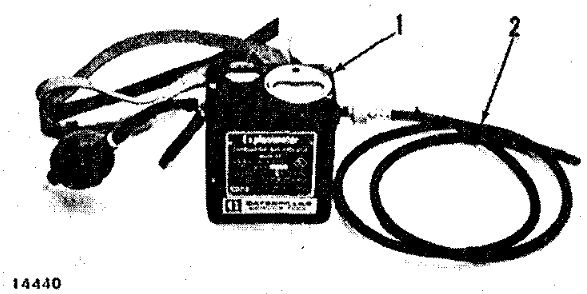
HOW TO FIND GAS LEAKS

Combustion gases leaking from natural gas engines can be a danger to safety. To find gas leaks, use the 1P1830 Explosimeter Group. It is made up of the explosimeter instrument (1) a five foot sampling line (2) and several replacement parts which are in a carrying case.

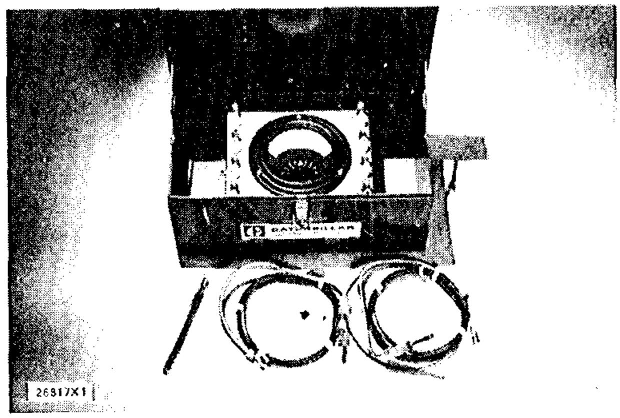
After there has been work on the fuel system, use the explosimeter to check connections and any other place gas leaks can be.

The concentration of flamable gases is shown in percent explosive by the indicator.

Detailed operating and maintenance instructions are with the group.



1P1830 EXPLOSIMETER
1. Explosimeter. 2. Sampling line.



1P3060 PYROMETER GROUP

EXHAUST TEMPERATURE

Use the 1P3060 Pyrometer Group to check the exhaust temperature. Take temperature readings soon after the engine is installed. Regulator checks are needed, and a record kept, to find any large increase or decrease in exhaust temperature.

Exhaust temperatures will not be the same for all engines of a similar type. Factors that have an affect on the exhaust temperatures are:

1. Restriction in the air inlet system
2. Restriction in the exhaust system
3. Temperature of the inlet air
4. Friction inside the engine
5. Fuel rate, fuel system condition or setting
6. Height of engine above sea level (altitude)
7. Size of valve openings
8. Condition of pyrometer thermocouple
9. Location of thermocouple

Checking the exhaust temperature, by itself, is not a complete method of making an analysis of an engine problem. A large or sudden temperature change will give an indication that something is wrong in the engine. Other checks must be made to find the cause. Special Instruction Form No. SMHS7179 is with the tool group and gives instructions for the test procedure.

CYLINDER HEAD

The cylinder head has valve seat inserts and valve guides that can be removed when they are worn or have damage. Replacement of these components can be made with the tools that follow.

Valves

Valve removal and installation is easier with use of 5S1330 Valve Spring Compressor Assembly and 5S1322 Valve Keeper Inserter.

Valve Seat Inserts

Tools needed to remove and install valve seat inserts are in the 9S3080 Valve Insert Puller Group. Special Instruction Form No. GMG02114 gives an explanation for this procedure. The insert can be more easily installed by lowering the temperature of the insert before installing it in the head.

Valve Guides

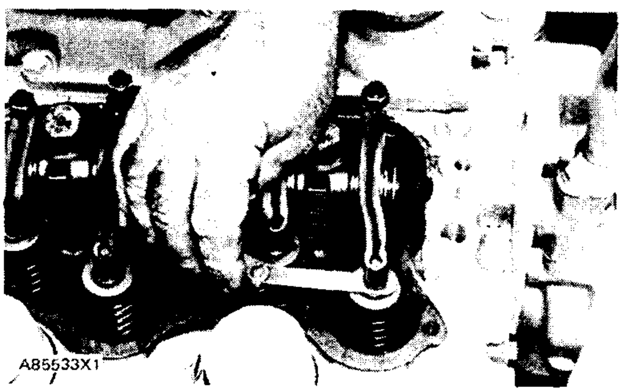
Tools needed to install valve guides are: 7S8858 Driver Bushing and 7S8859 Driver. The counterbore in the driver bushing installs the guide to the correct height. Use a 1P7450 Honing Arrangement to make a finished bore in the valve guide after the guide is installed in the head. Special Instruction Form No. SMHS7526 gives an explanation of this procedure. Grind the valves after new valve guides are installed.

VALVE CLEARANCE

NOTE: Valve clearance is measured between the rocker arm and the valves.

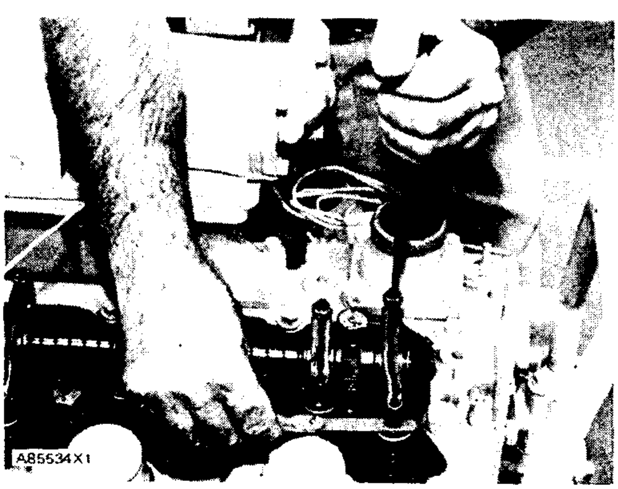
VALVE CLEARANCE CHECK: ENGINE STOPPED	
Exhaust	.027 to .033 in. (0.69 to 0.84 mm)
Intake	.012 to .018 in. (0.30 to 0.46 mm)

NOTE: When the valve lash (clearance) is checked, adjustment is NOT NECESSARY if the measurement is in the range given in the chart for VALVE CLEARANCE CHECK: ENGINE STOPPED. If the measurement is outside this range, adjustment is necessary. See the chart for VALVE CLEARANCE SETTING: ENGINE STOPPED, and make the setting to the normal (desired) specifications in this chart.



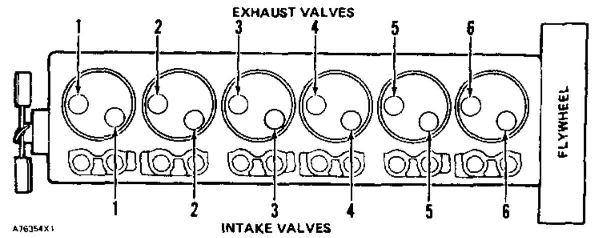
VALVE CLEARANCE CHECK

VALVE CLEARANCE SETTING WITH ENGINE STOPPED	
Exhaust	.030 in. (0.76 mm)
Intake	.015 in. (0.38 mm)



VALVE ADJUSTMENT

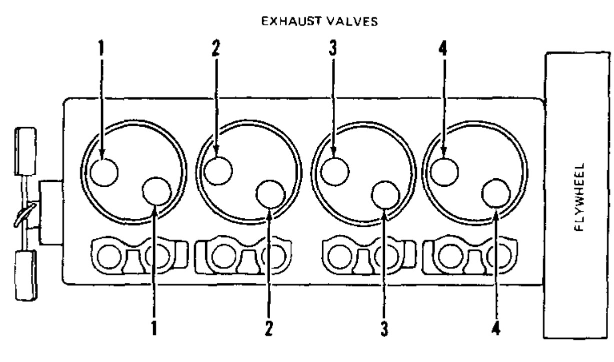
3306 Engines



CYLINDER AND VALVE IDENTIFICATION

1. Put No. 1 piston at top center (TC) on the compression stroke. Make reference to FINDING TOP CENTER COMPRESSION POSITION FOR NO. 1 PISTON.
2. Make an adjustment to the valve clearance on the intake valves for cylinders 1, 2, and 4. Make an adjustment to the valve clearance on the exhaust valves for cylinders 1, 3 and 5.
3. Turn the flywheel 360° in the direction of engine rotation. This will put No. 6 piston at top center (TC) on the compression stroke.
4. Make an adjustment to the valve clearance on the intake valve for cylinder 3, 5, and 6. Make an adjustment to the valve clearance on the exhaust valves for cylinders 2, 4, and 6.
5. After valve adjustment is correct, tighten the nuts for the valve adjustment screws to 22 ± 3 lb. ft. (28 ± 4 N·m).

3304 Engines



CYLINDER AND VALVE IDENTIFICATION

1. Put No. 1 piston at top center (TC) on the compression stroke. Make reference to FINDING TOP CENTER COMPRESSION POSITION FOR NO. 1 PISTON.

2. Make an adjustment to the valve clearance on the intake valves for cylinders 1 and 2. Make an adjustment to the valve clearance on the exhaust valves for cylinders 1 and 3.
3. Turn the flywheel 360° in the direction of engine rotation. This will put No. 1 piston at top center (TC) on the exhaust stroke.
4. Make an adjustment to the valve clearance on the intake valves for cylinders 3 and 4. Make an adjustment to the valve clearance on the exhaust valves for cylinders 2 and 4.
5. After valve adjustment is correct, tighten the nuts for the valve adjustment screws to 22 ± 3 lb. ft. (28 ± 4 N•m).

PROCEDURE FOR MEASURING CAMSHAFT LOBES

To find lobe lift, use the procedure that follows:

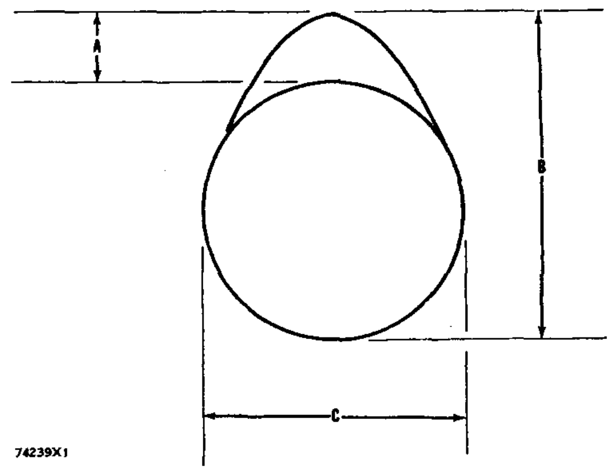
A. Measure camshaft lobe height (B).

B. Measure base circle (C).

C. Subtract base circle (STEP B) from lobe height (STEP A). The difference is actual lobe lift (A).

D. Specified camshaft lobe lift (A) is .3300 in. (8.382 mm).

Maximum permissible difference between actual lobe lift (STEP C) and specified lobe lift (STEP D) is .010 in. (0.25 mm).



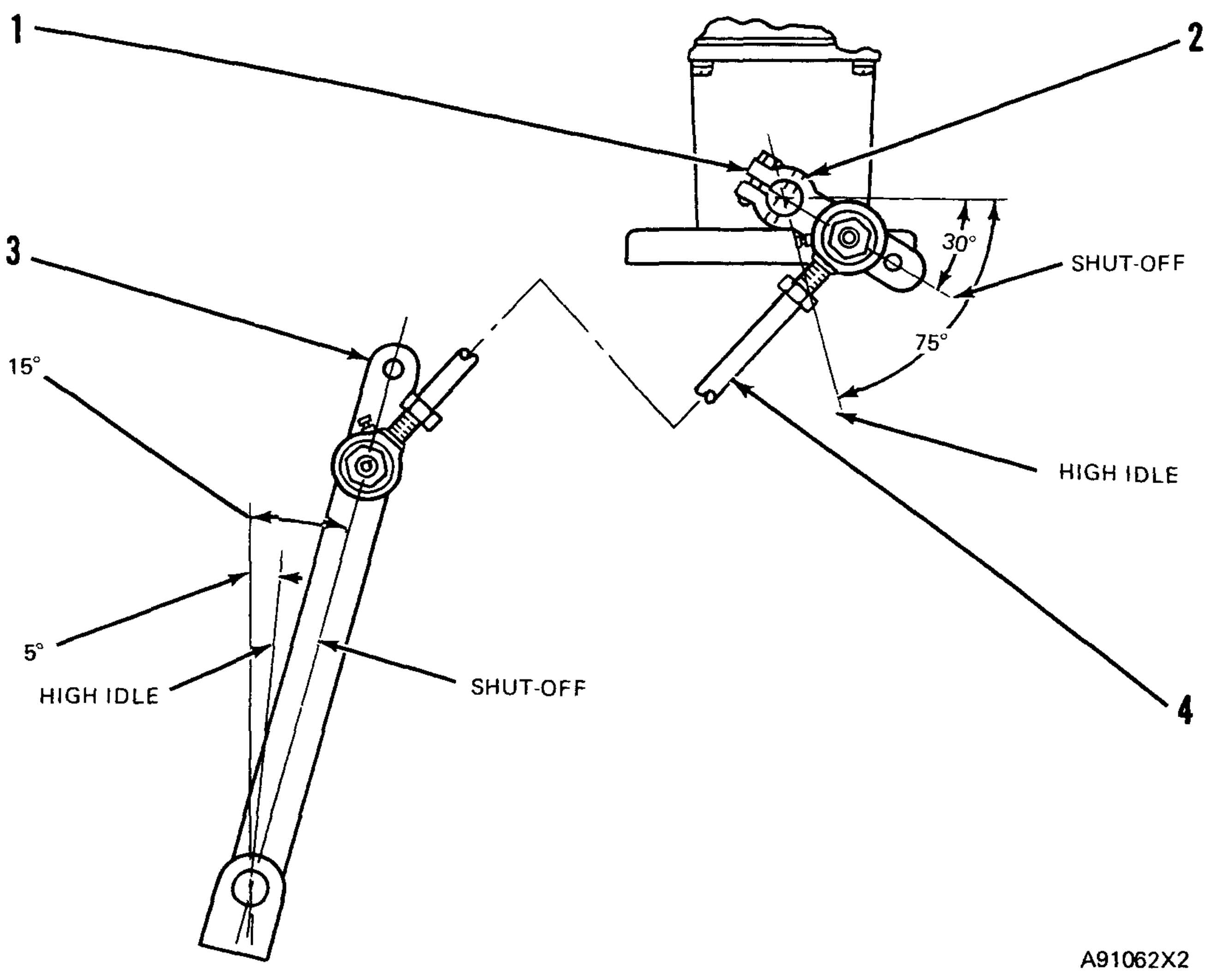
CAMSHAFT LOBE
A. Lobe lift. B. Lobe height. C. Base circle.

GOVERNOR ADJUSTMENTS (3304 ENGINE)

Adjustment of Linkage to the Carburetor

1. Clamp carburetor lever (1) on the carburetor throttle shaft at angle indicated when the throttle plate is closed.
2. Drill a .125 in. (3.2 mm) hole thru the shaft and lever and install pin (2) in the shaft.
3. Adjust the length of linkage rod (4) so the angles at carburetor lever (1) and governor lever (3) are maintained.

NOTE: Governor lever in shutoff position and throttle plate closed.



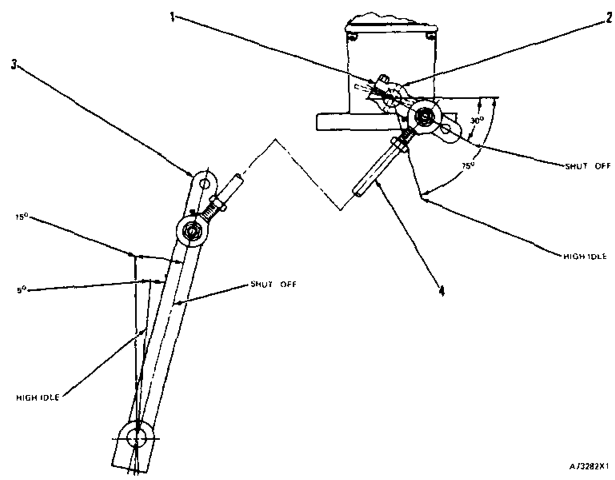
LINKAGE ADJUSTMENT
(Naturally Aspirated Engine)
1. Carburetor lever. 2. Pin. 3. Governor lever. 4. Linkage rod.

GOVERNOR ADJUSTMENTS (3306 ENGINES)

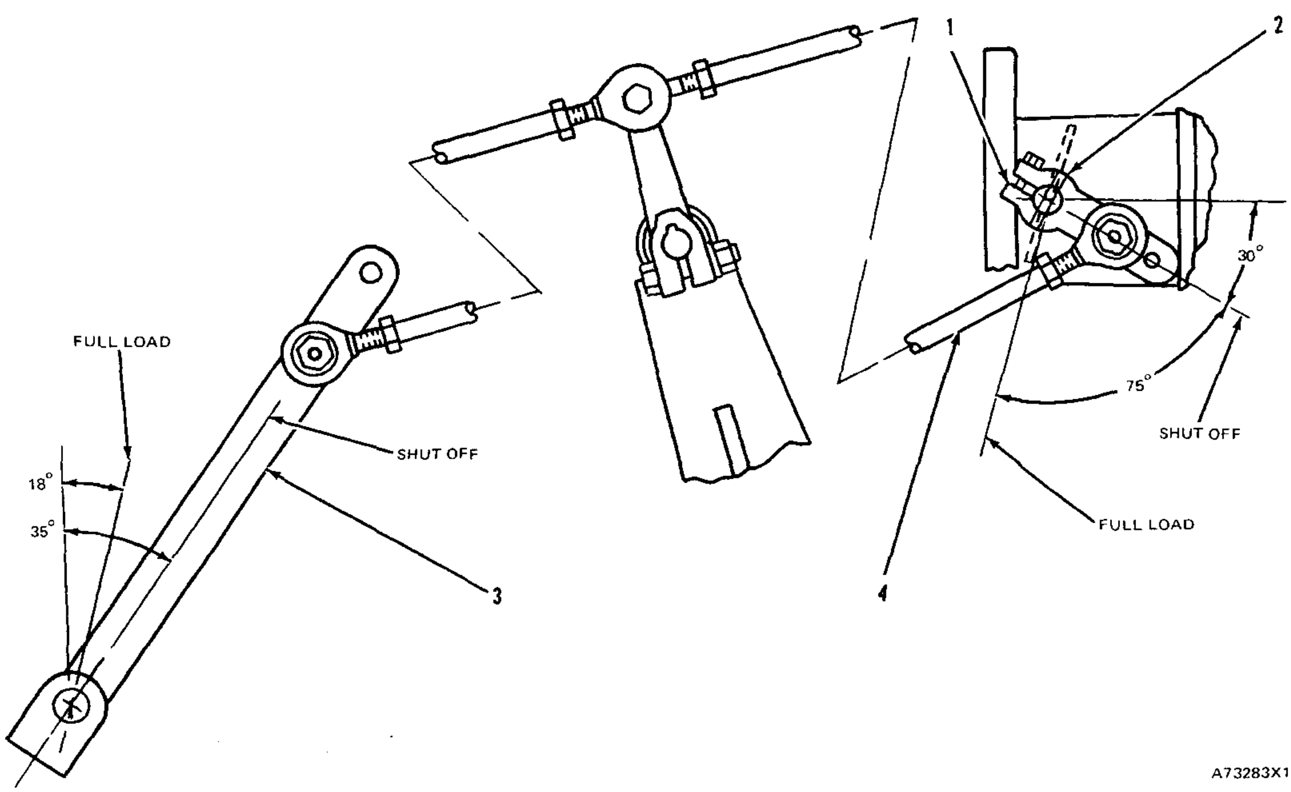
Adjustment of Linkage to the Carburetor

1. Clamp carburetor lever (1) on the carburetor throttle shaft at angle indicated when the throttle plate is closed.
2. Drill a .125 in. (3.2 mm) hole thru the shaft and lever and install pin (2) in the shaft.
3. Adjust the length of linkage rod (4) so the angles at carburetor lever (1) and governor lever (3) are maintained.

NOTE: Governor lever in shutoff position and throttle plate closed.



LINKAGE ADJUSTMENT
(Naturally Aspirated Engine)
1. Carburetor lever. 2. Pin. 3. Governor lever. 4. Linkage rod.

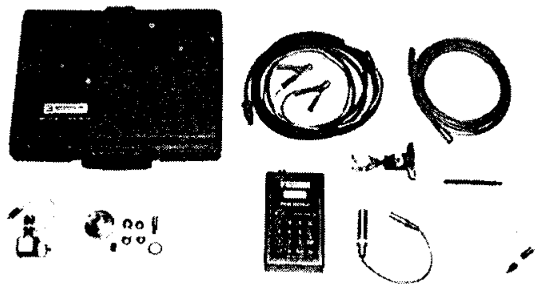


LINKAGE ADJUSTMENT
(Turbocharged Engine)
1. Carburetor lever. 2. Pin. 3. Governor lever. 4. Linkage rod.

MEASURING ENGINE SPEED

Tools Needed:
6V3121 Multitach Group

The 6V3121 Multitach Group can measure engine speed by the use of either the photo pickup and reflective tape, or a magnetic pickup or tachometer generator. Special Instruction Form No. SEHS7807 has instructions for its use.



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6V3121 MULTITACH GROUP

GOVERNOR ADJUSTMENTS

Low and High Idle Adjustment

NOTICE

A mechanic with training in governor adjustments is the only one to make the adjustment to the low idle and high idle rpm.

Engine rpm must be checked with an accurate tachometer. Make reference to MEASURING ENGINE SPEED.

NOTE: The correct low idle and high idle rpm are in the FUEL SETTING INFORMATION.

⚠ WARNING

To help prevent an accident caused by parts in rotation, work carefully around an engine that has been started.

Start the engine and run until the temperature of normal operation is reached. Check low and high idle rpm with no load on the engine. If an adjustment is necessary, use the procedure that follows:

1. Remove cover (2) from the top of the housing for the governor.
2. Turn adjustment screw (3) as necessary to change high idle rpm.

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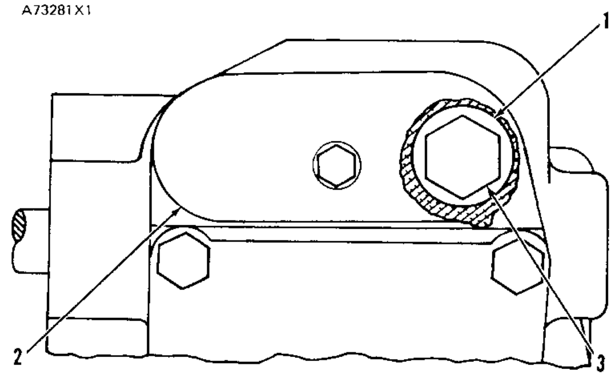


LOCATION OF ADJUSTMENTS

1. Retainer hole in cover. 2. Cover. 3. Adjustment screw for high idle.

3. After an idle adjustment is made, move the governor lever to change the rpm of the engine.
4. Now move the governor lever back to the point of first adjustment. Use this procedure until the idle rpm is the same as the idle rpm given in the FUEL SETTING INFORMATION.

NOTE: Turn the adjustment screw counterclockwise to increase the rpm. Turn the adjustment screw clockwise to decrease the rpm.

5. When governor adjustment is correct, put the cover on the governor.
6. The adjustment to the low idle rpm is made with the screw on the throttle shaft lever. See the subject CARBURETOR for the correct adjustment procedures.

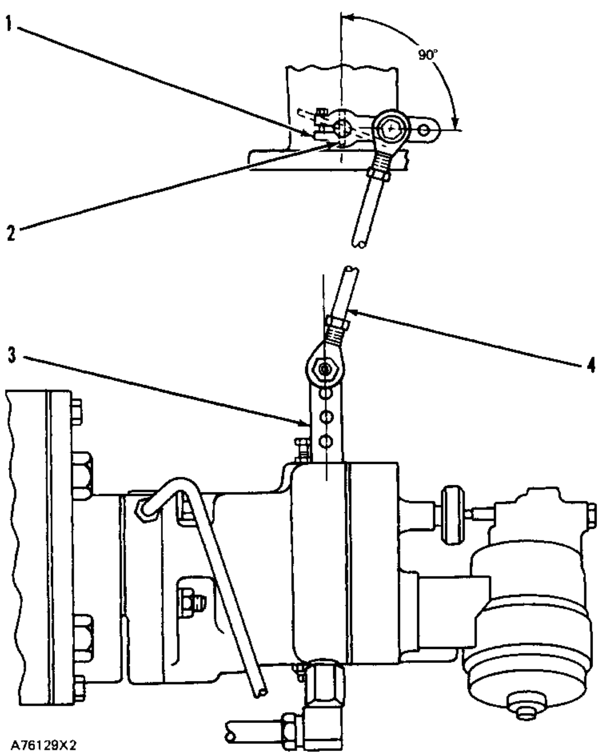
WOODWARD PSG GOVERNOR

GOVERNOR ADJUSTMENTS

Adjustment of Linkage to the Carburetor.

1. Clamp carburetor lever (1) on the carburetor throttle shaft at angle indicated when the throttle plate is closed.
2. Drill a .125 in. (3.2 mm) hole thru the shaft and lever and install pin (2) in the shaft.
3. Adjust the length of linkage rod (4) so the angles at carburetor lever (1) and governor lever (3) are maintained.

NOTE: Governor lever in shutoff position and throttle plate closed.



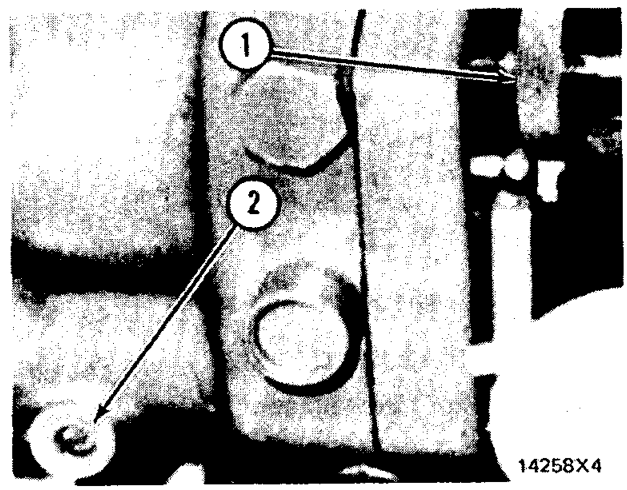
ADJUSTMENT OF LINKAGE TO THE CARBURETOR
(Naturally Aspirated Engine Illustrated)

1. Carburetor lever. 2. Pin. 3. Governor lever. 4. Linkage rod.

Installation Adjustments

When the governor linkage adjustments are correct, the installation adjustments that follow must be made.

1. Put the speed adjustment shaft at a position for the desired speed and let the engine get to the correct temperature for operation. When there is a synchronizing motor on the governor turn the knurled knob (1) to make an adjustment to the engine speed.
2. Open the compensating needle valve (2) two or three turns and permit the engine to run for about one half minute to let air out from the governor oil passages.



GOVERNOR ADJUSTMENTS

1. Knurled knob. 2. Location of compensating needle valve.

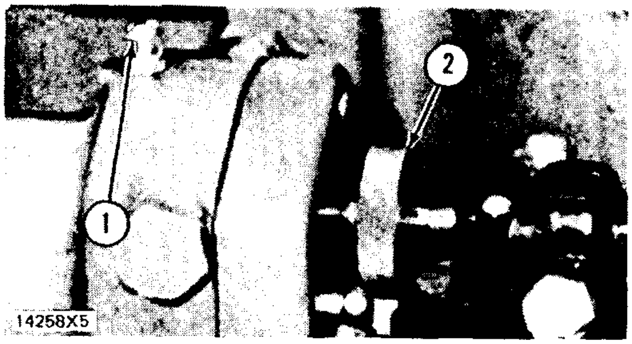
3. Gradually close the needle valve until hunting just stops. If the needle valve is closed farther than necessary it will make the governor slow to return to normal speed after a load change.

Low and High Idle Adjustment

Before this adjustment is made the installation adjustment must be made, and if done correctly, it will never need to be changed unless the governor is worked on.

High idle (maximum speed) settings are made by adjustment of stop screw (1) in the governor body.

1. Install a tachometer with known accuracy.
2. Loosen the locknut and stop screw (1).
3. With the engine at full speed, turn high speed stop screw until the correct rpm is read on the tachometer.
4. Tighten the locknut.



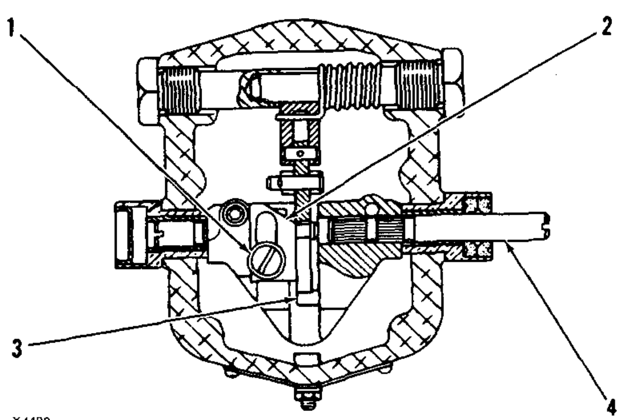
LOW AND HIGH IDLE ADJUSTMENTS

1. Stop screw. 2. Knurled knob.

Low idle (minimum speed) is controlled by the synchronizing motor. The location of the motor is on the governor cover. The motor takes a source of electric power. If the source of power is from the engine on which the governor is used, the engine low idle speed must be that given in the FUEL SETTING INFORMATION. When the engine speed is too slow to supply electric power, the electric motor will not run. Turn knurled knob (2) to increase engine speed so the generator will supply power.

Speed Droop Adjustment

Adjustment is made on the inside of the governor. To make this adjustment remove the cover and the synchronizing motor.



SPEED DROOP ADJUSTMENT

1. Clamp screw. 2. Adjustment bracket. 3. Speed droop lever. 4. Terminal shaft.

1. Loosen clamp screw (1).
2. Move speed droop adjustment bracket (2) toward terminal shaft (4) for minimum droop.

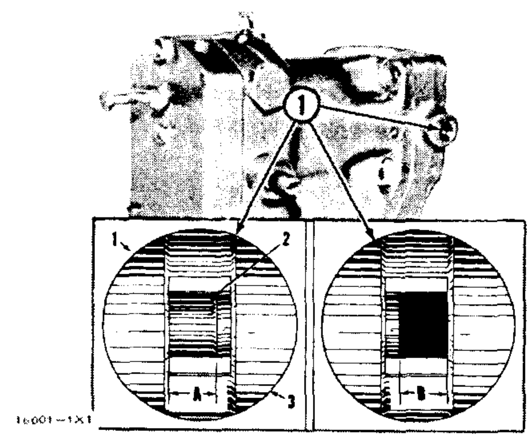
NOTE: Zero droop position can be set by an adjustment, then check the setting, and adjust again if necessary (trial and error) on the engine. It can also be set by use of a dial indicator on speed droop lever (3) during manual rotation of terminal shaft (4).

NOTE: When speed droop is necessary, make an adjustment to the position of bracket (2) and test by running engine. Adjust until the desired speed droop is found.

Pilot Valve Plunger Central Adjustment

Tools Needed: 1P87 Adjusting Wrench.

When the governor is disassembled, check and adjust if necessary, the pilot valve plunger central position.

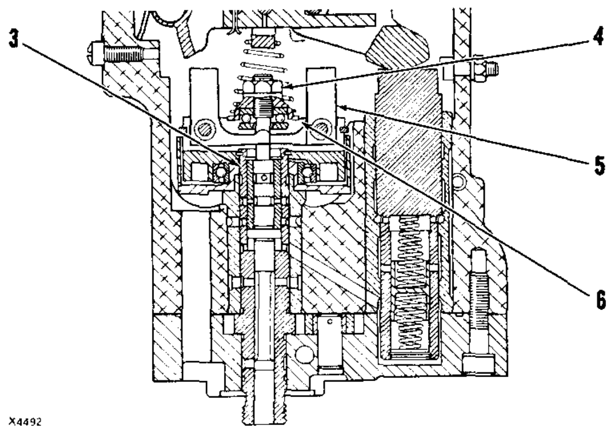


PILOT VALVE PLUNGER CENTRAL ADJUSTMENT

1. Pipe plug opening. 2. Pilot valve control land. 3. Pilot valve bushing. A. Port opening above land. B. Port opening below land.

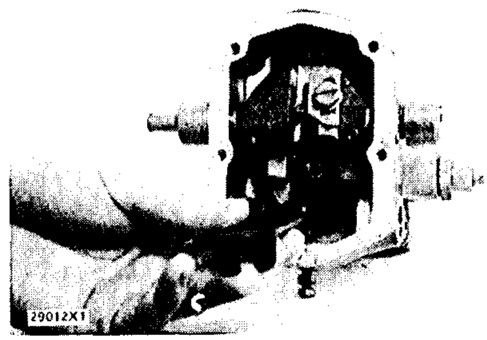
1. Use a small flashlight and look at the position of pilot valve control land (2) with relation to the port in the valve bushing (3). Look through the 1/16 in. pipe plug hole (1) in the straight side of the base.
2. Push pilot valve toward drive end as far as possible, this will move the flyweights (5) to inner position. Through the pipe plug hole, check the dimension of port opening (A) above the edge of the pilot valve control land.
3. Hold the pilot valve against the flyweight toes, move the flyweights out as far as they will go. Check the dimension of port opening (B) below the edge of the pilot valve control land.
4. The difference in amounts of port opening (A and B) with the flyweights at inner and outer positions must be within .010 in. (0.25 mm).

5. If the pilot valve plunger is too low, hold spring seat (6) with 1P87 Adjusting Wrench and turn the pilot valve counterclockwise to move it up. If the pilot valve plunger is too high, hold the spring seat and turn the pilot valve clockwise to move it down.



GOVERNOR CROSS SECTION

3. Pilot valve bushing. 4. Locknut. 5. Flyweight. 6. Spring seat.



HOLD SPRING SEAT WITH 1P87 ADJUSTING WRENCH TO MAKE AN ADJUSTMENT

6. When the pilot valve is in the center, tighten locknut (4) on the spring seat and check the valve setting again.

7. Install the 1/16 in. pipe plug. Put 8H5137 Sealing Compound on the threads to prevent leakage of oil.

LUBRICATION SYSTEM

One of the problems in the list that follows will generally be an indication of a problem in the lubrication system for the engine.

TOO MUCH OIL CONSUMPTION
OIL PRESSURE IS LOW
OIL PRESSURE IS HIGH
TOO MUCH BEARING WEAR

TOO MUCH OIL CONSUMPTION

Oil Leakage on Outside of Engine

Check for leakage at the seals at each end of the crankshaft. Look for leakage at the oil pan gasket and all lubrication system connections. Check to see if oil comes out of the crankcase breather. This can be caused by combustion gas leakage around the pistons. A dirty crankcase breather will cause high pressure in the crankcase, and this will cause gasket and seal leakage.

Oil Leakage Into Combustion Area of Cylinders

Oil leakage into the combustion area of the cylinders can be the cause of blue smoke. There are four possible ways for oil leakage into the combustion area of the cylinders:

1. Oil leakage between worn valve guides and valve stems.
2. Worn or damaged piston rings or dirty oil return holes.
3. Compression ring not installed correctly.
4. Oil leakage past the seal rings in the impeller end of the turbocharger shaft.

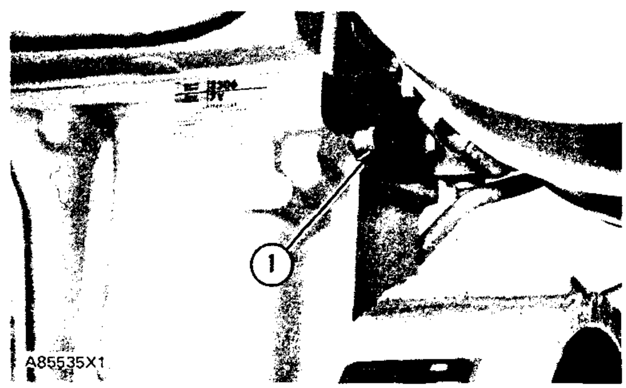
Too much oil consumption can also be the result of using oil with the wrong viscosity. Oil with a thin viscosity can be caused by the engine getting too hot.

OIL PRESSURE IS LOW

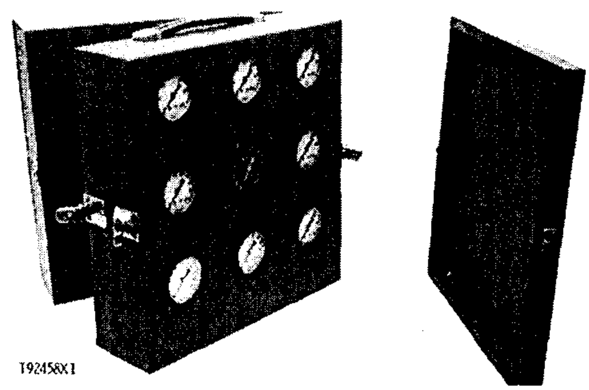
An oil pressure gauge that has a defect can give an indication of low oil pressure. Check the gauge with a test gauge.

Use the procedure that follows to check engine oil pressure. Do the procedure exactly or the pressure measurements are not good for comparison with the chart.

1. Be sure that the engine is filled to the correct level with either SAE 10 or SAE 30 oil. If any other viscosity of oil is used, the information in the engine oil pressure chart is not good.
2. Find a location on the engine oil manifold to install a tee. The easiest method is to remove the sending unit for the present gauge and install a tee at this location. Install a probe from the 9S9102 Thermistor Thermometer Group in one side of the tee. Connect an 8M2744 Gauge from the 7S8875 Hydraulic Test Box to the other side of the tee.



OIL MANIFOLD
1. Pressure Test Location.



7S8875 HYDRAULIC TEST BOX

3. Run the engine to get the engine oil temperature at 210°F (99°C).

NOTE: A 5°F (3°C) increase in temperature gives approximately 1 psi (7 kPa) decrease in engine oil pressure.

4. Keep the engine oil temperature constant. With the engine at the rpm from the chart, read the pressure gauge. Make a comparison between the pressure reading on the test gauge and the minimum permissible pressure from the ENGINE OIL PRESSURE CHART. If the pressure reading on the test gauge is below the minimum permissible pressure, find the cause and correct it. Operation of the engine with low oil pressure can be the cause of engine failure or of a reduction in engine life.

ENGINE OIL PRESSURE CHART			
		MINIMUM PERMISSIBLE PRESSURE	
TEST rpm	SAE NO. OF TEST OIL	psi	kPa
1500 rpm or above	10 30	20 24	140 165
600 to 800 rpm	10 30	6 7	40 60

Crankcase Oil Level

Check the level of the oil in the crankcase. Add oil if needed. It is possible for the oil level to be too far below the oil pump supply tube. This will cause the oil pump to not have the ability to supply enough lubrication to the engine components.

Oil Pump Does Not Work Correctly

The inlet screen of the supply tube for the oil pump can have a restriction. This will cause cavitation (the sudden making of low pressure bubbles in liquids by mechanical forces) and a loss of oil pressure. Air leakage in the supply side of the oil pump will also cause cavitation and loss of oil pressure. If the bypass valve for the oil pump is held in the open (unseated) position, the lubrication system can not get to maximum pressure. Oil pump gears that have too much wear will cause a reduction in oil pressure.

Oil Filter and Oil Cooler Bypass Valves

If the bypass valve for the oil filter or oil cooler is held in the open position (unseated) and the oil filter or oil cooler has a restriction, a reduction in oil pressure can be the result. To correct this problem, install a new Caterpillar oil filter.

Too Much Clearance at Engine Bearings Or Open (Broken or Disconnected Oil Line or Passage) Lubrication System

Components that are worn and have too much bearing clearance can cause oil pressure to be low. Low oil pressure can also be caused by an oil line or oil passage that is open, broken or disconnected.

Oil Cooler

Look for a restriction in the oil passages of the oil cooler. If the oil cooler has a restriction, the oil temperature will be higher than normal when the engine is in operation. The oil pressure of the engine will not get low just because the oil cooler has a restriction.

OIL PRESSURE IS HIGH

Oil pressure will be high if the bypass valve for the oil pump can not move from the closed position.

TOO MUCH BEARING WEAR

When some components of the engine show bearing wear in a short time, the cause can be a restriction in an oil passage. A broken oil passage can also be the cause.

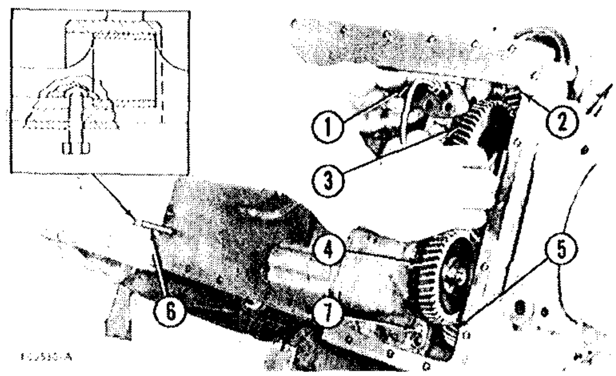
If the gauge for oil pressure shows enough good oil pressure, but a component is worn because it is not getting enough lubrication, look at the passage for oil supply to that component. A restriction in a supply passage will not let enough lubrication get to a component and this will cause early wear.

OIL PUMP INSTALLATION
(Four Cylinder Engines Only)

The oil pump can be removed for inspection and service without removing the timing gear cover. With the cover in place, timing marks are not easy to see. Therefore, time both balancer shafts, with respect to No. 1 piston at TC or compression stroke, in the following steps.

1. Rotate the crankshaft to bring No. 1 piston to TC on compression stroke.
2. Drive dowel (7) back so it is flush with mounting face of oil pump mounting bracket.
3. Rotate both balancer shafts so the flat portion is away from the oil pan plate. Install bolts (6) so they enter in countersunk holes in balancer shafts and limit shaft movement. The bolts should not be tight against the shaft countersunk hole bottom.
4. Position oil pump on bottom of engine block and install the mounting bolts loosely.
5. Install shims if necessary, between pump mounting pads and cylinder block to adjust backlash to .002 to .006 in. (0.05 to 0.15 mm) between gear (4) and (5) and between gears (2) and (3).
6. Drive dowel (7) back in place, through mounting bracket and into cylinder block. Tighten the mounting bolts.
7. Remove bolts (6) and check to see that the countersunk holes are aligned with holes in oil pan plate when No. 1 cylinder is in TC position.

Timing mark alignment information shown in the SPECIFICATIONS is to be used when the timing gear cover is removed.



OIL PUMP INSTALLATION
(Typical Example)

1. *Right side balancer shaft.* **2.** *Right side balancer shaft gear.* **3.** Idler gear. **4.** Oil pump drive gear. **5.** Left side balancer shaft gear. **6.** Bolt. **7.** Dowel.

COOLING SYSTEM

The engine has a pressure type cooling system. A pressure type cooling system gives two advantages. The first advantage is that the cooling system can operate safely at a temperature that is higher than the normal point where water changes to steam. The second advantage is that this type system prevents cavitation (air in inlet of pump) in the water pump. With this type system it is more difficult for an air or steam pocket to form in the cooling system.

The cause for an engine getting too hot is generally because regular inspections of the cooling system were not done. Make a visual inspection of the cooling system before testing with testing equipment.

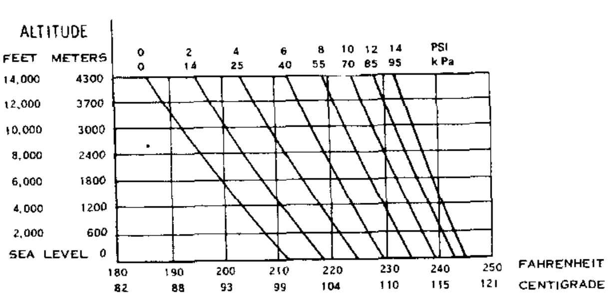
VISUAL INSPECTION OF THE COOLING SYSTEM

1. Check coolant level in the cooling system.
2. Look for leaks in the system.
3. Look for bent radiator fins. Be sure that air flow through the radiator does not have a restriction.
4. Inspect the drive for the fan.
5. Check for damage to the fan blades.
6. Look for air or combustion gas in the cooling system.
7. Inspect the pressure cap and the sealing surface for the cap. The sealing surface must be clean.
8. Look for large amounts of dirt in the radiator core and on the engine.

TESTING THE COOLING SYSTEM

Remember that temperature and pressure work together. When making a diagnosis of a cooling system problem, temperature and pressure must both be checked. Cooling system pressure will have an effect on cooling system temperatures. For an example, look at the chart to see the effect of pressure and the height above sea level on the boiling point (steam) of water.

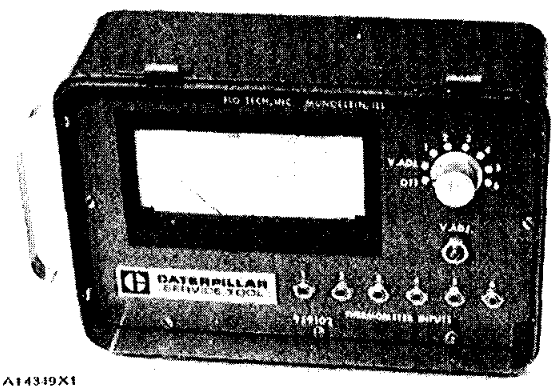
COOLING SYSTEM PRESSURE A28417-1X1



Checking Coolant Temperatures

Tools Needed: 9S9102 Thermistor Thermometer Group.

The 9S9102 Thermistor Thermometer Group is used in the diagnosis of overheating (engine running too hot) or overcooling (engine running too cool) problems. This group can be used to check the different parts of the cooling system. The complete testing procedure is in Special Instruction Form No. SMHS7140.



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9S9102 THERMISTOR THERMOMETER GROUP

Checking Radiator Air Flow

Tools Needed: 9S7373 Air Meter Group.

The 9S7373 Air Meter Group is used to check the air flow through the radiator core. Overheating can be caused by installing the wrong fan guard, low fan speed, or a restriction in the radiator core (clogging). The meter will give aid in finding a restriction in the core. The testing procedure and the correct readings are in Special Instruction Form No. SMHS7063.

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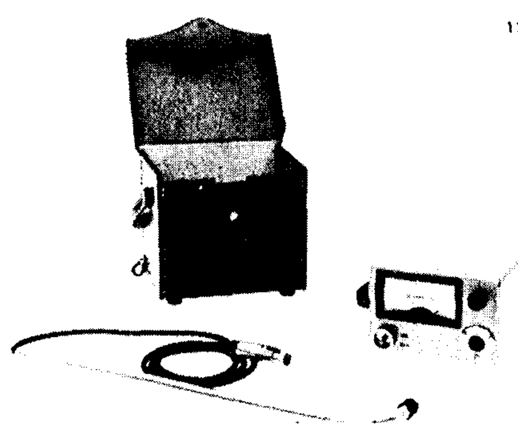
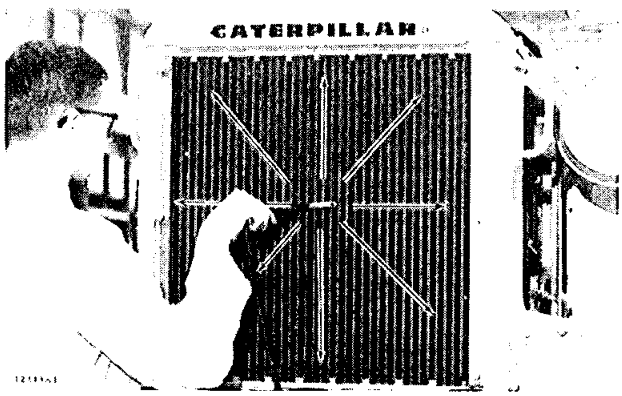


9S7373 AIR METER GROUP

⚠ WARNING

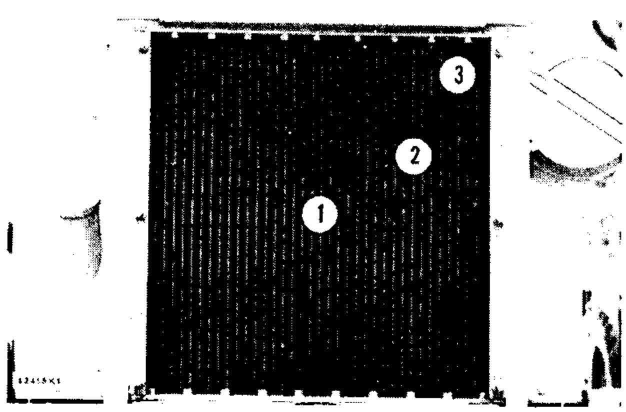
Make all checks at engine LOW IDLE and on the side of the radiator opposite the fan. Wear eye protection.



CHECKING AIR FLOW IN CROSS AND DIAGONAL LINES
(Typical Illustration)

Take readings in a cross and diagonal pattern. Make a comparison of the readings in each line the same distance from the center of the fan. Permit differences for restrictions such as guards, braces and engine components which will cause a change in the rate of air flow.

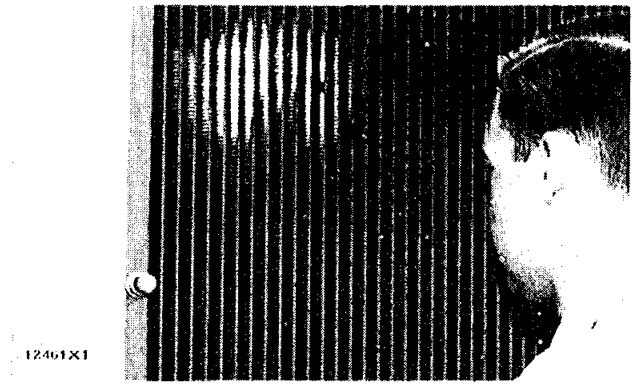
NOTE: All readings are taken at engine LOW IDLE.



AIR FLOW
(Typical Illustration)

1. Fan hub area. 2. Fan blade area. 3. Area outside fan blade.

If the readings are not within the ranges, stop the engine, put a strong light behind the core and inspect for a restriction. If the restriction is from dirt, remove by steam cleaning. If the restriction is from bent fins use 2H1822 Radiator Fin Comb to make the fins straight.

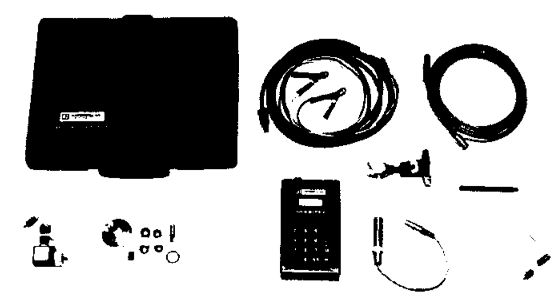


INSPECTING RADIATOR CORE FOR RESTRICTION
(Typical Illustration)

Checking Fan Speed

Tools Needed:
6V3121 Multitach Group

The 6V3121 Multitach Group can measure fan speed by the use of the photo pickup and reflective tape. Special Instruction Form No. SEHS7807 has instructions for its use.



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6V3121 MULTITACH GROUP

Pressure Cap

One cause for a pressure loss in the cooling system can be a bad seal on the pressure cap of the system. Inspect the pressure cap carefully. Look for damage to the seal or the sealing surface. Any foreign material or deposits on the cap, seal or sealing surface must be removed.

To check the pressure cap for the pressure that makes the pressure cap open, use the following procedure:

1. Remove the pressure cap from the radiator.

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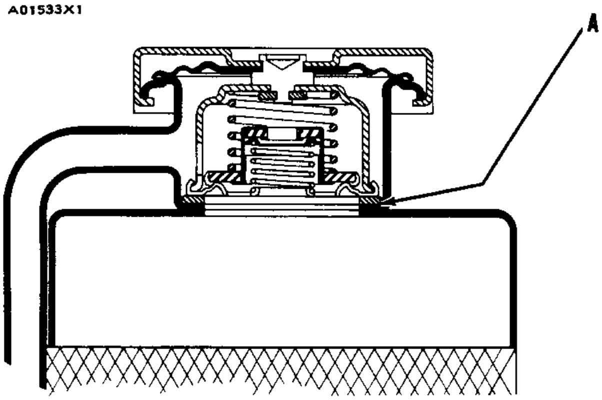
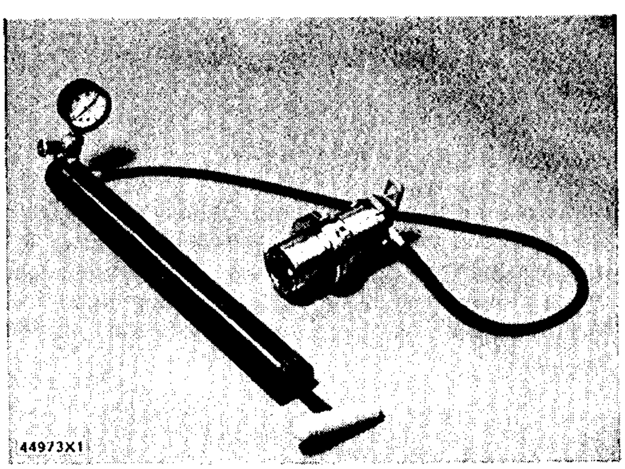


SCHEMATIC OF PRESSURE CAP
A. Sealing surface of cap and radiator.

⚠ WARNING

Always stop the engine to inspect the cooling system. Loosen the pressure cap to the first stop and let the pressure out of the cooling system, then remove the pressure cap. Hot coolant and steam can cause personal injury. Let coolant become cool before it is drained.

2. Put the pressure cap on the 9S8140 Cooling System Pressurizing Pump Group.
3. Look at the gauge for the exact pressure that makes the pressure cap open.



9S8140 COOLING SYSTEM PRESSURIZING PUMP GROUP

4. Make a comparison of the reading on the gauge with the correct pressure at which the pressure cap must open.

NOTE: The correct pressure that makes the pressure cap open is on the pressure cap and is also in the SPECIFICATIONS.

5. If the pressure cap is bad, install a new pressure cap.

Testing Radiator and Cooling System for Leaks (Systems That Use Pressure Cap)

To test the radiator and cooling system for leaks, use the procedure that follows:

1. Remove the pressure cap from the radiator.

⚠ WARNING

Always stop the engine to inspect the cooling system. Loosen the pressure cap to the first stop and let the pressure out of the cooling system, then remove the pressure cap. Hot coolant and steam can cause personal injury. Let coolant become cool before it is drained.

2. Make sure the coolant is over the top of the radiator core.
3. Put the 9S8140 Cooling System Pressurizing Pump Group on the radiator.
4. Get the pressure reading on the gauge to 3 psi (20 kPa) more than the pressure on the pressure cap.
5. Check the radiator for outside leakage.
6. Check all connections and hoses for the cooling system for outside leakage.
7. If you do not see any outside leakage and the pressure reading on the gauge is still the same after 5 minutes, the radiator and cooling system does not have leakage. If the reading on the gauge goes down and you do not see any outside leakage, there is leakage on the inside of the cooling system. Make repairs as necessary.

Gauge for Water Temperature

Tools Needed: 9S9102 Thermistor Thermometer Group.
or
2F7112 Thermometer and 6B5072 Bushing.

If the engine gets too hot and a loss of coolant is a problem, a pressure loss in the cooling system can be the cause. If the gauge for water temperature shows that the engine gets too hot, look for coolant leakage. If a place can not be found where there is coolant leakage, check the accuracy of the gauge for water temperature. Use the 9S9102 Thermistor Thermometer Group or the 2F7112 Thermometer and 6B5072 Bushing.

⚠ WARNING

To help prevent an accident caused by parts in rotation, work carefully around an engine that has been started.

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THERMOMETER INSTALLED
1. 2F7112 Therometer.

6330X1

9S9102 THERMISTOR THERMOMETER GROUP

For Direct Reading Gauges

Install the test thermometer. Get the coolant temperature at 200°F (93°C) according to the test thermometer. The centerline of the pointer of the gauge on the instrument panel must be .030 in. (0.76 mm) or less on either side of the centerline for the 200°F (93°C) mark.

Water Temperature Regulators

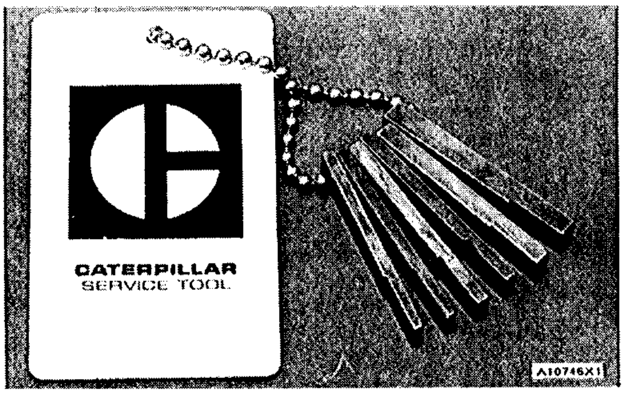
1. Remove the regulator from the engine.
2. Heat water in a pan until the temperature is correct for opening the regulator according to the chart. Move the water around in the pan to make it all be the same temperature.
3. Hang the regulator in a pan of water. The regulator must be below the surface of the water and it must be away from the sides and bottom of the pan.
4. Keep the water at the correct temperature for 10 minutes.
5. Remove the regulator from the water. Immediately make a measurement of the distance the regulator is open.
6. If the regulator is open to a distance less than given in the chart, install a new regulator.

WATER TEMPERATURE REGULATOR				
Part No.	Minimum Open Distance		Temperature	
	in.	mm	°F	°C
7N208 6N1848	.375	9.53	195°	90°

BASIC BLOCK

PISTON RING GROOVE GAUGE

A 5P3519 Piston Ring Groove Gauge is available for checking ring grooves with straight sides. For instructions on the use of the gauge, see the GUIDELINE FOR REUSABLE PARTS; PISTONS AND CYLINDER LINERS, Form No. SEBF8001.



PISTON RING GROOVE GAUGE

CONNECTING RODS AND PISTONS

Use the 7S9470 Piston Ring Expander to remove or install piston rings.

Use the 7S9417 or 5P3525 Piston Ring Compressor to install pistons into cylinder block.

Tighten the connecting rod nuts in the step sequence that follows:

1. Put 2P2506 Thread Lubricant on threads.
2. Tighten both nuts to 30 ± 3 lb. ft. (40 ± 4 N·m).
3. Put a mark on each nut and cap.
4. Tighten each nut 90° from the mark.

The connecting rod bearings should fit tightly in the bore in the rod. If bearing joints or backs are worn (fretted), check for bore size as this is an indication of wear because of looseness.

CONNECTING ROD AND MAIN BEARINGS

Bearings are available with .010 in. (0.25 mm), .020 in. (0.51 mm) and .030 in. (0.76 mm) smaller inside diameter than the original size bearings. These bearings are for crankshafts that have been "ground" (made smaller) than the original size.

CYLINDER LINER PROJECTION

Tools Needed:
- **1P5510 Liner Projection Tool Group**
  - **1P2403 Dial Indicator**
  - **1P5512 Contact Point, .88 in. (22.4 mm) long**
  - **1P2402 Gauge Body**
  - **1P5507 Gauge**
- **1P2394 Adapter Plate**
- **8B7548 Push-Puller (crossbar only)**
- **3H465 Plates (2)**
- **S1589 Bolt**
- **1S379 Washer (copper)**
- **1D4595 Bolt**
- **2S736 Washer**

The correct cylinder liner projection is important to prevent a leak between the liner, cylinder head, and block. Check cylinder liner projection above the spacer plate as follows:

1. Be sure that the surfaces of the cylinder block, cylinder liner, and the spacer plate are clean.
2. Install the spacer plate gasket and spacer plate (4) on the cylinder block. Use S1589 Bolts (1) with two 1S379 Washers on each bolt to hold the spacer plate to the cylinder block. Put two bolts with washers on each side of the opening for the cylinder liner. Tighten the bolts evenly, in four steps; 10 lb. ft. (14 N•m), 25 lb. ft. (35 N•m), 50 lb. ft. (70 N•m), and 70 lb. ft. (95 N•m).

NOTE: To keep from moving bolts and washers as each liner is checked install two bolts with washers on each side of each cylinder liner, along the complete length of the spacer plate.

3. Install the cylinder liner without seals in the cylinder block. Put adapter plate (7) on the cylinder liner as shown. Install crossbar (2) with 1D4595 Bolts (3), and 2S736 Washers, and 3H465 Plates (5) as shown. Tighten the bolts evenly, in four steps; 5 lb. ft. (7 N•m), 15 lb. ft. (20 N•m), 25 lb. ft. (35 N•m), and 50 lb. ft. (70 N•m). The measurement from the bottom of crossbar (2) to the spacer plate, must be the same on both sides of the cylinder liner.
4. Install the 1P5512 Contact Point on dial indicator (6). Put the dial indicator in the 1P2402 Gauge Body. To adjust the dial indicator to zero, put dial indicator and gauge body on the 1P5507 Gauge. Move the dial indicator until the hand moves ¼ turn. Tighten bolt on body to hold the dial indicator in this position. Turn the dial face until the zero is in alignment with the hand.

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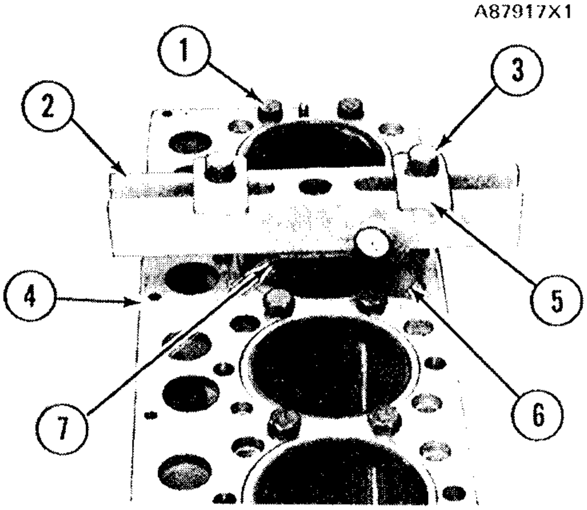


MEASURING CYLINDER LINER PROJECTION

1. S1589 Bolt with two 1S379 Washers. 2. Crossbar. 3. 1D4595 Bolt. 4. Spacer plate. 5. 3H465 Plates. 6. 1P2403 Dial Indicator. 7. 1P2394 Adapter plate.

5. Measure the cylinder liner projection as close as possible to the four corners of the adapter plate on the liner. The liner projection must be .0013 to .0069 in. (0.033 to 0.175 mm). The difference between the four measurements must not be more than .002 in. (0.05 mm). The difference in the average cylinder liner projection of liners next to each other must not be more than .002 in. (0.05 mm). The difference in the average cylinder liner projection of all cylinder liners under one cylinder head must not be more than .003 in. (0.08 mm) for 3304 and .004 in. (0.10 mm) for 3306.

NOTE: If the liner projection changes from point to point around the liner, turn the liner to a new position in the bore. If the liner projection is still not to specifications, move the liner to a different bore.

6. When the cylinder liner projection is correct, put a temporary mark on the liner and the spacer plate so at final installation the liner can be installed in the correct position.

Cylinder liner projection can be adjusted by the removal of material from (machining) the contact face of the cylinder block with the use of 8S3140 Cylinder Block Counterboring Tool Arrangement. The instructions for the use of the tool group are in Special Instruction Form No. FM055228.

SHIM THICKNESS, COLOR CODE, AND PART NUMBER				
.007 in. (0.18 mm)	.008 in. (0.20 mm)	.009 in. (0.23 mm)	.015 in. (0.38 mm)	.030 in. (0.76 mm)
BLACK	**RED**	**GREEN**	**BROWN**	**BLUE**
8S6045	8S6046	8S6047	8S6048	8S6049

CYLINDER BLOCK

The bore in the block for main bearings can be checked with the main bearing caps installed without bearings. Tighten the nuts holding the caps to the torque shown in the SPECIFICATIONS. Alignment error in the bores must not be more than .003 in. (0.08 mm). Special Instruction Form No. SMHS7606 gives instructions for the use of 1P4000 Line Boring Tool Group for making alignment in the main bearing bores. 1P3537 Dial Bore Gauge Group can be used to check the size of the bores. Special Instruction Form No. GMG00981 is with the group.

1P3537 DIAL BORE GAUGE GROUP

FLYWHEEL AND FLYWHEEL HOUSING

Install Ring Gear

Heat the ring gear to install it. Do not heat to more than 600°F (315°C). Install the ring gear so the chamfer on the gear teeth is next to the starter pinion when the flywheel is installed.

Face Runout (axial eccentricity) of the Flywheel Housing

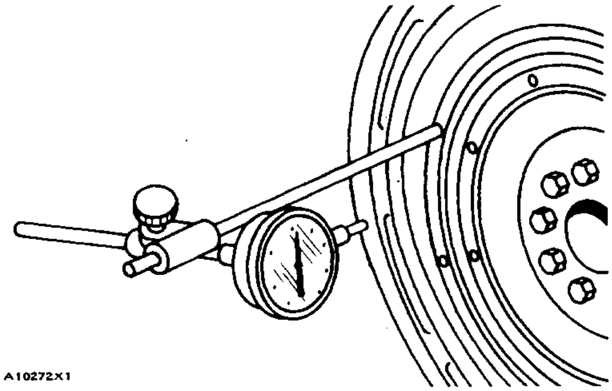
Tools Needed: 8S2328 Dial Indicator Group.

If any method other than given here is used, always remember bearing clearances must be removed to get correct measurements.

1. Fasten a dial indicator to the crankshaft flange so the anvil of the indicator will touch the face of the flywheel housing.

2. Put a force on the crankshaft toward the rear before reading the indicator at each point.

3. With dial indicator set at .000 in. (0.0 mm) at location (A), turn the crankshaft and read the indicator at locations (B), (C) and (D).



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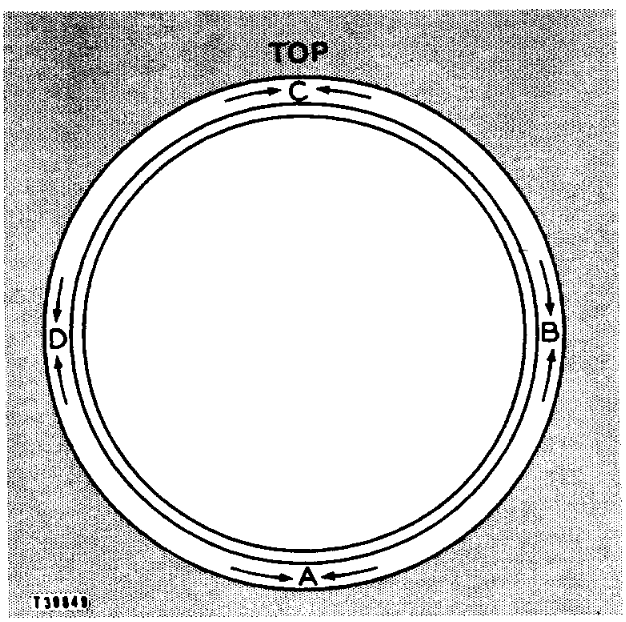
8S2328 DIAL INDICATOR GROUP INSTALLED

4. The difference between lower and higher measurements taken at all four points must not be more than .012 in. (0.30 mm), which is the maximum permissible face runout (axial eccentricity) of the flywheel housing.



T39949

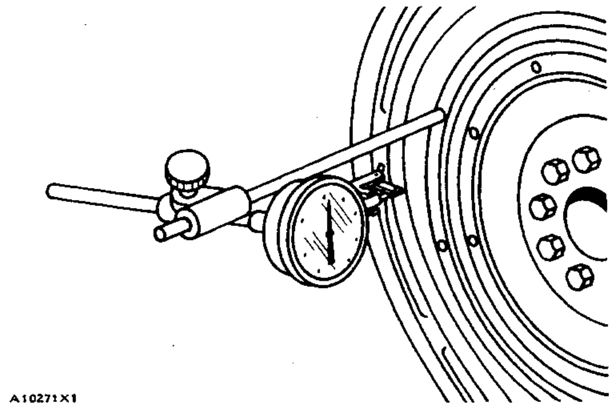
CHECKING FACE RUNOUT OF THE FLYWHEEL HOUSING

A. Bottom. B. Right side. C. Top. D. Left side.

Bore Runout (radial eccentricity) of the Flywheel Housing

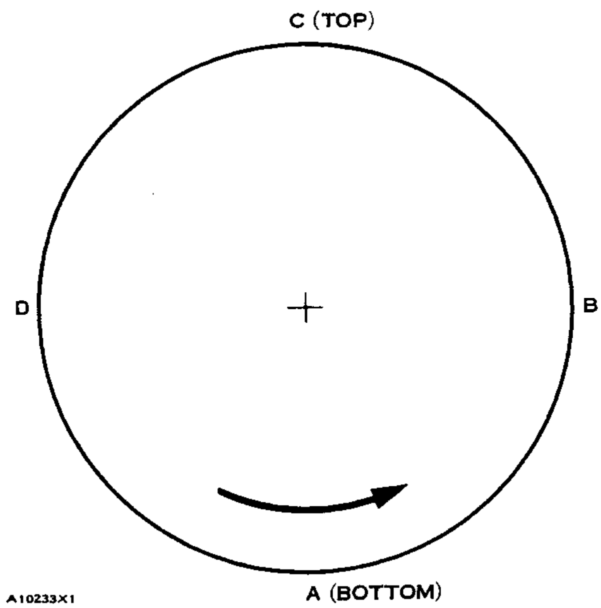
1. With the dial indicator in position at (C), adjust the dial indicator to "0" (zero). Push the crankshaft up against the top bearing. Write the measurement for bearing clearance on line 1 in column (C).

NOTE: Write the dial indicator measurements with their positive (+) and negative (−) notation (signs). This notation is necessary for making the calculations in the chart correctly.



A10271X1

8S2328 DIAL INDICATOR GROUP INSTALLED



A10233X1

CHECKING BORE RUNOUT OF THE FLYWHEEL HOUSING

CHART FOR DIAL INDICATOR MEASUREMENTS

		Position of dial indicator			
	Line No.	A	B	C	D
Correction for bearing clearance	I	0			
Dial Indicator Reading	II	0			
Total of Line 1 & 2	III	0	**	*	**

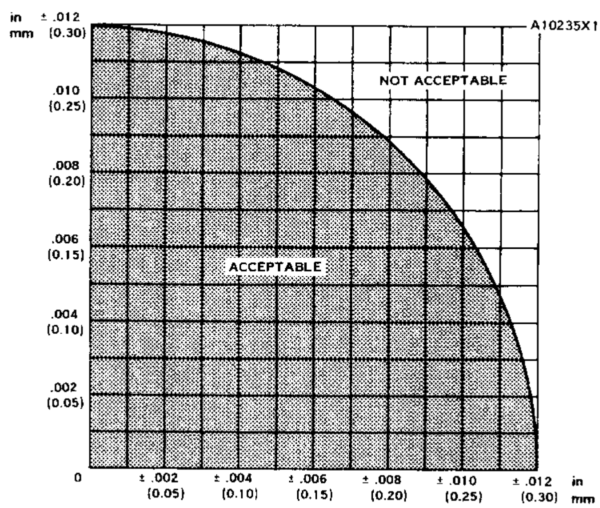
*Total Vertical eccentricity (out of round).
**Subtract the smaller No. from the larger No. The difference is the total horizontal eccentricity.

A10234X1

2. Divide the measurement from Step 1 by 2. Write this number on line 1 in columns (B) & (D).

3. Turn the crankshaft to put the dial indicator at (A). Adjust the dial indicator to "0" (zero).

4. Turn the crankshaft counterclockwise to put the dial indicator at (B). Write the measurement in the chart.
5. Turn the crankshaft counterclockwise to put the dial indicator at (C). Write the measurement in the chart.
6. Turn the crankshaft counterclockwise to put the dial indicator at (D). Write the measurement in the chart.
7. Add lines I & II by columns.
8. Subtract the smaller number from the larger number in line III in columns (B) & (D). The result is the horizontal "eccentricity" (out of round). Line III, column (C) is the vertical eccentricity.

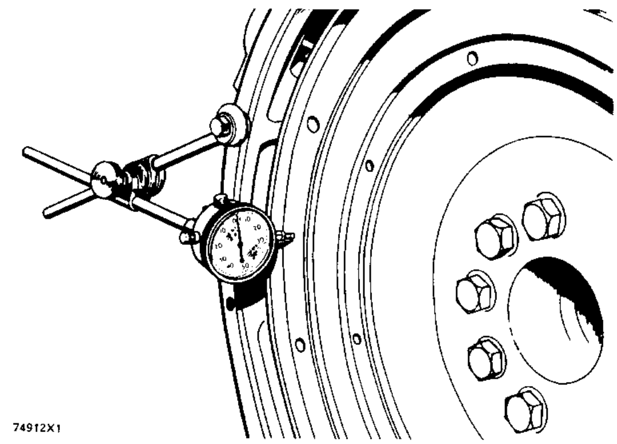


GRAPH FOR TOTAL ECCENTRICITY

9. On the graph for total eccentricity find the point of intersection of the lines for vertical eccentricity and horizontal eccentricity.
10. If the point of intersection is in the range marked "Acceptable" the bore is in alignment. If the point of intersection is in the range marked "Not Acceptable" the flywheel housing must be changed.

Face Runout (axial eccentricity) of the Flywheel

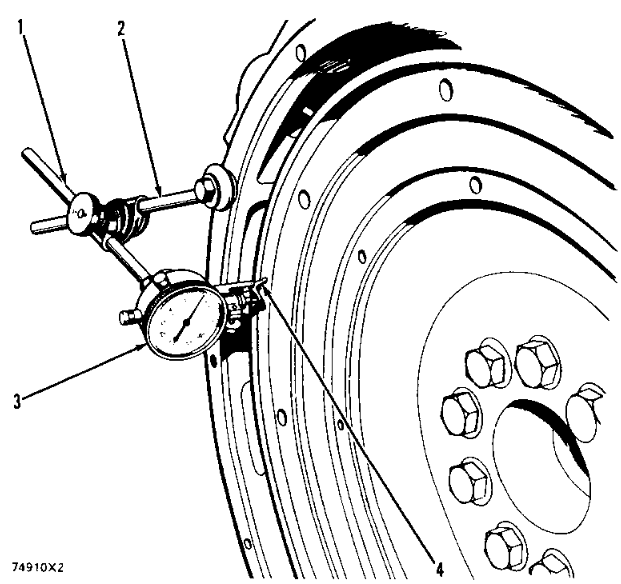
1. Install the dial indicator as shown. Put a force on the crankshaft the same direction before the indicator is read to be sure the crankshaft end clearance (movement) is always removed.
2. Set the dial indicator to read .000 in. (0.0 mm).
3. Turn the flywheel and read the indicator every 90°.
4. The difference between the lower and higher measurements taken at all four points must not be more than .006 in. (0.15 mm), which is the maximum permissible face runout (axial eccentricity) of the flywheel.



CHECKING FACE RUNOUT OF THE FLYWHEEL

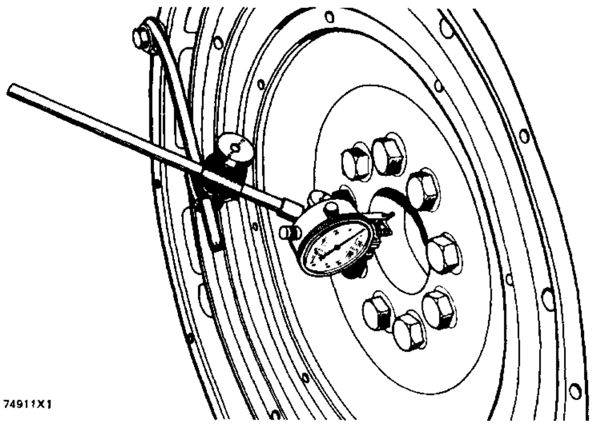
Bore Runout (radial eccentricity) of the Flywheel

1. Install dial indicator (3) and make an adjustment of universal attachment (4) so it makes contact as shown.
2. Set the dial indicator to read .000 in. (0.0 mm).
3. Turn the flywheel and read the indicator every 90°



CHECKING BORE RUNOUT OF THE FLYWHEEL

1. 7H1945 Holding Rod. 2. 7H1645 Holding Rod. 3. 7H1942 Indicator. 4. 7H1940 Universal Attachment.



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CHECKING FLYWHEEL CLUTCH PILOT BEARING BORE

4. The difference between the lower and higher measurements taken at all four points must not be more than .006 in. (0.15 mm), which is the maximum permissible bore runout (radial eccentricity) of the flywheel.

5. Runout (eccentricity) of the bore for the pilot bearing for the flywheel clutch, must not exceed .005 in. (0.13 mm).

VIBRATION DAMPER

Damage to or failure of the damper will increase vibrations and result in damage to the crankshaft. It will cause more gear train noise at variable points in the speed range.

ELECTRICAL SYSTEM

Most of the tests of the electrical system can be done on the engine. The wiring insulation must be in good condition, the wire and cable connections must be clean and tight, and the battery must be fully charged. If the on the engine test shows a defect in a component, remove the component for more testing.

The service manual TESTING AND ADJUSTING ELECTRICAL COMPONENTS, Form No. REG00636 has complete specifications and procedures for the components of the starting circuit and the charging circuit.

BATTERY

Tools Needed: 5P300 Electrical Tester.
9S1990 or 1P7470 Battery Charger Tester.
5P957 or 5P3414 Coolant and Battery Tester.

NOTE: Make reference to Special Instruction Form No. SEHS7006 and the instructions inside of the cover of the tester, when testing with the 5P300 Electrical Tester.

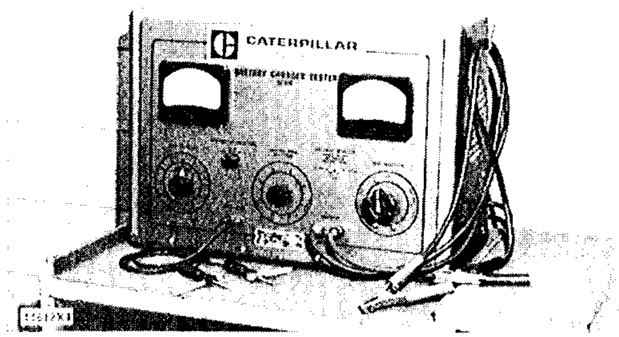
The battery circuit is an electrical load on the charging unit. The load is variable because of the condition of the charge in the battery. Damage to the charging unit will result, if the connections, (either positive or negative) between the battery and charging unit are broken while the charging unit is charging. This is because the battery load is lost and there is an increase in charging voltage. High voltage will damage, not only the charging unit but also the regulator and other electrical components.

⚠ WARNING

Never disconnect any charging unit circuit or battery circuit cable from battery when the charging unit is operated. A spark can cause an explosion from the flammable vapor mixture of hydrogen and oxygen that is released from the electrolyte through the battery outlets. Injury to personnel can be the result.

Load test a battery that does not hold a charge when in use. To do this, put a resistance, across the main connections (terminals) of the battery. For a 6, 8 or 12 V battery, use a test load of three times the ampere/hour rating (the maximum test load on any battery is 500 amperes). Let the test load remove the charge (discharge) of the battery for 15 seconds and with the test load still applied test the battery voltage. A 6 V battery in good condition will show 4.5 V; an 8 V battery will show 6 V; a 12 V battery will show 9 V. Each cell of a battery in good condition must show 1.6 V on either a 6, 8 or 12 V battery.

The Special Instruction Form No. SEHS6891 with the 9S1990 or 1P7470 Battery Charger Tester gives the battery testing procedure.



9S1990 BATTERY CHARGER TESTER

CHARGING SYSTEM

Tools Needed: 5P300 Electrical Tester.

NOTE: Make reference to Special Instruction Form No. SEHS7006 and to the instructions inside of the cover of the tester, when testing with the 5P300 Electrical Tester.

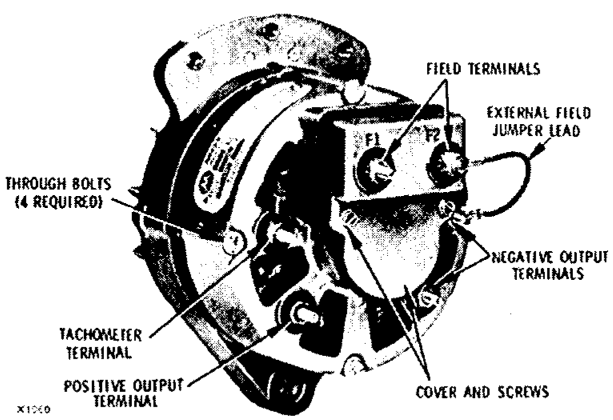
The condition of charge in the battery at each regular inspection will show if the charging system is operating correctly. An adjustment is necessary when the battery is constantly in a low condition of charge or a large amount of water is needed (more than one ounce of water per cell per week or per every 50 service hours).

Make a test of the charging unit and voltage regulator on the engine, when possible, using wiring components that are a permanent part of the system. Off the engine (bench) testing will give a test of the charging unit and voltage regulator operation. This testing will give an indication of needed repair. After repairs are made, again make a test to give proof that the units are repaired to their original operation condition.

Before the on engine test is done, the charging system and battery must be checked as given in the Steps that follow.

1. Battery must be at least 75% (1.240 Sp. Gr.) full charged and held tightly in place. The battery holder must not put too much stress on the battery.
2. Cables between the battery, starter and engine ground must be the correct size. Wires and cables must be free of corrosion and have cable support clamps to prevent stress on battery connections (terminals).
3. Leads, junctions, switches and panel instruments that have direct relation to the charging circuit must give correct circuit control.
4. Inspect the drive components for the charging unit to be sure they are free of grease and oil and have the ability to operate the charging unit.

Alternator (Motorola)



TERMINAL AND PARTS IDENTIFICATION

Before making adjustments, consider the battery condition. See the subject BATTERY.

Battery Circuit Test

Condition: Engine stopped; oil pressure switch open.

1. Connect test ammeter between alternator POSITIVE OUTPUT terminal and battery positive terminal.

NOTE: This is the position for the test ammeter for all the tests.

2. Connect voltmeter positive lead to battery positive terminal. Connect lead to battery negative terminal. Read voltages. Correct voltage on 12 volt system is 11.9 to 12.6 volts.
3. Move voltmeter positive lead to battery side of oil pressure switch. Read voltage. Then move positive lead to alternator POSITIVE OUTPUT terminal. Read voltage. Voltages must be the same as in Step 2. If voltage is lower, check and repair cables, leads or terminals as necessary.
4. Ammeter must read zero at all times during these tests. If ammeter reads down scale, it is an indication of a bad diode in the alternator.

Control Switch Positive Diode Test

Condition: Engine stopped; Oil pressure switch open.

1. Connect positive lead of voltmeter to alternator TACHOMETER terminal. Connect negative lead to battery negative terminal. Voltmeter must read zero. If voltmeter reads above zero, one or more of the positive rectifier diodes in alternator is bad.
2. Connect voltmeter positive lead to alternator side of oil pressure switch. Voltmeter must read zero. If voltmeter reads zero, oil pressure switch can have a defect.
3. Test ammeter must show zero for these tests.

Rotor (Field) Current Draw Test

Condition: Engine stopped; Oil pressure switch open.

NOTE: To make this test you may need a test carbon pile to lower voltage to reference level and a field rheostat.

1. Turn load control knob of carbon pile to OFF position and connect leads to battery.
2. Remove lead from No. 1 FIELD terminal of alternator.
3. Place field rheostat knob in maximum resistance position; connect leads to No. 1 FIELD terminal and POSITIVE OUTPUT terminal of alternator.
4. Connect test voltmeter negative lead to NEGATIVE OUTPUT terminal of alternator. Connect positive lead to No. 1 FIELD terminal.
5. Read all test instruments. Carbon pile voltmeter must read battery voltage. Ammeter must read zero amps. Test voltmeter and test ammeter can be near zero because of the resistance value of field rheostat.

6. Slowly decrease resistance of rheostat to zero. Test voltmeter will give an indication of battery voltage. Ammeter will give an indication of current draw of rotor (field winding). If ammeter reads too much current (more than 5 amps), reverse rheostat to maximum resistance. This is an indication of a problem. Disconnect leads and inspect brushes and rotor circuit for cause of high current draw.

7. Slowly put carbon pile load to battery until test voltmeter is at reference point shown in the chart. Check test ammeter for rotor (field) current draw; it must be the same as the limits shown in the chart.

SYSTEM VOLTAGE	BATTERY VOLTAGE REDUCED TO	ROTOR (FIELD) CURRENT DRAW IN AMPS
12	10	1.65 to 2.25

8. If field current draw is the same as the limits shown, rotor winding is good. If field current is more than the maximum, bench test the alternator. Check for bad brushes, brushes not in alignment, defects in brush leads, foreign material between slip rings or bad rotor (field) winding.

9. Turn carbon pile load off immediately after the test, so the battery will not discharge.

Regulator Load Circuit Loss Test

Condition: Engine stopped; Jumper cable to take current around oil pressure switch.

1. Connect negative lead of test voltmeter to alternator NEGATIVE OUTPUT terminal. Connect positive lead to No. 1 FIELD terminal. Voltmeter must be .9 to 1.5 volts less than battery voltage for all systems. This is the maximum that voltage can go down through the voltage regulator. A reading lower than .9 volts or higher than 1.5 volts is an indication that the voltage regulator has a defect.

2. Remove jumper wire from oil pressure switch after the test is done.

Current Output Test

Condition: Engine stopped; Oil pressure switch open.

1. Connect voltmeter and ammeter leads from carbon pile to battery terminals.

2. Turn load control knob to OFF.

3. Connect test voltmeter and ammeter. Voltmeter will read battery; ammeter must read zero amps.

4. Start engine (oil pressure switch will activate alternator) and run for 5 minutes to make the temperature of the alternator normal.

5. Slowly increase load with carbon pile and increase engine speed until you get minimum rated current output.

6. Check voltage on test voltmeter.

SYSTEM VOLTAGE	MINIMUM CURRENT OUTPUT	VOLTAGE OUTPUT	
		MIN	MAX.
12	25 amps	13 volts	15 volts

7. If volts is more than the maximum limit, check or replace voltage regulator. If system operates normally at low speeds but can not get to minimum rated current output at high engine speeds, check alternator belt for proper tension.

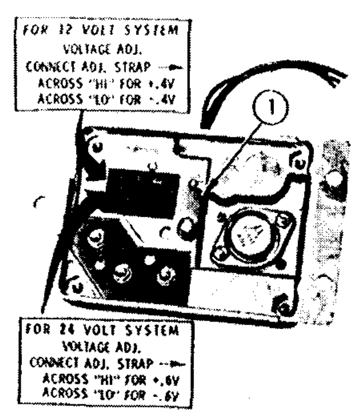
8. Disconnect carbon pile load immediately after alternator is stopped, so the battery will not discharge.

Alternator Regulator (Motorola)

NOTE: Total adjustment is one half a turn.

NOTICE

Do not let screwdriver make contact with cover.



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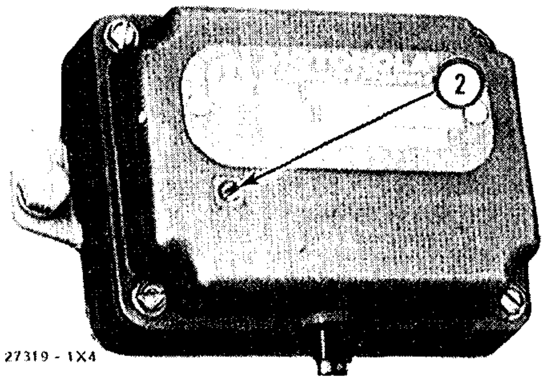
VOLTAGE ADJUSTMENT

1. Metal strap.

When the alternator is either charging the battery too much or not enough, an adjustment can be made to the alternator charging rate. To make an adjustment to the voltage output, remove the cover from the voltage regulator and change the location of the metal strap (1).

To make an increase in the voltage (approximately .4 volt in a 12 volt system and .6 volt in a 24 volt system), remove the nuts from the two studs nearest to the word "HI". Install the metal strap on these studs and install the nuts.



FINE VOLTAGE ADJUSTMENT
2. Cover screw.

To make a decrease in the voltage (approximately .4 volt in a 12 volt system and .6 volt in a 24 volt system), remove the nuts from the two studs nearest to the word "LO". Install the metal strap on these studs and install the nuts.

To make a fine adjustment remove cover screw (2) from the insulator and turn the adjustment screw with a Phillips screwdriver. Turn clockwise to make an increase in voltage.

STARTING SYSTEM

Tools Needed: 5P300 Electrical Tester.

NOTE: Make reference to Special Instruction Form No. SEHS7006 and to the instructions inside of the cover of the tester, when testing with the 5P300 Electrical Tester.

Use a D.C. Voltmeter to find starting system components which do not function.

Move the starting control switch to activate the starter solenoid. Starter solenoid operation can be heard as the pinion of the starter motor is engaged with the ring gear on the engine flywheel.

If the solenoid for the starter motor will not operate, it is possible that the current from the battery does not get to the solenoid. Fasten one lead of the voltmeter to the connection (terminal) for the battery cable on the solenoid. Put the other lead to a good ground. No voltmeter reading shows there is a broken circuit from the battery. More testing is necessary when there is a reading on the voltmeter.

The solenoid operation also closes the electric circuit to the motor. Connect one lead of the voltmeter to the solenoid connection (terminal) that is fastened to the motor. Put the other lead to a good ground. Activate the starter solenoid and look at the voltmeter. A reading of battery voltage shows the problem is in the motor. The motor must be removed for more testing. No reading on the voltmeter shows that the solenoid contacts do not close. This is an indication of the need for repair to the solenoid or an adjustment to be made to the starter pinion clearance.

Make a test by fastening one voltmeter lead to the connection (terminal) for the small wire at the solenoid and the other lead to the ground. Look at the voltmeter and activate the starter solenoid. A voltmeter reading shows that the problem is in the solenoid. No voltmeter reading shows that the problem is in the heat-start switch or wiring.

Fasten one voltmeter lead to the heat-start switch at the connection (terminal) for the wire from the battery. Fasten the other lead to a good ground. No voltmeter reading indicates a broken circuit from the battery. Make a check of the circuit breaker and wiring. If there is voltmeter reading, the malfunction is in the heat-start switch or in the wiring.

Fasten one lead of the voltmeter to the battery wire connection of the starter switch and put the other lead to a good ground. A voltmeter reading indicates a failure in the switch.

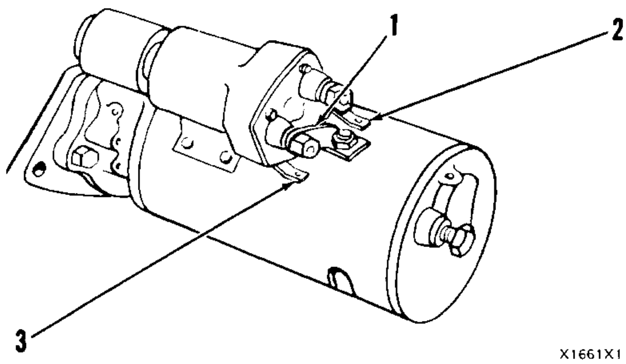
A starter motor that operates too slow can have an overload because of too much friction in the engine being started. Slow operation of the starter motor can also be caused by shorts, loose connections, and/or dirt in the motor.

Pinion Clearance Adjustment (Delco-Remy)

When the solenoid is installed, adjust the pinion clearance. Make the adjustment with the starter motor removed.

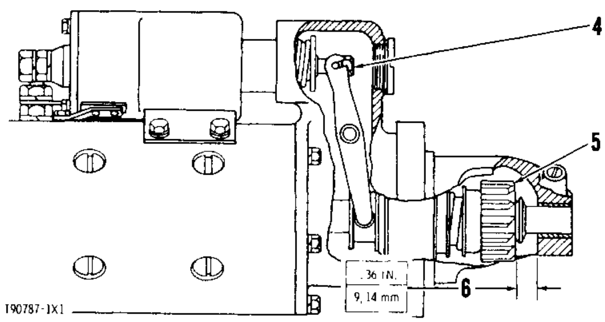
Bench test and adjust the pinion clearance at installation of solenoid as follows:

1. Install the solenoid without connector (1) from the MOTOR terminal on solenoid to the motor.
2. Connect a battery, of the same voltage as the solenoid, to the terminal (2), marked SW.
3. Connect the other side of battery to ground terminal (3).



CONNECTIONS FOR CHECKING PINION CLEARANCE

1. Connector from MOTOR terminal on solenoid to motor. 2. SW terminal. 3. Ground terminal.



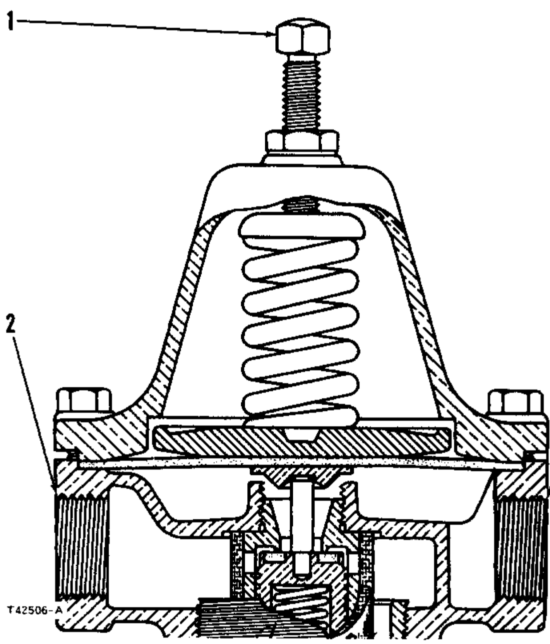
PINION CLEARANCE ADJUSTMENT

4. Shaft nut. 5. Pinion. 6. Pinion clearance.

4. MOMENTARILY flash a jumper wire from the solenoid terminal marked MOTOR to the ground terminal. The pinion will shift into cranking position and will remain there until the battery is disconnected.
5. Push pinion towards commutator end to eliminate free movement.
6. Pinion clearance (6) is .33 to .39 in. (8.3 to 9.9 mm).
7. To adjust clearance remove the plug and turn shaft nut (4).

AIR STARTING SYSTEM

Pressure Regulating Valve



PRESSURE REGULATING VALVE (TYPICAL ILLUSTRATION)

1. Adjustment screw. 2. Regulator inlet. 3. Regulator outlet.

Use the procedure that follows to check and adjust the pressure regulating valve.

1. Drain the line to the pressure regulating valve or drain the air storage tank.
2. Disconnect the regulator from the starter control valve.
3. Connect an 8M2885 Pressure Gauge to the regulator outlet.
4. Put air pressure in the line or tank.
5. Check the pressure.
6. Adjust the pressure regulating valve to 100 to 150 psi (690 to 1030 kPa).
7. Remove the air pressure from the line or tank.
8. Remove the 8M2885 Pressure Gauge and connect the air pressure regulator to the line to the air starting motor.

Each engine application will have to be inspected to get the most acceptable starting results. Some of the factors that affect regulating valve pressure setting are: attachment loads pulled by engine during starting, ambient temperature conditions, oil viscosity, capacity of air reservoir, and condition of engine (new or worn).

The advantages of setting the valve at the higher pressures are increased torque for starting motor and faster rotation of engine. The advantage of setting the valve at the lower pressures is longer time of engine rotation for a given reservoir capacity of supply air.

Lubrication

Always use an air line lubricator with these Starters.

For temperatures above 32°F (0°C), use a good quality SAE 10 motor oil.

For temperatures below 32°F (0°C), use diesel fuel.

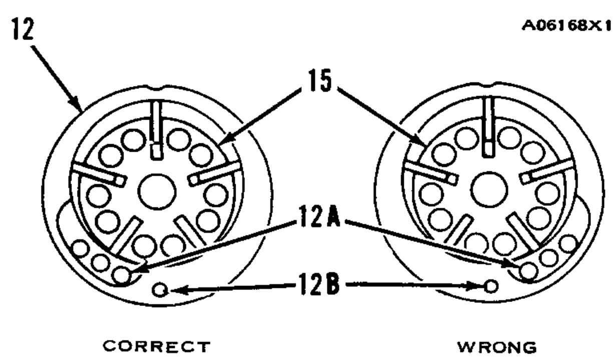
To maintain the efficiency of the starting motor flush it at regular intervals. Put approximately 1 pt. (0.5 litre) of diesel fuel into the air inlet of the starting motor and operate the motor. This will remove the dirt, water and oil mixture (gummy coating) from the vanes of the motor.

Air Starting Motor

The cylinder (12) must be assembled over the rotor (15) and on the front end plate (16) so the dowel hole (12B) and the inlet passages (12A) for the air are as shown in the rear view illustration of the cylinder and rotor. If the installation is not correct, the starter drive (42) will turn in the wrong direction.

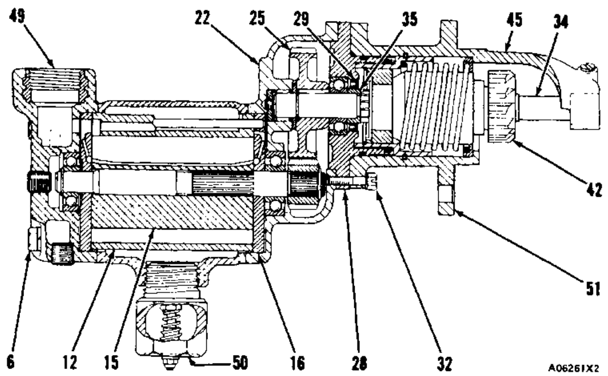
Tighten the bolts (6) of the rear cover in small increases of torque for all bolts until all bolts are tightened to 20 to 25 lb. ft. (25 to 35 N·m).

Put a thin layer of lubricant on the lip of the seal (29) and on the outside of the collar (35), for installation of drive shaft (34). After installation of the shaft through the cover (28), check the lip of the grease seal (29). It must be turned correctly toward the drive gear (25). If the shaft turned the seal lip in the wrong direction, remove the shaft and install again. Use a tool with a thin point to turn the seal lip in the correct direction.



REAR VIEW OF THE CYLINDER AND ROTOR FOR CLOCKWISE ROTATION

12. Cylinder. 12A. Air inlet passages. 12B. Dowel hole. 15. Rotor.



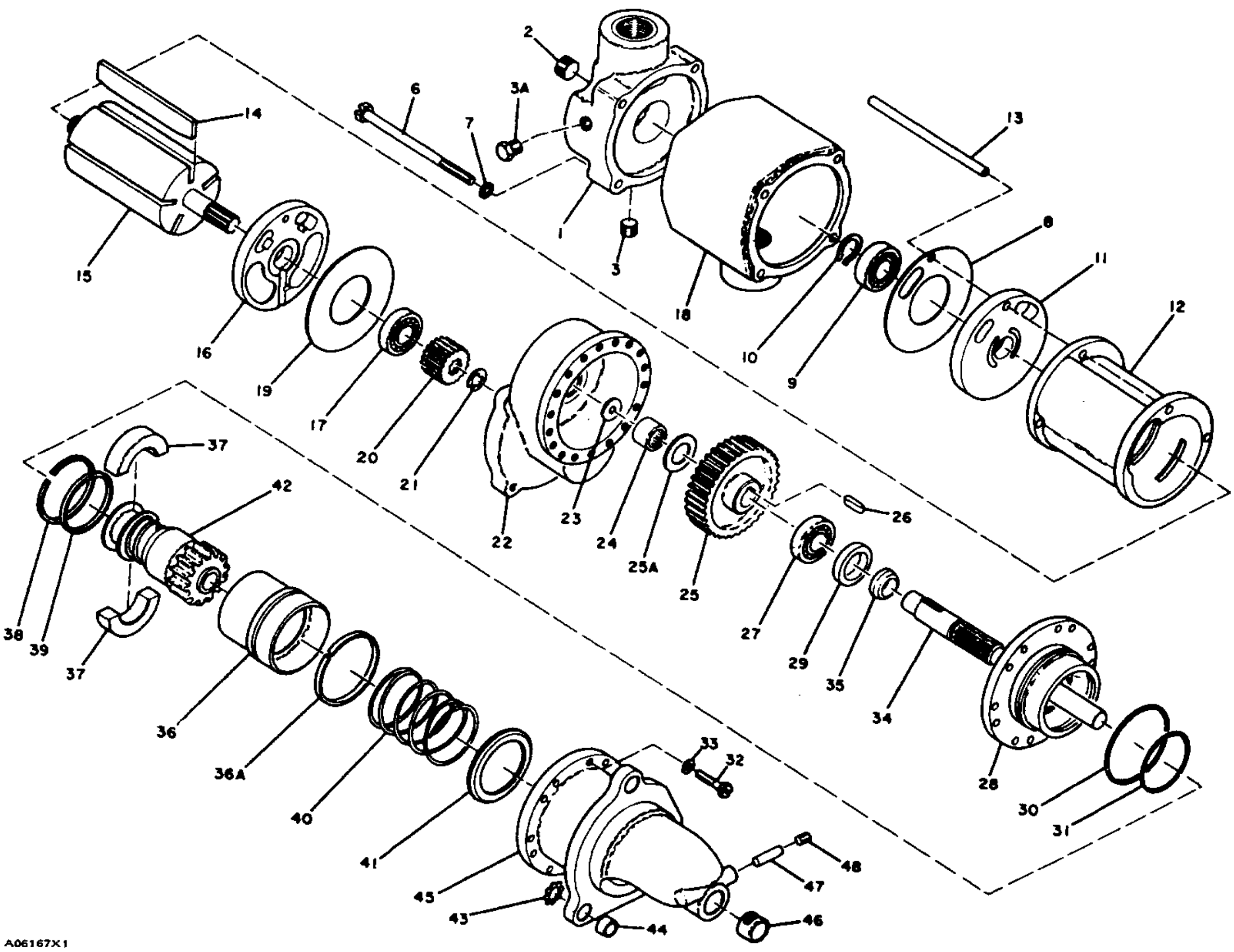
AIR STARTER (INGERSOLL-RAND)

6. Bolt. 12. Cylinder. 15. Rotor. 16. Front end plate. 22. Gear case. 25. Drive gear. 28. Gear case cover. 42. Starter drive (pinion). 45. Drive housing. 49. Air inlet. 50. Deflector (air outlet). 51. Mounting flange on the drive housing.

Tighten the bolts (32) of the drive housing in small increases of torque for all bolts until all bolts are tighten to 100 lb. in. (11.3 N·m).

Check the motor for correct operation. Connect an air hose to the air inlet (49) and make the motor turn slowly. Look at the drive pinion (42) from the front of the drive housing (45). The pinion must turn clockwise.

Connect an air hose to the small hole with threads in the drive housing (45), near the gear case (22). When a little air pressure goes to the drive housing, the drive pinion (42) must move forward to the engaged postion. Also, the air must get out through the other hole with threads nearer the mounting flange (51).



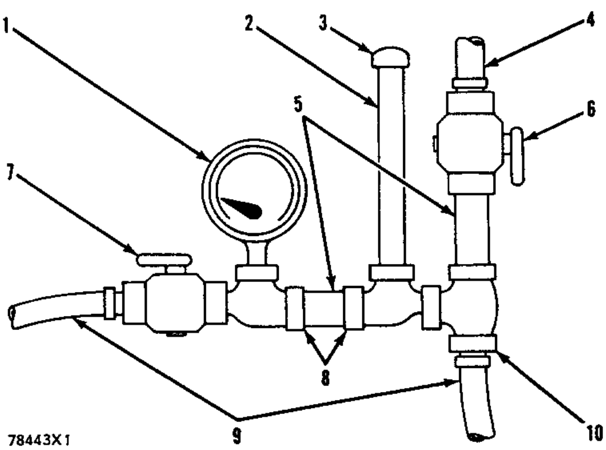
COMPONENTS OF THE AIR STARTER (INGERSOLL-RAND, SIZE 150 BMP,MODEL C OR E)

1. Motor housing cover. 2. Plug. 3. Plug. 3A. Plug. 6. Bolt (cap screw). 7 lockwasher. 8. Gasket. 9. Rotor rear bearing. 10. Bearing retainer. 11. Rear end plate. 12. Cylinder. 13. Dowel. 14. Rotor vane. 15. Rotor. 16. Front end plate. 17. Rotor front bearing. 18. Motor housing. 29. Gear case gasket. 20. Rotor pinion. 21. Rotor pinion retainer. 22. Gear case. 23. Bearing ejecting washer. 24. Rear bearing for the drive shaft. 25. Drive gear. 25A. Thrust washer. 26. Key for the drive gear. 27. Front bearing for the drive shaft. 28. Gear case cover. 29. Grease seal for the drive shaft. 30. Cover seal. 31. Piston seal. 32. Bolt. 33. Lockwasher. 34. Drive shaft. 35. Drive shaft collar. 36. Piston. 36A. Piston ring. 37. Shift ring. 38. Shift ring retainer. 39. Shift ring spacer. 40. Piston return spring. 41. Return spring seat. 42. Starter drive (pinion). 43. Lockwasher. 44. Bushing for the bolts. 45. Drive housing. 46. Drive housing bushing. 47. Oiler felt for the bushing. 48. Oiler plug.

PROTECTION DEVICES

CONTACTOR SWITCH FOR OIL PRESSURE

Tools Needed: 3P1564 Pressure Gauge (0 to 60 psi).
3B7734 Pipe Nipple, 1/8 in. X 3.5 in.
3B6483 Cap. Two 3B7263 Pipe Nipples, 1/8 in. X 2 in.
Two 3B9389 Shutoff Cock Fittings.
Two 1F9369 Tees.
44914 Tee.
Two 5K3772 Hose Assemblies.
8S4627 Circuit Tester.



TEST EQUIPMENT

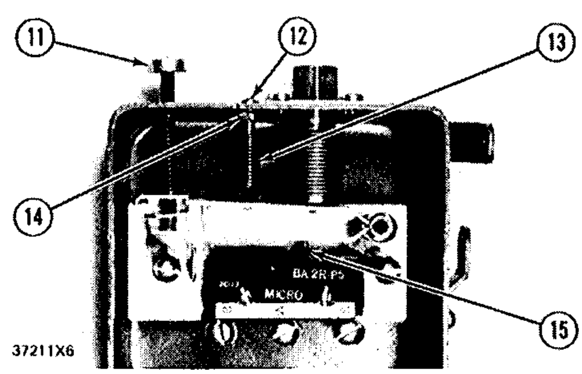
1. 3P1564 Pressure Gauge (0 to 60 psi). 2. 3B7734 Pipe Nipple. 3. 3B6483 Cap. 4. Oil supply line. 5. 3B7263 Pipe Nipple. 6. 3B9389 Shutoff Cock Fitting. 7. 3B9389 Shutoff Cock Fitting. 8. 1F9369 Tee. 9. 5K3772 Hose Assemblies. 10. 44914 Tee.

Test Procedure

1. Remove the cover of the contactor switch and disconnect the wires from the normally closed terminal.
2. Disconnect the oil supply line from the contactor switch and install the test equipment as shown.
3. Connect 5K3772 Hose from tee (10) to the contactor switch. Put the end of the other 5K3772 Hose in a pan.
4. Connect the 8S4627 Circuit Tester between the common terminal and the normally closed terminal. The light of the circuit tester will be activated.
5. Close shutoff fitting (7) and open shutoff fitting (6).
6. Look at the pressure gauge, start the engine and run it at low idle rpm. The light must go out, with an increase in oil pressure, at the specification of the switch.
7. Close shutoff fitting (6) and slowly open shutoff fitting (7). The light must be activated, with a decrease in oil pressure, at the specification of the switch.
8. Stop the engine.
9. Connect the wire(s) to the normally closed terminal.
10. On contactor switches with a button or a control knob either push the button or turn the knob to the OFF position.
11. Close shutoff fitting (7) and open shutoff fitting (6).
12. Start the engine and run it at low idle rpm.
13. Put a jumper wire between the common terminal and the normally closed terminal. This will check the sytem beyond the contactor switch.
14. Remove the jumper wire.

Adjustment of Micro Switch Type

1. Loosen locknut (14) and turn adjustment screw (12) counterclockwise to make a decrease in the tension of spring (13).

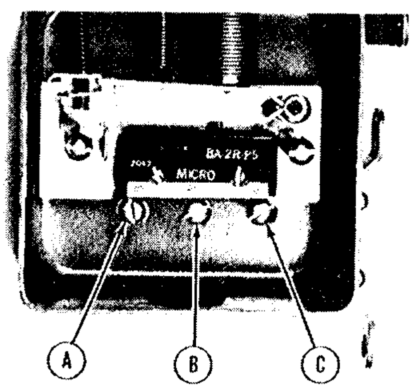


CONTACTOR SWITCH FOR OIL PRESSURE (Micro Switch Type)

11. Set for start button. 12. Adjustment screw. 13. Spring. 14. Locknut. 15. Contact button.

2. Disconnect the wires from the normally closed terminal of the switch.
3. Start the engine and run it at low idle rpm.
4. Close shutoff fitting (6) and slowly open shutoff fitting (7) until the pressure gauge shows the pressure specification at which the switch must close with a decrease in pressure. Close shutoff fitting (7).

5. Make sure the set for start button (11) is in the RUN position.
6. Connect the 8S4627 Circuit Tester between the common terminal and the normally closed terminal. The light of the circuit tester must not be activated.
7. Turn adjustment screw (12) clockwise until the light of the circuit tester is activated.
8. Tighten the locknut.
9. To check the adjustment, close shutoff fitting (7) and open shutoff fitting (6).
10. Connect the wires to the normally closed terminal.
11. Close shutoff fitting (6) and slowly open shutoff fitting (7) until the engine stops or the alarm operates.
12. The pressure gauge must show the correct pressure specification of the switch as the engine stops or the alarm operates.



37211X7

WIRING CONNECTIONS

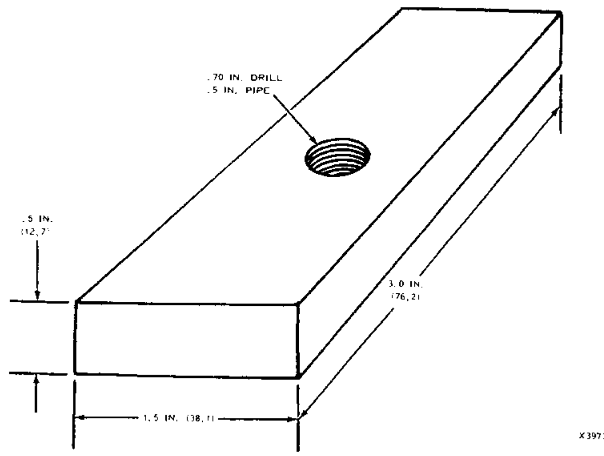
A. Normally closed B terminal. B. Normally open W terminal. C. Common R terminal.

CONTACTOR SWITCH FOR WATER TEMPERATURE

Tools Needed: Fabricated heat sink.
2F7112 Thermometer.
3J5389 Plug.
8S4627 Circuit Tester.

First Method of Checking

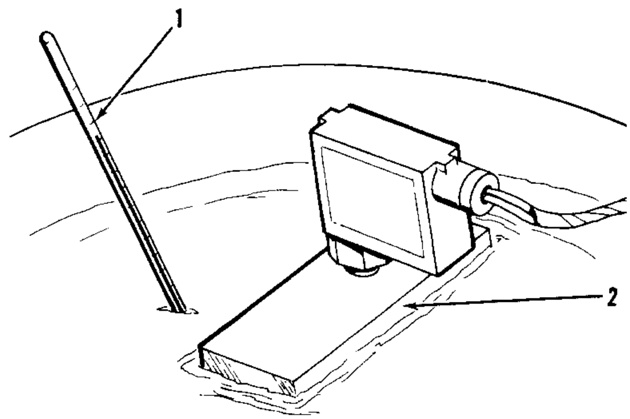
1. Make a heat sink as shown. Material can be brass, steel or cast iron. Drill a 23/32 in. hole through the plate and use a tap to make ½ in. NPT threads.
2. Put marks on the two contactor wires that connect the contactor to the circuit. Disconnect the two wires.



X3973

HEAT SINK
[Dimensions in inches (mm)]

3. Remove the contactor and install a 3J5389 Plug. Install the contactor switch in the heat sink.
4. Put the heat sink and contactor in water as shown. Use blocks to support the heat sink at surface level.



X3974

TEST OF CONTACTOR SWITCH

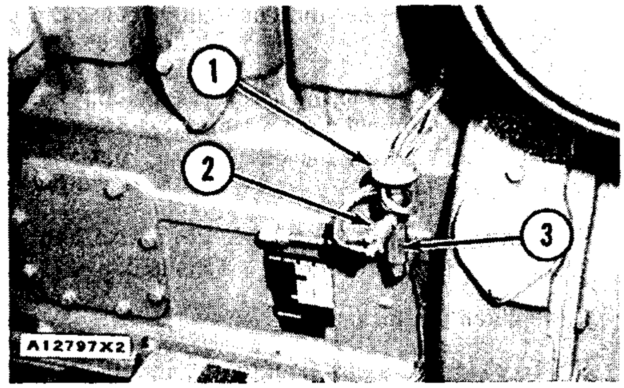
1. 2F7112 Thermometer. 2. Fabricated heat sink.

5. Connect the 8S4627 Circuit Tester between the wires that connected the contactor to the circuit.
6. Put the 2F7112 Therometer in the water.
7. Use a torch to heat the water to the temperature range at which the contactor must activate. If the circuit tester light does not come on within the temperature range given in the specifications make a replacement of the contactor.
8. Let the water temperature go down. If the circuit tester light does not go out within the temperature range given in the specifications make a replacement of the contactor.

PRESSURE SWITCH WITH TIME DELAY

**Tools Needed: 8M2743 Gauge.
8S4627 Circuit Tester.**

1. Disconnect the wires from pressure switch (2). Remove the pressure switch from the tee.
2. Install a short nipple, shutoff valve and short nipple and another tee in the place of pressure switch (2). Make sure that the valve is closed.
3. Install pressure switch (2) and a 8M2743 Gauge in the open ends of the tee.
4. Connect the 8S4627 Circuit Tester between the terminals of the pressure switch.
5. Start the engine. Open the shutoff valve a small amount. Look at the pressure on the 8M2743 Gauge. When the pressure gets to the range given in the specifications the circuit tester light must go on.
6. Close the shutoff valve. Stop the engine. Open the shutoff valve a small amount. Look at the pressure on the 8M2743 Gauge.



**OIL PRESSURE SWITCH WITH TIME DELAY INSTALLED
(Typical Example)**

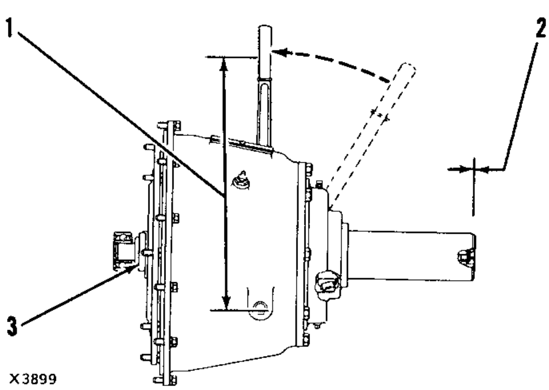
1. Damper. 2. Pressure switch. 3. Valve.

ENCLOSED CLUTCH

CLUTCH ADJUSTMENT

NOTE: Before clutch is installed, check the flywheel housing for face and bore runout.

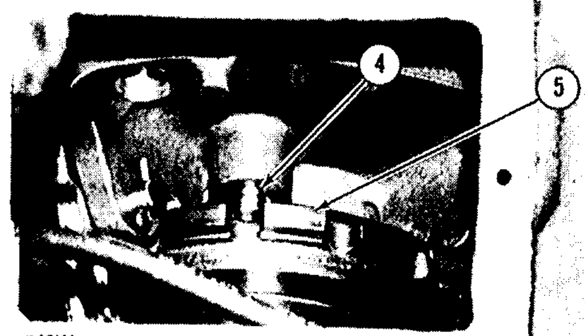
1. To get shaft bearing end clearance, tighten adjusting nut (3) to remove all clearance and seat bearing cups. The shaft should turn with no grease in bearings at a torque of 60 lb. in. (6.8 N•m) plus seal drag.
2. Loosen adjusting nut (3) two or three notches.
3. Hit the end of the output shaft with a soft hammer to move bearings forward and check end clearance for shaft. End clearance should be .006 to 0.10 in. (0.15 to 0.25 mm). Bend lock into notch in adjusting nut (3).



CLUTCH ADJUSTMENT

1. Location to check pull on clutch lever, 21.3 in. (541 mm) from center of shaft. 2. Place to check end clearance, .006 to 0.10 in. (0.15 to 0.25 mm). 3. Adjusting nut.

4. Adjust the clutch for clutch plate pressure and engagement pull. Push in on lock pin (4) and turn adjusting ring (5).



CLUTCH ADJUSTMENT

4. Lock pin. 5. Adjusting Ring.

CLUTCH ASSEMBLIES	2N6961 and 2N7078
Engagement Lever Pull Adjustment	123 to 163 lb. (545 to 725 N)
Measurement from Center of Shaft at (3)	21.3 in. (541 mm)
Torque on Shaft for Engagement	262.5 lb. ft. (356 N•m)
Thickness of one New Drive Plate and two New Driven Plates	.620 to .630 in. (15.8 to 16.0 mm)
Torque for Adjusting Nut (3)	30 lb. ft. (40 N•m) Then Tighten 150° to 180° more
End Clearance for Shaft	.006 to 0.10 in. (0.15 to 0.25 mm)

5. After adjustment, lock pin (4) must be in one of the slots in adjusting ring (5).
6. Check pull on lever at (1). Pull should be 123 to 163 lb. (545 to 725 N).

D & A GENERAL INSTRUCTIONS (Section 4)

GENERAL INSTRUCTIONS

The following instructions will prove helpful to disassemble and assemble engine components. The information should be read and then referred to as necessary.

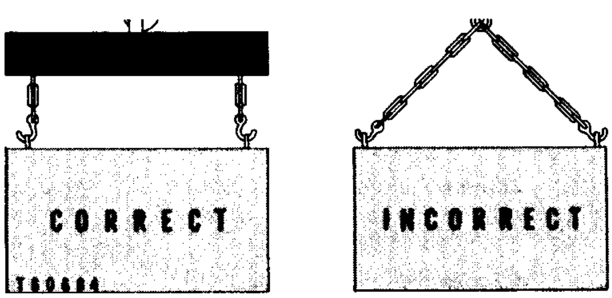
CLEANLINESS

Whenever hydraulic, fuel, lubricating oil or air lines are disconnected, clean the point of disconnection and the adjacent area. As soon as the disconnection is made, cap, plug or tape the line or opening to prevent entry of foreign material. The same recommendations for cleaning and covering apply when access covers or inspection plates are removed.

Clean and inspect all parts. Be sure all passages and holes are open. Cover all parts to keep them clean. Be sure parts are clean when installed. Leave new parts in their containers until ready for assembly.

REMOVAL AND INSTALLATION

Unless otherwise specified, all removals should be accomplished using an adjustable lifting beam. All supporting members (chains and cables) should be parallel to each other and as near perpendicular as possible to the top of the object being lifted.



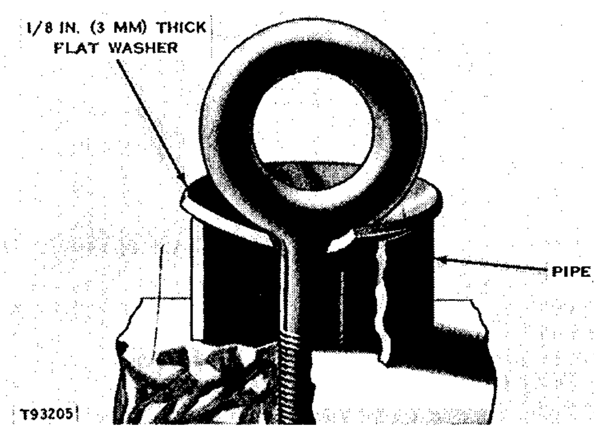
When it is necessary to remove a component on an angle, remember that the capacity of an eyebolt diminishes as the angle between the supporting members and the object becomes less than 90°. Eyebolts and brackets should never be bent and should only have stress in tension. A length of pipe and a washer can be used, as shown, to help relieve these stresses on eyebolts.

Forged eyebolts are available. Each size eyebolt has a maximum load recommendation.

Some removals require the use of lifting fixtures to obtain proper balance and to provide safe handling.

If a part resists removal, check to be certain all nuts and bolts have been removed and that an adjacent part is not interfering.

EYEBOLT LOAD RECOMMENDATION			
SIZE	PART NO.	MAXIMUM LOAD lbs.	MAXIMUM LOAD kg
¼"—20	1P7403	600	272.3
5/16"—18	1P7404	1125	510.6
⅜"—16	1P7405	1625	737.6
7/16"—14	1P7406	2250	1021.3
½"—13	1P7407	3000	1361.7
⅝"—11	2D1201	5000	2269.5
¾"—10	1P7409	6250	2836.9



DISASSEMBLY AND ASSEMBLY

When assembling an engine, complete each step in turn. Do not partially assemble one part and start assembling some other part. Make all adjustments as recommended. Always check the job after it is completed to see nothing has been overlooked.

LUBRICATION FOR A REBUILT ENGINE

It is very important for a rebuilt engine to have "adequate" (needed) lubrication during the first seconds of operation. A "dry start" (without needed lubrication) on a rebuilt engine or an engine that has been in storage can cause bearing damage.

To prevent the possibility of a "dry start" and bearing damage during the first seconds of running, use the 1P540 Flow Checking Tool Group and shop air pressure to pressure lubricate (fill the main oil passage with oil under pressure) all rebuilt engines and all engines that have been in storage.

Procedure for Pressure Lubrication

1. Clean the tank of the 1P540 Flow Checking Tool Group thoroughly, and set the pressure regulator to 35 ± 5 psi (240 ± 35 kPa).

⚠ WARNING

Air pressure should not be more than 50 psi (345 kPa) at any time.

2. Put engine oil in the tank. Use a minimum of 30% of the engine oil capacity. For some engines it will be necessary to fill the tank several times to get the correct amount of oil in the engine.
3. Connect the tooling to the main oil passage of the engine.
4. Add air pressure to the tank, with the regulator set at 35 ± 5 psi (240 ± 35 kPa). Although the tank does have a hand pump, it is difficult to get enough air pressure to do the job with the hand pump. Therefore, use of shop air is recommended.
5. Let the engine oil flow into the oil passage under pressure.

Fill the crankcase with the correct oil. The amount of oil used in the pressure lubrication procedure must be subtracted from the recommended refill capacity in the Lubrication and Maintenance Guide. If the engine is not going to be used for a long time, do the above procedure again before the first starting.

If shop air is not available for charging the tank, the hand pump may be used to get the minimum required pressure.

NOTICE

Do not use the same 1P540 Flow Checking Tool Group for both "pressure lubrication application" and for checking fuel flow. Incorrect cleaning is probable if the tool is used for both fuel and lube oil. Even a minute amount of dirt in the fuel system can cause fuel nozzle failure.

INITIAL OPERATION AFTER ENGINE RECONDITIONING

The quality of oil control components used in Caterpillar engines is such that, following engine reconditioning (with Caterpillar Service Parts), only an initial operational check is necessary before continued operation in normal service.

The purpose of this initial operational check is to: insure that the engine has been assembled properly; determine if proper pressures and temperatures are maintained in the lubrication, cooling and fuel systems; correct any leaks; perform necessary adjustments (such as valve clearance, governor high and low idle speeds, etc.); check the power setting of the engine.

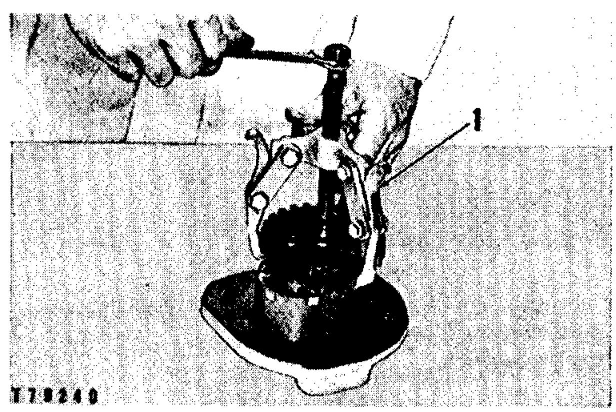
To provide a safe, uniform initial operational check, the following procedure is recommended:

1. Motor engine at cranking speed until oil pressure is observed.
2. Operate engine for 10 minutes at low idle.
3. Operate engine for 15 minutes at half-load and 3/4 rated speed.
4. Operate engine for 30 minutes at rated load and speed.

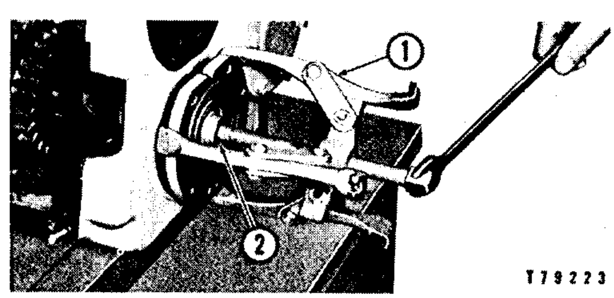
SERVICE TOOLS

Puller Assembly (2 or 3 Arm)

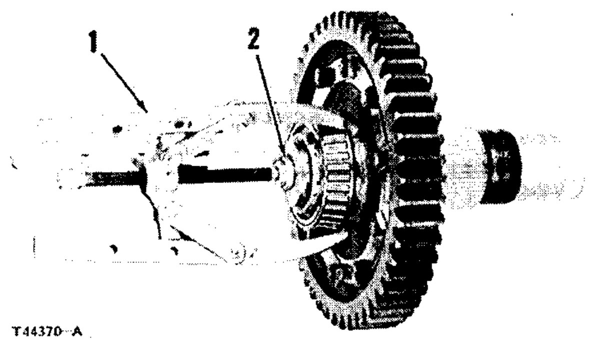
Two or three arm puller assemblies can be used to remove gears, bearing cages, hubs, bearings, shafts, etc.



TYPICAL EXAMPLE
1. Puller.



TYPICAL EXAMPLE
1. Puller. 2. Step Plate.

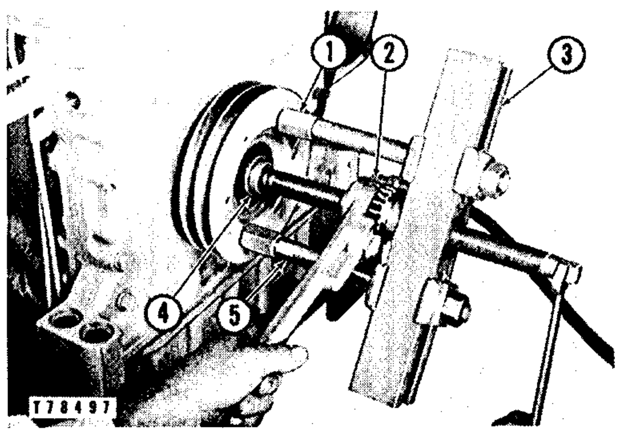


TYPICAL EXAMPLE

1. Puller. 2. Step Plate.

Push Pullers

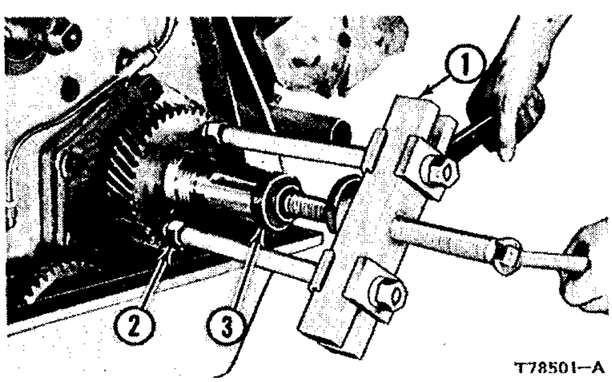
Push Pullers can be used to remove pulleys, gears, shafts, etc., and can be used in a variety of pulling combinations.



TYPICAL EXAMPLE

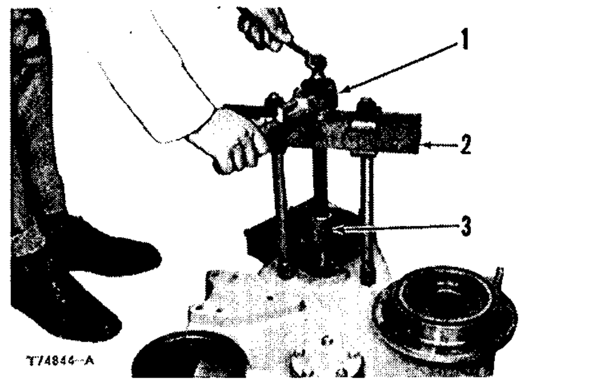
*1. Adapters. 2. Ratchet Box Wrench. 3. Push Puller. 4. Step Plate. 5. Legs.

*Use as required.



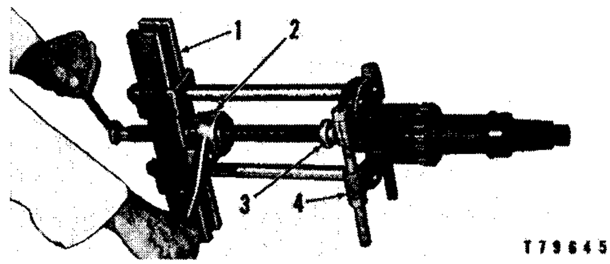
TYPICAL EXAMPLE

1. Push Puller. 2. Adapter. 3. Step Plate.



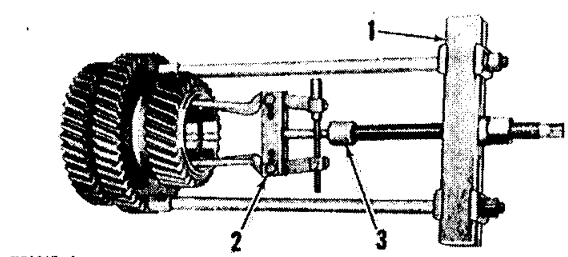
TYPICAL EXAMPLE

1. Ratchet Box Wrench. 2. Push Puller. 3. Reducing Adapter.



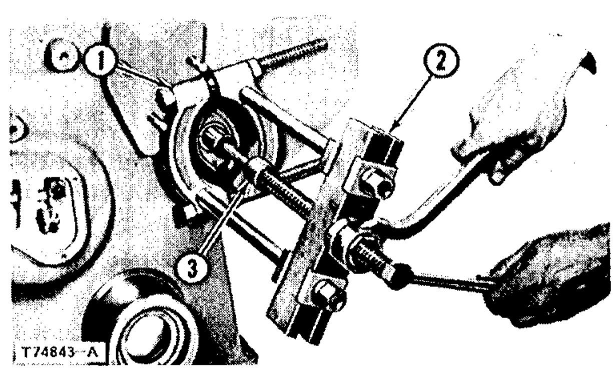
TYPICAL EXAMPLE

1. Push Puller. 2. Ratchet Box Wrench. 3. Step Plate. 4. Bearing Pulling Attachment.



TYPICAL EXAMPLE

1. Push Puller. 2. Bearing Cup Pulling Attachment. 3. Reducing Adapter.

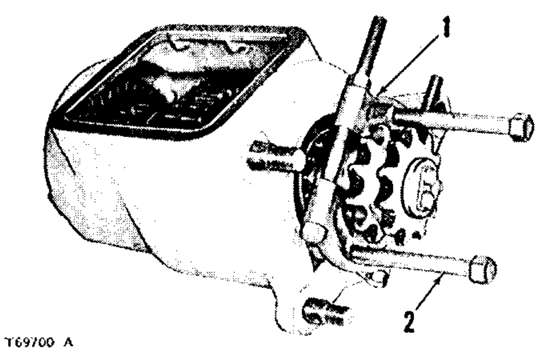


TYPICAL EXAMPLE

1. Bearing Pulling Attachment. 2. Push Puller. 3. Reducing Adapter.

Bearing Pulling Attachment

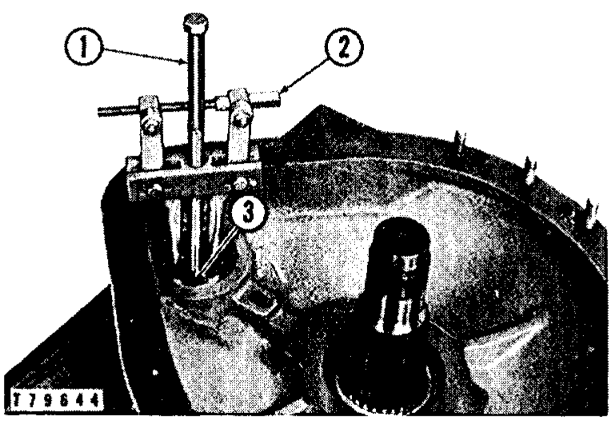
Bearing Pulling Attachments can be used with forcing bolts, to remove shafts, bearings, gears, etc. They can be used with Push Pullers to provide a variety of pulling combinations.



TYPICAL EXAMPLE
1. Bearing Pulling Attachment. 2. Forcing Bolts.

Bearing Cup Pulling Attachment

Bearing Cup Pulling Attachments are used to remove bearing races or cups, sleeve-type bearings, bearings, seats, etc. and can be used with Push Pullers.



TYPICAL EXAMPLE
1. Screw. 2. Bearing Cup Pulling Attachment. 3. Step Plate.

RULES FOR USE OF TOOLS

RULE 1: Always use safe tools.
RULE 2: Keep tools in safe working condition.
RULE 3: Use the correct tool for the job.
RULE 4: Common sense with tools pays off.

PRESSING PARTS

When pressing one part into another, use 5P3931 Anti-Seize Compound or a molybdenum disulfide base compound to lubricate the mating surfaces.

Assemble tapered parts dry. Before assembling parts with tapered splines, be sure the splines are clean, dry and free from burrs. Position the parts together by hand to mesh the splines before applying pressure.

If parts which are fitted together with tapered splines are not tight, inspect the tapered splines and discard if worn.

BOLTS AND BOLT TORQUE

A bolt which is too long may "bottom" before the head is tight against the part it is to hold. The threads can be damaged when a "long" bolt is removed.

If a bolt is too short, there may not be enough threads engaged to hold the part securely.

Apply proper torque values to all bolts and nuts when assembling Caterpillar equipment. When a specific torque value is required, the value is listed in the SPECIFICATIONS section of the Service Manual. Tighten all other bolts and nuts for general usage, hydraulic valve bodies, or taperlock studs to the torque values given in the torque charts.

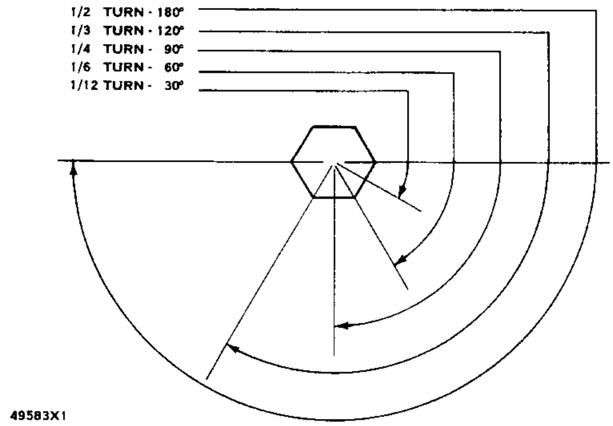
T-T-T Procedure

A torque-turn-tighten (T-T-T) procedure is used in many specifications and instructions.

1. Clean the bolt and nut threads.
2. Put lubricant on the threads and the seat face of the bolt and the nut.
3. Turn the bolt or the nut tight according to the torque specification.
4. Put a location mark on the part and on the bolt or the nut.
5. Turn the bolt or the nut tighter the amount of degrees according to the specifications.

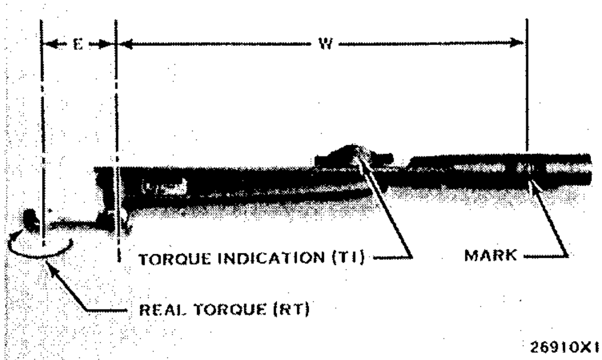
TURN TIGHTER CHART	
TURN (BOLT OR NUT)	TURN DEGREES
1	360°
1/2	180°
1/3	120°
1/4	90°
1/6	60°
1/12	30°

NOTE: The side of a nut or bolt head can be used for reference if a mark can not be put on.



Torque Wrench Extension

When a torque wrench extension is used with a torque wrench, the torque indication on the torque wrench will be less than the real torque.



TORQUE WRENCH WITH TORQUE WRENCH EXTENSION

E: Torque wrench drive axis-to-torque wrench extension drive axis. W: Mark on handle-to-torque wrench drive axis.

1. Put a mark on the handle. Measure the handle from the mark to the axis of the torque wrench drive (W).
2. Measure the torque wrench extension from the torque wrench drive to the axis of the torque wrench extension drive (E).
3. To get correct torque indication (TI) when the real torque (RT) is known:

$$TI = \frac{RT \times W}{W + E}$$

Example: W = 12 in. (304.8 mm); E = 2.56 in. (65.0 mm); RT (from specifications) = 125 lb. ft. (170 N•m).

$$TI = \frac{125 \times 12}{12 + 2.56} \text{ or } 103 \text{ lb. ft.}$$

$$TI = \frac{(170 \times 304.8)}{(304.8 + 65.0)} \text{ or } (140 \text{ N•m})$$

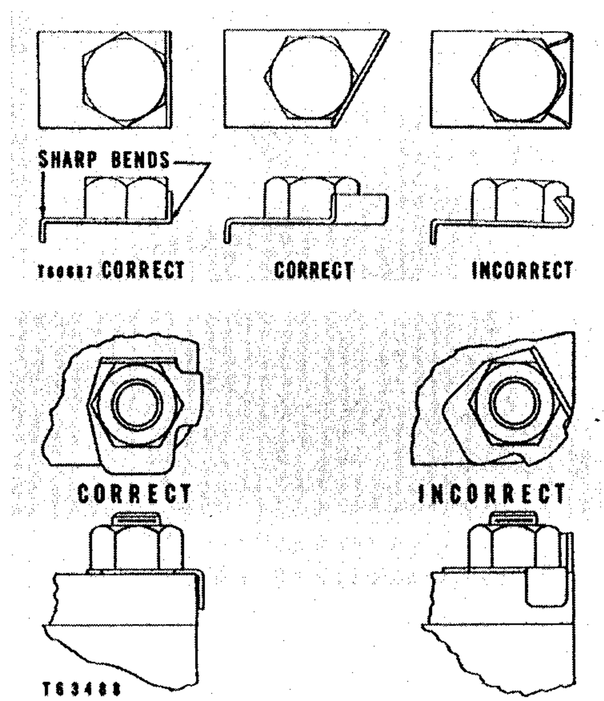
4. Hold the torque wrench handle with the longest finger of the hand over the mark on the handle to get the real torque (RT) with low torque indication (TI) on the torque wrench.

LOCKS

Flat metal locks must be installed properly to be effective. Bend one end of the lock around the edge of the part. Bend the other end against one flat surface of the nut or bolt head.

Always install new locks in compartments which house moving parts.

If lockwashers are installed on housings made of aluminum, use a flat washer between the lockwasher and the housing.



LINES AND WIRES

When removing or disconnecting a group of lines or wires, tag each one to assure proper assembly.

LUBRICATION

Where applicable, fill the compartments of the components serviced with the amount, type and grade of lubricant recommended in the Lubrication and Maintenance Guide.

RUST PREVENTIVE COMPOUND

Clean the rust preventive compound from all machined surfaces of new parts before installing them.

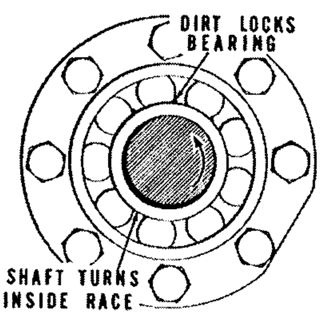
SHIMS

When shims are removed, tie them together and identify them as to location. Keep shims clean and flat until they are reinstalled.

BEARINGS

Anti-Friction Bearings

When an anti-friction bearing is removed, cover it to keep out dirt and abrasives. Wash bearings in nonflammable cleaning solution and allow them to drain dry. The bearing may be dried with compressed air, but DO NOT SPIN THE BEARING.



T55296

Discard the bearings if the races and balls or rollers are pitted, scored or burned. If the bearing is serviceable, coat it with oil and wrap it in clean paper. Do not unwrap new bearings until time of installation.

The life of an anti-friction bearing will be shortened if not properly lubricated.

Double Row, Tapered Roller

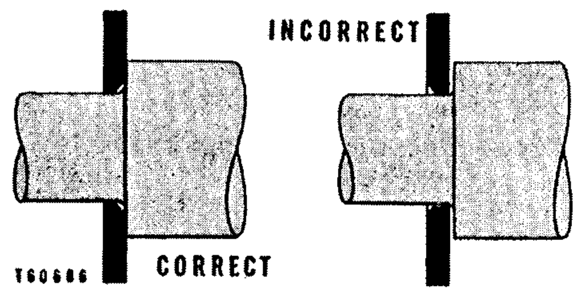
Double row, tapered roller bearings are precision fit during manufacture and the components are not interchangeable. The cups, cones and spacers are usually etched with the same serial number and letter designator. If no letter designators are found, wire the components together to assure correct installation. Reusable bearing components should be installed in their original positions.

Heating Bearings

Bearings which require expansion for installation should be heated in oil not to exceed 250° F. (121° C.). When more than one part is heated to aid in assembly, they must be allowed to cool and then pressed together again. Parts often separate as they cool and shrink.

Installation

Lubricate new or used bearings before installation. Bearings that are to be preloaded must have a film of oil over the entire assembly to obtain accurate preloading. When installing a bearing, spacer or washer against a shoulder on a shaft, be sure the chamfered side is toward the shoulder.



T60686

When pressing bearings into a retainer or bore, apply pressure to the outer race. If the bearing is pressed on the shaft, apply pressure on the inner race.

Preload

Preload is an initial force placed on the bearing at the time of assembly.

Determine preload or end clearance from the SPECIFICATIONS. Care should be exercised in applying preload. Misapplication of preload to bearings requiring end clearance can result in bearing failure.

Sleeve Bearings

DO NOT INSTALL SLEEVE BEARINGS WITH A HAMMER. Use a press, if possible, and apply the pressure directly in line with the bore. If it is necessary to drive on a bearing, use a driver or a bar with a smooth flat end. If a sleeve bearing has an oil hole, align it with the oil hole in the mating part.

GASKETS

Be sure the holes in the gaskets correspond with the lubricant passages in the mating parts. If it is necessary to make gaskets, select stock of the proper type and thickness. Be sure to cut holes properly. Blank gaskets can cause serious damage.

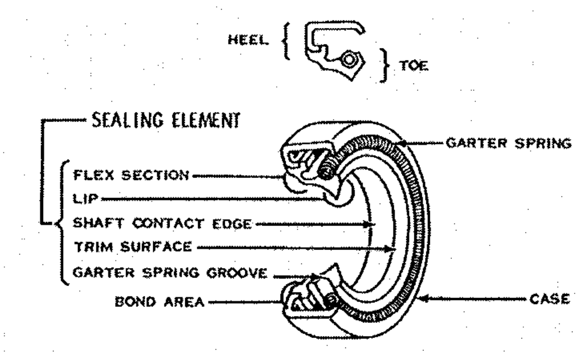
BATTERIES

Clean batteries by scrubbing with a solution of baking soda and water. Rinse with clear water. After cleaning, dry thoroughly and coat terminals and connections with anti-corrosion compound or grease.

If an engine is not to be used for a long period of time, remove the batteries. Store them in a cool, dry place. A small charge should be introduced periodically to keep the specific gravity rating at recommended level.

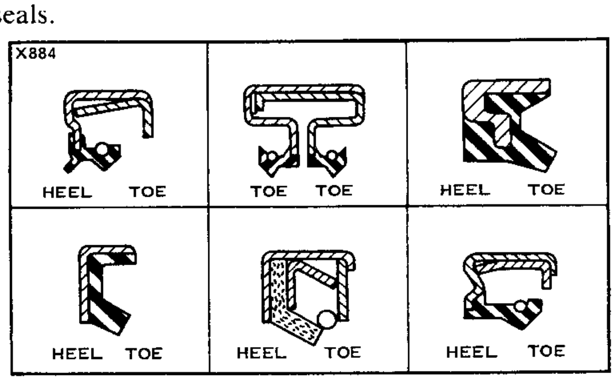
SEALS (Lip-Type)

Generally the toe or spring-loaded lip of an oil seal faces the oil being sealed or the oil having the higher pressure. The toe or lip of a grease seal faces away from the lubricant being sealed. Unless otherwise specified, use the preceding rules for installing lip-type seals.



T87198

The main parts of a lip-type seal are the case, sealing element, and garter spring. The picture illustrates the construction of a simple lip-type seal. The cross sections show the terms "heel" and "toe" used to identify the sides of various types of seals.



Lubricate the lips of lip-type seals before installation. Use the same type lubricant in which the seal will be operating. Do not use grease on any seal except a grease seal.

If, during installation, the seal lip must pass over a shaft that has splines, a keyway, rough surface or a sharp edge, the lip can be easily damaged. Shim stock or other such material can be formed around the area to provide a smooth surface over which to slide the seal.

CONVERSION CHART (inches to mm)

inches		mm	inches		mm
1/64	.016	0.40	33/64	.516	13.10
1/32	.031	0.79	17/32	.531	13.49
3/64	.047	1.19	35/64	.547	13.89
1/16	.062	1.59	9/16	.562	14.29
5/64	.078	1.98	37/64	.578	14.68
3/32	.094	2.38	19/32	.594	15.08
	.100	2.54		.600	15.24
7/64	.109	2.78	39/64	.609	15.48
1/8	.125	3.18	5/8	.625	15.88
9/64	.141	3.57	41/64	.641	16.27
5/32	.156	3.97	21/32	.656	16.67
11/64	.172	4.37	43/64	.672	17.07
3/16	.188	4.76	11/16	.688	17.46
13/64	.203	5.16	45/64	.703	17.86
7/32	.219	5.56	23/32	.719	18.26
15/64	.234	5.95	47/64	.734	18.65
1/4	.250	6.35	3/4	.750	19.05
17/64	.266	6.75	49/64	.766	19.45
9/32	.281	7.14	25/32	.781	19.84
19/64	.297	7.54	51/64	.797	20.24
5/16	.312	7.94	13/16	.812	20.64
21/64	.328	8.33	53/64	.828	21.03
11/32	.344	8.73	27/32	.844	21.43
23/64	.359	9.13	55/64	.859	21.83
3/8	.375	9.53	7/8	.875	22.23
25/64	.391	9.92	57/64	.891	22.62
	.400	10.16		.900	22.86
13/32	.406	10.32	29/32	.906	23.02
27/64	.422	10.72	59/64	.922	23.42
7/16	.438	11.11	15/16	.938	23.81
29/64	.453	11.51	61/64	.953	24.21
15/32	.469	11.91	31/32	.969	24.61
31/64	.484	12.30	63/64	.984	25.00
1/2	.500	12.70	1	1.000	25.40

T93967—A

DISASSEMBLY AND ASSEMBLY (Section 5)

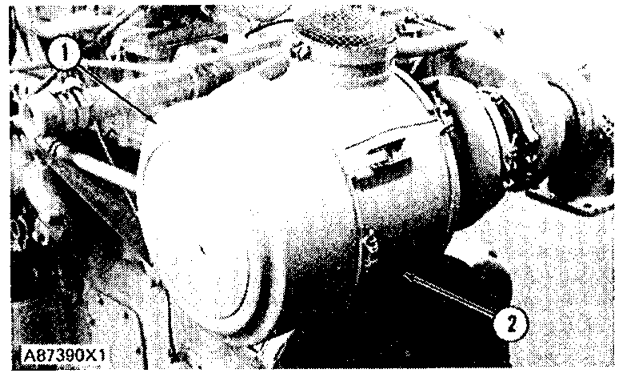
⚠ WARNING

DISCONNECT BATTERIES BEFORE PERFORMANCE OF ANY SERVICE WORK.

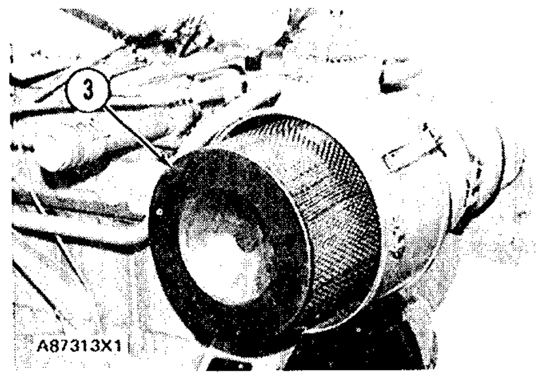
AIR CLEANER (3306)

REMOVE AIR CLEANER (3306) 1051-11

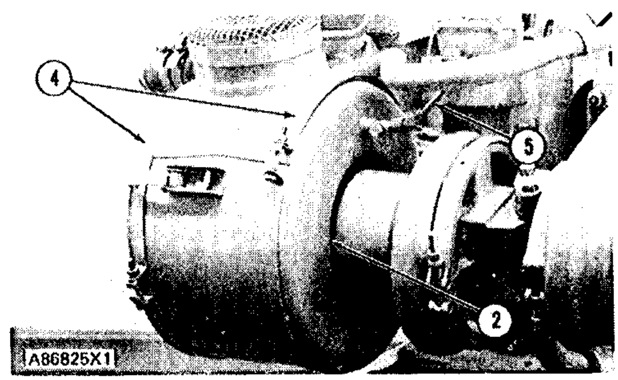
1. Remove cover (1) from the air cleaner body (2).



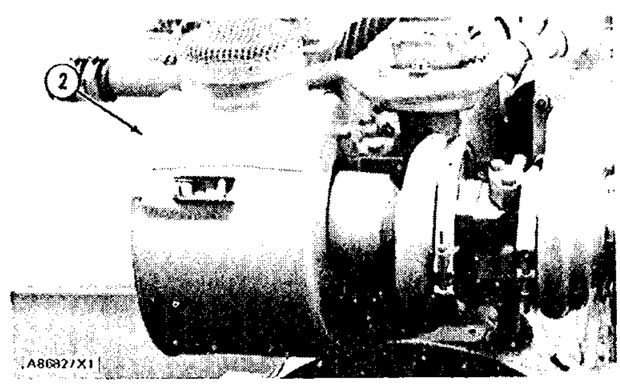
2. Remove element (3).



3. Disconnect vent tube (5) from air cleaner body (2).



4. Remove mounting bands (4).



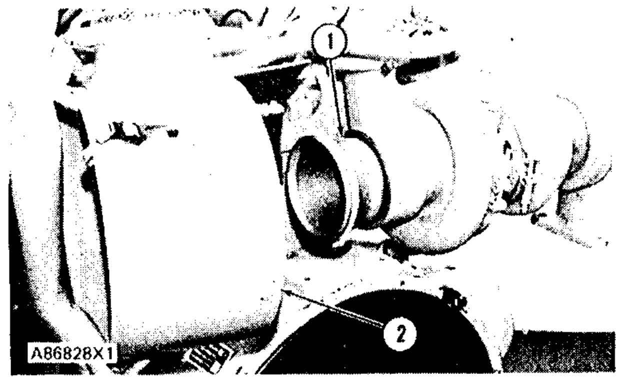
5. Remove air cleaner body (2) and coupling.

AIR CLEANER (3306)

INSTALL AIR CLEANER (3306) 1051-12

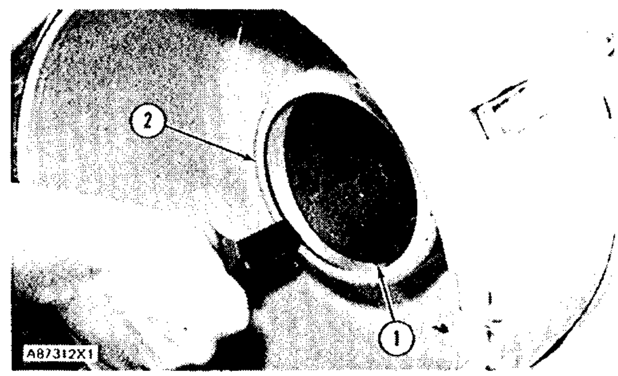
1. Put a thin layer of clean engine oil on the O-ring seals and the bores of body (2) and turbocharger inlet.

2. Fully install coupling (1) in the inlet bore of the turbocharger.

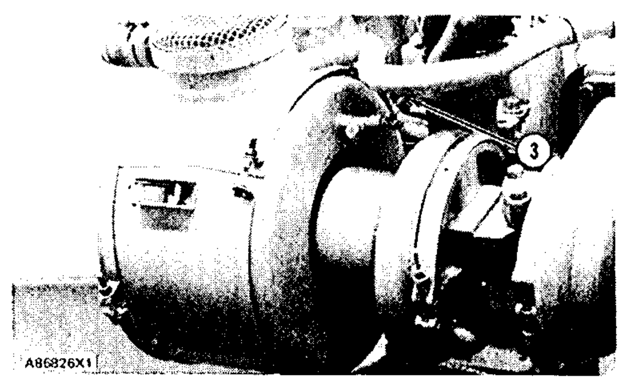


3. Put air cleaner body (2) into position over coupling (1).

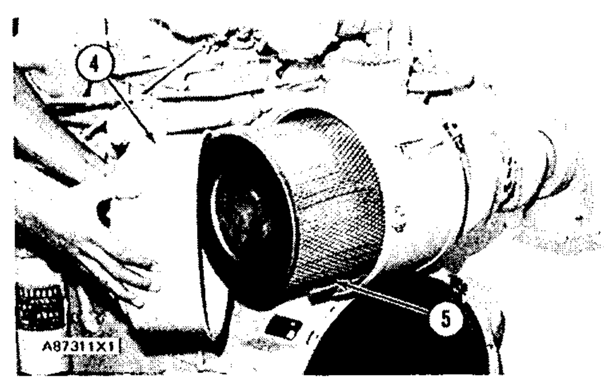
4. Install the mounting bands loosely.



5. Adjust air cleaner body (2) to give a clearance of .250 ± .062 in. (6.35 ± 1.57 mm) between the inside lip of the air cleaner body (2) and the face of the coupling (1). Tighten the mounting bands.



6. Connect vent tube (3).

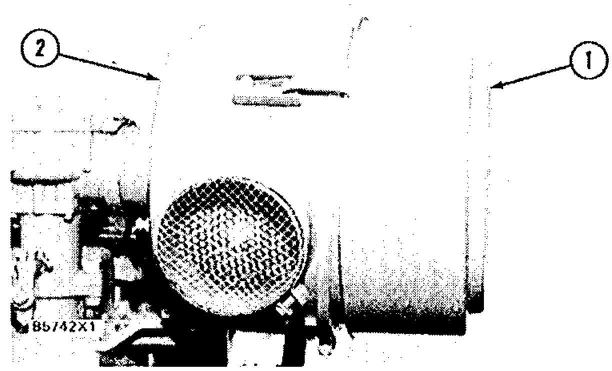


7. Install element (5) and cover (4).

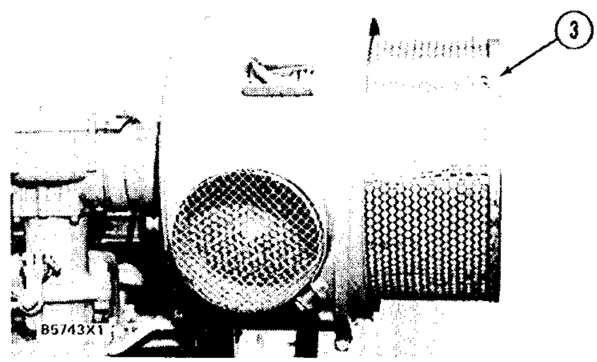
AIR CLEANER (3304)

REMOVE AIR CLEANER (3304) 1051-11

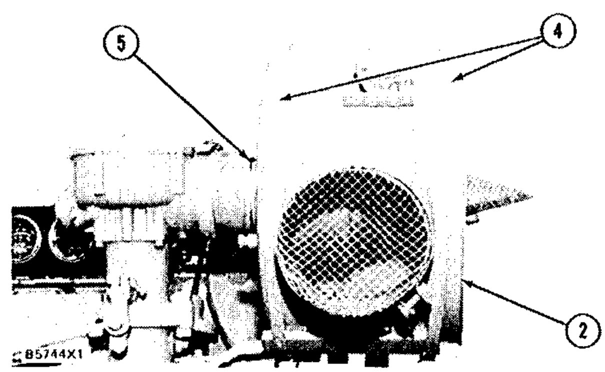
1. Remove cover (1) from air cleaner body (2).



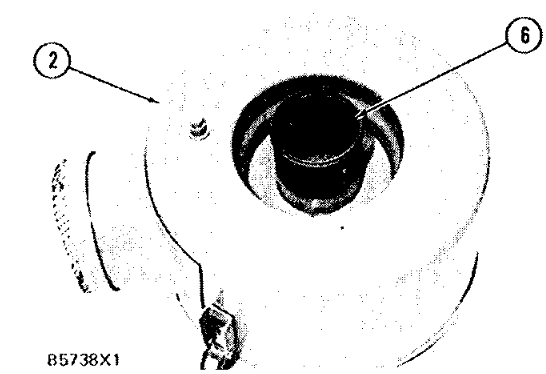
2. Remove element (3) from the air cleaner body.



3. Loosen clamp (5) and remove mounting bands (4).



4. Remove air cleaner body (2).

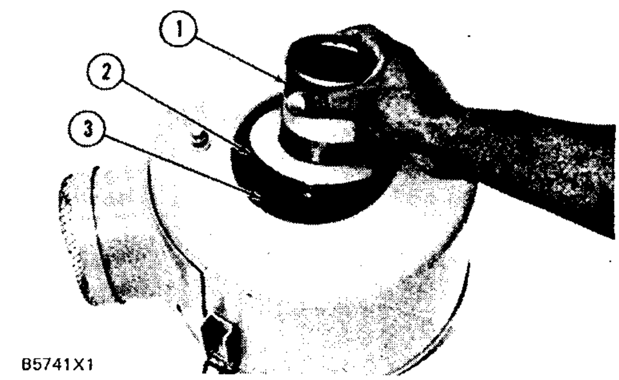


5. Remove tube assembly (6), arrestor and the O-ring seal from body (2) as a unit.

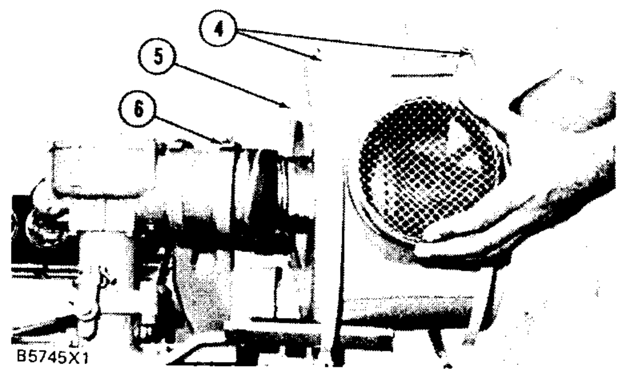
AIR CLEANER (3304)

INSTALL AIR CLEANER (3304) 1051-12

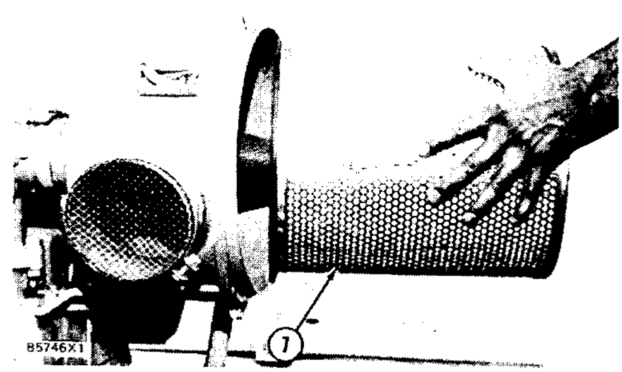
1. Put clean engine oil on the O-ring seal (2) and install the O-ring seal on tube assembly (1).



2. Install tube assembly (1) and arrestor (3) in the body.

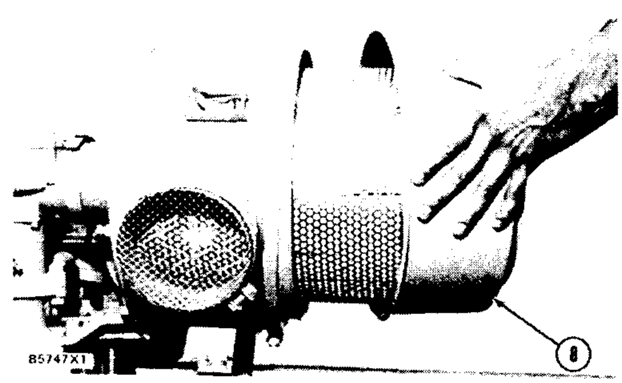


3. Install body (5) and mounting bands (4).



4. Tighten clamp (6) and mounting bands (4).

5. Install element (7) in the body.



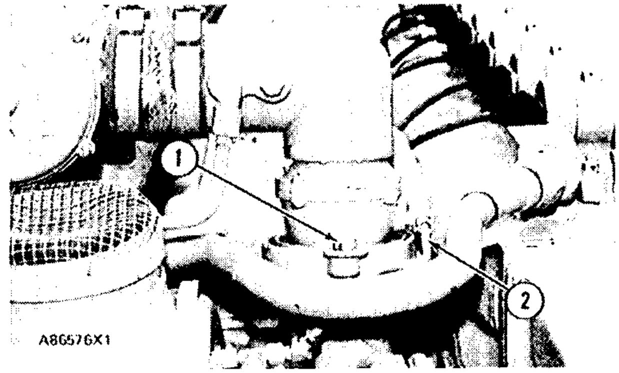
6. Install cover (8).

BOOST CONTROL VALVE (3306)

REMOVE BOOST CONTROL VALVE (3306) 1076-11

1. Remove bolt (1) and washer that hold the boost control valve in place.

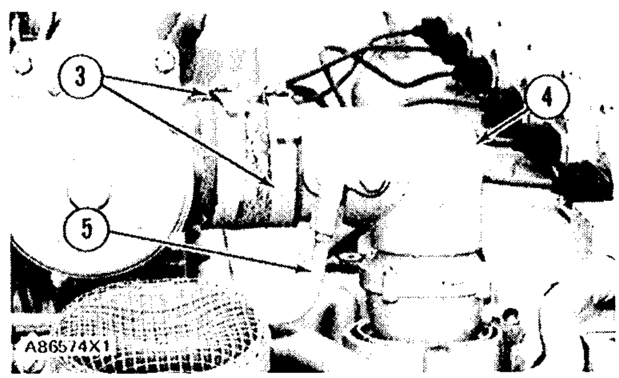
2. Remove vent tube (2).



3. Remove balance tube (5).

4. Loosen clamps (3) and slide the hose toward the boost control.

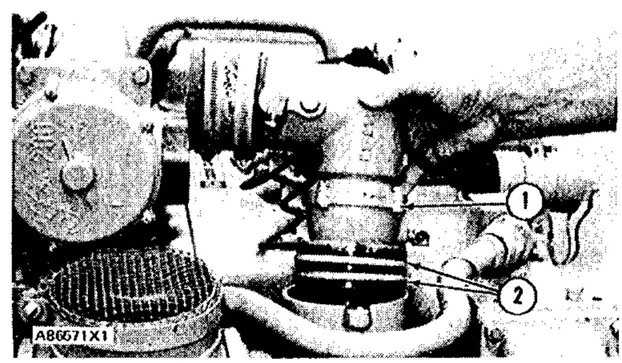
5. Remove the boost (4) control from the turbocharger.



INSTALL BOOST CONTROL VALVE (3306) 1076-12

1. Put lubrication on O-ring seals (2) and the bore of the turbocharger with a small amount of engine oil.

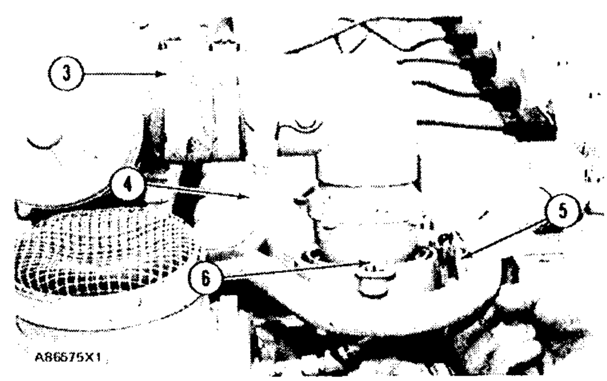
2. Put boost control valve (1) into position on the turbocharger.



3. Slide hose on to carburetor inlet and tighten clamps (3).

4. Install washer and bolt (6).

5. Install balance tube (4) and vent tube (5).

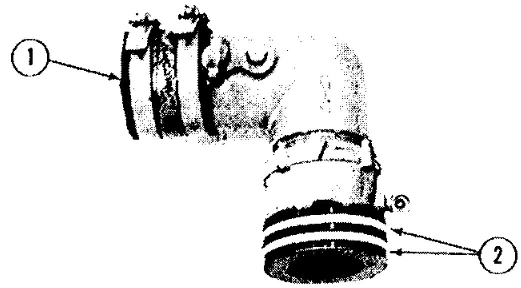


BOOST CONTROL VALVE (3306)

DISASSEMBLE BOOST CONTROL VALVE (3306) 1076-15

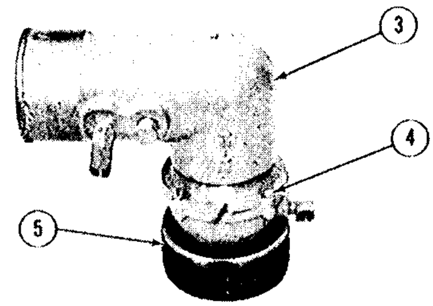
start by:
a) remove boost control valve (3306)

1. Remove hose (1), clamps and O-ring seals (2) from the boost control valve.



A85496X1

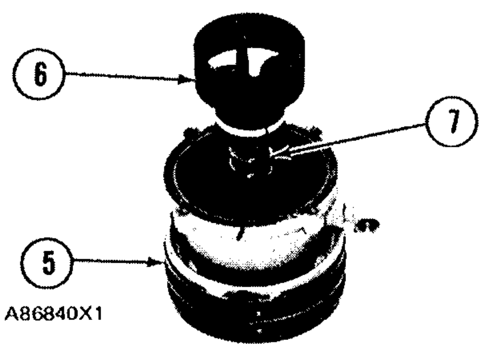
2. Put an identification mark on valve body (3) and cylinder (5) for use at assembly.



A86833X1

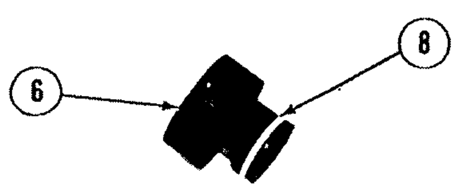
3. Remove screws (4) and lockwashers that hold valve body (3) in place.

4. Remove valve body (3) and gasket from cylinder (5).



A86840X1

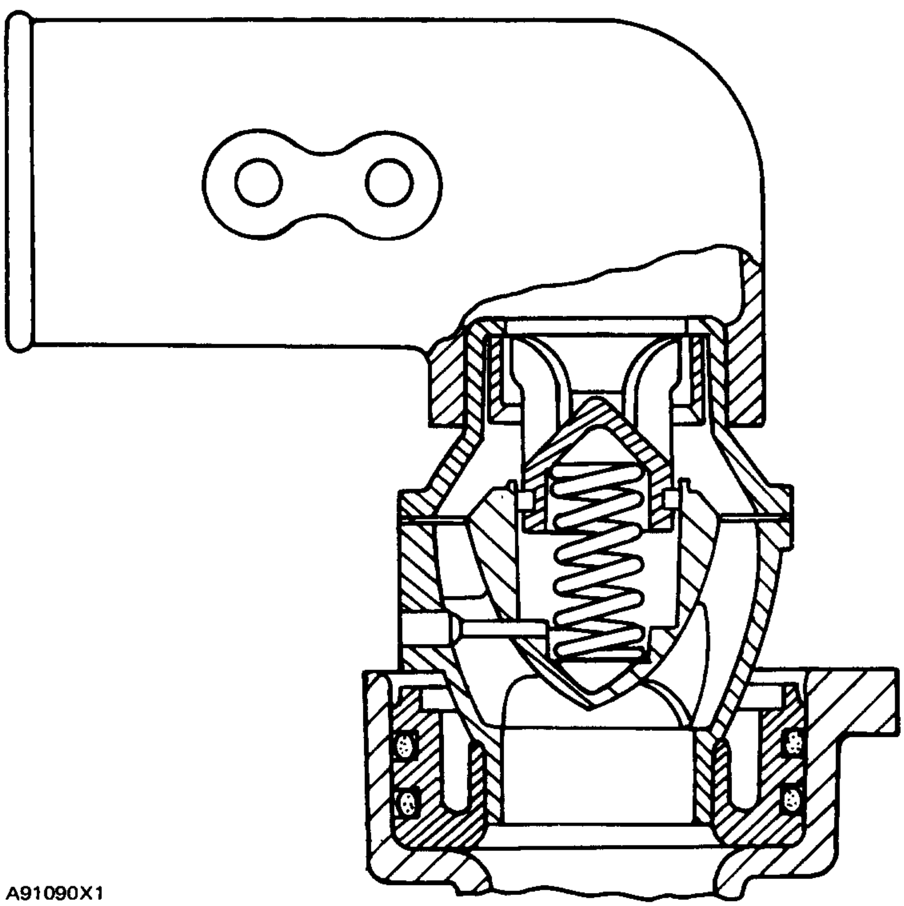
5. Remove valve piston (6) and spring (7) from cylinder (5).



A86567X1

6. Remove ring (8) from valve piston (6).

BOOST CONTROL VALVE (3306)

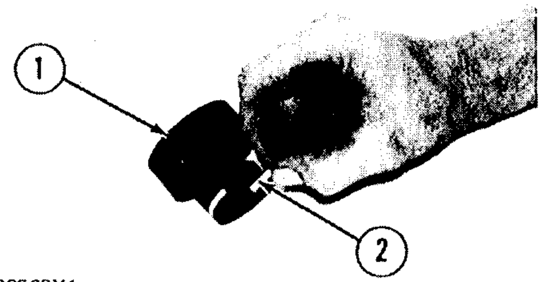


A91090X1

BOOST CONTROL VALVE (3306)

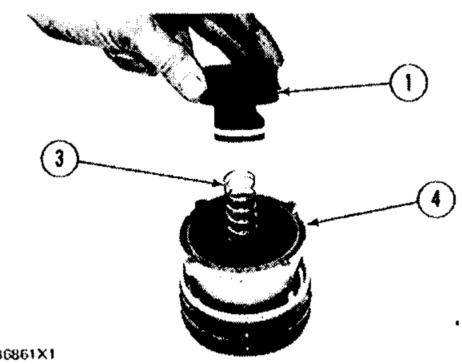
ASSEMBLE BOOST CONTROL VALVE (3306) 1076-16

1. Install a new ring (2) on the valve piston (1).



A86568X1

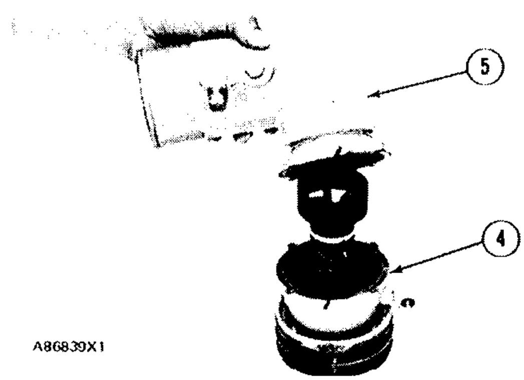
2. Put spring (3) and valve piston into position on cylinder (4).



A86861X1

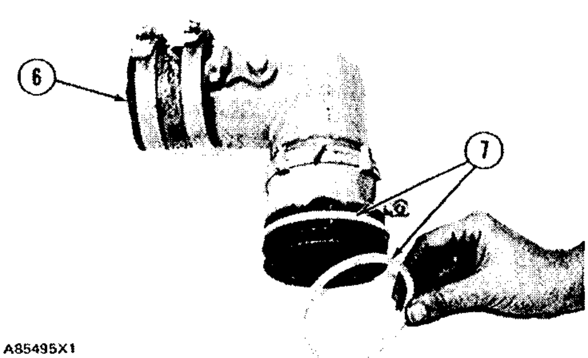
3. Put a new gasket and valve body (5) into position on cylinder (4). Make an alignment of the identification marks.

4. Install the screws and lockwashers that hold the valve body (5) in place. Evenly tighten the screws.



A86839X1

5. Put hose (6) and clamps in position on the valve body.



A85495X1

6. Install O-ring seals (7) on the cylinder.

end by:

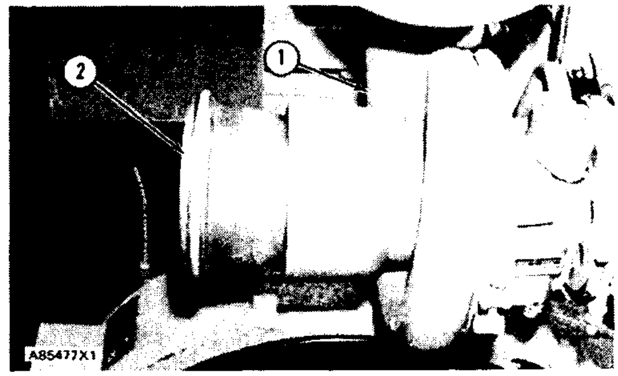
a) install boost control valve (3306)

TURBOCHARGER (3306)

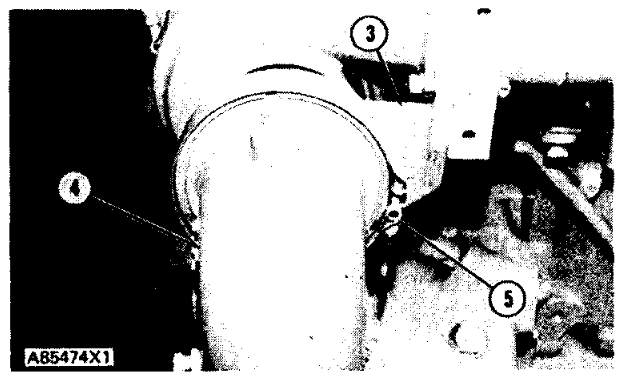
REMOVE TURBOCHARGER (3306) 1052-11

start by:
a) remove boost control valve (3306)
b) remove air cleaner

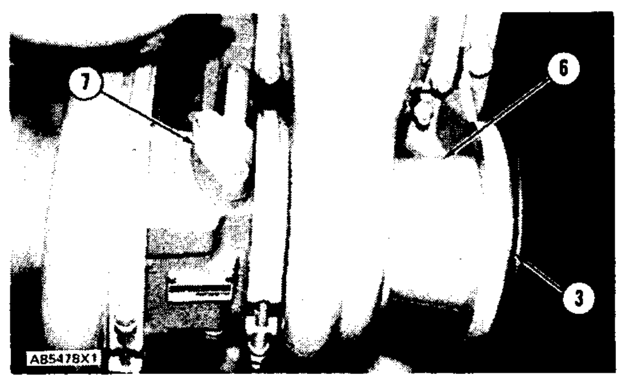
1. Remove coupling (2) and seals from the turbocharger (1).



2. Loosen clamp (5) and remove exhaust elbow (4) and clamp from the support (3).

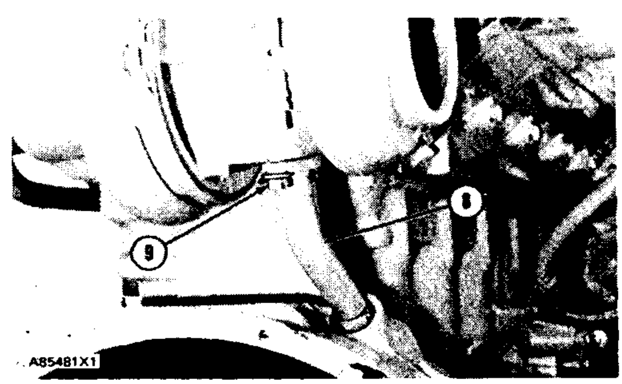


3. Remove bolts and nuts that hold support (3) to the exhaust manifold. Remove support and coupling (6).



4. Remove seal rings from coupling (6).

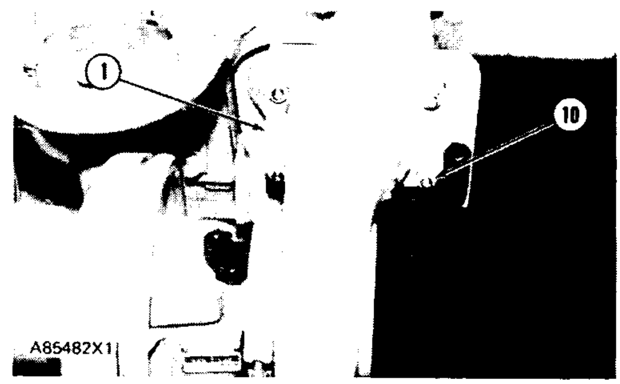
5. Remove oil supply tube (7) and gasket.



6. Remove bolts (9) and washers. Disconnect oil drain line (8) from the turbocharger.

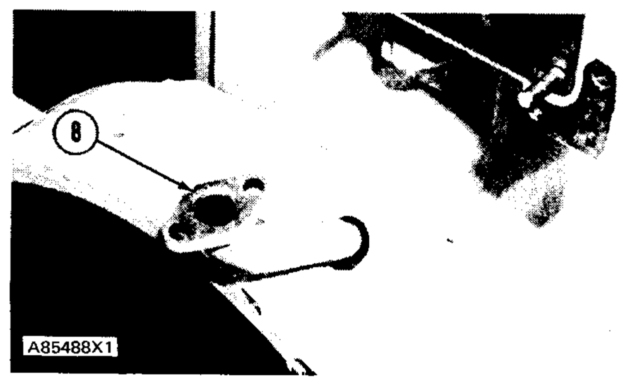
TURBOCHARGER (3306)

7. Remove four nuts (10). Remove turbocharger (1) and gasket from the exhaust manifold.



A85482X1

8. Remove oil drain tube (8) and O-ring seal.

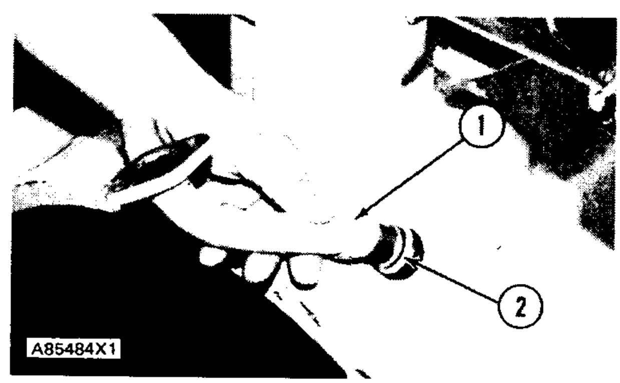


A85488X1

INSTALL TURBOCHARGER (3306) 1052-12

1. Put clean engine oil on a new O-ring seal (2) and install on oil drain tube (1).

2. Install oil drain tube (1) in the flywheel housing.

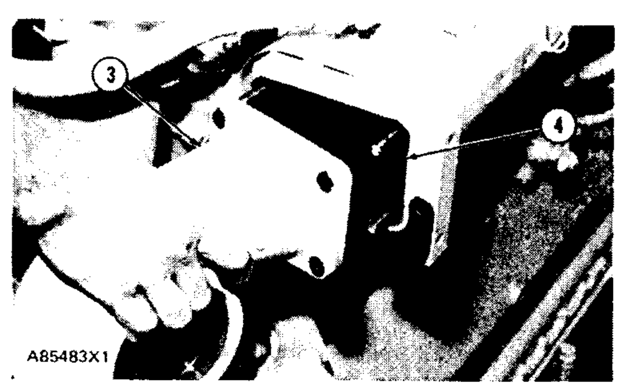


A85484X1

3. Put a new gasket (4) in position on the exhaust manifold.

4. Put 5P3931 Anti-Seize Compound on the threads of the four studs that hold the turbocharger to the exhaust manifold.

5. Put turbocharger (3) in position on the exhaust manifold and install the four nuts that hold it in place. Tighten the nuts to a torque of 40 ± 4 lb.ft. (55 ± 5 N·m).

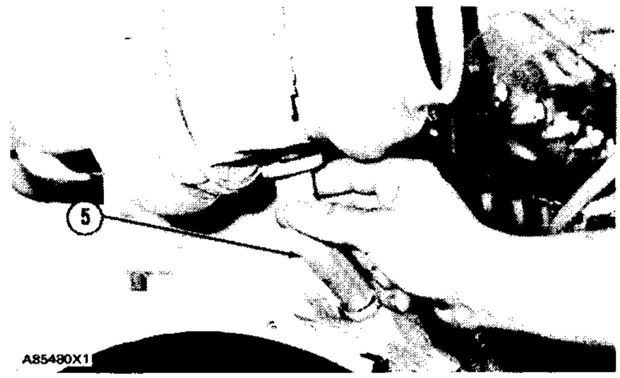


A85483X1

TURBOCHARGER (3306)

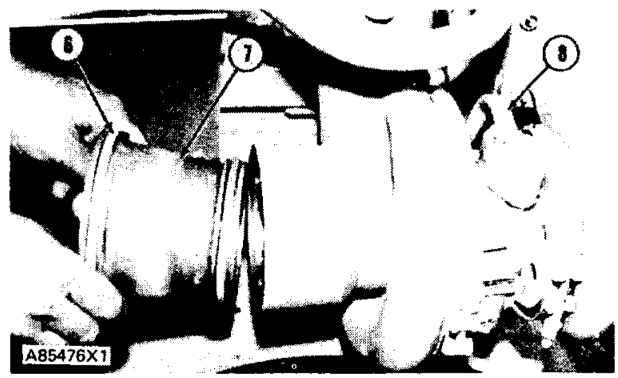
6. Install a new gasket and connect oil drain line (5) to the turbocharger.

7. Install a new gasket and oil supply tube (8).



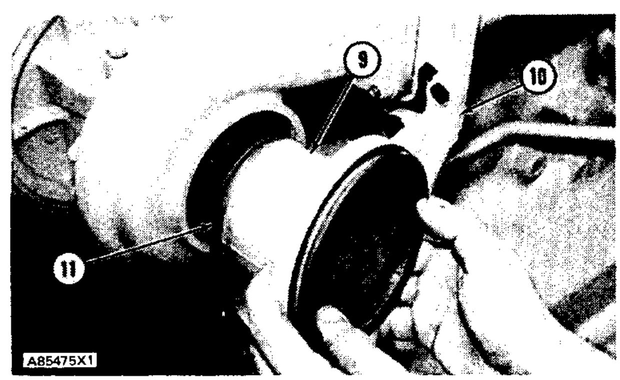
8. Put clean engine oil on two O-ring seals (6) and install on coupling (7).

9. Install coupling (7) in turbocharger housing.



10. Put 5P3931 Anti-Seize Compound on new seal rings (11) and in the grooves of coupling (9).

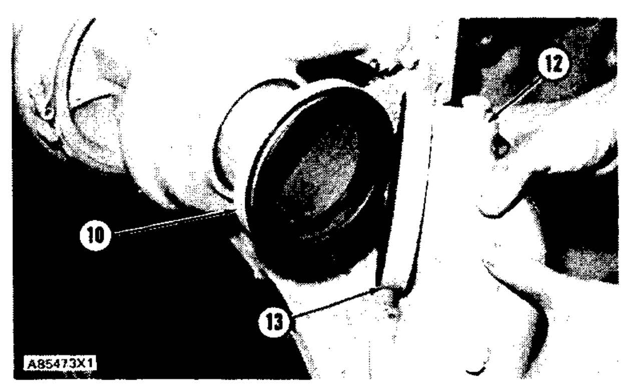
11. Install the new seal rings (11) in the grooves on the coupling.



12. Put coupling (9) and support (10) in position on the turbocharger housing. Fasten the support to the exhaust manifold.

13. Install exhaust elbow (12) and clamp on the support (10). Tighten clamp nut (13) to a torque of 10 lb.ft. (14 N·m).

   end by:
   a) install boost control valve (3306)
   b) install air cleaner



TURBOCHARGER (3306)

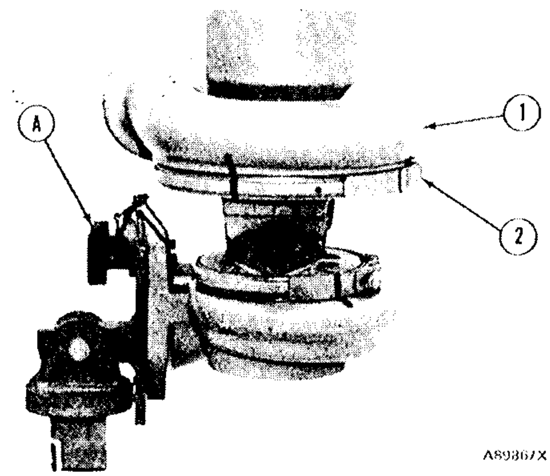
DISASSEMBLE TURBOCHARGER (3306) 1052-15

	Tools Needed	A	B	C	D
9S6363	Turbocharger Fixture Group	1			
9S6343	Fixture Assembly		1		
1P1861	Pliers			1	
FT745	Modified Pliers				1

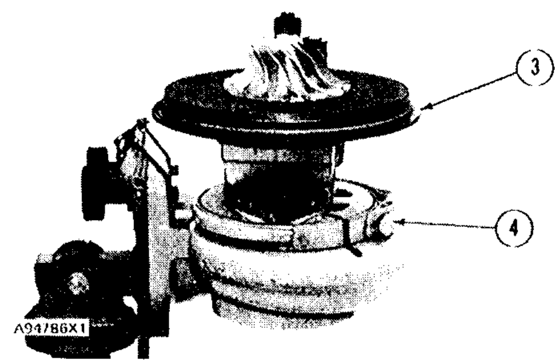
start by:

a) remove turbocharger (3306)

1. Put the turbocharger in position on tool (A).



2. Put marks on the housings and cartridge for correct installation and alignment at assembly.

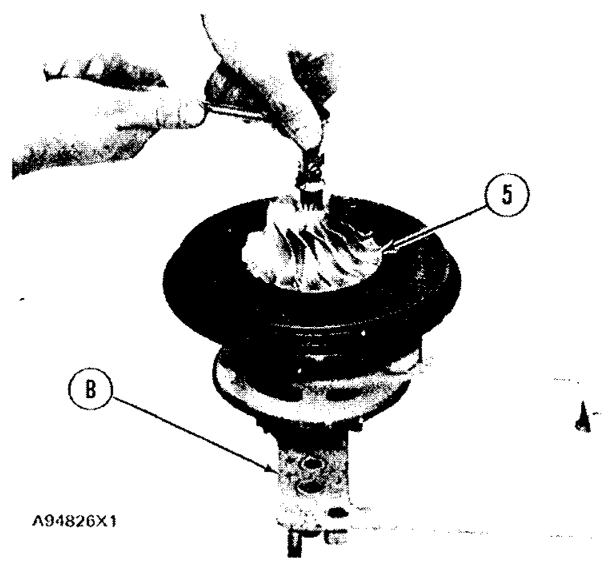


3. Remove "V" clamp (2) and compressor housing (1).

4. Remove "V" clamp (4) and cartridge housing (3) from the turbine housing. Remove the O-ring seal from the compressor side of the cartridge housing.

NOTICE

When the nut is loosened, do not put a side force on the shaft.

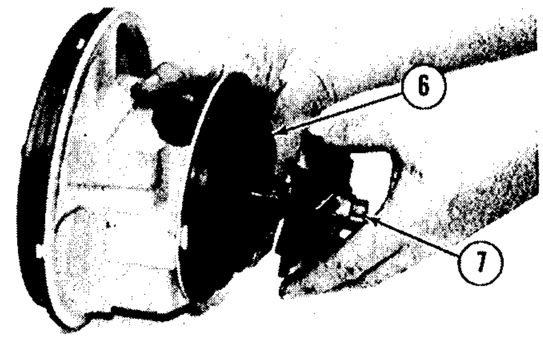


5. Put turbine wheel assembly in position on tool (B).

6. Remove nut and compressor wheel (5) from the turbine wheel shaft.

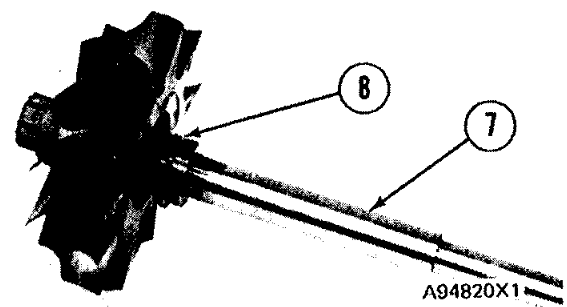
TURBOCHARGER (3306)

7. Remove turbine wheel assembly (7) and shroud (6) from the cartridge housing.



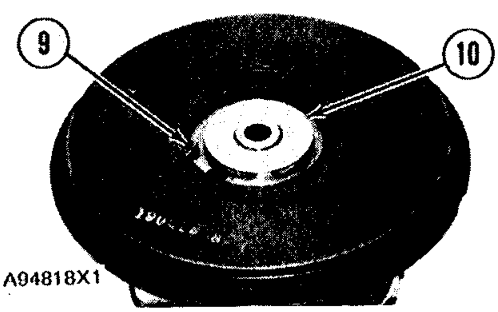
A94824X1

8. Remove seal ring (8) from turbine wheel shaft (7).

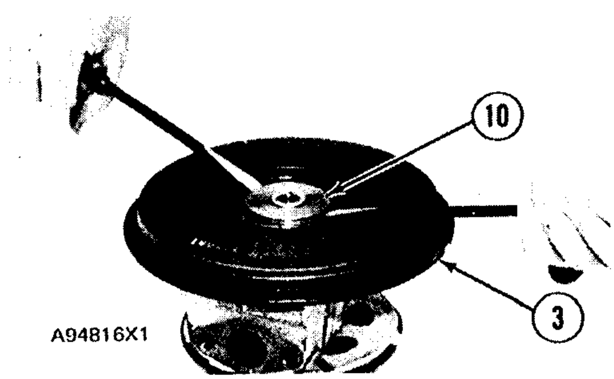


A94820X1

9. Use tool (C) to remove snap ring (9) that holds insert.



A94818X1

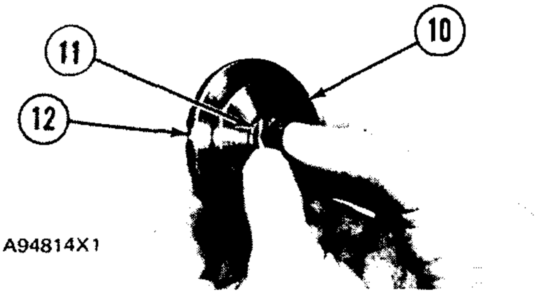


A94816X1

10. Use two screwdrivers to remove insert (10) from cartridge housing (3).

TURBOCHARGER (3306)

11. Push sleeve (11) out of insert (10). Remove O-ring seal (12) from the insert.



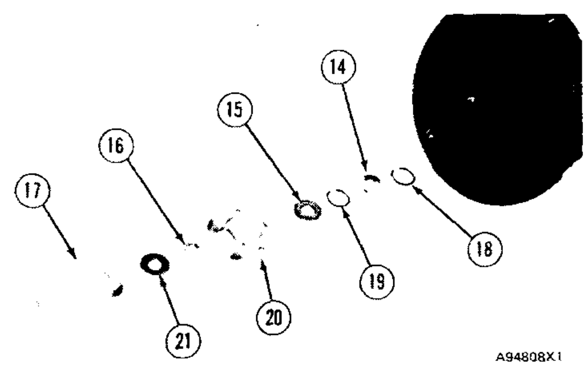
A94814X1

12. Remove two seal rings (13) from sleeve (11).

A94813X1

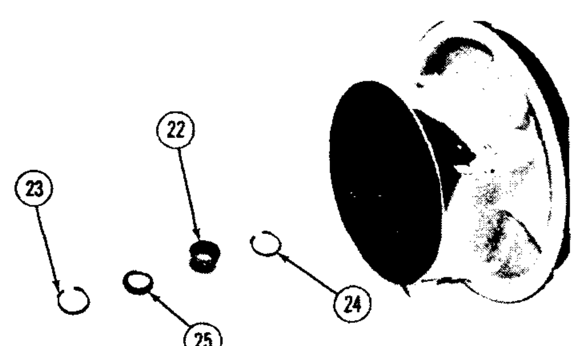
13. Remove deflector (17), ring (21), sleeve (16), bearing (20), ring (15), snap ring (19), bearing (14) and snap ring (18). Use tool (D) to remove snap rings (18) and (19).

NOTE: Check the oil hole in bearing (20). If the oil hole is not open this will cause bearing failure.



A94808X1

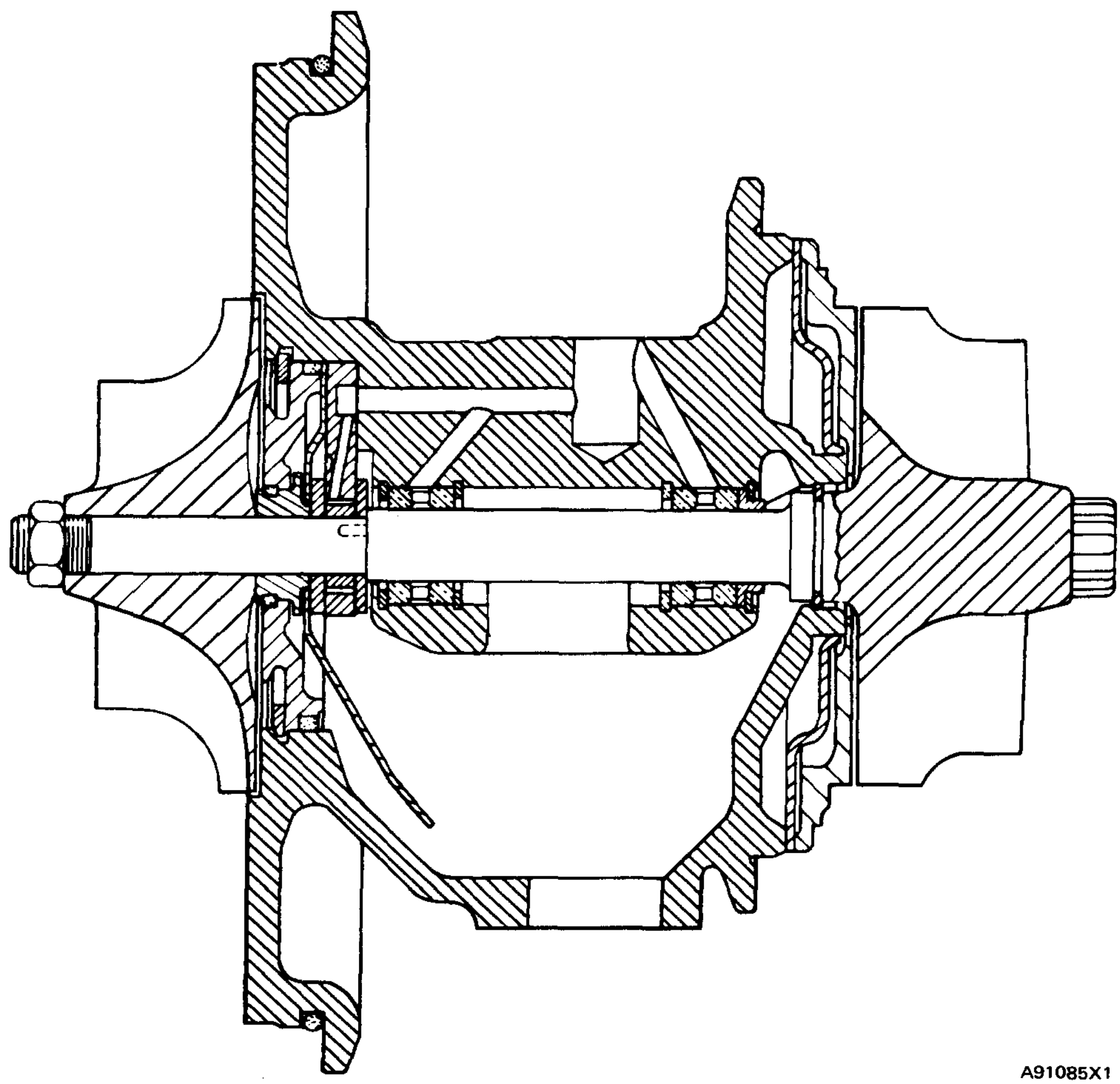
14. Turn housing around and use tool (D) to remove snap rings (23) and (24). Remove snap ring (23), sleeve (25), bearing (22) and snap ring (24).



A94805X1

15. Check all the parts of the turbocharger for damage. If the parts have damage, use new parts for replacement. See SPECIAL INSTRUCTION FORM NO. SMHS6854 for TURBOCHARGER RECONDITIONING. Also see GUIDELINE FOR REUSABLE PARTS FORM NO. SEBF8018 and TURBOCHARGER (SCHWITZER E MODEL) in SPECIFICATIONS.

TURBOCHARGER (3306)

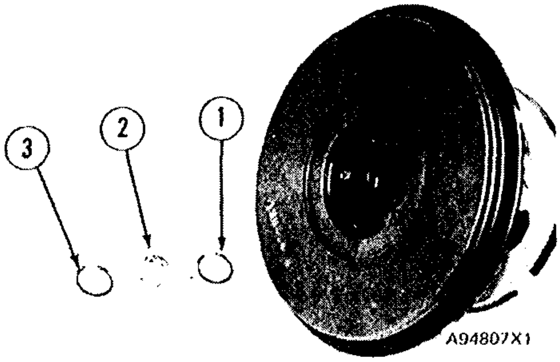


A91085X1

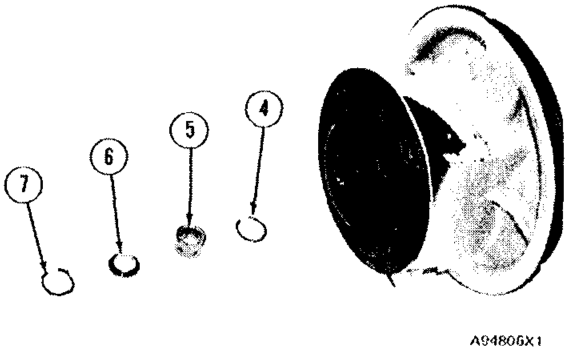
TURBOCHARGER (3306)

ASSEMBLE TURBOCHARGER (3306) 1052-16

	Tools Needed	A	B	C	D	E
FT745	Modified Pliers	1				
1P1861	Pliers		1			
9S6343	Fixture Assembly			1		
8S2328	Dial Test Indicator Group				1	
9S6363	Turbocharger Fixture Group					1



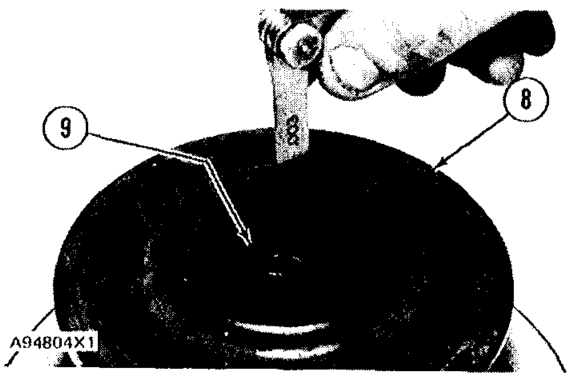
1. Make sure that all of the oil passages in the turbocharger cartridge housing are clean and free of dirt and foreign material.



2. Put clean engine oil on all parts of the cartridge assembly.

NOTICE

Snap rings (1), (3), (4) and (7) must be installed with the round edge of the snap rings toward the bearing.

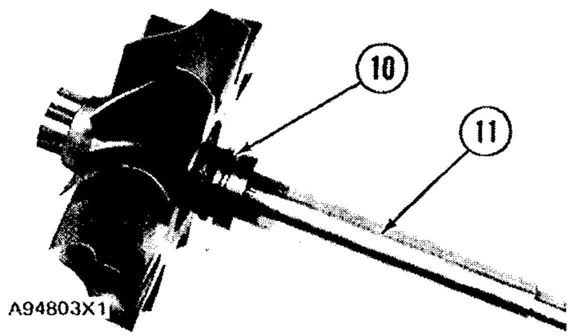


3. Use tool (A) to install snap rings (1) and (3). Install snap ring (1), bearing (2) and snap ring (3) in the compressor end of the cartridge housing.

4. Turn the cartridge housing around and use tool (A) to install snap rings (4) and (7).

5. Install snap ring (4), bearing (5), sleeve (6) and snap ring (7) in the turbine end of the cartridge housing.

6. Put oil seal ring (9) into position in the turbine end bore of the cartridge housing (8). Check the seal ring end clearance. The maximum permissible end clearance is .009 in. (0.23 mm).

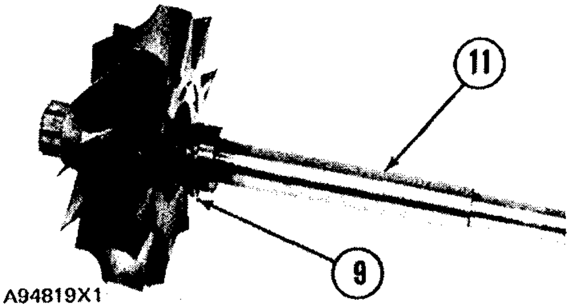


7. Put 6V2055 High Vacuum Grease in the groove (10) for seal ring (9) at assembly to one half or more of the depth of the groove all the way around.

TURBOCHARGER (3306)

NOTE: Be careful not to break oil seal ring (9) during installation.

8. Install oil seal ring (9) on turbine shaft (11).

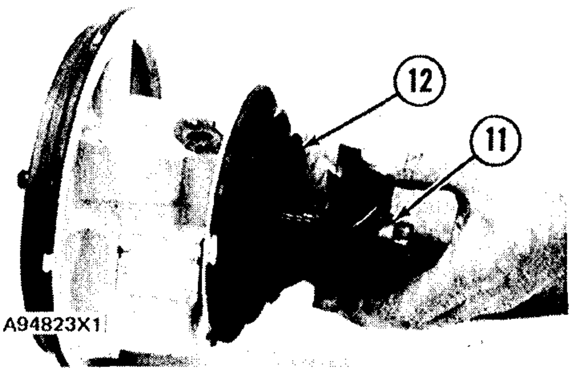


A94819X1

NOTICE

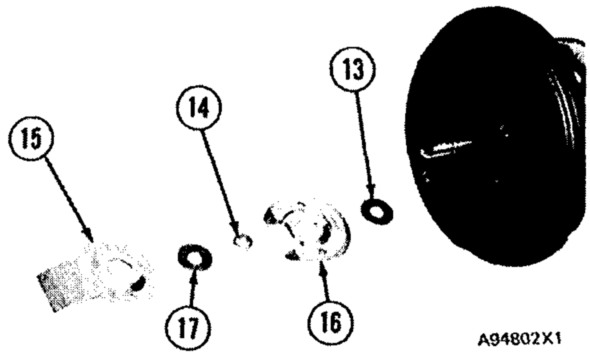
Make sure the oil seal ring on turbine shaft (11) is fitted correctly in the cartridge housing.

9. Put shroud (12) in position on the cartridge housing.



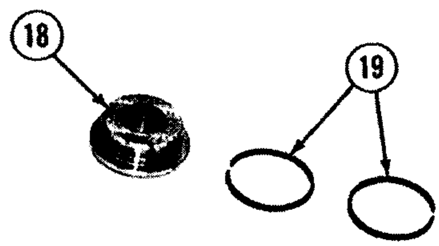
A94823X1

10. Install turbine shaft (11) in the cartridge housing.



A94802X1

11. Install ring (13), bearing (16), sleeve (14), ring (17) and deflector (15) in the housing.



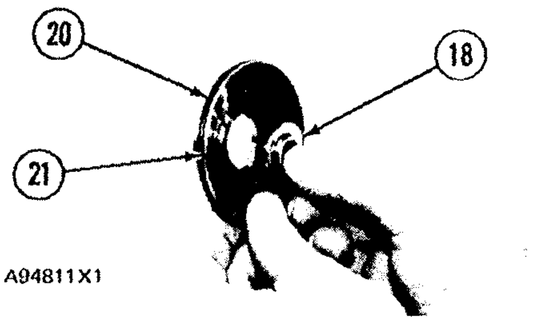
A94812X1

NOTE: Install seal rings (19) with the end gaps 180° apart on sleeve (18).

12. Install seal rings (19) in the groove of sleeve (18).

TURBOCHARGER (3306)

13. Install O-ring seal (21) on insert (20).
14. Install sleeve (18) in insert (20).
15. Put insert (20) in position over the turbine shaft in the housing.
16. Use tool (B) to install the snap ring that holds the insert in the housing.
17. Put the cartridge housing assembly in position on tool (C).

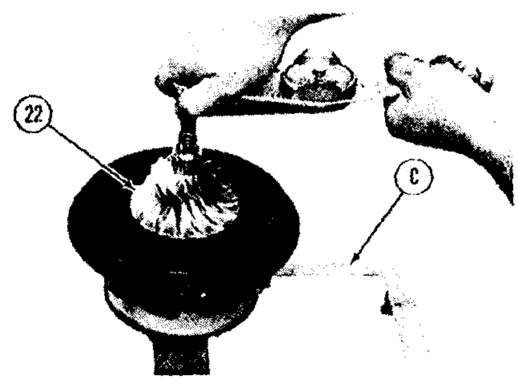


A94811X1

18. Put compressor wheel (22) in position on the turbine shaft.

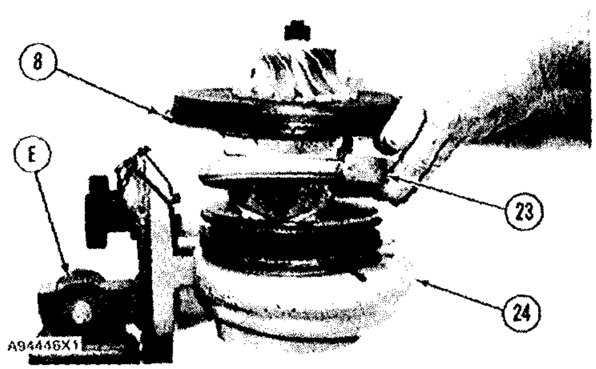
NOTICE

Do not put a side force on the shaft when the nut is installed or removed.



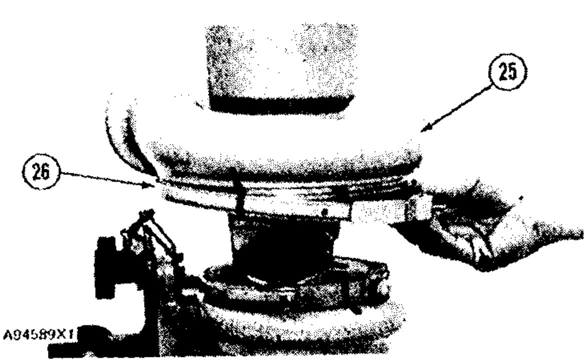
A94825X1

19. Install the nut that holds the compressor wheel. Use a torque wrench and a universal socket of the correct size to tighten the nut to a torque of 22 ± 2 lb.ft. (28 ± 3 N·m).
20. Put the cartridge housing in a vise. Check the shaft end play with tool (D). The end play must be .003 to .008 in. (0.08 to 0.20 mm) (worn).
21. Install turbine housing (24) on tool group (E). Put the cartridge assembly (8) in position in the turbine housing. Make an alignment of the mark put on at disassembly. Put 5P3931 Anti-Seize Compound on the threads of the "V" clamps (23) and (26). Install "V" clamp (23) and tighten the bolt to a torque of 120 ± 24 lb.in. (13.6 ± 2.8 N·m).



A94446X1

22. Install the O-ring seal on the cartridge assembly for the compressor housing.
23. Install compressor housing (25) on the cartridge assembly. Make an alignment of the marks on the compressor housing and the cartridge. Install "V" clamp (26) and tighten the bolt to a torque of 120 ± 24 lb.in. (13.6 ± 2.8 N·m).
24. Hit (tap) both "V" clamps completely around and tighten again to a torque of 120 ± 24 lb.in. (13.6 ± 2.8 N·m).
end by:
a) install turbocharger (3306)



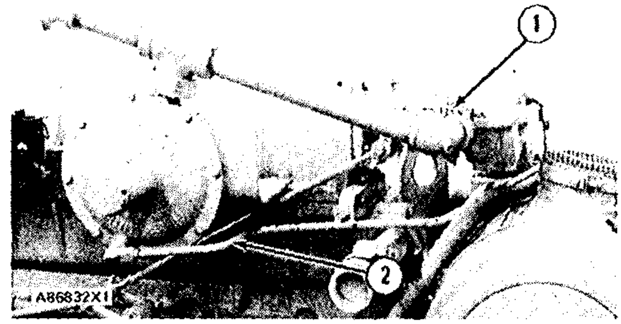
A94589X1

GAS PRESSURE REGULATOR

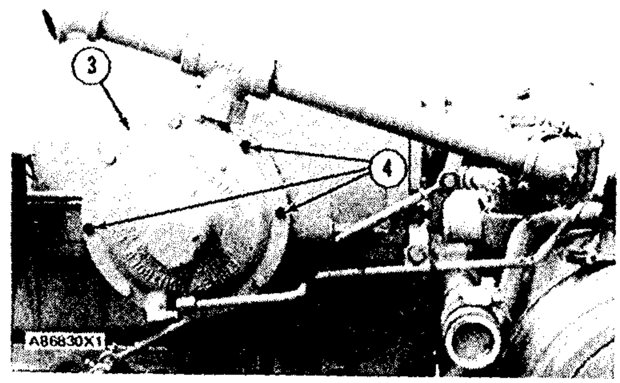
REMOVE GAS PRESSURE REGULATOR 1270-11

NOTE: Photos shown are on 3306 engine.

1. Turn off gas supply valve and disconnect line to gas pressure regulator.



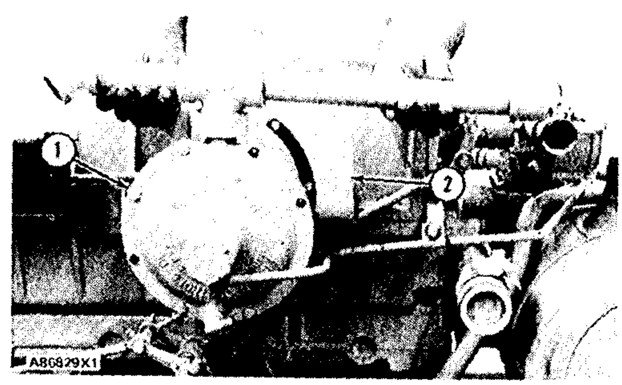
2. Remove clamp (1) from joint assembly.
3. Disconnect tube (2) (balance line) from the fitting on the gas pressure regulator.



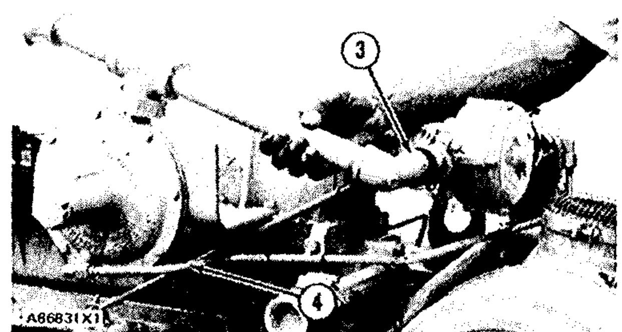
4. Remove bolts (4) that hold the gas pressure regulator (3) in position on the braces.

INSTALL GAS PRESSURE REGULATOR 1270-12

1. Put gas pressure regulator (1) in position and fasten to braces (2).

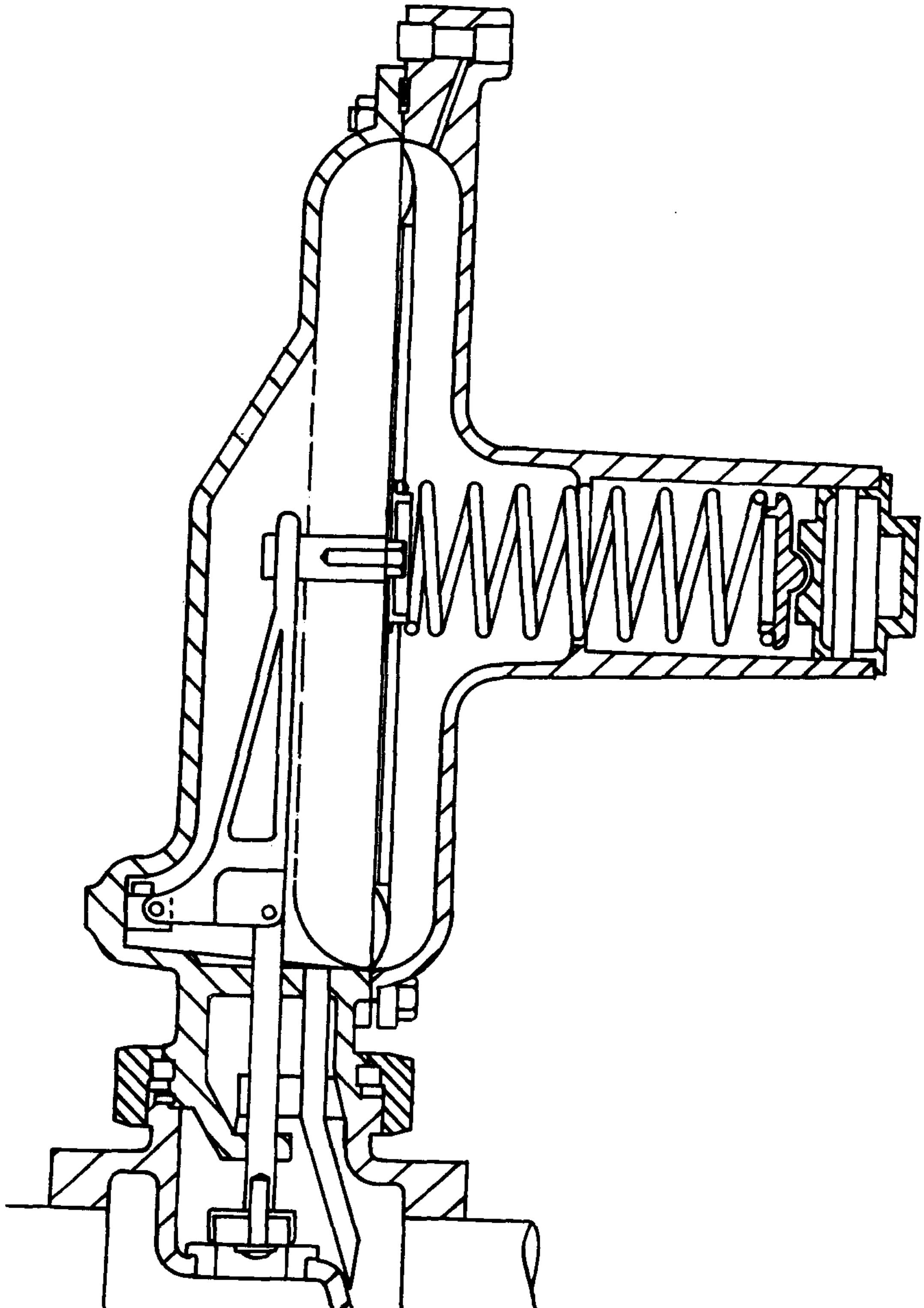


2. Connect tube (4) (balance line) to the fitting on the gas pressure regulator (1).
3. Connect nipple (3) to the joint assembly with a clamp, bolt and nut. Tighten nut to a torque of 49 ± 4 lb.in. (5.5 ± 0.5 N·m).



4. Connect line to gas pressure regulator and turn on gas supply.

GAS PRESSURE REGULATOR



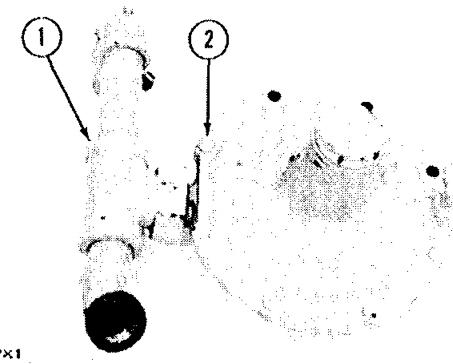
X3912X3

GAS PRESSURE REGULATOR

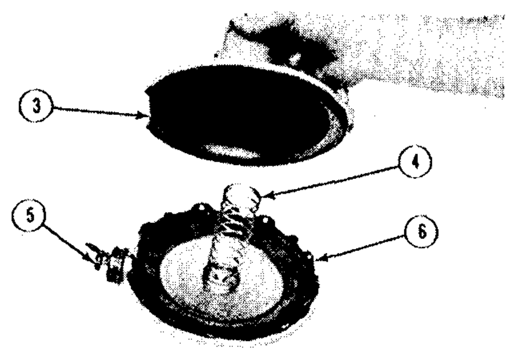
DISASSEMBLE GAS PRESSURE REGULATOR 1270-15

start by:
a) remove gas pressure regulator

1. Remove the gas line (1) from the regulator.
2. Remove the valve seat from the tee fitting of the gas line.
3. Remove the retainer ring and coupling from the regulator.
4. Remove the fastening bolts (2) and cover (3) from the regulator.
5. Remove the spring (4) and diaphragm assembly (6) from the regulator.
6. Remove the valve (5) from the regulator.



52677X1

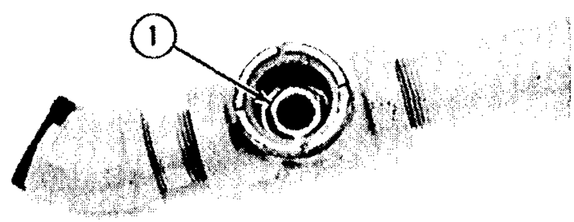


52681X1

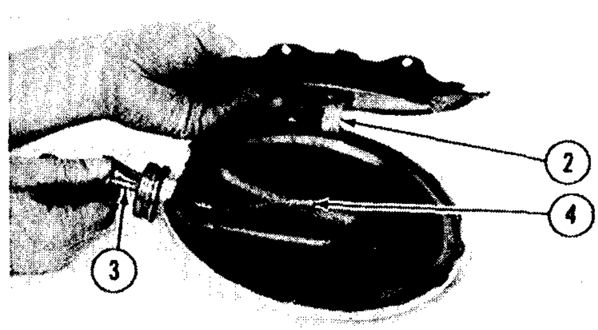
ASSEMBLE GAS PRESSURE REGULATOR 1270-16

1. Install the valve seat (1) in the tee fitting of the gas line.
2. Install the valve (3) in the regulator. Be sure the valve is engaged with lever (4).
3. Install the diaphragm assembly (2) in the regulator. Be sure the diaphragm assembly is engaged with the lever (4).
4. Install the spring and cover on the regulator.
5. Install the coupling and retainer ring on the regulator.
6. Install the gas line on the regulator.

end by:
a) install gas pressure regulator



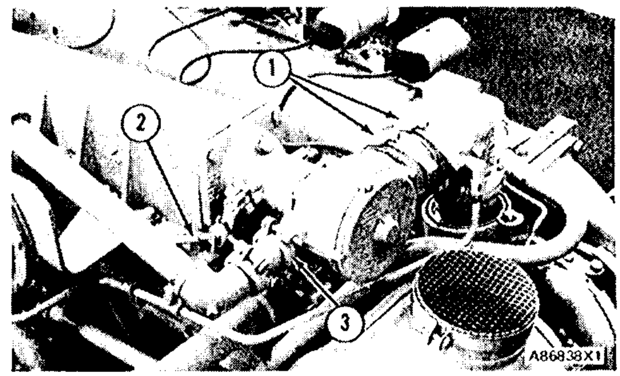
52689X1



52682X1

CARBURETOR (3306)

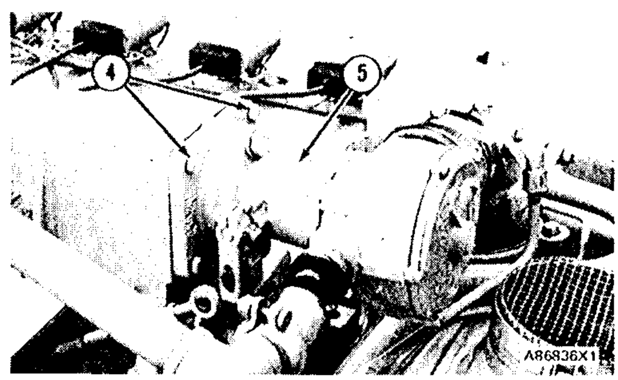
REMOVE CARBURETOR (3306) 1266-11



1. Shut off gas supply line to gas pressure regulator.

2. Loosen clamps (1) and slide hose away from the carburetor.

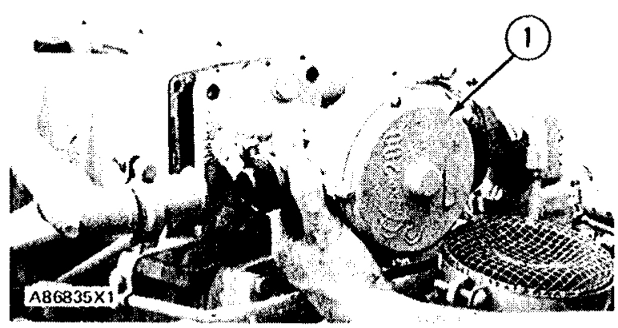
3. Disconnect control rod (2) from the carburetor lever.



4. Remove clamp (3) from the joint assembly.

5. Remove bolts (4) and remove carburetor (5) and gasket from the aftercooler housing.

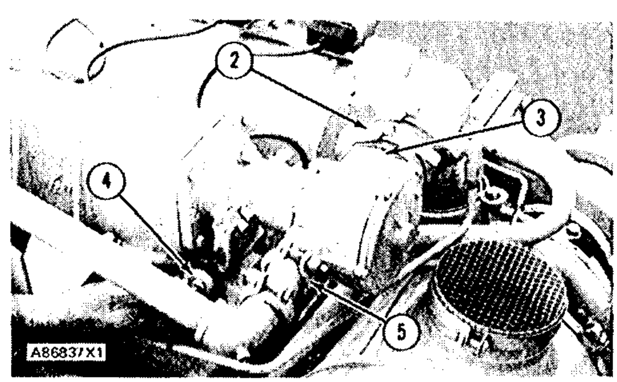
INSTALL CARBURETOR (3306) 1266-12



1. Put a new gasket and carburetor (1) in position and fasten to the aftercooler housing.

2. Slide hose (3) into position on the carburetor and tighten clamps (2).

3. Connect the joint assembly to the carburetor with clamp (5), bolt and nut. Tighten nut to a torque of 49 ± 4 lb.in. (5.5 ± 0.5 N·m).



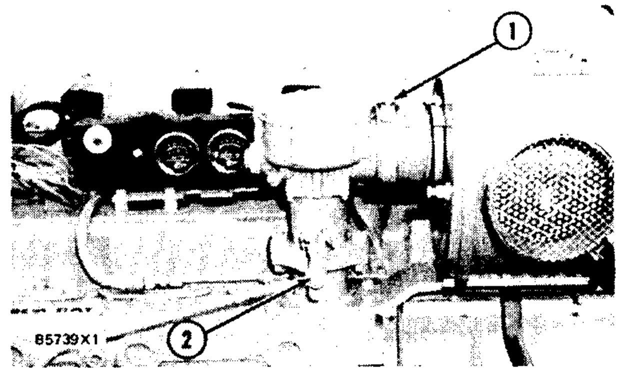
4. Fasten control rod (4) to the lever on the carburetor.

5. Check the linkage adjustment. See GOVERNOR LINKAGE ADJUSTMENT in TESTING AND ADJUSTING.

6. Turn on gas supply line to gas pressure regulator.

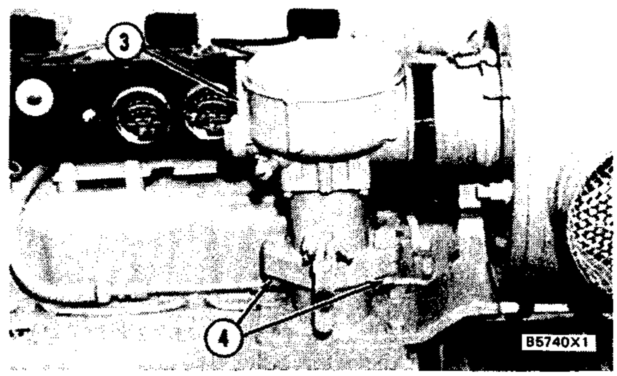
CARBURETOR (3304)

REMOVE CARBURETOR (3304) 1266-11



1. Loosen clamp (1) and move the clamp to the right.

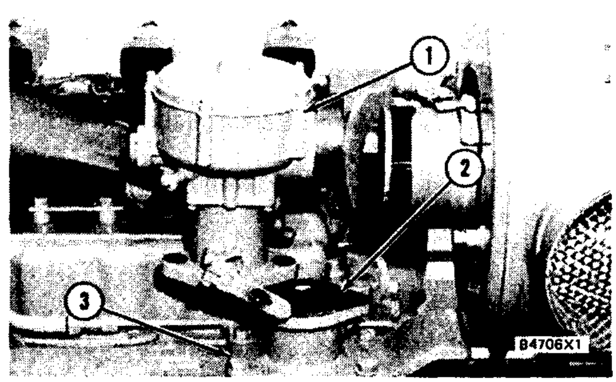
2. Remove bolt (2) from the control rod.



3. Remove two bolts (4), washers and nuts.

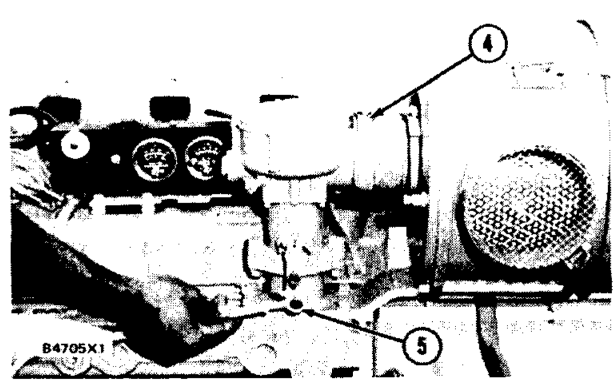
4. Remove carburetor (3) from the engine.

INSTALL CARBURETOR (3304) 1266-12



1. Put gasket (2) and carburetor (1) in position. Install the bolts, washers and nuts that hold the carburetor to adapter (3).

2. Put clamp (4) in position and tighten.



3. Fasten control rod (5) to the lever on the carburetor.

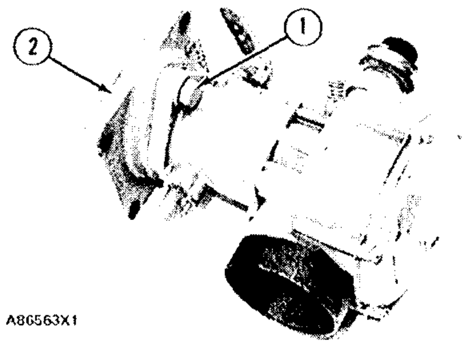
4. Check the linkage adjustment. See GOVERNOR LINKAGE ADJUSTMENT in TESTING AND ADJUSTING.

CARBURETOR

DISASSEMBLE CARBURETOR 1266-15

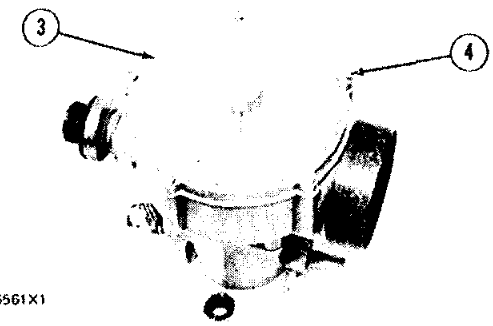
start by:
a) remove carburetor

1. Remove bolts (1), washers, gasket and adapter (2) from the carburetor.



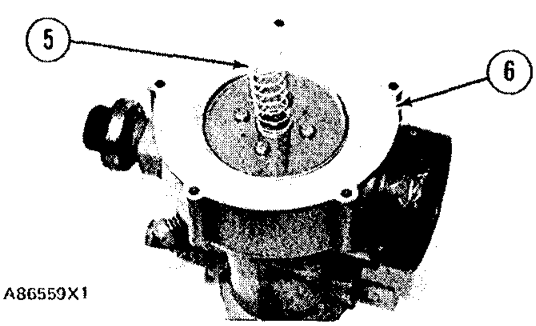
A86563X1

2. Remove screws (4), lockwashers and cover (3).



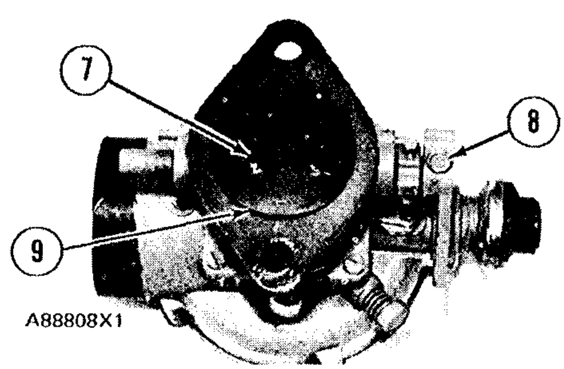
A86561X1

3. Remove spring (5) and diaphragm assembly (6).



A86559X1

4. Remove screws (7) and throttle plate (disc) (9).



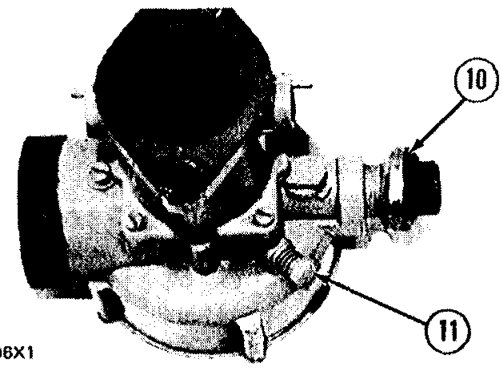
A88808X1

5. Remove throttle lever (8), lever stop and shaft as a unit.

CARBURETOR

6. Remove seal (10) from the nipple.

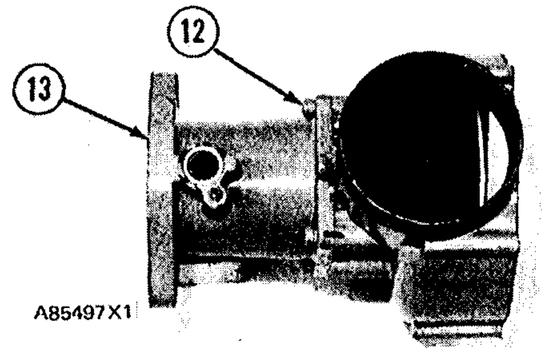
7. Remove idle screw (11) and spring.



A84906X1

NOTE: Put identification marks on throttle (base) (13) and base assembly for use at assembly.

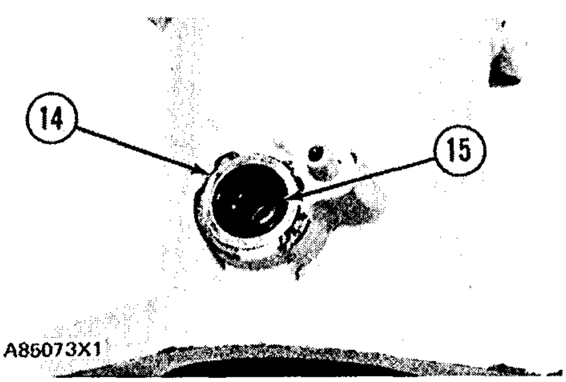
8. Remove screws (12), lockwashers, throttle base (13) and gasket from the base assembly.



A85497X1

9. Use a screwdriver to remove retainer (14).

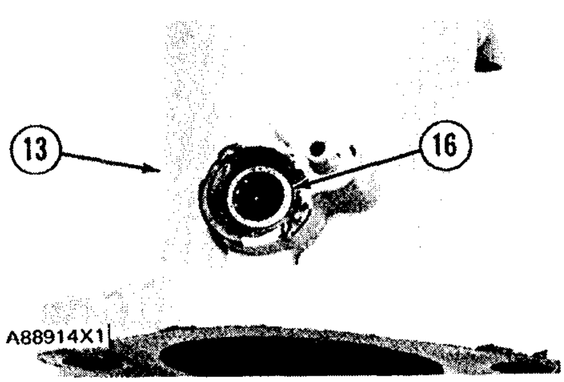
10. Remove seal (15).



A85073X1

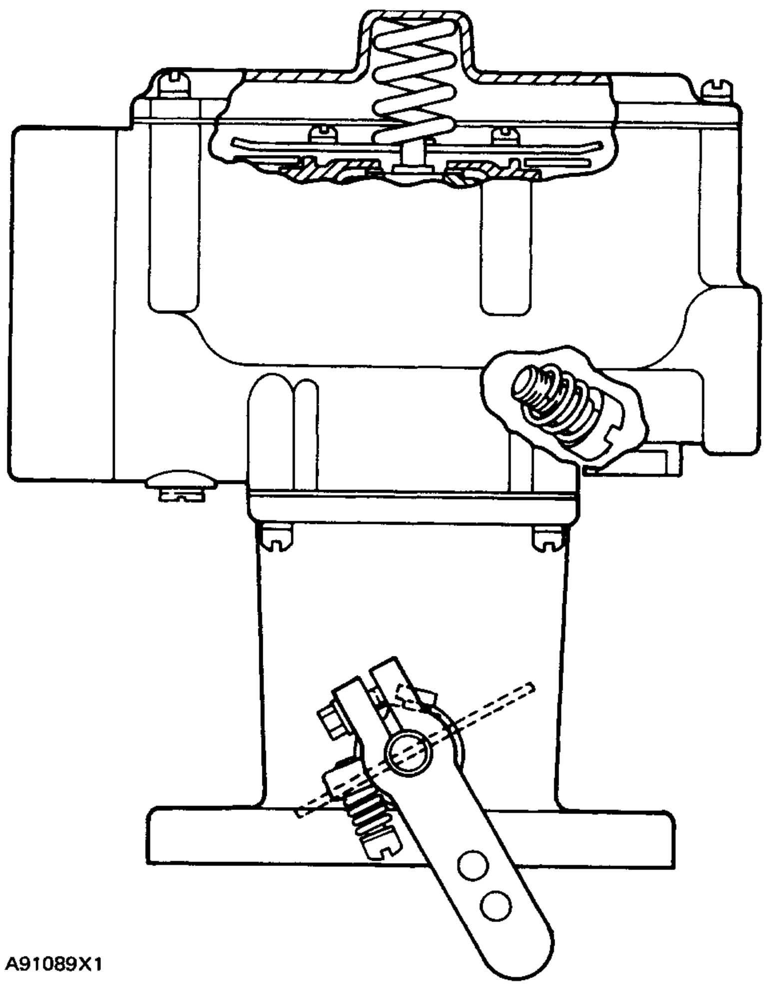
11. Remove bearing (16) from the throttle base (13).

12. Turn the throttle base (13) over and do Steps 9 through 11.



A88914X1

CARBURETOR



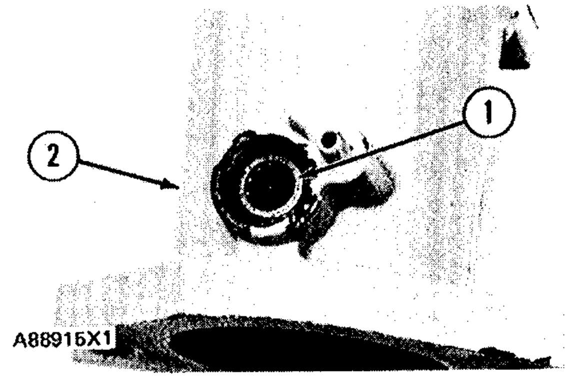
A91089X1

CARBURETOR

ASSEMBLE CARBURETOR 1266-16

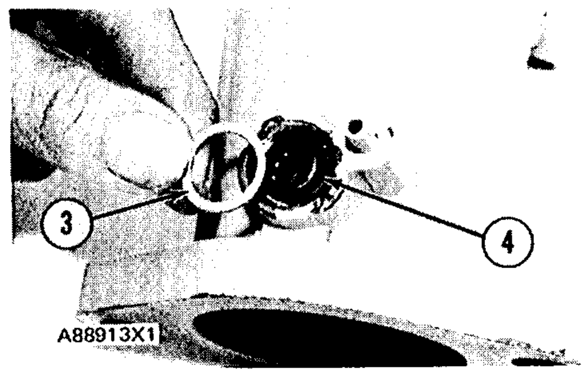
	Tools Needed	A
1P510	Driver Group	1

1. Install bearing (1) with tooling (A) to the bottom of the bearing bore in throttle base (2).



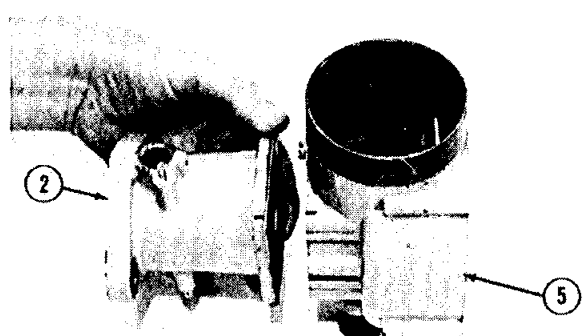
A88916X1

2. Put seal (4) in position in the seal and retainer counterbore.
3. Install retainer (3) with tooling (A).
4. Turn throttle base (2) over and do Steps 1 through 3.



A88913X1

5. Make an alignment of the identification marks and install the gasket and throttle base (2) on base assembly (5).

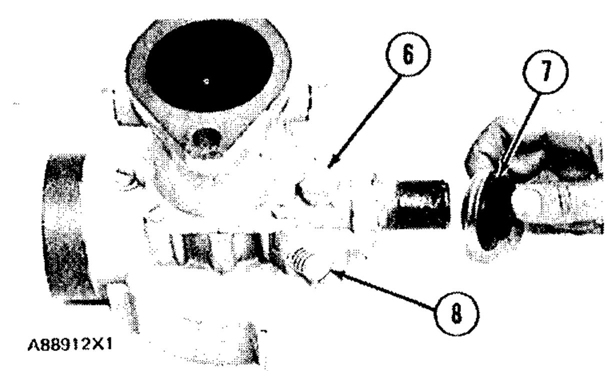


A85081X1

NOTICE

Be careful when the throttle shaft is installed not to cause damage to the seals.

6. Install idle screw (8), spring and seal (7).
7. Turn power mixture adjustment (6) to center position between "R" (rich) and "L" (lean).

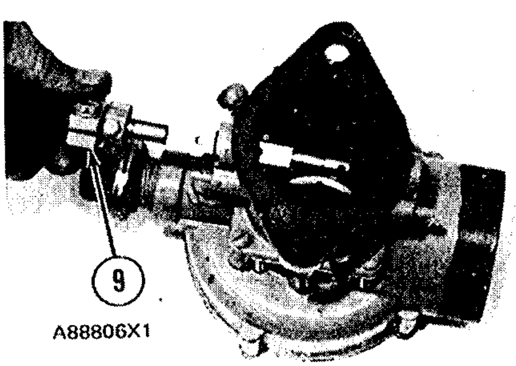


A88912X1

NOTICE

Be careful when the throttle shaft is installed not to cause damage to the seals.

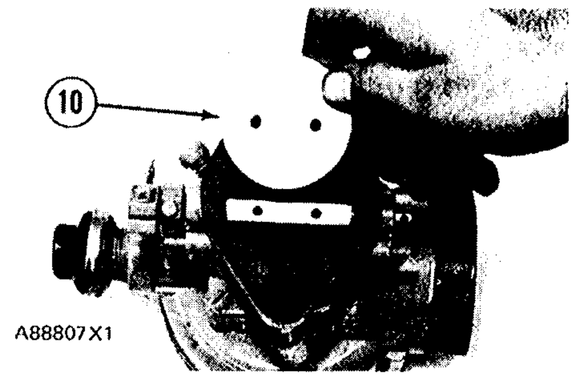
8. Install throttle lever (9), lever stop and shaft.



A88806X1

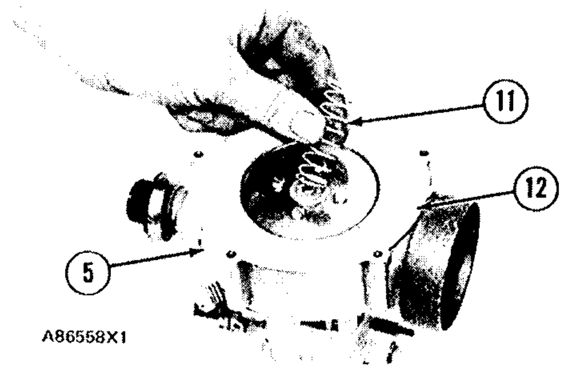
CARBURETOR

9. Put throttle plate (disc) (10) in position on the throttle shaft. Install the screws and lockwashers that hold the throttle plate (disc) in position finger tight.



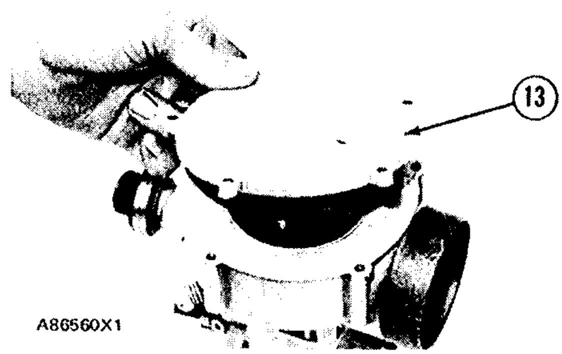
A88807X1

10. Turn the throttle plate (disc) with throttle lever (9) from fully closed to fully open position to put the throttle plate (disc) in the center of the bore. Tighten the screws and make sure that the throttle lever turns freely.



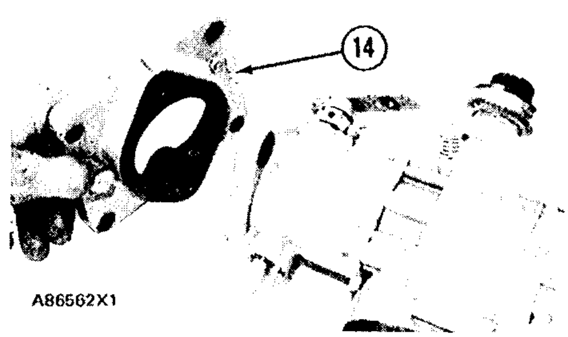
A86558X1

11. Put diaphragm assembly (12) in position on base assembly (5). Install spring (11) on diaphragm assembly (12).



A86560X1

12. Put cover (13) in position on the diaphragm assembly. Install the five bolts and lockwashers that hold the cover in position.



A86562X1

13. Install adapter (14) and gasket to the throttle base.
    end by:
    a) install carburetor

SPARK PLUGS, SPARK PLUG ADAPTERS

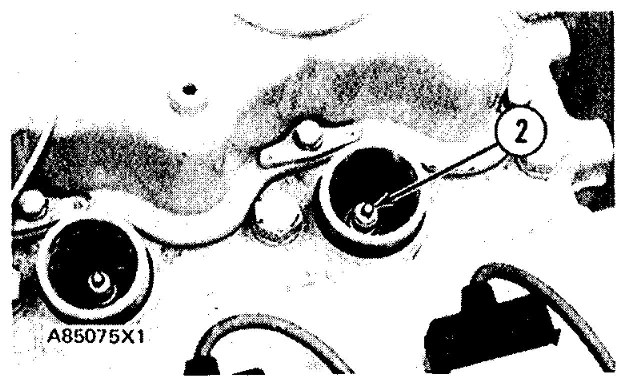
REMOVE AND INSTALL SPARK PLUGS 1415-10

	Tools Needed	A
2P5481	Spark Plug Socket	1

1. Remove covers (1) from the spark plugs and adapters.

2. Use tool (A) to remove the spark plugs (2).

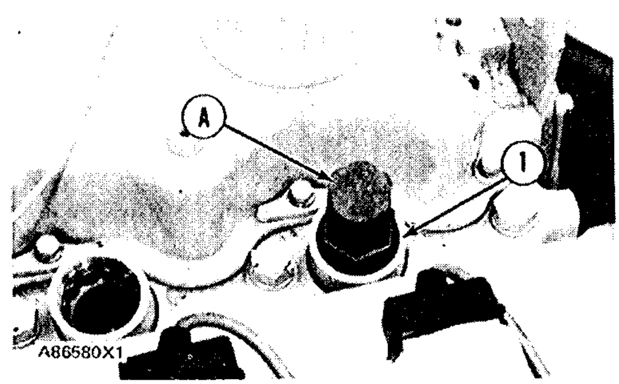
3. Use tool (A) to install the spark plugs (2). Tighten the spark plugs to a torque of 25 ± 4 lb.ft. (35 ± 5 N·m).



4. Install the spark plug covers (1). Make sure the cover makes a good connection with the spark plug.

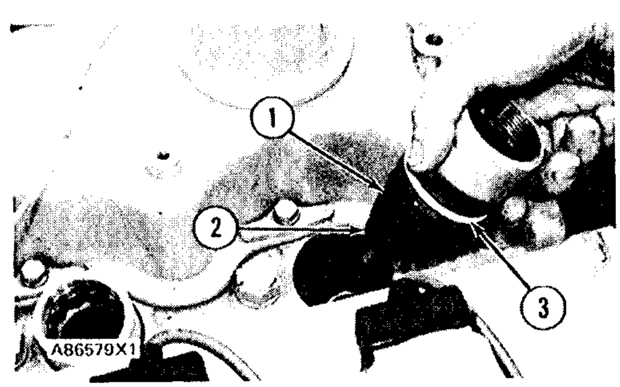
REMOVE AND INSTALL SPARK PLUG ADAPTERS 1114-10

	Tools Needed	A
1F479	Wrench	1



start by:
a) remove spark plugs

1. Drain the coolant from the cooling system to a level below the cylinder head.
2. Use tool (A) to remove the spark plug adapters (1) and gaskets.
3. Install a new seal (3) and gasket (2) on each of the spark plug adapters (1). Put liquid soap on the seal and in the bore of the cylinder head. Put 5P3931 Anti-Seize Compound on the threads of the spark plug adapters.



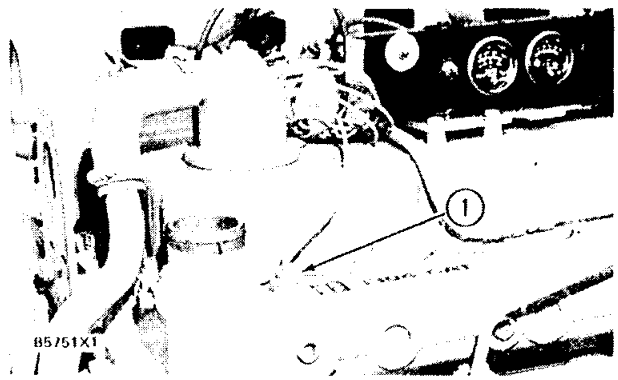
4. Install the spark plug adapters in the cylinder head. Use tool (A) to tighten the adapters to a torque of 70 ± 5 lb.ft. (95 ± 7 N·m).
5. Fill the cooling system with coolant to the correct level.

end by:
a) install spark plugs

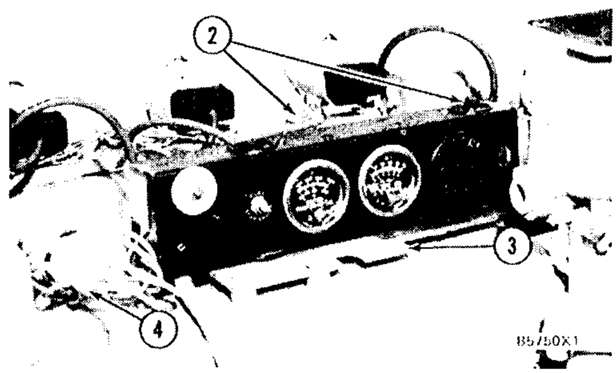
INSTRUMENT PANEL

REMOVE INSTRUMENT PANEL 7450-11

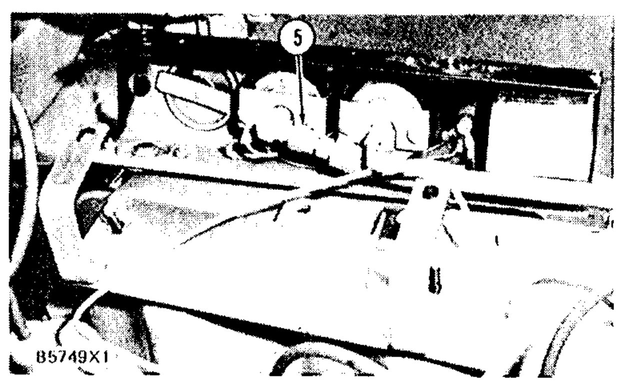
1. Drain the coolant from the cooling system below the level of the cylinder head.



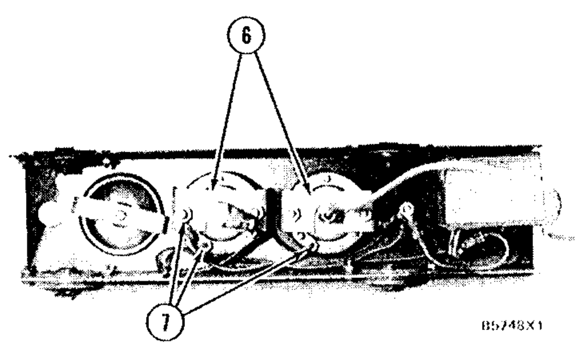
2. Remove water temperature sending unit (1) from the cylinder head.



3. Remove four bolts (2) that hold the instrument panel to bracket (3). Remove clip (4). Move the instrument panel forward.



4. Disconnect oil pressure sensing line (5) and the wire that is connected to the bottom of the instrument panel. Remove the instrument panel.

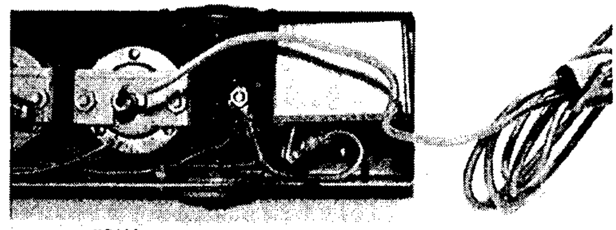


5. Put identification on wires (7) and disconnect the wires from the gauges.

6. Remove brackets (6) that hold the gauges in position.

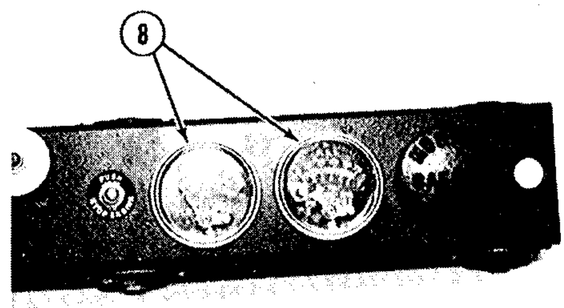
INSTRUMENT PANEL

7. Put identification on the wires connected to the stop switch and the magnetic switch. Disconnect the wires.



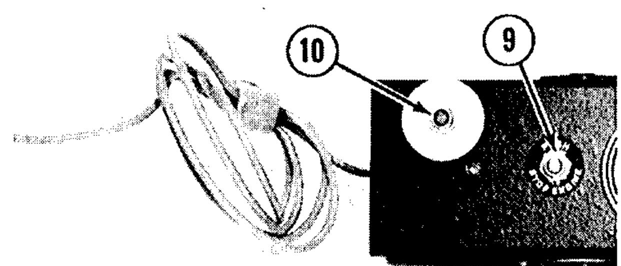
B5579X1

8. Remove gauges (8) from the instrument panel.



B5578X1

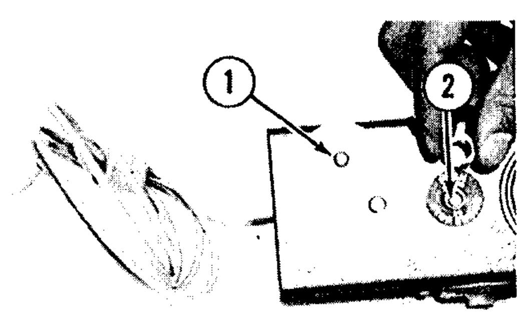
9. Remove the nuts from stop switch (9) and magnetic switch (10). Remove the switches.



B5580X1

INSTALL INSTRUMENT PANEL 7450-12

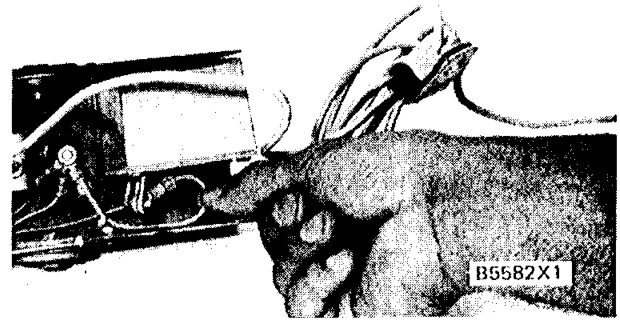
1. Install the nuts which hold magnetic switch (1) and stop switch (2) in position.



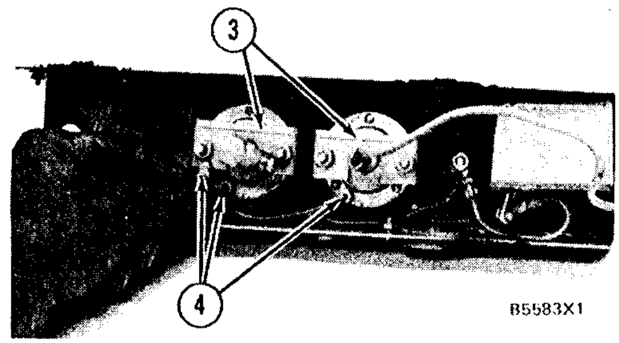
B5581X1

INSTRUMENT PANEL

2. Connect the wires to the magnetic switch and the stop switch.

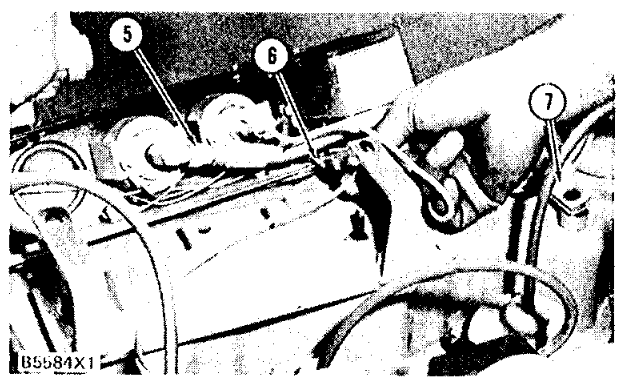


3. Put the water temperature gauge and the oil pressure gauge in position. Install brackets (3) that hold the gauges in position.

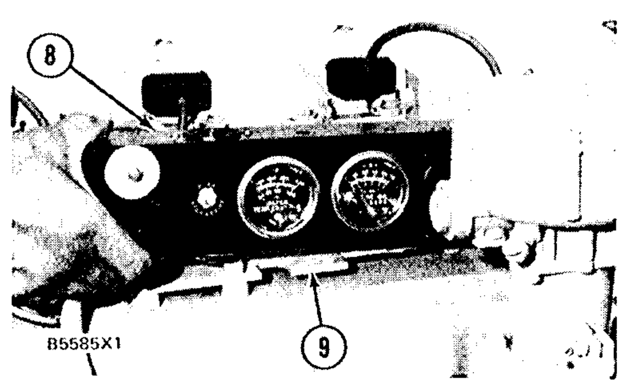


4. Connect wires (4) to the gauges.

5. Connect oil line (5) and wire (6). Install clip (7) on the valve cover.



6. Put instrument panel (8) in position. Install four bolts which hold the instrument panel to bracket (9).



7. Install the water temperature sending unit in the cylinder head.

8. Fill the cooling system with coolant to the correct level.

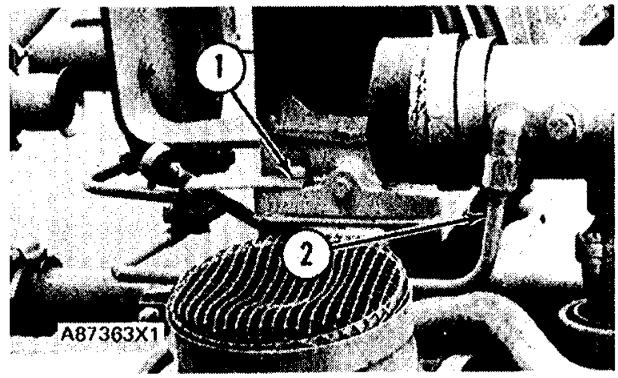
AFTERCOOLER (3306)

REMOVE AFTERCOOLER (3306) 1063-11

start by:
a) remove carburetor
b) remove instrument panel

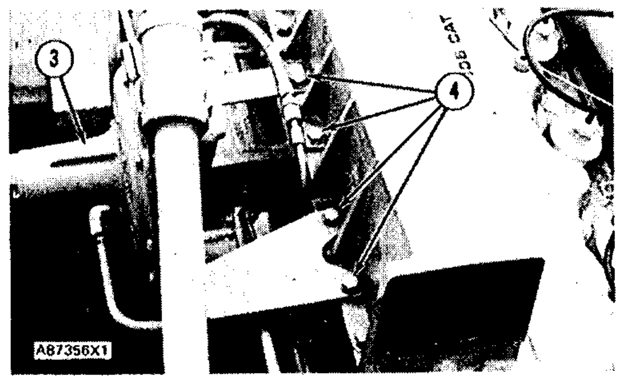
1. Shut off and disconnect gas supply line to the gas pressure regulator.

2. Remove bolt (1) and washer from the balance tube (2) support.

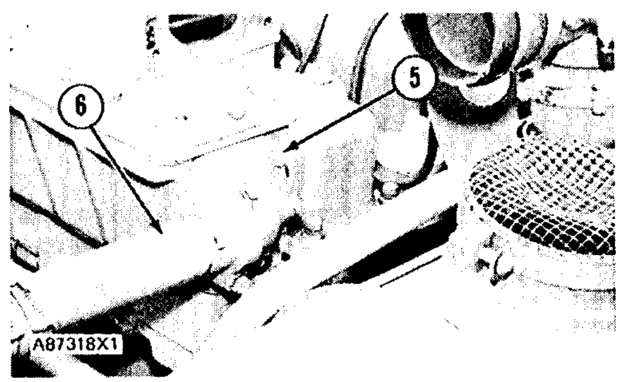


3. Disconnect balance tube (2) from the boost control valve.

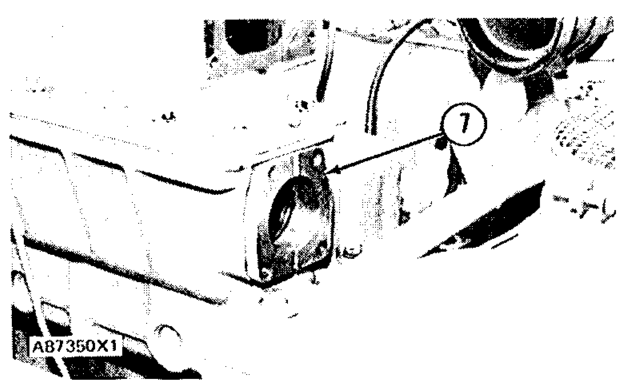
4. Remove bolts (4) and washers. Remove gas pressure regulator (3) and braces as a unit.



5. Remove bolts (5) and washers that hold tube assembly (6) in place. Remove tube assembly (6).



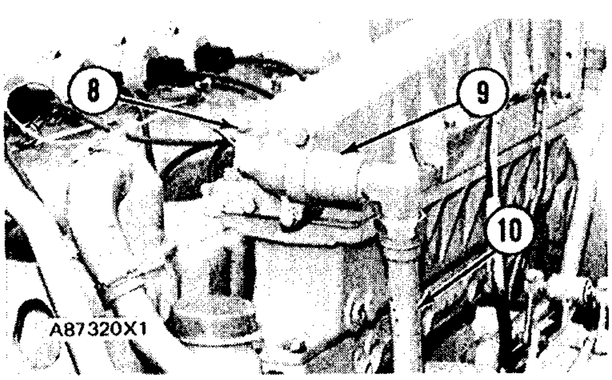
6. Remove adapter (7) and gasket from the aftercooler housing.



7. Remove bolts (8) and washers from elbow (9).

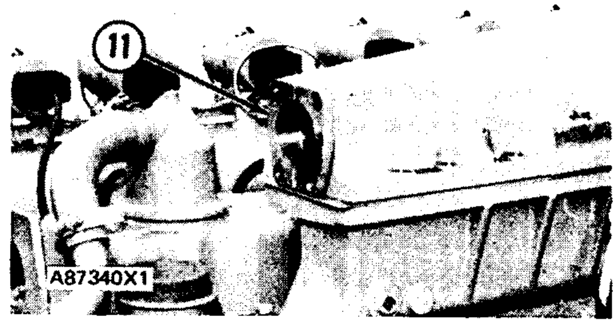
8. Disconnect water inlet tube (10) from the fitting on the auxiliary water pump.

9. Remove elbow (9) and water inlet tube (10) as a unit.

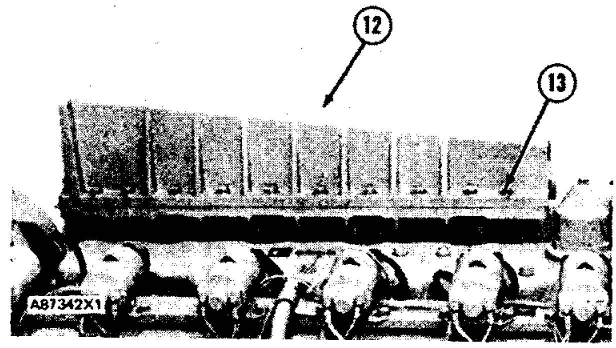


AFTERCOOLER (3306)

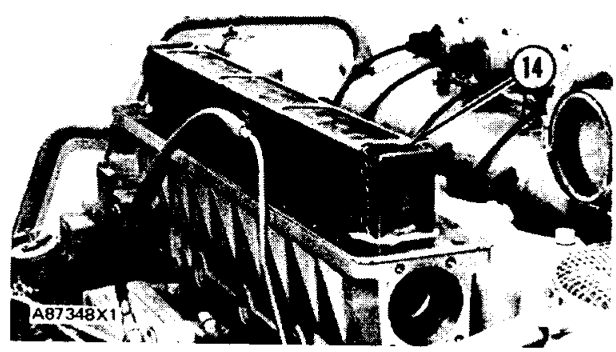
10. Remove adapter (11) and gasket from the aftercooler cover.



11. Remove bolts (13) and washers that hold aftercooler cover (12) in place. Remove aftercooler cover (12) and gasket.

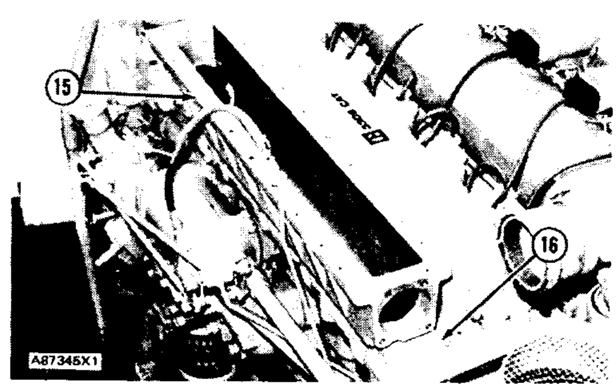


12. Remove aftercooler core (14) and gasket.



13. Remove eight bolts (16) and washers that hold the aftercooler housing (15) in place.

14. Remove aftercooler housing (15) and gaskets from the cylinder head.

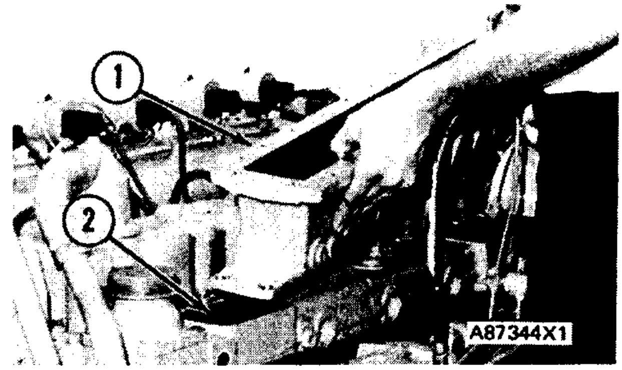


AFTERCOOLER (3306)

INSTALL AFTERCOOLER (3306) 1063-12

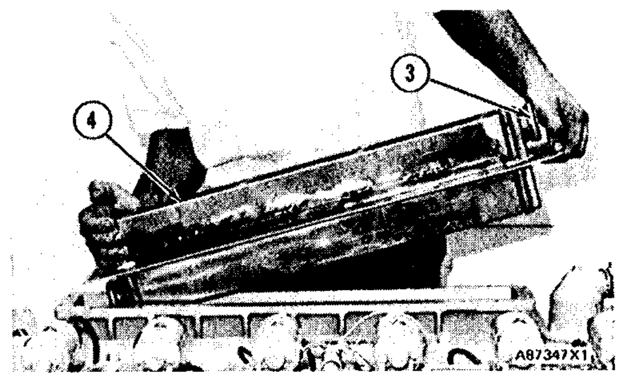
NOTE: Put a thin layer of clean engine oil on all O-ring seals and the bores of each adapter.

1. Put new gaskets (2) in position and install aftercooler housing (1).



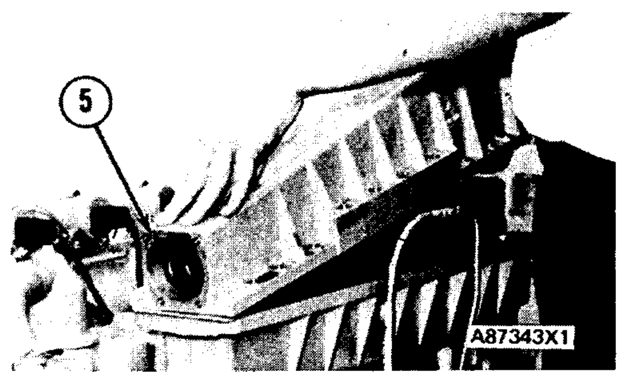
2. Install O-ring seals (3) on the aftercooler core (4).

3. Put a new gasket and aftercooler (4) into position in the aftercooler housing.



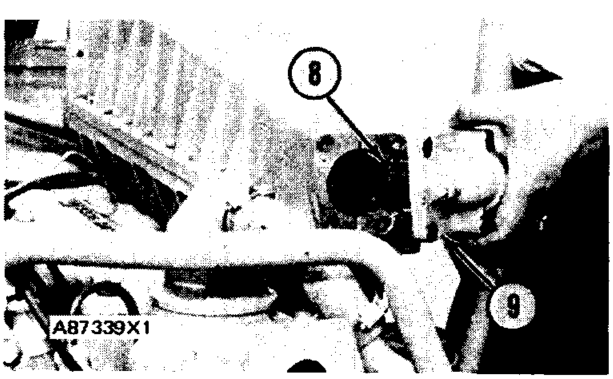
4. Put a new gasket and aftercooler cover (5) into position. Install the washers and bolts loosely that hold aftercooler cover (5) in place.

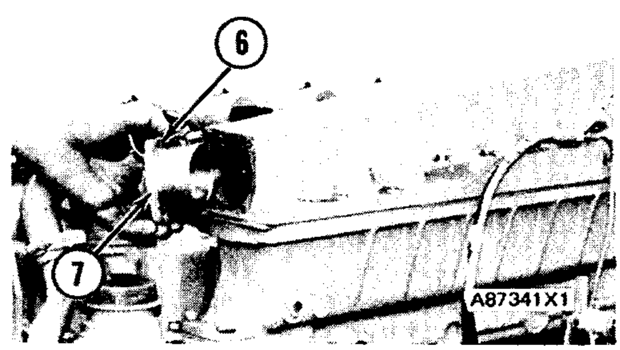
5. Install a new gasket (6) and adapter (7) in the aftercooler cover.



6. Put O-ring seal (8) in position and install elbow (9) on the aftercooler cover.

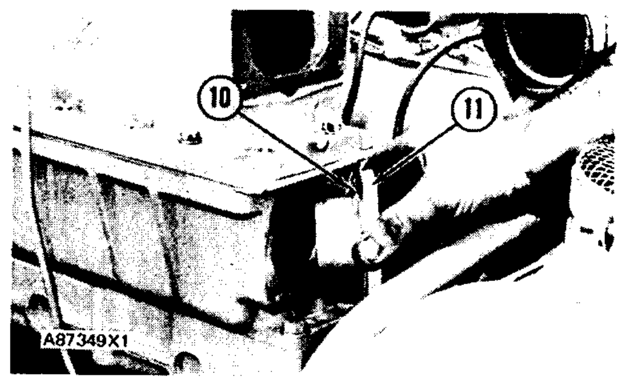
7. Connect the water inlet tube to the auxiliary water pump.



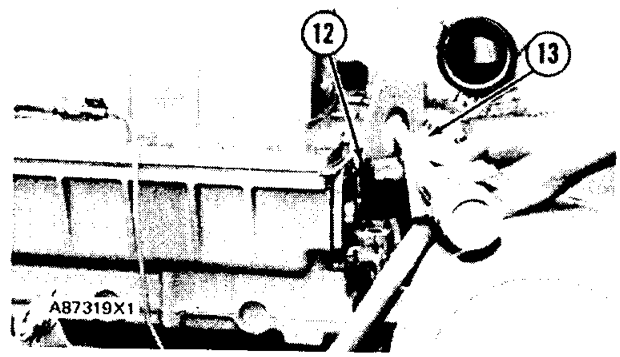


AFTERCOOLER (3306)

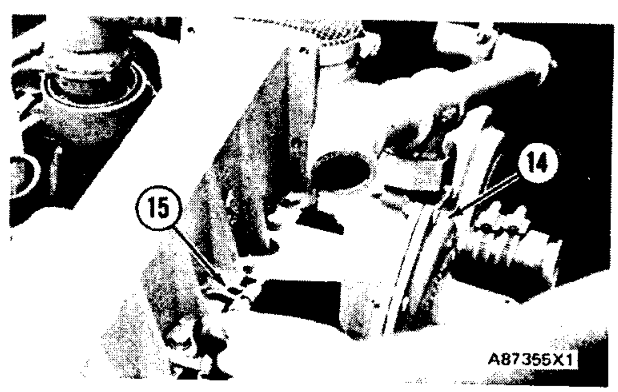
8. Put a new gasket (10) and adapter (11) into position in the aftercooler housing.
9. Install O-ring seal (12) on tube assembly (13).
10. Install tube assembly (13) in the aftercooler housing.



11. Put gas pressure regulator (14) into position and fasten to the aftercooler housing.
12. Fasten clip (15) to the aftercooler housing.



13. Connect balance tube (17) to the boost control valve.
14. Fasten balance tube support (16) to the aftercooler housing.

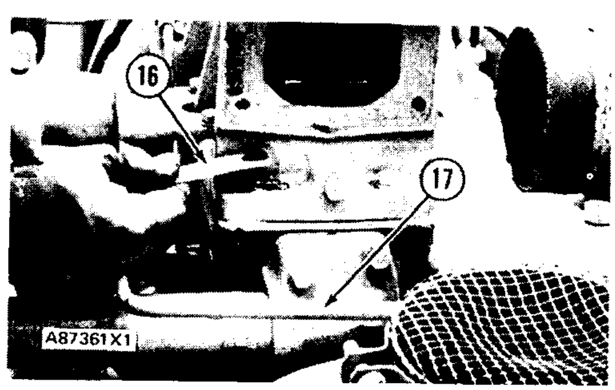


15. Tighten all of the bolts that hold the aftercooler cover in place to a torque of 18 ± 5 lb.ft. (25 ± 7 N·m).
16. Connect the gas supply line to the gas pressure regulator.

NOTE: After the end by steps have been completed, run engine and tighten all aftercooler cover bolts to a torque of 18 ± 5 lb.ft. (25 ± 7 N·m).

end by:

a) install carburetor
b) install instrument panel

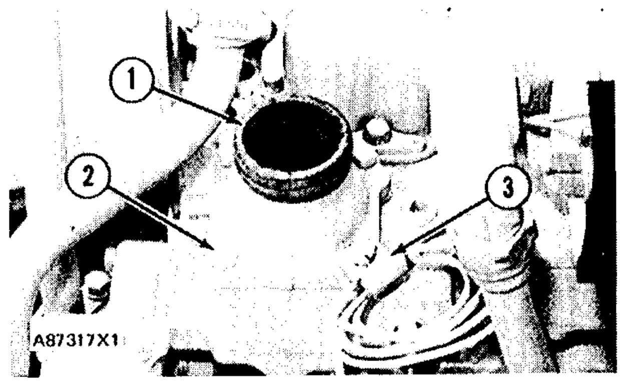


WATER TEMPERATURE REGULATOR

REMOVE WATER TEMPERATURE REGULATOR 1355-11

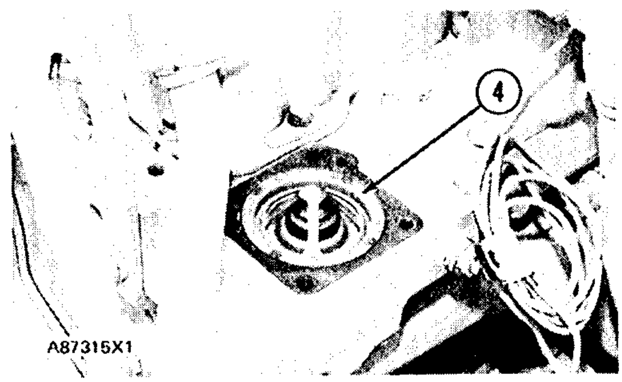
NOTE: Photos shown are on 3306.

1. Drain the coolant from the cooling system below the level of the water temperature regulator.



2. Remove bolts (2) and clip (3).

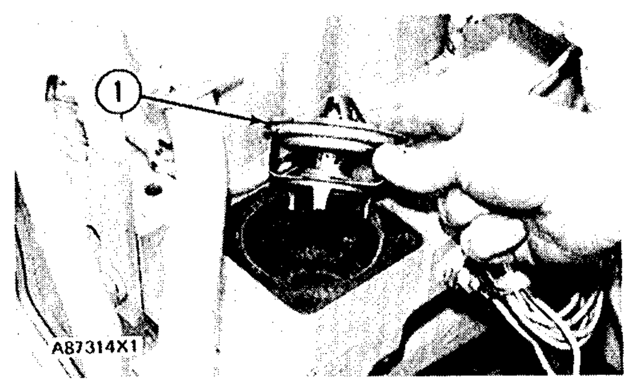
3. Remove pipe (1) and gasket from the cylinder head.



4. Remove water temperature regulator (4).

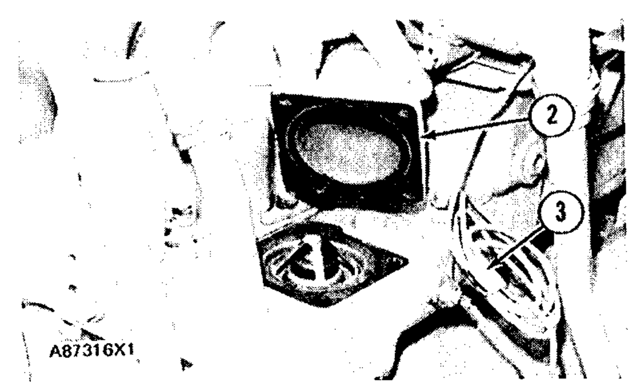
INSTALL WATER TEMPERATURE REGULATOR 1355-12

1. Put the water temperature regulator (1) into position in the cylinder head.



2. Install a new gasket and pipe (2) over the water temperature regulator.

3. Install clip (3) and bolts that hold pipe (2) in place.



4. Fill the cooling system with coolant to the correct level.

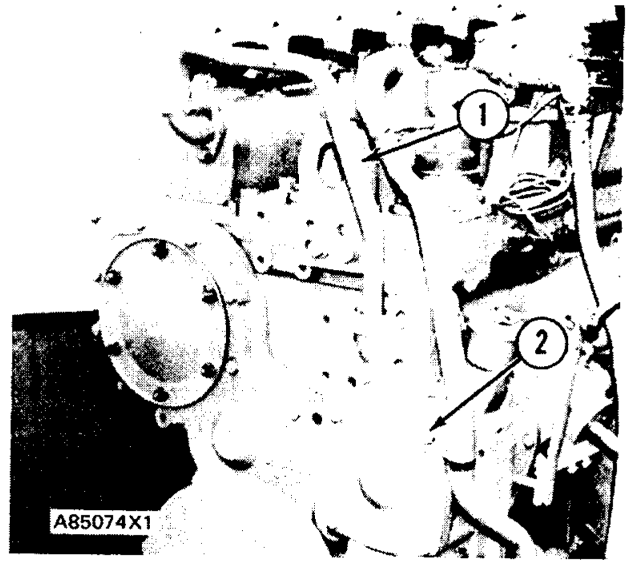
WATER PUMP

REMOVE WATER PUMP 1361-11

NOTE: Photos shown are on 3306.

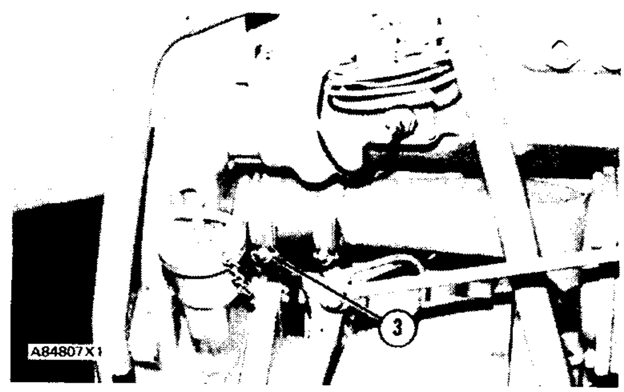
1. Drain the coolant from the cooling system.

2. Remove tube (1) from the water pump elbow to the exhaust manifold.



3. Remove bolt (2) that holds the breather tube clip to the water pump.

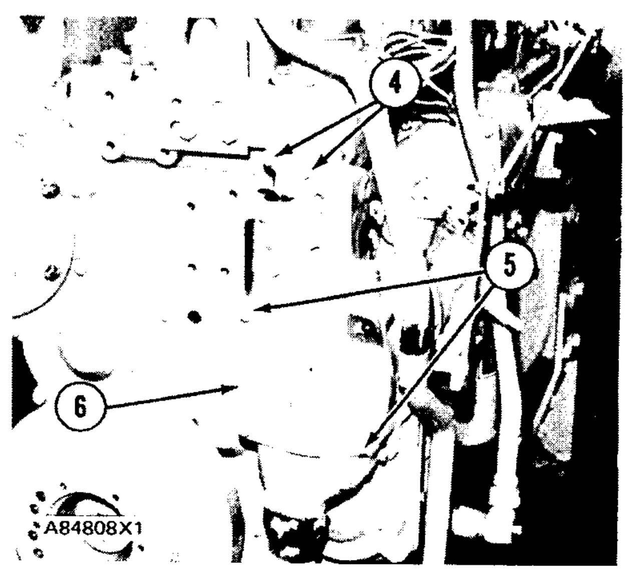
4. Loosen hose clamp (3) and slide the clamp away from the water pump elbow.



5. Disconnect the hose from the radiator at the water pump.

6. Remove bolts (4) that hold the water pump elbow to the cylinder head.

7. Remove two bolts (5) and washers that hold water pump (6) to the front housing. Remove the water pump and elbow as a unit.

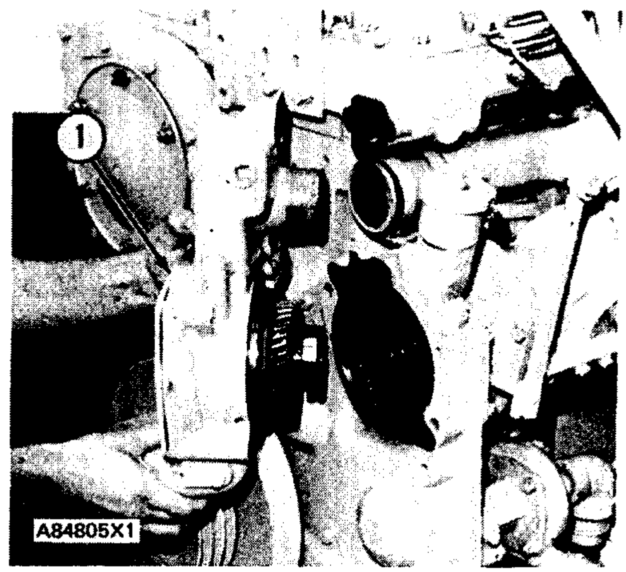


WATER PUMP

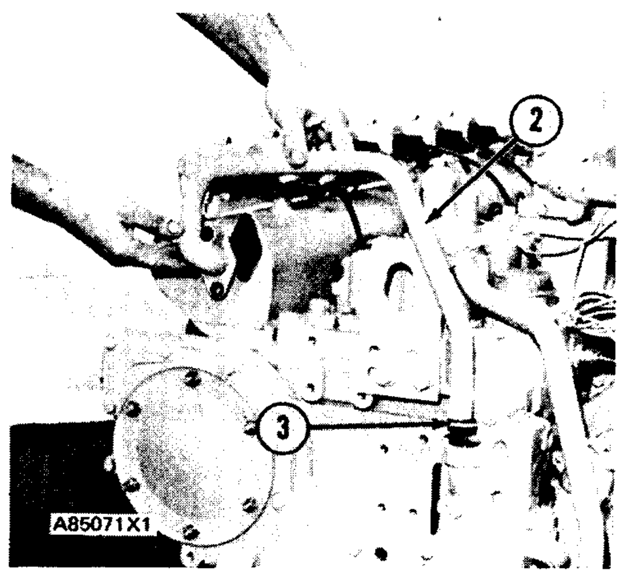
INSTALL WATER PUMP 1361-12

NOTE: Photos shown are on 3306.

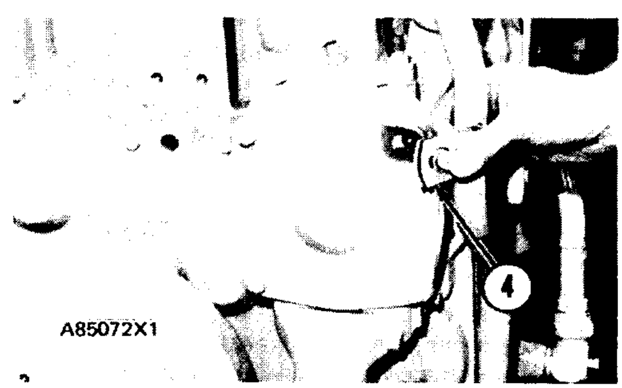
1. Put a new water pump elbow gasket in place and install water pump (1). Install the bolts and washer that hold the water pump and elbow in place.



2. Put a thin layer of engine oil on seal (3).
3. Put a new gasket between the exhaust manifold and tube (2) in position. Install tube (2) and bolts that hold the tube in place.
4. Tighten the hose clamp on the hose to the oil cooler.



5. Install the bolt and washer that hold the breather tube clip (4) in place.
6. Connect the hose from the radiator to the water pump.

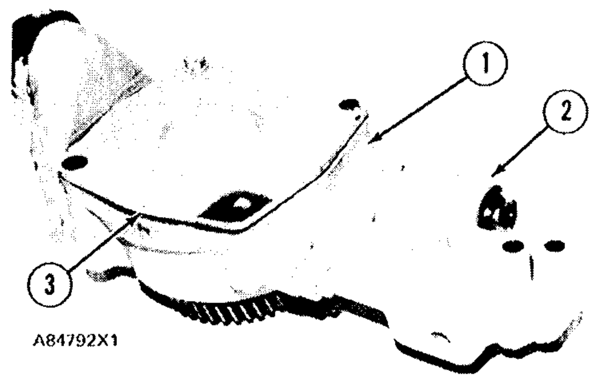


7. Fill the cooling system with coolant to the correct level.

WATER PUMP

DISASSEMBLE WATER PUMP 1361-15

	Tools Needed	A	B	C	D
8B7548	Puller Assembly	1			
8H684	Ratchet Box Wrench	1			
8H663	Bearing Puller Attachment	1		1	
8B7560	Step Plate	1			
	Bolt (3/8"-16 NC x 2 3/4 in. long)	1			
5P4758	Pliers		1		
1P510	Driver Group				1

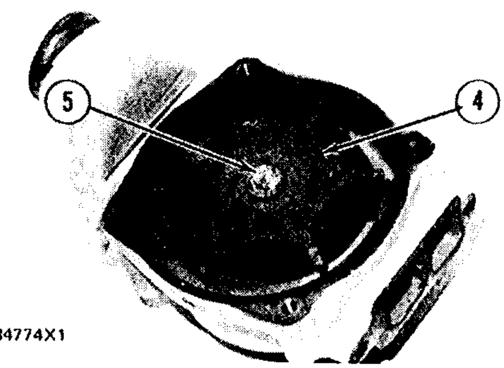


A84792X1

start by:
a) remove water pump

1. Remove cover (3) and gasket from water pump (1).

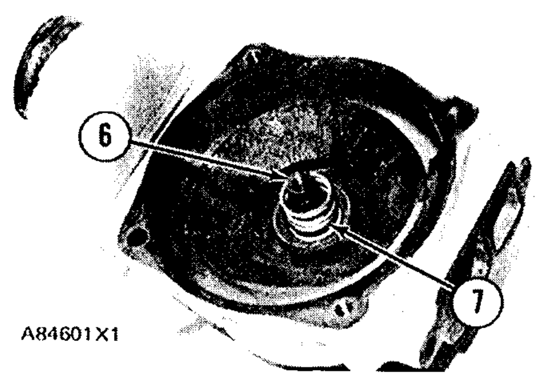
2. Remove elbow (2) and gasket from water pump (1).



A84774X1

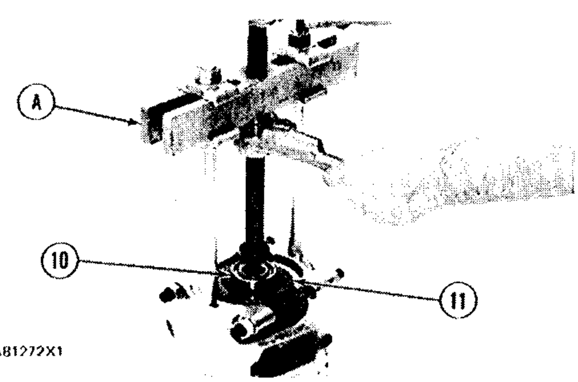
3. Loosen bolt (5) .25 in. (6.35 mm). Hit (tap) the bolt with a soft hammer to remove impeller (4) from the shaft.

4. Remove spring and seal assembly (7) from shaft (6).

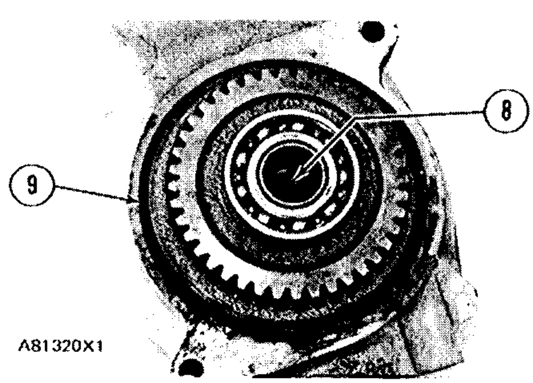


A84601X1

5. Turn the water pump over and remove bolt (8) and lockwasher.
6. Remove O-ring seal (9) from the housing.
7. Use tooling (A) to remove gear (11) and bearing (10) from the water pump.
8. Remove bearing (10) from gear (11).



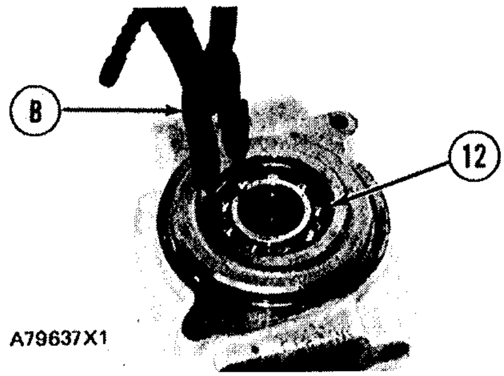
A81272X1



A81320X1

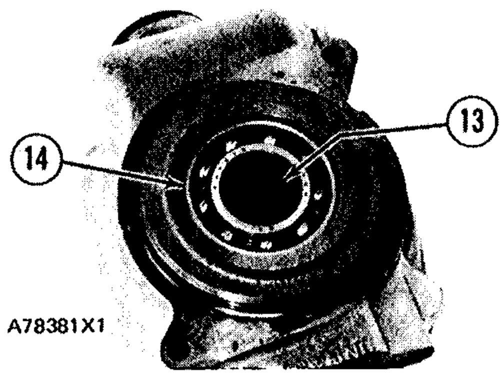
WATER PUMP

9. Remove snap ring (12) with tool (B).



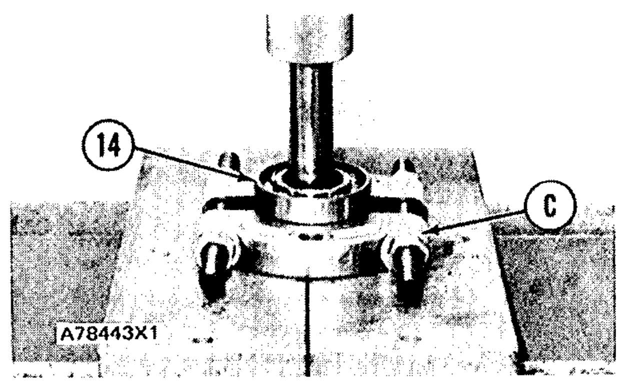
A79637X1

10. Remove bearing (14) and shaft (13) as a unit.
11. Use tool (C) and a press to remove bearing (14) from the shaft.



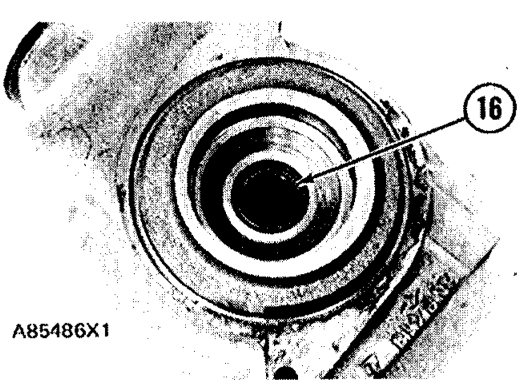
A78381X1

12. Remove the ceramic ring and seal (15) from the housing.

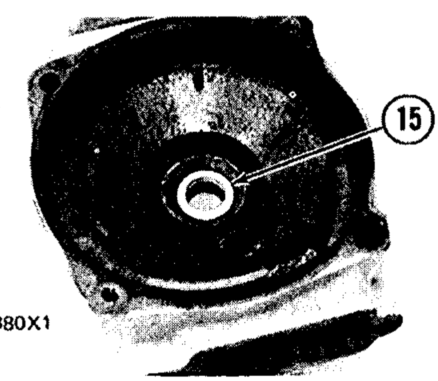


A78443X1

13. Remove the lip type seal (16) from the housing with tooling (D).

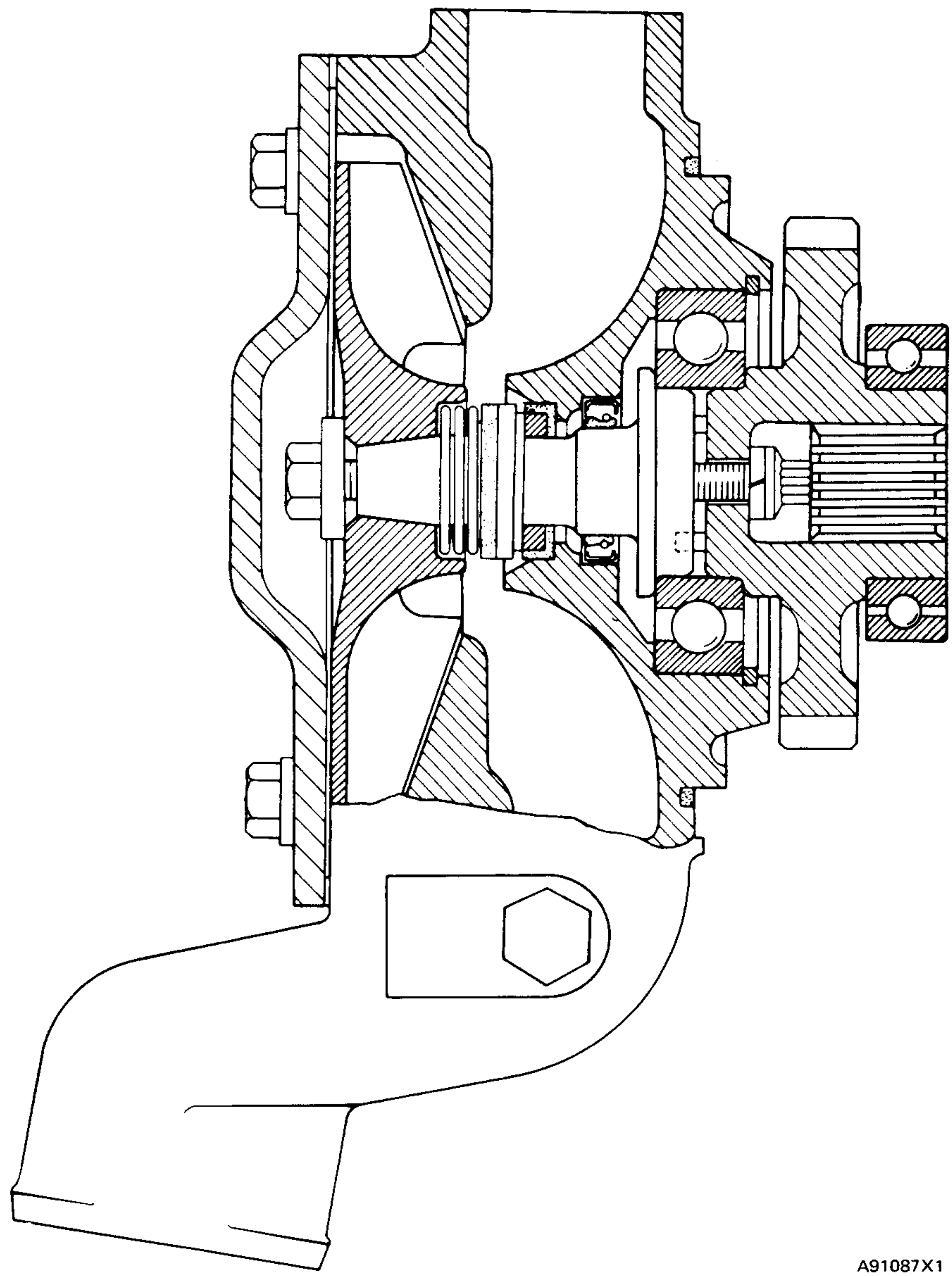


A85486X1



A78380X1

WATER PUMP

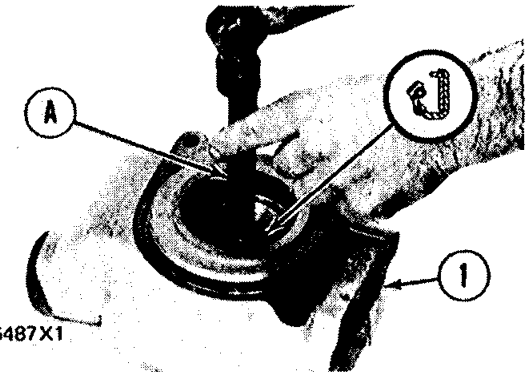


A91087X1

WATER PUMP

ASSEMBLE WATER PUMP 1361-16

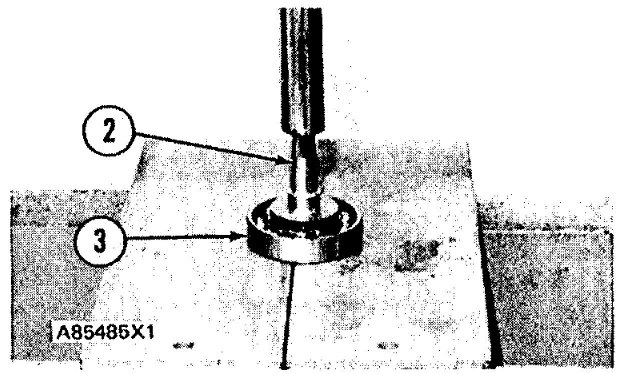
	Tools Needed	A	B
1P510	Driver Group	1	
5P4758	Pliers		1



A85487X1

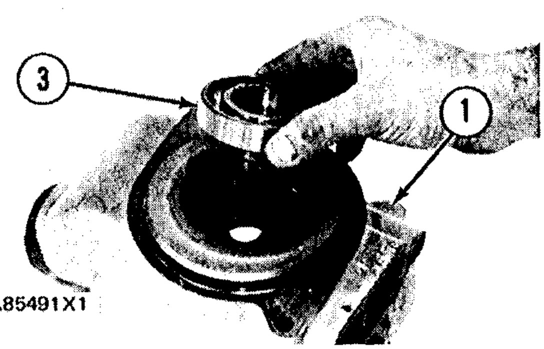
NOTE: The seal must be installed with the lip toward the bearings.

1. Install the lip type seal in housing (1) with tooling (A) to the bottom of the seal counterbore. Put a thin layer of engine oil on the lip of the seal.



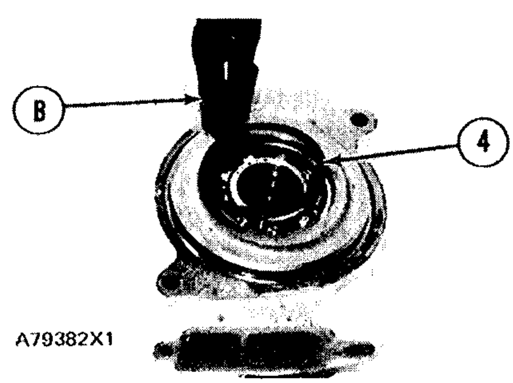
A85485X1

2. Use a press to install shaft (2) in bearing (3).



A85491X1

3. Install the shaft and bearing (3) in housing (1).

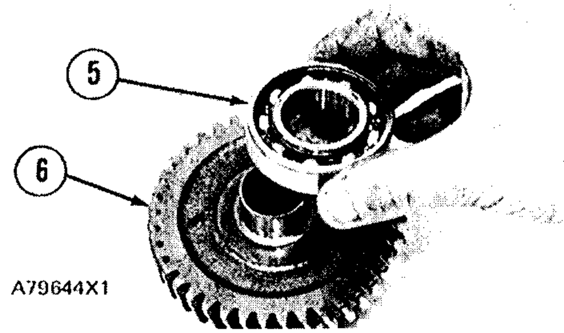


A79382X1

4. Install snap ring (4) in the housing with tool (B).

WATER PUMP

5. Install bearing (5) on gear (6).

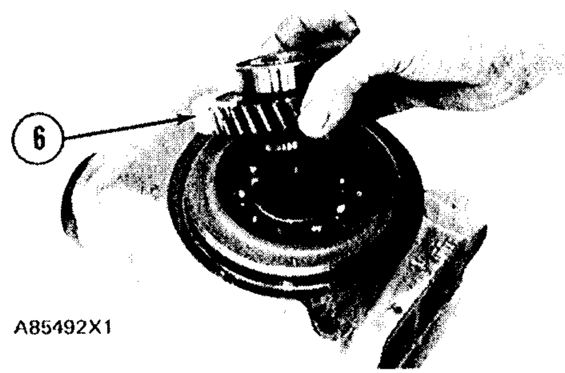


A79644X1

NOTICE

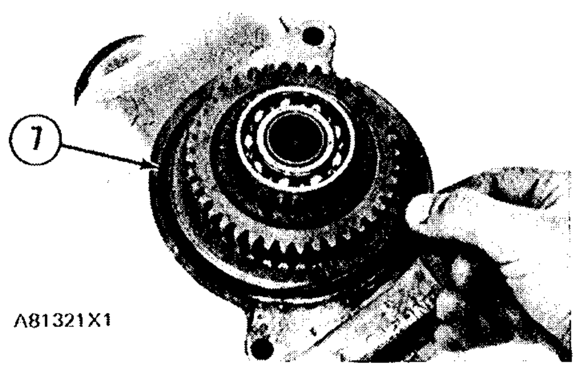
When gear (6) is installed, make sure the pins on the gear engage the holes in the shaft.

6. Put gear (6) and bearing in position on the shaft and install washer and bolt.



A85492X1

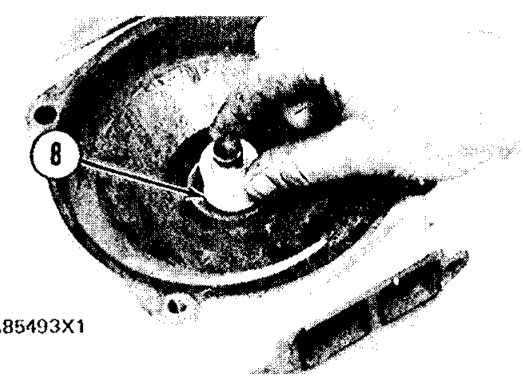
7. Install O-ring seal (7) on the housing.



A81321X1

NOTICE

Clean water only is permitted for use as a lubricant to make assembly easier. Do not damage or put hands on the wear surface of the carbon ring or the ceramic ring. Install the ceramic ring with the smoothest face of the ring toward the carbon seal assembly.

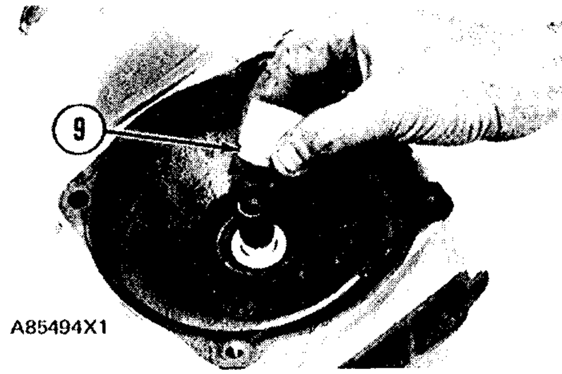


A85493X1

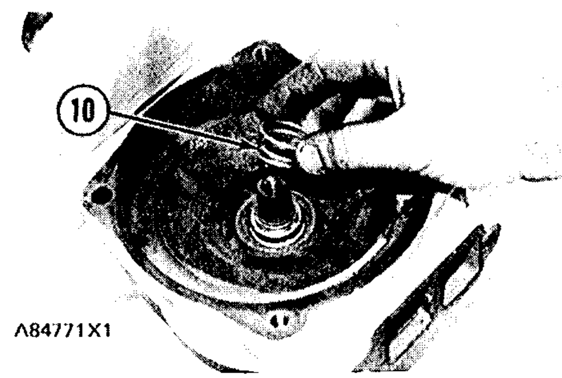
8. Put the ceramic ring (8) in position in the rubber seal. Use hand pressure and tool (which is with the replacement ring) to install the ceramic ring and rubber seal.

WATER PUMP

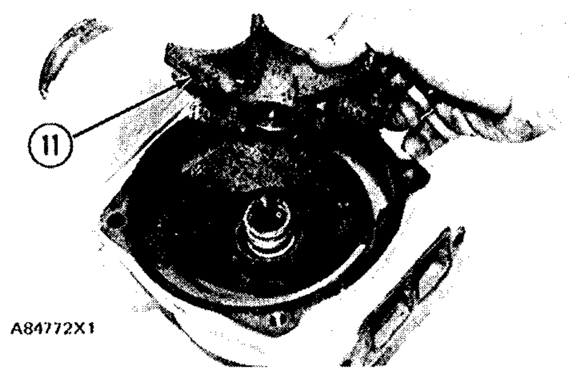
9. Remove the spring from the seal assembly (9). Use hand pressure and the tool (which is with the replacement ring) to install the seal assembly. Push seal assembly on the shaft until seal faces make light contact.



10. Install spring (10) on the seal assembly.



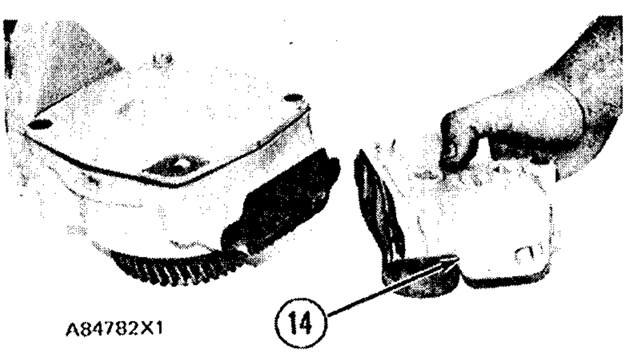
11. Put impeller (11) in position on the shaft.

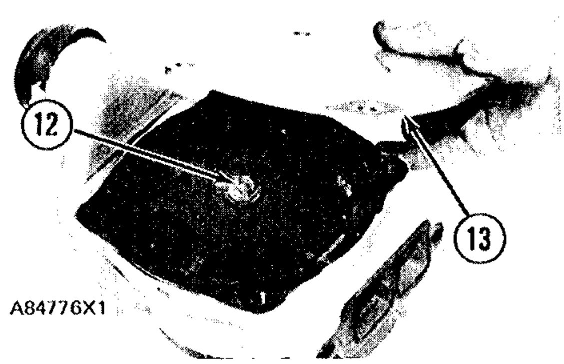


12. Install washer and bolt (12). Tighten the bolt to a torque of 28 ± 1 lb.ft. (39 ± 1 N·m).

13. Install a new gasket and cover (13) on the housing.

14. Install a new gasket and elbow (14) on the housing.
    end by:
    a) install water pump

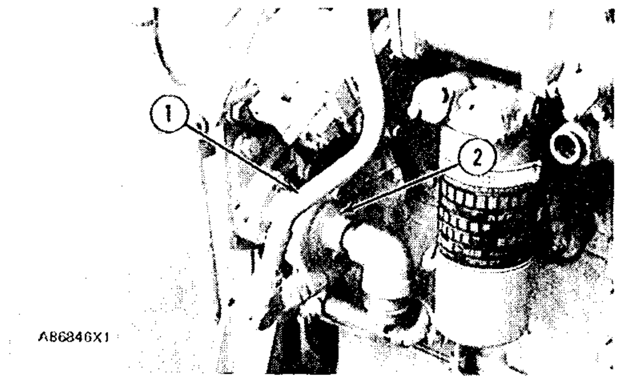




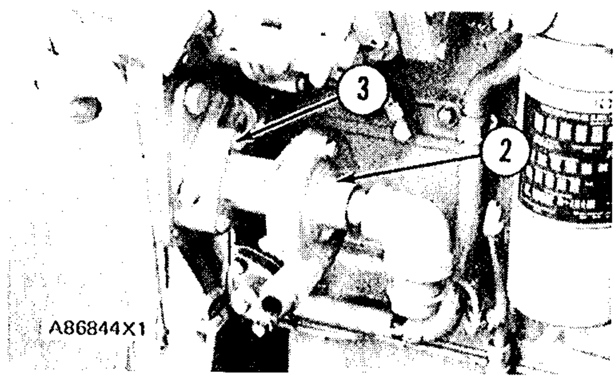
AUXILIARY PUMP (FRESH WATER-3306)

REMOVE AUXILIARY PUMP (FRESH WATER-3306) 1371-11

1. Disconnect water inlet line from the auxiliary water pump (2).



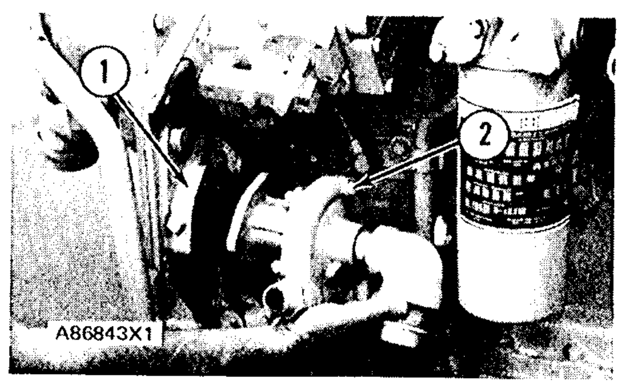
2. Disconnect water outlet tube (1) at the fittings on the auxiliary water pump (2) and the aftercooler housing. Remove tube (1).



3. Remove bolts (3), auxiliary water pump (2) and gasket from the accessory drive housing.

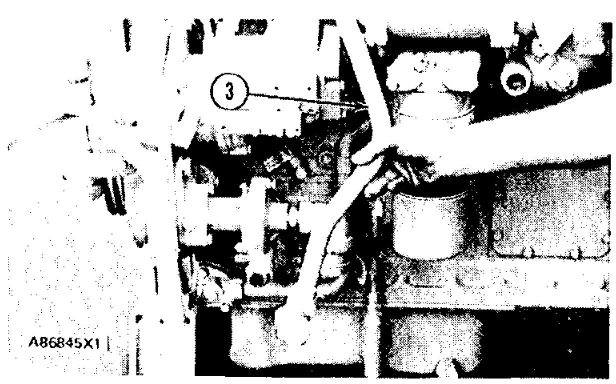
INSTALL AUXILIARY PUMP (FRESH WATER-3306) 1371-12

1. Install a new gasket on the accessory drive housing (1).



2. Put auxiliary water pump (2) into position over dowels and fasten with the bolts.

3. Put water outlet tube (3) into position and fasten to the fittings on the auxiliary water pump and aftercooler housing.



4. Connect inlet water line to the auxiliary water pump.

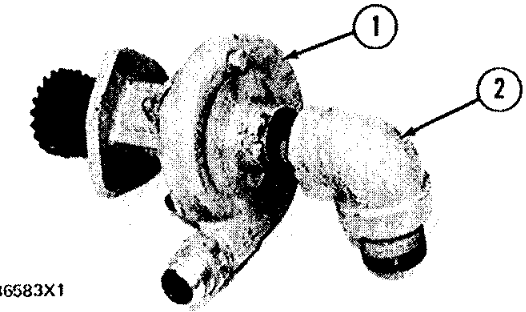
AUXILIARY PUMP (FRESH WATER-3306)

DISASSEMBLE AUXILIARY PUMP (FRESH WATER-3306) 1371-15

	Tools Needed	A	B	C	D
1P1857	Pliers	1			
1P510	Driver Group		1		
1P1855	Pliers			1	
9S9152	Bearing Puller Attachment				1

start by:
a) remove auxiliary pump (fresh water-3306)

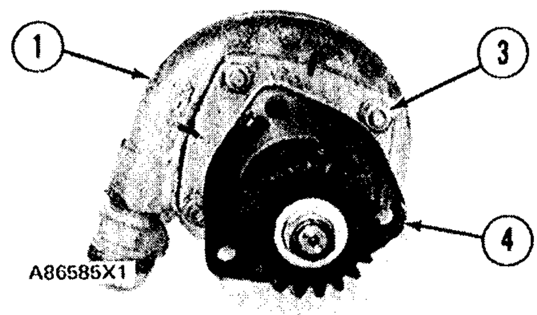
1. Remove elbow (2) and pipe nipple from housing (1).



A86583X1

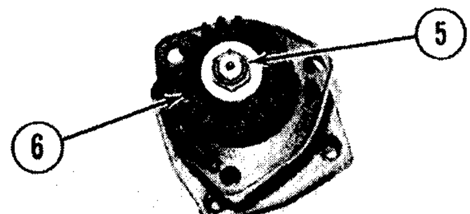
NOTE: Put identification on body (4) and housing (1) for use at assembly.

2. Remove nuts (3) lockwashers, body (4) and gaskets from housing (1).



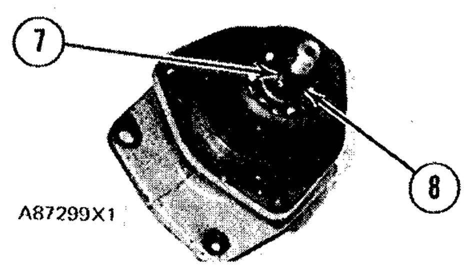
A86585X1

3. Remove nut (5), washer and gear (6) from the shaft.



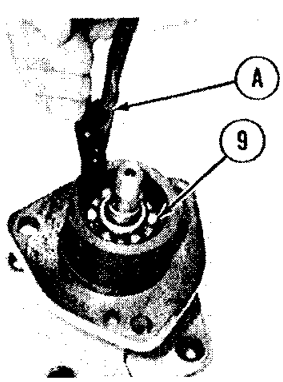
A87301X1

4. Remove key (7) and spacer (8) from the shaft.



A87299X1

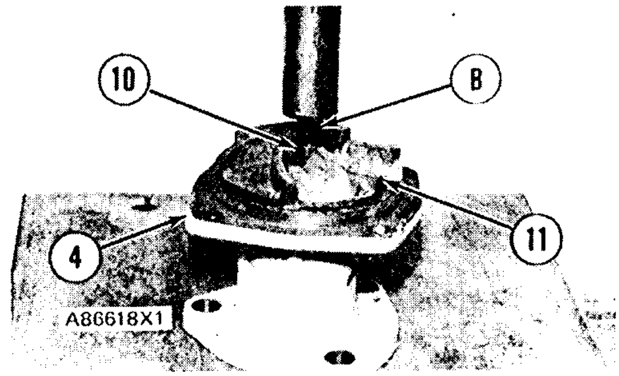
5. Use tool (A) and remove snap ring (9).



A86620X1

AUXILIARY PUMP (FRESH WATER-3306)

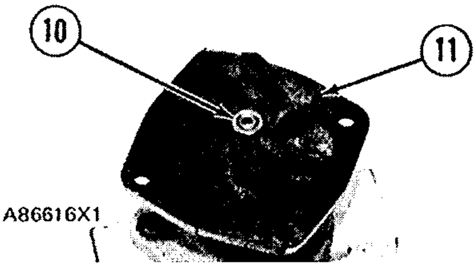
6. Remove the locknut that holds impeller (11) in place.



A86618X1

7. Install a 3/8''-24 NF jam nut (10) even with the end of the shaft.

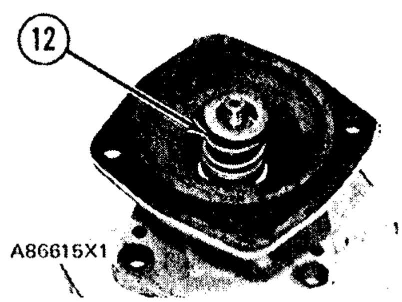
8. Put body (4) in position in a press. Use tooling (B) and press as shown to loosen impeller (11) on the shaft.



A86616X1

9. Remove jam nut (10) and impeller (11) from the shaft.

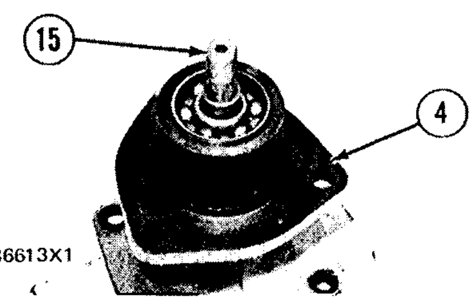
10. Remove spring (12).



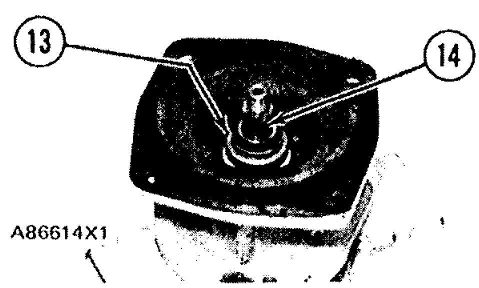
A86615X1

11. Remove key (14), shims and seal assembly (13).

12. Turn pump body (4) over and remove shaft (15) and bearings as a unit.



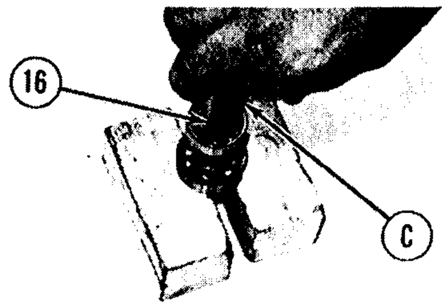
A86613X1



A86614X1

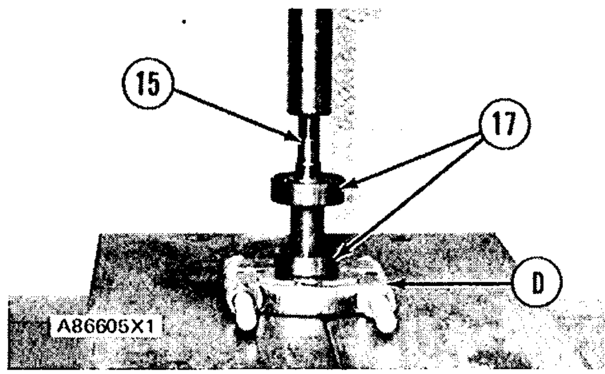
AUXILIARY PUMP (FRESH WATER-3306)

13. Use tool (C) and remove snap ring (16) from shaft (15).



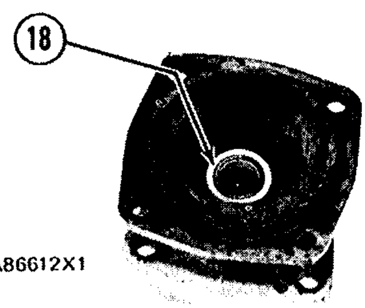
A86606X2

14. Put shaft (15) and bearings (17) into position in a press on tool (D). Use the press to push shaft (15) from bearings (17) and spacer.



A86605X1

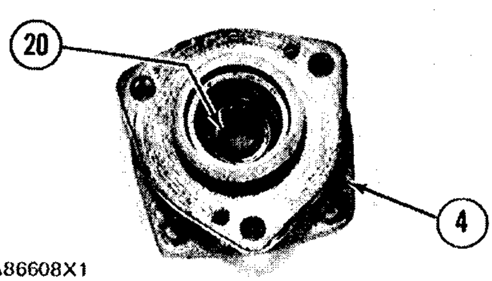
15. Remove ceramic ring (18) and seal.



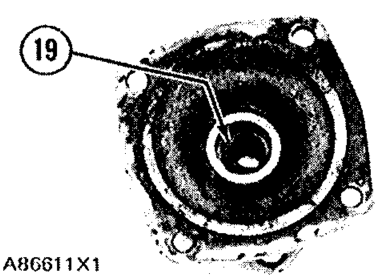
A86612X1

16. Remove slinger (19).

17. Remove seal (20) from the body (4).

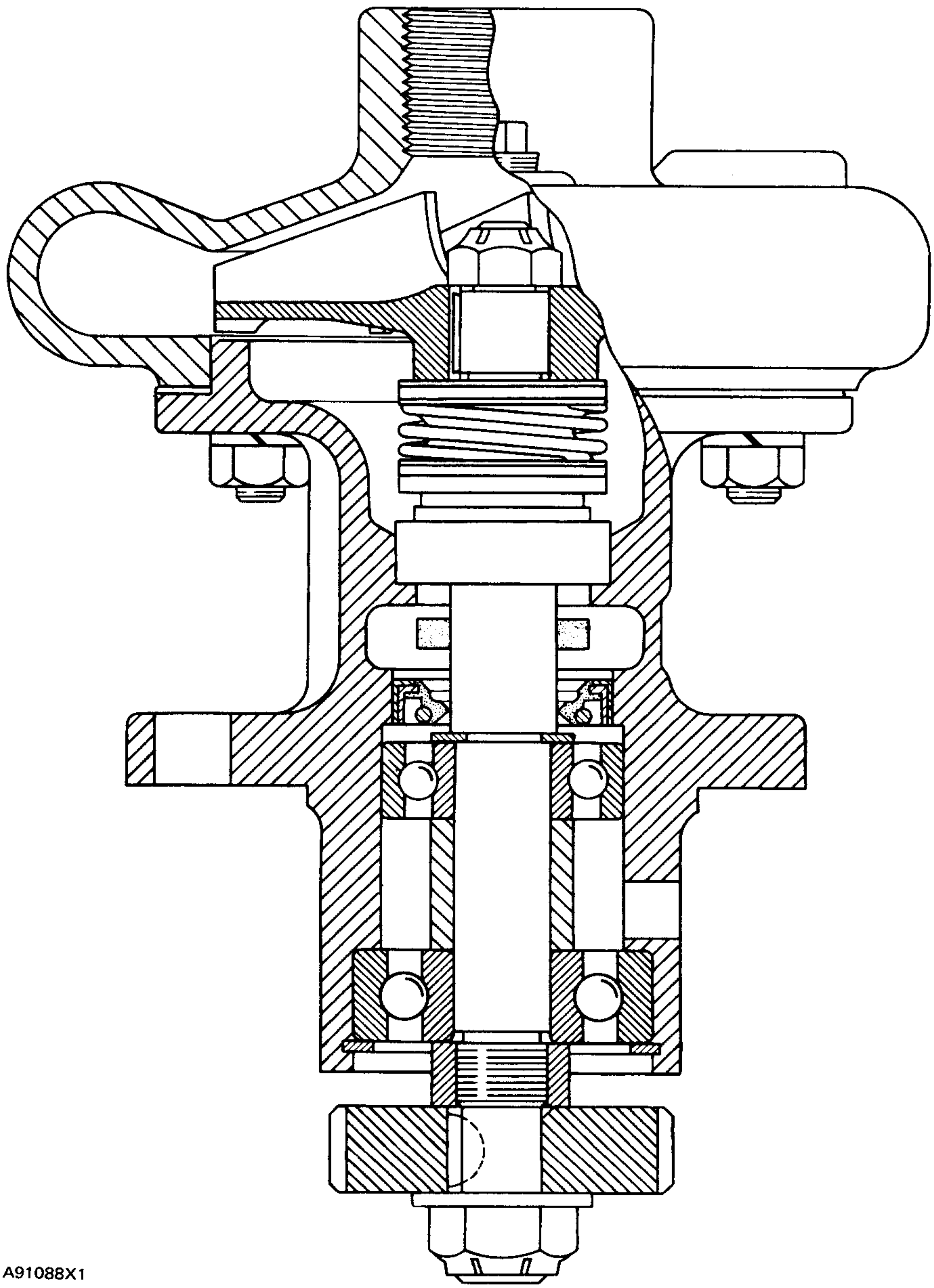


A86608X1



A86611X1

AUXILIARY PUMP (FRESH WATER-3306)

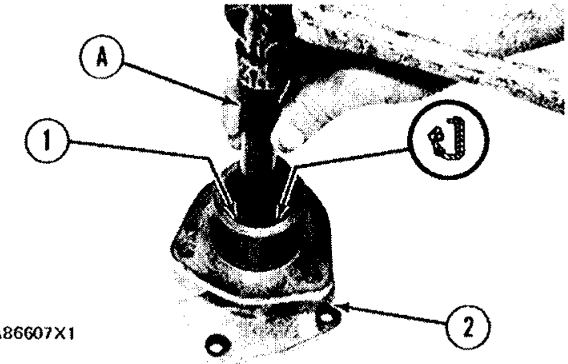


A91088X1

AUXILIARY PUMP (FRESH WATER-3306)

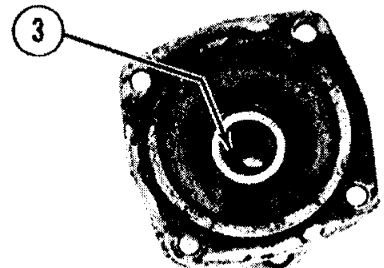
ASSEMBLE AUXILIARY PUMP (FRESH WATER-3306) 1371-16

	Tools Needed	A	B	C
1P510	Driver Group	1		
1P1855	Pliers		1	
1P1857	Pliers			1



A86607X1

1. Install lip seal (1) in body (2) with tooling (A). Install lip seal even with bottom of bearing bore with the lip of the seal toward the bearings. Put a small layer of engine oil on the lip of the seal.

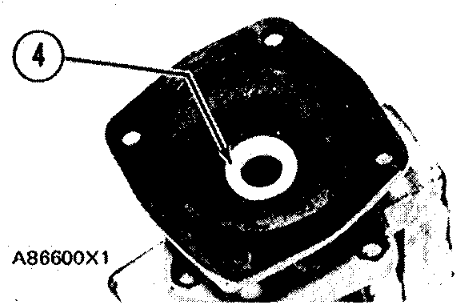


A86610X1

2. Put slinger (3) in position above the lip type seal.

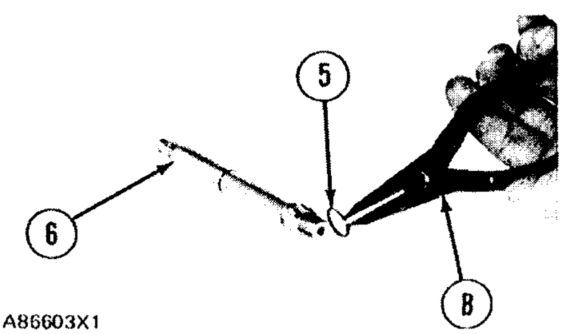
NOTICE

Clean water only is permitted for use as a lubricant for assembly. Do not damage or put hands on the wear surface of the carbon ring or the ceramic ring. Install the ceramic ring with the smoothest face of the ring toward the carbon seal assembly.



A86600X1

3. Put the ceramic ring (4) in position in the rubber seal. Use a cover for protection to install the ceramic ring. Install the ceramic ring evenly with hand pressure.

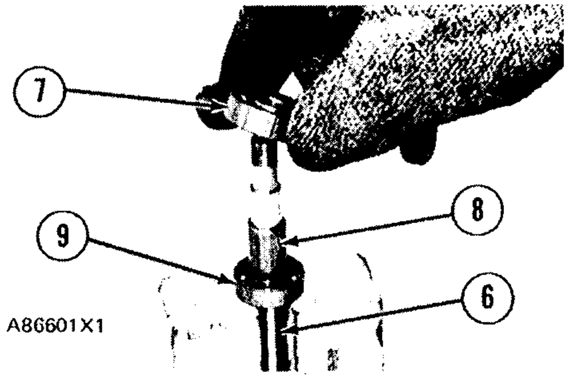


A86603X1

4. Install snap ring (5) on shaft (6) with tool (B).

AUXILIARY PUMP (FRESH WATER-3306)

5. Heat bearings (7) and (9) to a maximum temperature of 275°F (135°C).

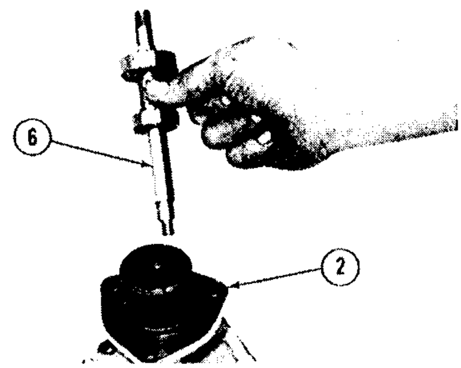


A86601X1

6. Install bearing (9) on shaft (6) against the snap ring.

7. Install spacer (8) and bearing (7). Make sure bearing (7) is in full contact with the spacer.

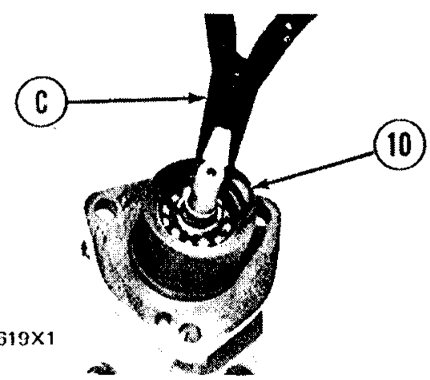
NOTE: Make sure when shaft (6) is installed in body (2), that the slinger is in the correct position on the shaft.



A86599X1

8. Install shaft (6) and bearings in body (2) through the slinger.

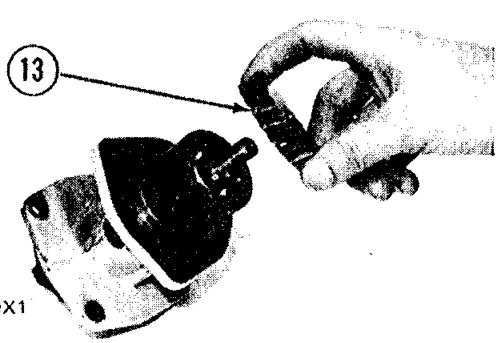
9. Install snap ring (10) that holds the shaft assembly in place with tool (C).



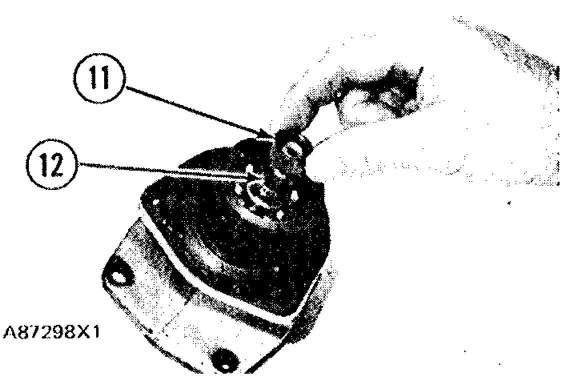
A86619X1

10. Install key (12) in the shaft.
11. Put spacer (11) in position over the shaft.

12. Install gear (13), washer and locknut. Tighten the locknut to a torque of 45 ± 5 lb.ft. (60 ± 7 N·m).



A87300X1

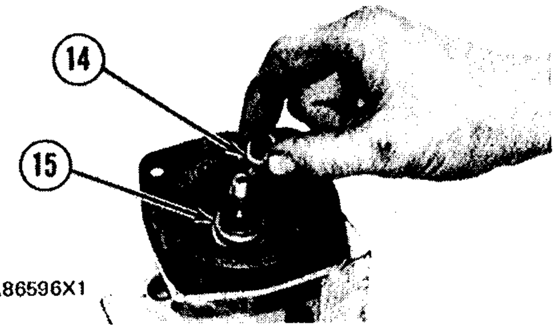


A87298X1

AUXILIARY PUMP (FRESH WATER-3306)

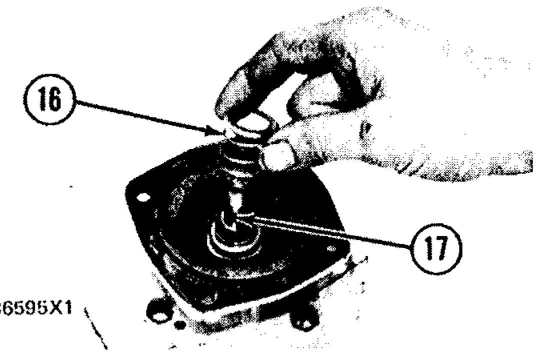
NOTICE

Use clean water only as a lubricant for assembly. Do not damage or put hands on the wear surface of the carbon ring or the ceramic ring.



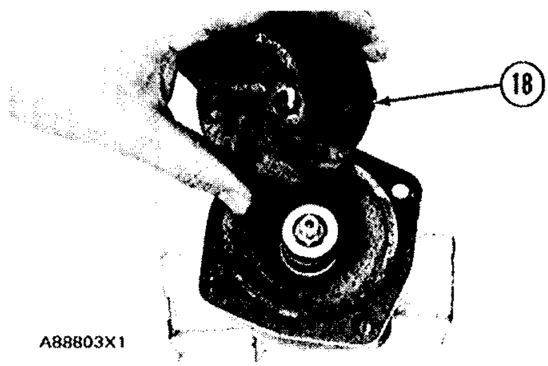
A86596X1

13. Install carbon ring seal assembly (15) over the shaft. Push carbon ring seal assembly on the shaft until seal faces make light contact.



A86595X1

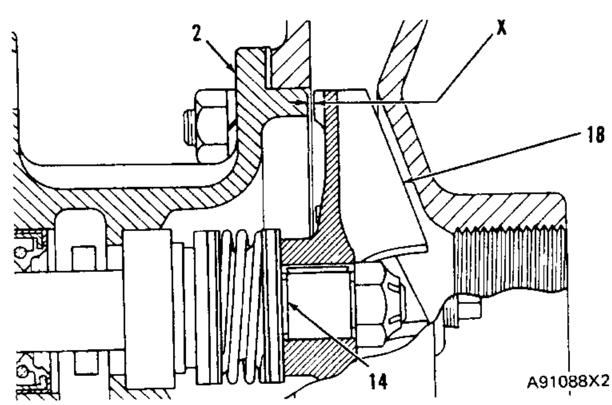
14. Put original thickness of shims (14) on the shaft.
15. Install key (17) in the shaft.



A88803X1

16. Put spring (16) in position on the carbon ring seal assembly.

17. Install impeller (18) and locknut. Tighten the locknut to a torque of 30 ± 5 lb.ft. (40 ± 7 N·m).

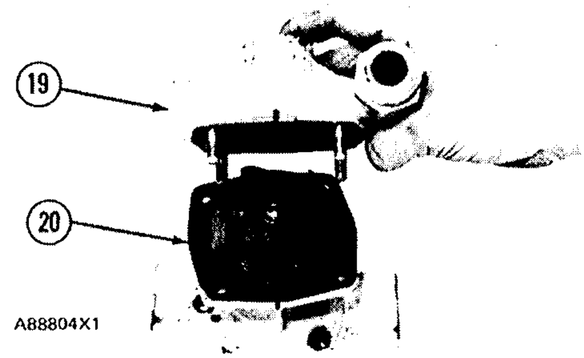


A91088X2

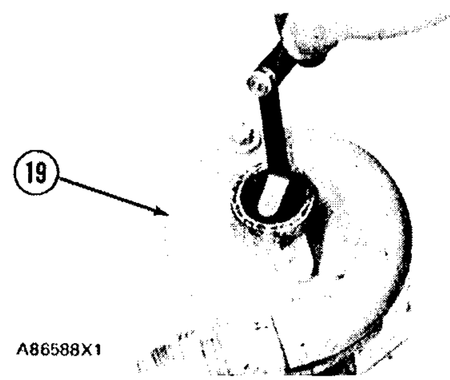
18. Check clearance (X) between the body (2) and the impeller (18). The clearance must be .005 to .015 in. (0.13 to 0.38 mm). If necessary add or remove shims (14) behind the impeller.

AUXILIARY PUMP (FRESH WATER-3306)

19. Put gaskets (20) in position on the body. Make an alignment of identification marks put on at disassembly and install housing (19).

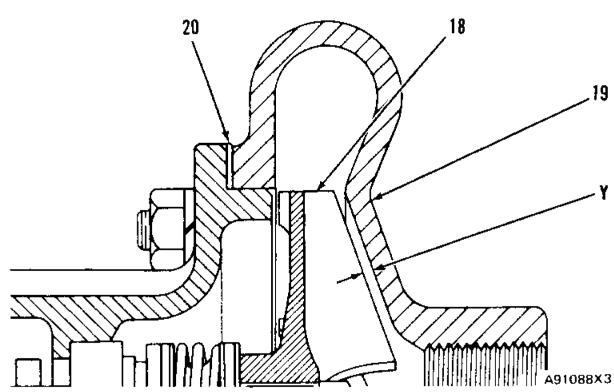


A88804X1

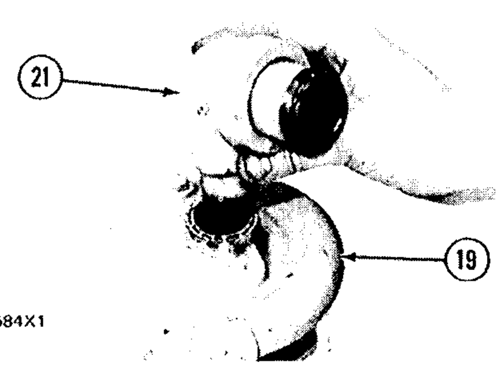


A86588X1

20. Measure the clearance (Y) between the impeller (18) and the inside of housing (19). The clearance between the impeller and housing must be .015 to .030 in. (0.38 to 0.76 mm). If necessary, add or remove gaskets (20) between the body and housing.



A91088X3



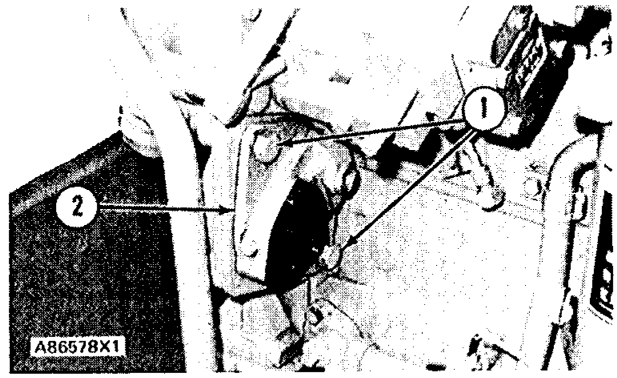
A86584X1

21. Put 5P3413 Pipe Sealant on the threads of the pipe nipples on elbow (21). Install elbow (21) and pipe nipples in housing (19).
end by:
a) install auxiliary pump (fresh water-3306)

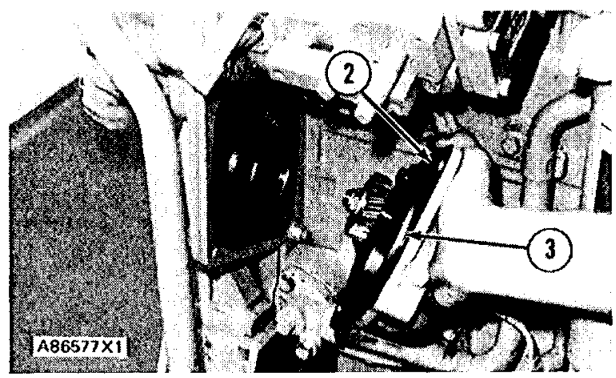
ACCESSORY DRIVE (3306), SERVICE METER

REMOVE AND INSTALL ACCESSORY DRIVE (3306) 1207-10

start by:
a) remove auxiliary pump (fresh water-3306)



1. Remove bolts (1) and remove accessory drive (2) from the front housing plate.

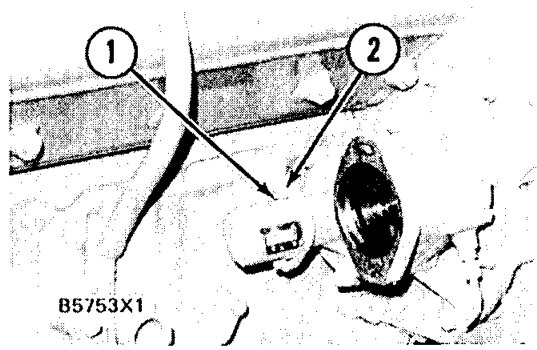


2. Put engine oil on O-ring seal (3) and the bore of the front housing plate.

3. Install accessory drive (2) on the front housing plate.
end by:
a) install auxiliary pump (fresh water-3306)

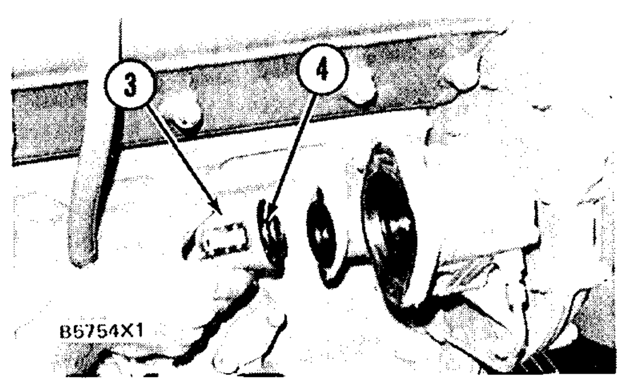
REMOVE AND INSTALL SERVICE METER 7478-10

NOTE: Magneto is removed for photo purposes only.



1. Remove bolts (1), clamps (2) and service meter from the drive group.

2. Inspect seal (4) for damage and make a replacement if needed.



3. Put clean engine oil on seal (4) and install on service meter.

4. Put service meter (3) into position on the drive group. Make sure service meter is in correct position with the groove (slot) in the drive shaft.

5. Install clamps (2) and bolts (1). Tighten bolts (1) to a torque of 96 ± 24 lb.in. (10.9 ± 2.8 N·m).

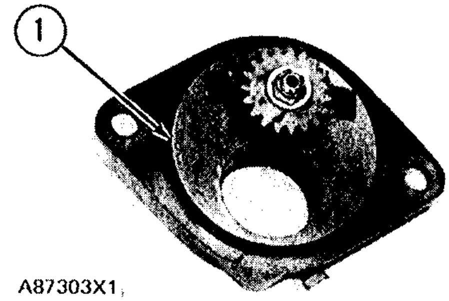
ACCESSORY DRIVE (3306)

DISASSEMBLE ACCESSORY DRIVE 1207-15 (3306)

	Tools Needed	A
1P510	Driver Group	1
8H663	Bearing Puller Attachment	1

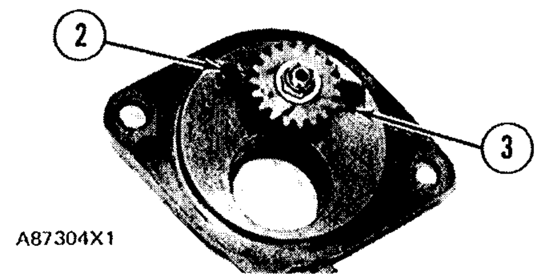
start by:

a) remove accessory drive (3306)



A87303X1

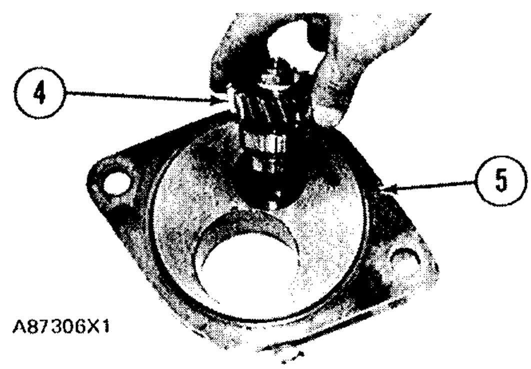
1. Remove O-ring seal (1).



A87304X1

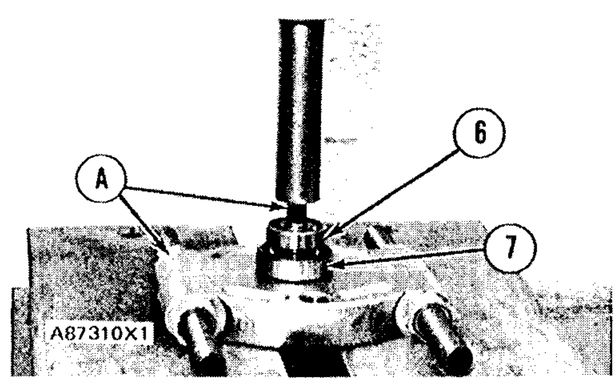
2. Remove bolts (2) and washers that hold retainer plate (3) in place.

3. Remove retainer plate (3).



A87306X1

4. Remove shaft assembly (4) and bearings from housing (5).



A87310X1

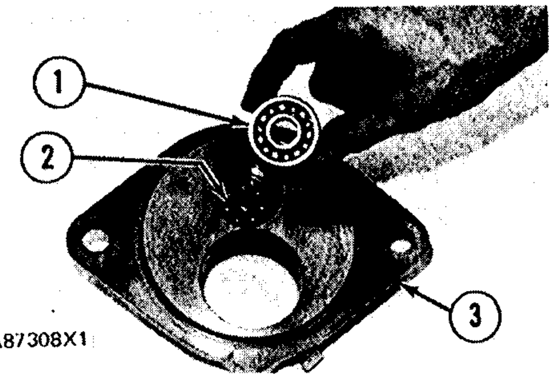
5. Install tooling (A) on the shaft assembly (4).

6. Use a press to remove bearings (6) and (7) from the shaft assembly.

ACCESSORY DRIVE (3306)

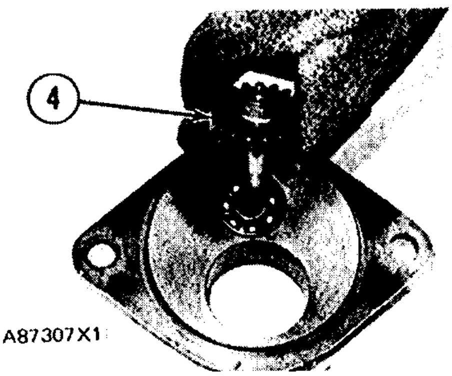
ASSEMBLE ACCESSORY DRIVE (3306) 1207-16

1. Install bearings (2) and (1) fully in the bore of the housing (3).



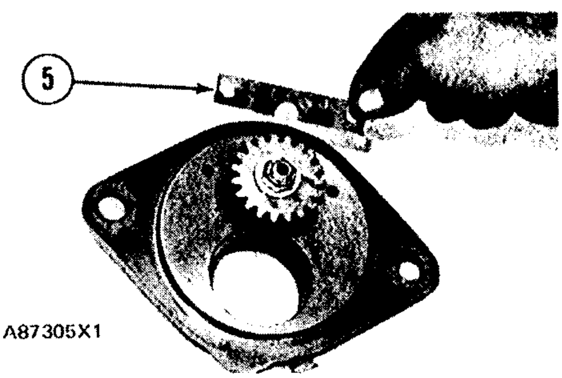
A87308X1

2. Lower the temperature of the shaft assembly (4). Install the shaft assembly (4). Make sure bearing (2) is installed fully against the shoulder on the shaft assembly.



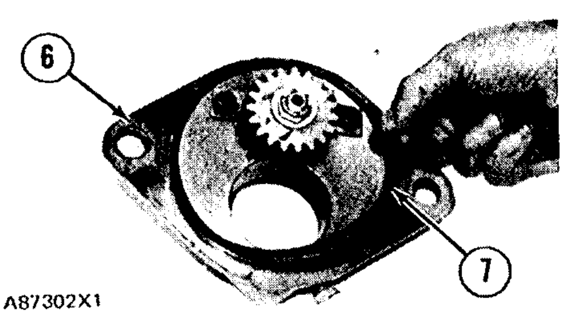
A87307X1

3. Put retainer plate (5) into position in the shaft groove.



A87305X1

4. Put the washers and the bolts that hold the retainer plate in position, but do not tighten. Push thrust plate (5) toward the shaft groove as far as possible. Tighten the bolts that hold the thrust plate (5) in place.



A87302X1

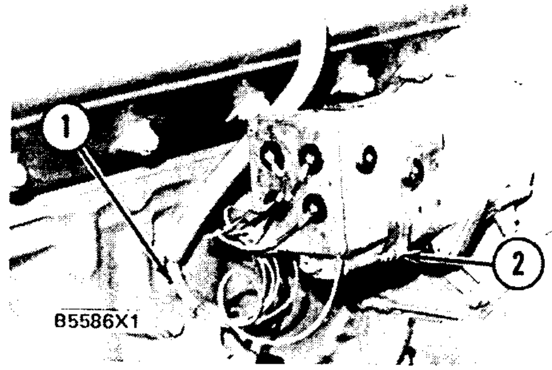
5. Put lubrication on O-ring seal (7) with engine oil and install on housing (6).
   end by:
   a) install accessory drive (3306)

MAGNETO

REMOVE MAGNETO 1413-11

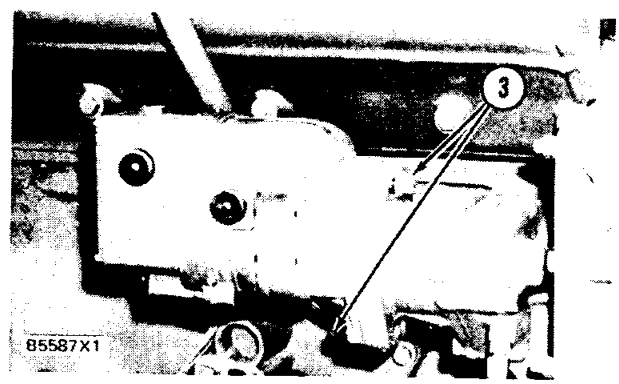
NOTE: Photos shown are on 3304.

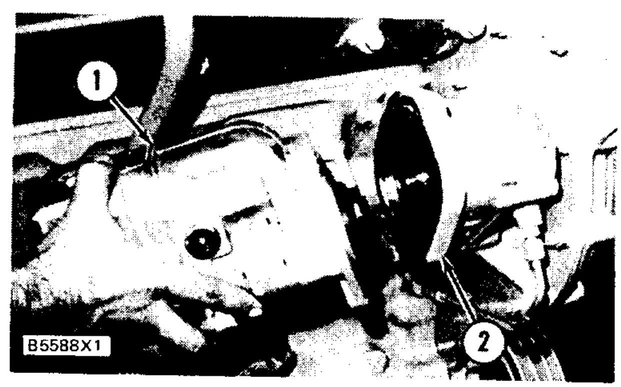
1. Put identification on each wire and screw on magneto (2).
2. Disconnect wires (1) from the magneto.
3. Remove mounting bolts (3) and washers.
4. Remove the magneto and gasket.

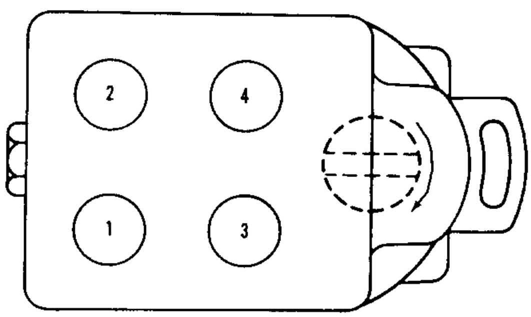


INSTALL MAGNETO 1413-12

1. For correct timing of magneto to engine, see TIMING MAGNETO TO ENGINE in TESTING AND ADJUSTING.
2. Make an alignment of the ear (tang) on magneto (1) with the groove (slot) on magneto drive (2). Put the gasket and the magneto in position on the magneto drive.
3. Install mounting bolts and washers.
4. Connect wires (3) to the magneto. Each wire must be connected to the same terminal from which it was removed.

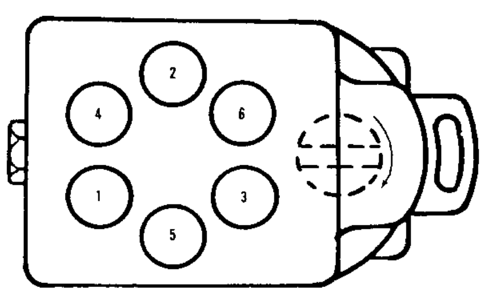






A91070X1

3304



90410X4

3306

MAGNETO

DISASSEMBLE MAGNETO 1413-15

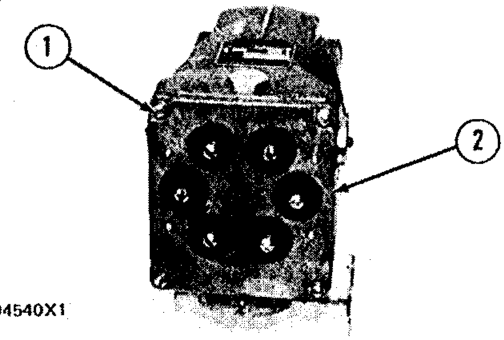
	Tools Needed	A	B
1P1855	Pliers	1	
1P1857	Pliers		1

start by:
a) remove magneto

NOTICE

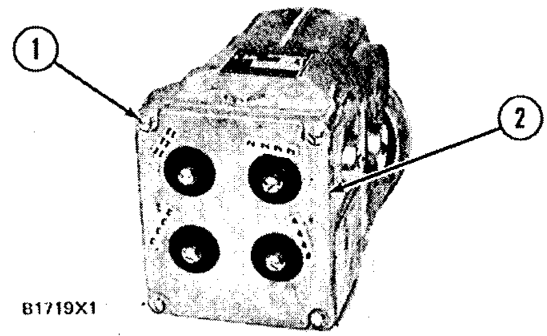
Care must be taken when cover (2) is removed, because grounding wire is fastened to the cover.

1. Remove screws (1) and lockwashers that hold cover (2) in place. Turn cover (2) over to show the grounding wire connection.



A94540X1

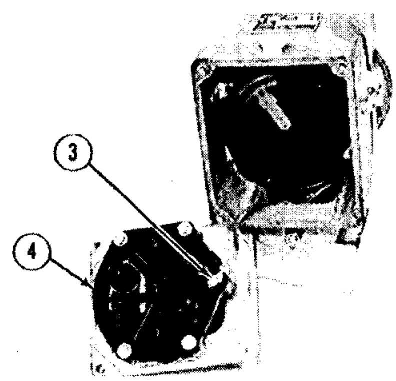
3306



B1719X1

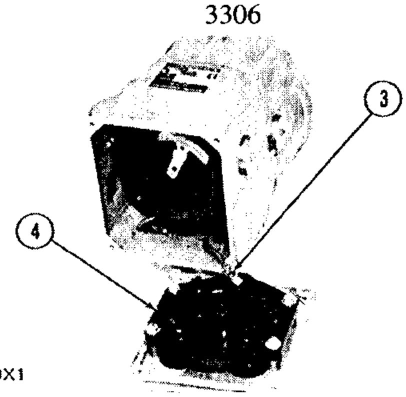
3304

2. Remove screw (3) and disconnect the grounding wire from block assembly (4).



A94571X1

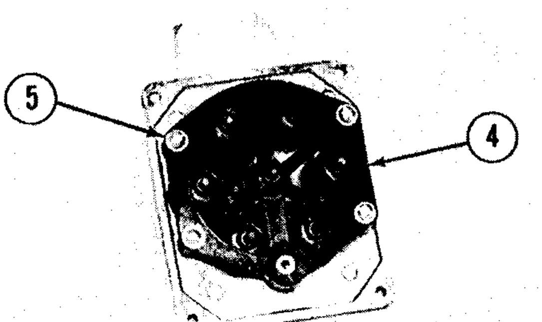
3306



B1710X1

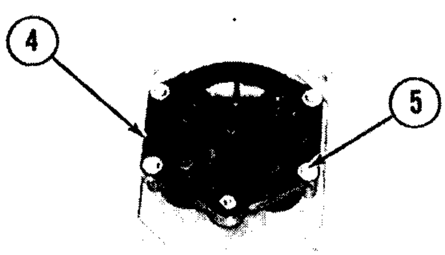
3304

3. Remove screws (5), washers and lockwashers. Remove block assembly (4) from the cover.



A94594X1

3306



B4310X1

3304

MAGNETO

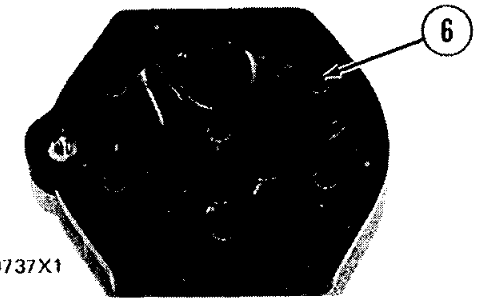
4. Remove brushes (6) and springs from the block assembly.

5. Remove four screws (8) and lockwashers. Pull end cap (7) away from the housing far enough to disconnect the grounding wire from the contact points.

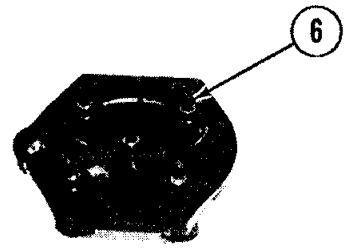
6. Disconnect grounding wire (9) from the contact points.

7. Disconnect grounding wires (9) from end cap (7).

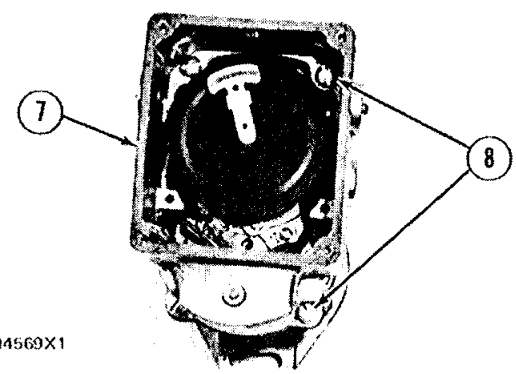
8. Remove vent cover (10) and screens from each side of the end cap.

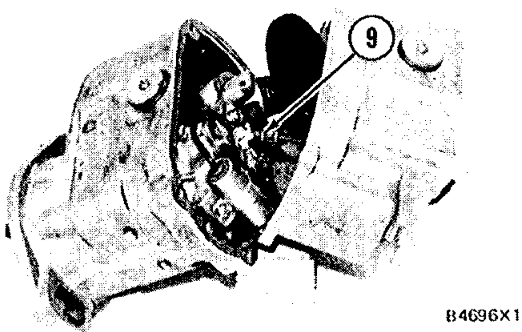


3306

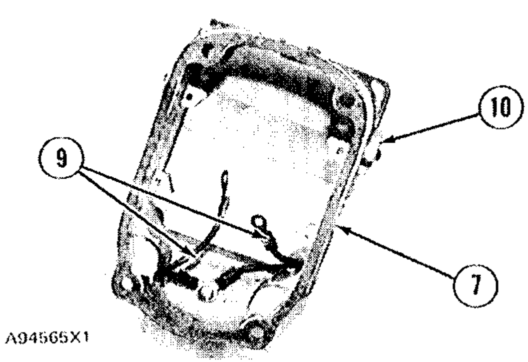


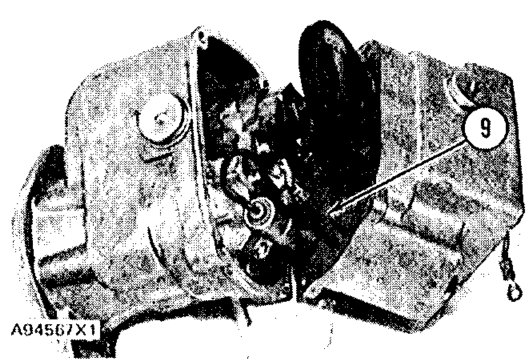
3304





3304



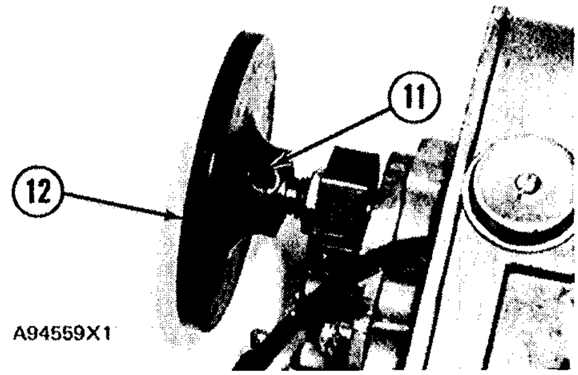


3306

MAGNETO

9. Remove screw (11), lockwasher and distributor disc (12).

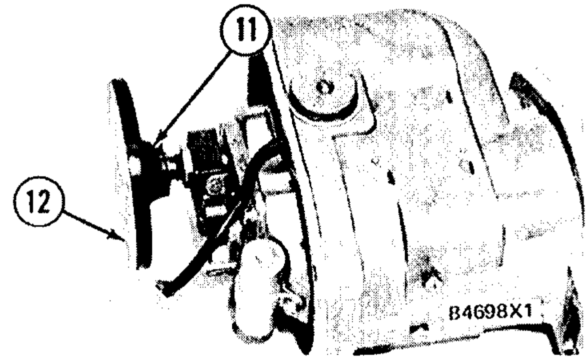
10. Remove contact points (13) and condenser (14). NOTE: Put a mark on cam (15) for the correct keyslot to be used at assembly.



3306

11. Remove nut (16), cam (15) and key from the shaft.

12. Remove two screws, washers, lockwashers and plate (17) from the bearing support.



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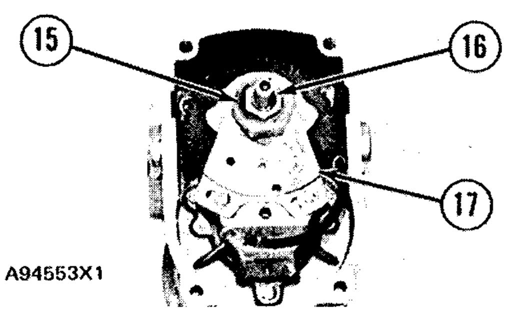

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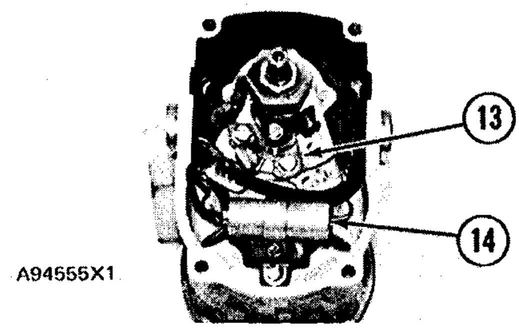
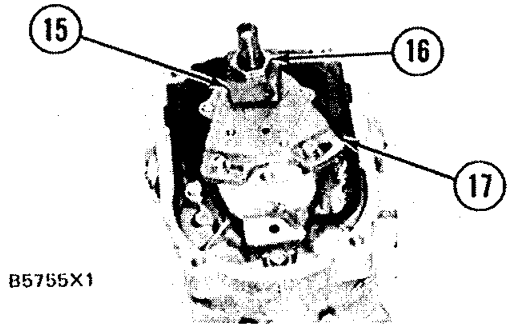


3306



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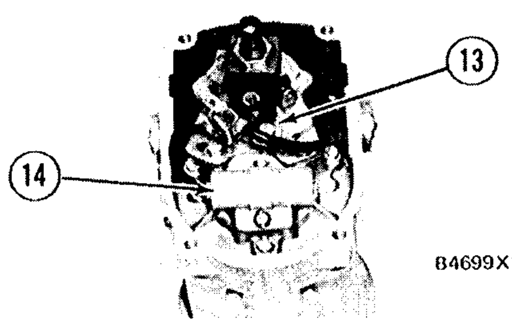
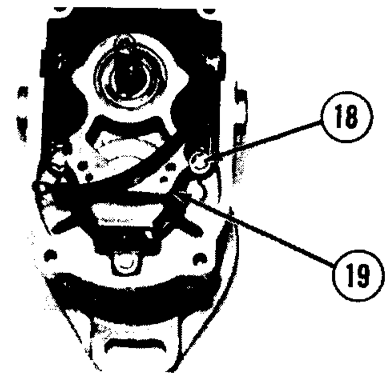


3304

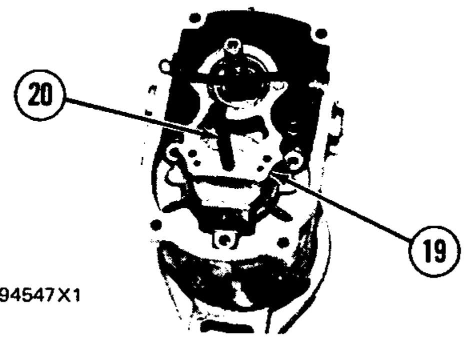
MAGNETO

13. Remove three screws (18) and lockwashers that hold bearing support (19) in position.



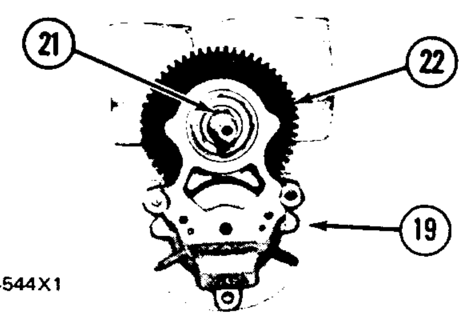
A94548X1

14. Install a ¼"-20 NC forcing screw (20) 1 ½" long as shown and remove bearing support (19) from the housing.



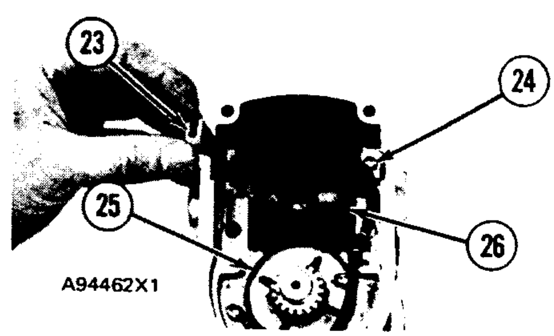
A94547X1

15. Use tool (A) to remove snap ring (21).



A94544X1

16. Use a press to remove distributor gear and shaft assembly (22) from the bearing support.



A94462X1

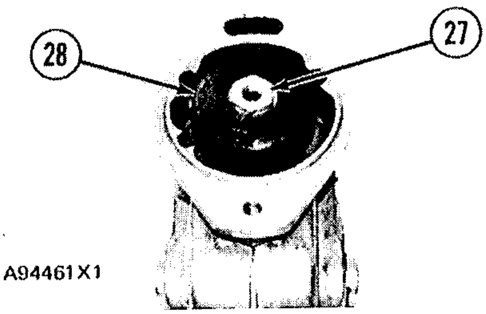
17. Loosen screws (24) and wedges (23) and turn rotor shaft assembly (25) until flux lock (magnetic field) is broken. Remove screws, wedges and coil (26) from the housing.

MAGNETO

18. Turn the housing over and remove nut (27) and washer from the impulse coupling.

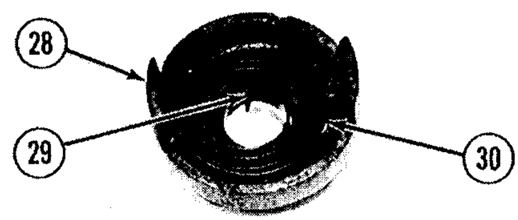
⚠ WARNING

Care must be taken when coupling shell (28) and spring are removed. The coupling shell is under spring force.



A94461X1

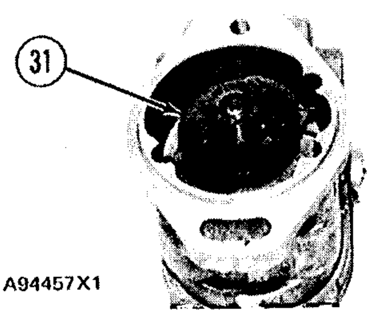
19. Use pliers on one of the drive lugs of coupling shell (28). Turn and pull the coupling shell at the same time until the spring releases. To make a separation of the coupling shell from the hub, the spring end must be removed from the (slot) groove in the hub.



A94459X1

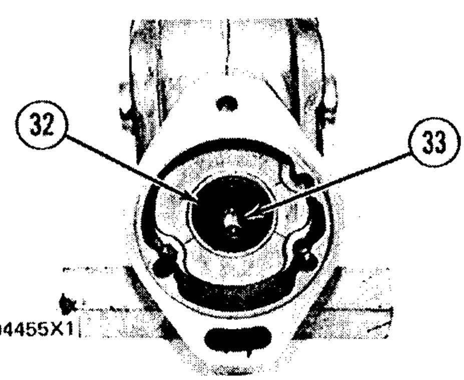
NOTE: The coil of spring (30) must be in correct direction for magneto rotation. For counterclockwise rotation the coil of the spring must be in a clockwise direction from end (29).

20. Remove spring (30) from coupling shell (28).



A94457X1

21. Remove hub (31) from the shaft.

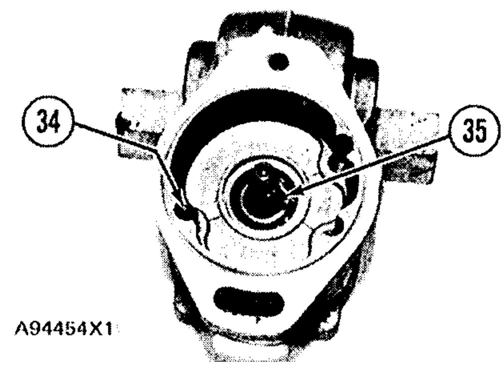


A94455X1

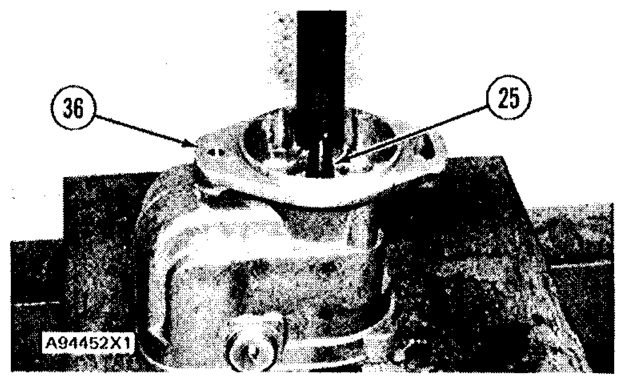
22. Remove key (33) and seal (32). Seal must be destroyed to remove.

MAGNETO

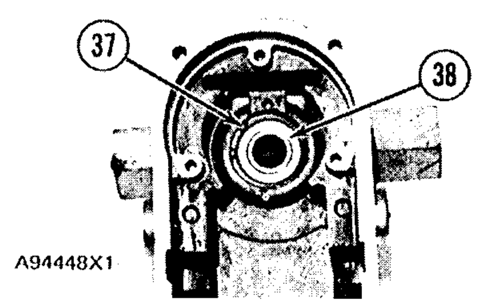
23. Use tool (B) to remove snap ring (35). Remove coupling pawl stop pin (34).



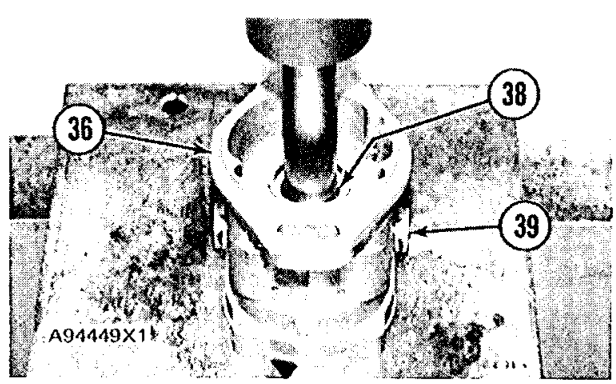
24. Use a press to remove rotor shaft assembly (25) from housing (36).



25. Remove snap ring (37) that holds bearing (38) in position with tool (B).

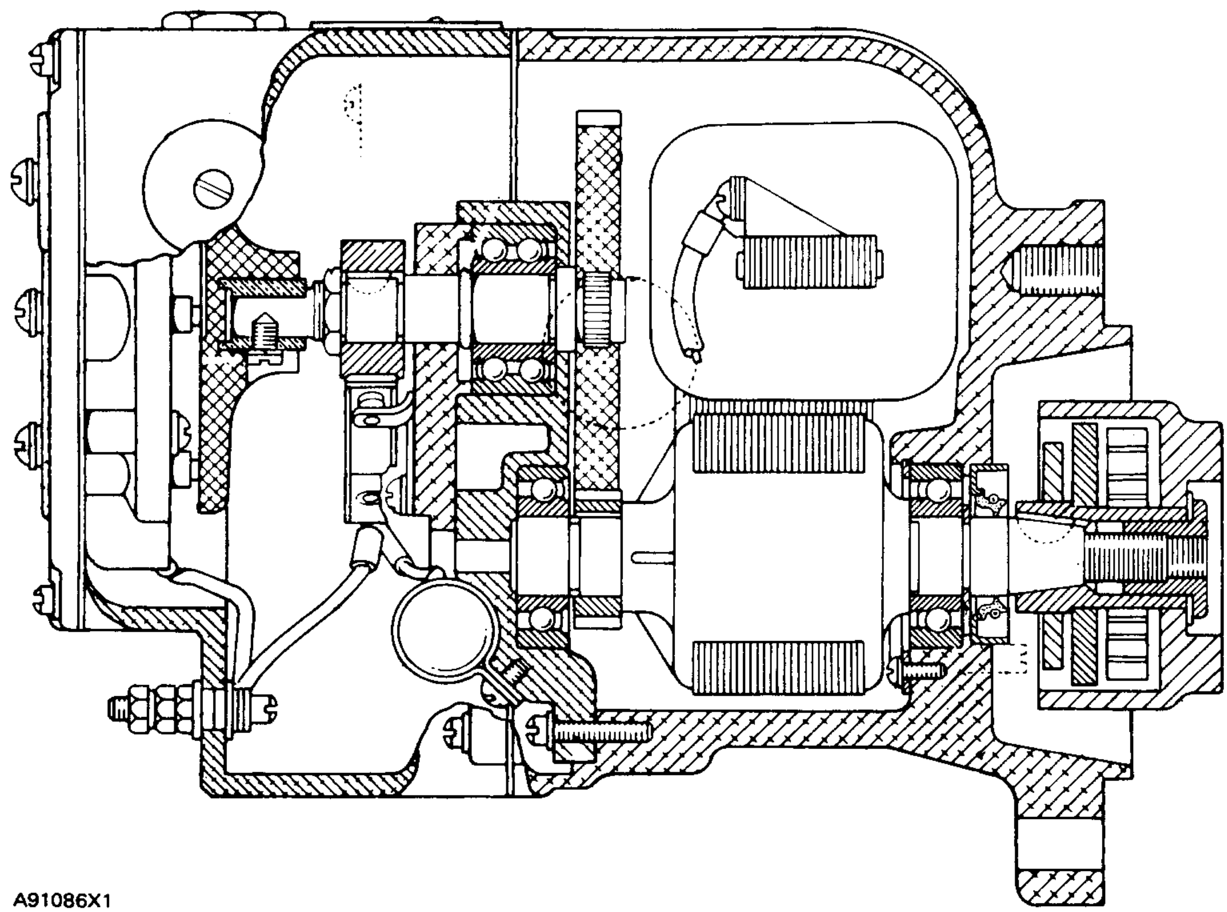


26. Use a press to remove bearing (38) from housing (36).



27. Remove vent cover (39) and screens from each side of housing (36).

MAGNETO

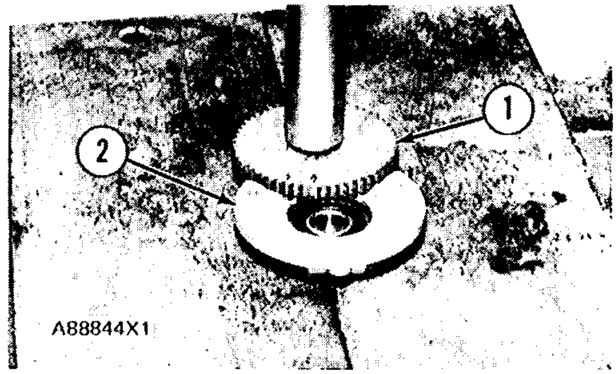


A91086X1

MAGNETO

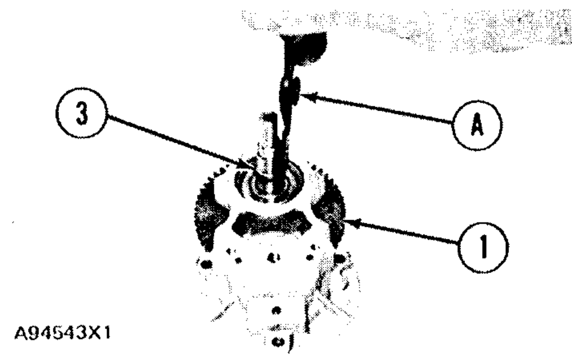
ASSEMBLE MAGNETO 1413-16

	Tools Needed	A	B	C
1P1855	Pliers	1		
1P510	Driver Group		1	
1P1857	Pliers			1



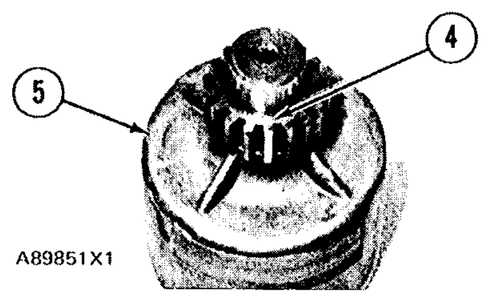
A88844X1

1. Thoroughly clean and inspect all parts for wear and damage.
2. If a replacement of the bearings in bearing support (2) is needed, they must be made as a unit.



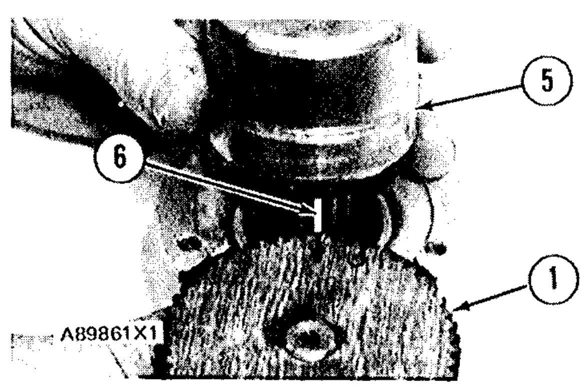
A94543X1

3. Use a press to install distributor gear and shaft assembly (1) in bearing support (2).
4. Use tool (A) to install snap ring (3) that holds distributor gear and shaft assembly (1) in position.



A89851X1

5. Put an identification mark on the tooth by mark (4) on rotor shaft assembly (5) pinion.

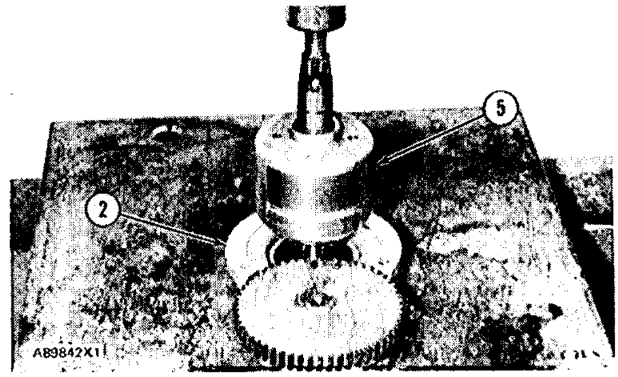


A89861X1

6. Make an alignment of mark (6) on rotor shaft assembly (5) pinion with the letter "A" for counterclockwise (anti-clockwise) rotation on the distributor gear and shaft assembly (1).

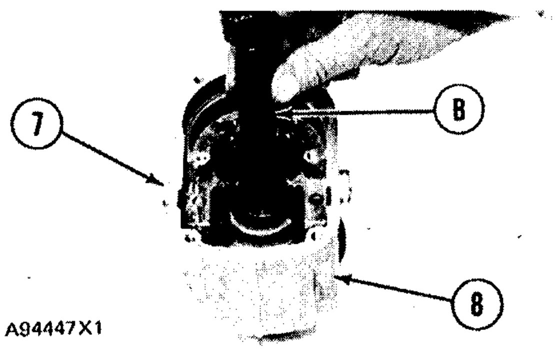
MAGNETO

7. Use a press to install rotor shaft assembly (5) in bearing support (2).



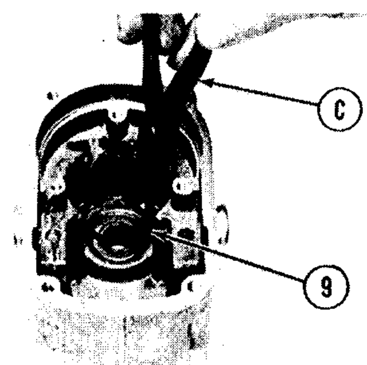
NOTE: Vent cap (7) opening is to be installed in a "down" position with the magneto installed on the engine.

8. Install two vent screens and vent cap (7) on each side of housing (8).



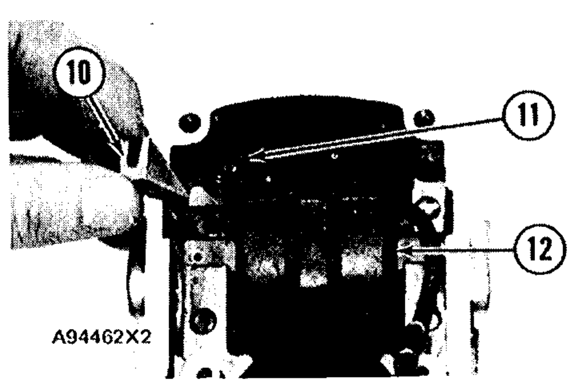
A94447X1

9. Use tool (B) to install the bearing in housing (8).



A88842X1

10. Install snap ring (9) that holds the bearing in position with tool (C).

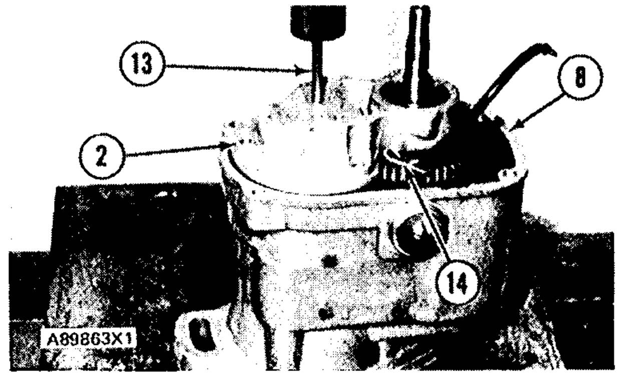


A94462X2

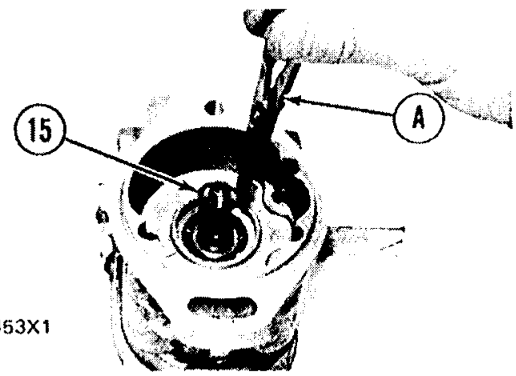
11. Put coil (12) in position in the housing with the shorter wire (11) to the left as shown. Install wedges (10). Fasten short wire (11) under left coil wedge (10) screw.

MAGNETO

12. Put bearing support (2) and rotor shaft assembly in position in housing (8). Use a press and a 3/16" diameter rod (13) 1 ¾" long to install the rotor shaft assembly in the bearing in housing (8).

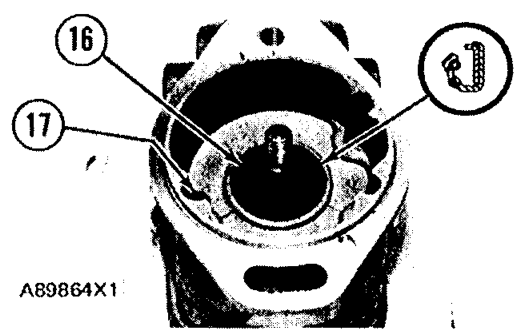


13. Install the three screws that hold bearing support (2) and clip (14) in position.



A94453X1

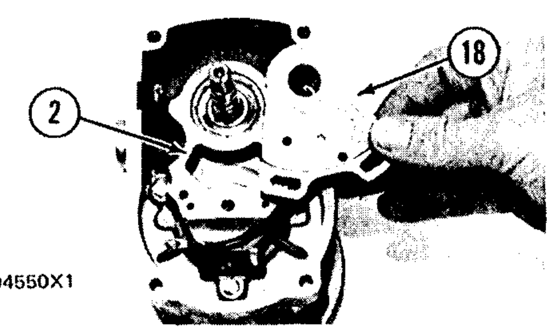
14. Use tool (A) to install snap ring (15) that holds the rotor shaft assembly in position.



A89864X1

15. Install seal (16) with the lip of the seal away from the housing.

16. Install coupling pawl stop pin (17). Use the left hole as shown for counterclockwise rotation.



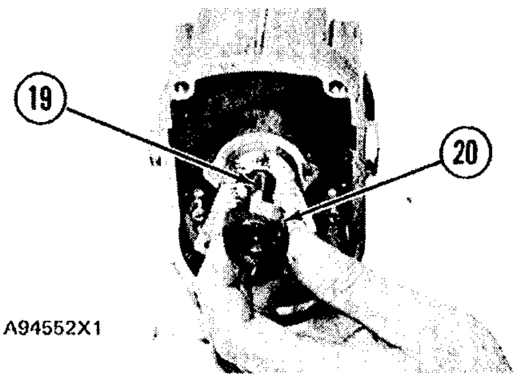
A94550X1

17. Install plate (18) on bearing support (2).

MAGNETO

18. Install key (19) on the distributor shaft.

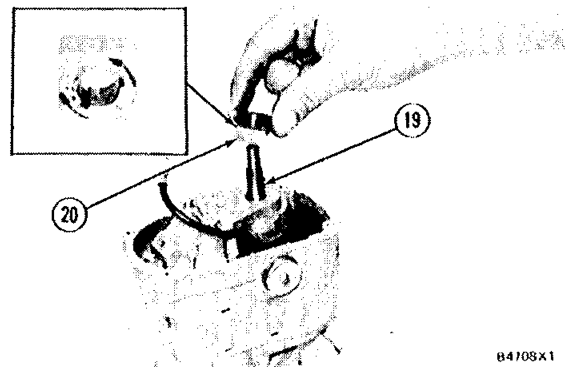
NOTE: Cam (20) has two keyslots, one for each direction of magneto rotation. Each keyslot has an arrow for each direction of rotation.



A94552X1

3306

19. Make an alignment of the key in the distributor shaft and the keyslot by the counterclockwise direction arrow on cam (20). Put cam (20) in position on the shaft.
20. Install nut (22) that holds the cam in position.



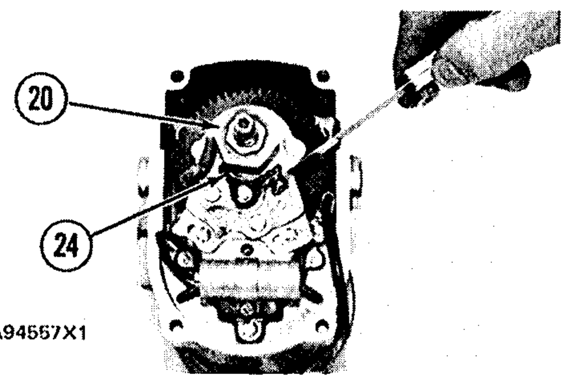
B4708X1

3304

21. Install condenser (23) and contact points (21).

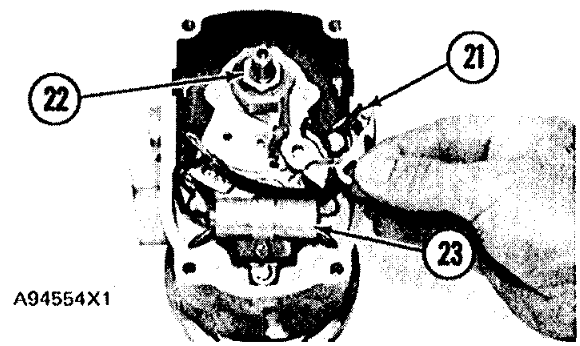
NOTE: Do not use lubrication again. Make a replacement if necessary.

22. Turn cam (20) until the high point of the cam is against arm (24) of the contact points. Adjust the contact point gap to .017 in. (0.43 mm).



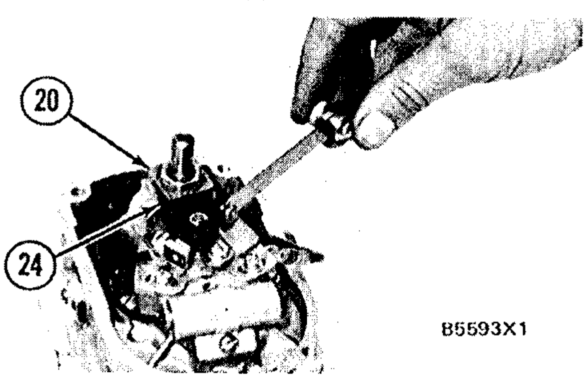
A94557X1

3306



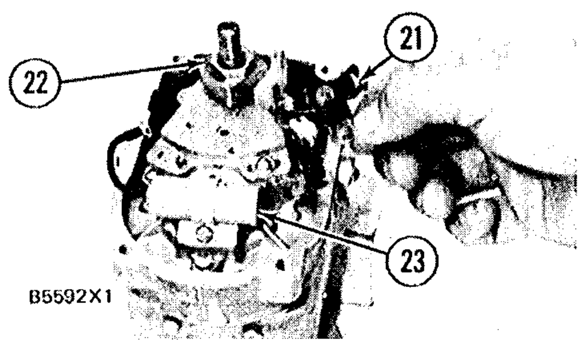
A94554X1

3306



B5593X1

3304

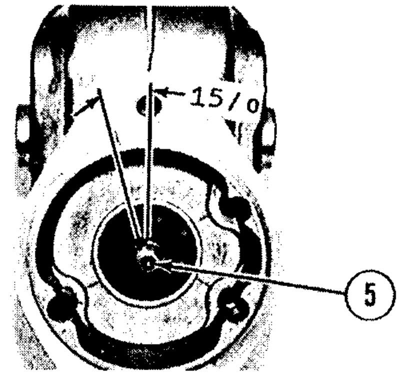


B5592X1

3304

MAGNETO

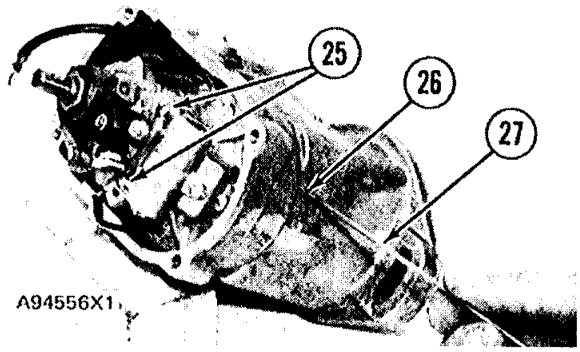
23. Adjust the magneto edge gap by rotation of the rotor shaft assembly (5) until the keyway is in an "up" position, then turn the shaft approximately 15° in the direction of magneto direction as shown.



A89865X1

24. Loosen plate screws (25).

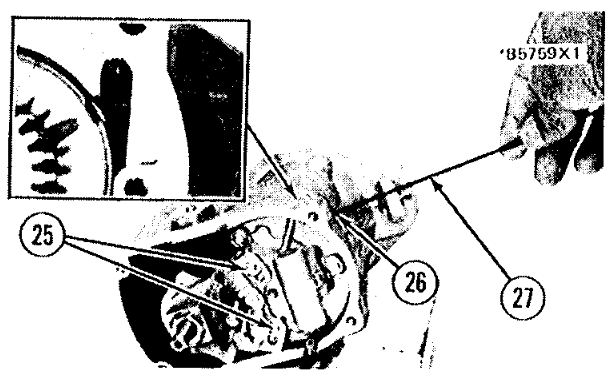
25. Install a .094 in. (2.39 mm) diameter rod (27) in timing hole (26) until it makes contact with the rotor shaft. Timing hole (26) is used for counter-clockwise rotation magnetos. Turn rotor shaft clockwise, the direction opposite normal rotation, until rod (27) locks between rotor pole shoe and housing field.



A94556X1

3306

26. With rotor shaft in this position move the plate right or left until the contact points start to open. Tighten support screws (25).

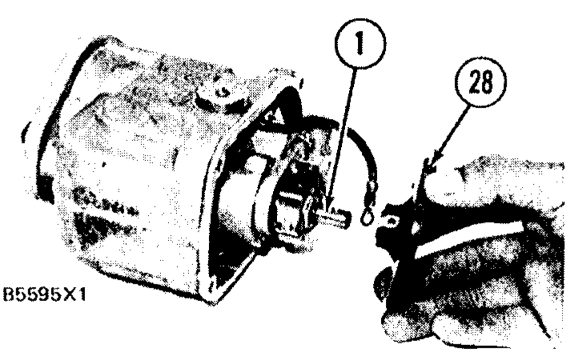


B5759X1

3304

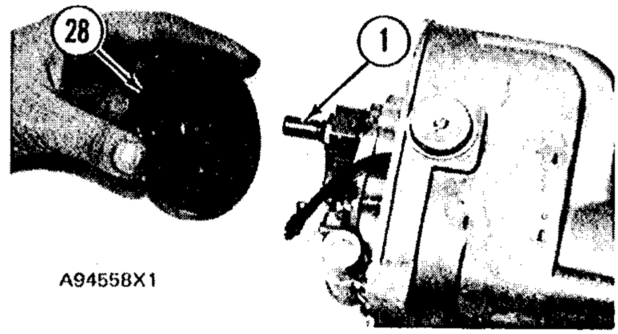
NOTE: Use a timing light or a thin piece of cellophane to find the point where contacts open.

27. Put distributor disc (28) in position on distributor shaft (1). Install lockwasher and screw that hold it in place.



B5595X1

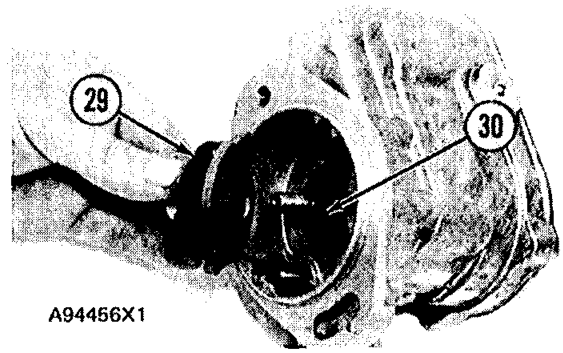
3304



A94558X1

MAGNETO

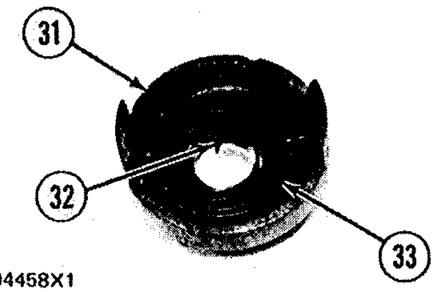
28. Install key (30) and put hub assembly (29) in position on the rotor shaft.



A94456X1

NOTE: The coil of spring (33) must be in correct direction for magneto rotation. For counterclockwise rotation, the coil of the spring must be in a clockwise direction from end (32).

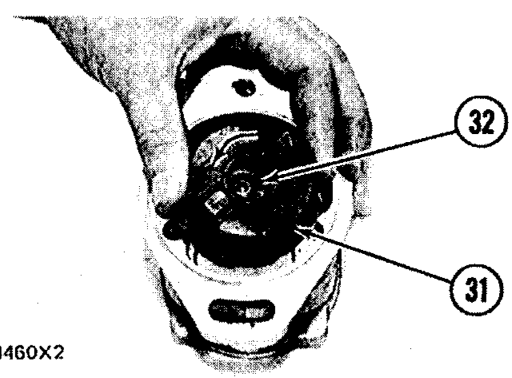
29. Put spring (33) in position in coupling shell (31).



A94458X1

30. Put spring end (32) in position in the anchor groove (slot).

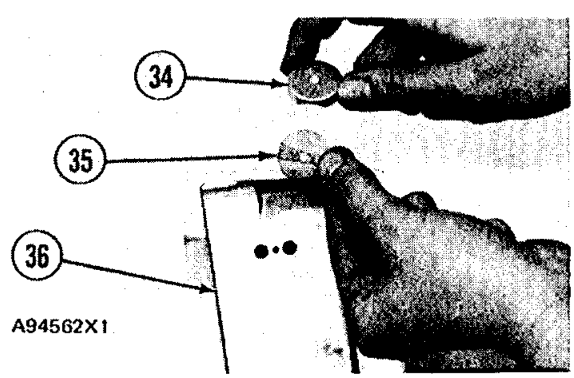
31. Turn coupling shell (31) one full turn counterclockwise as shown and push coupling shell and hub assembly together. Install washer and nut that hold the coupling shell in position.



A94460X2

NOTE: Vent cap opening is to be installed in a "down" position when the magneto is installed on the engine.

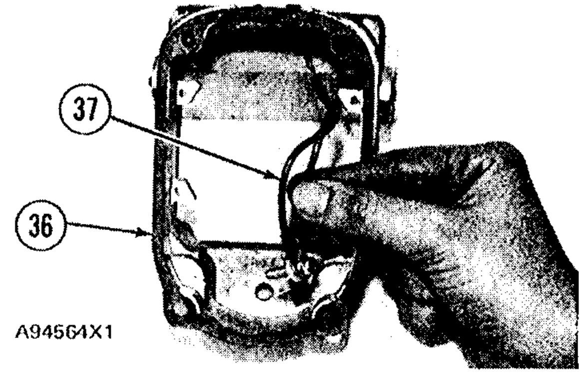
32. Install two screens (35) and vent cap (34) on each side of end cap (36).



A94562X1

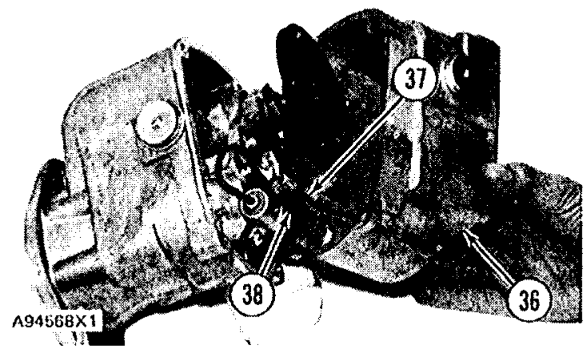
MAGNETO

33. Connect grounding wires (37) to end cap (36).



A94564X1

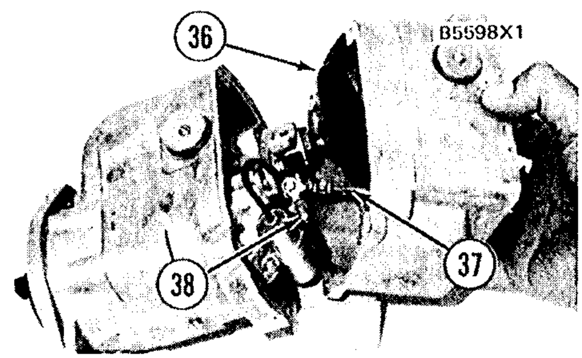
34. Put gasket and end cap (36) in position and connect grounding wire (37), coil wire (38) and the condenser wire to the contact points.



A94568X1

3306

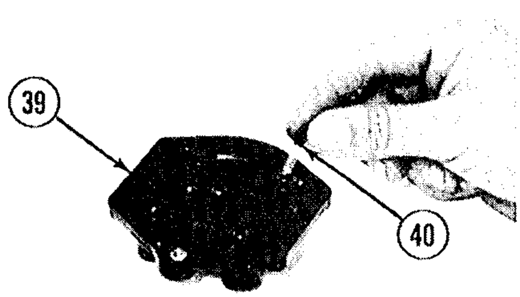
35. Fasten end cap (36) to the housing with four lockwashers and screws.



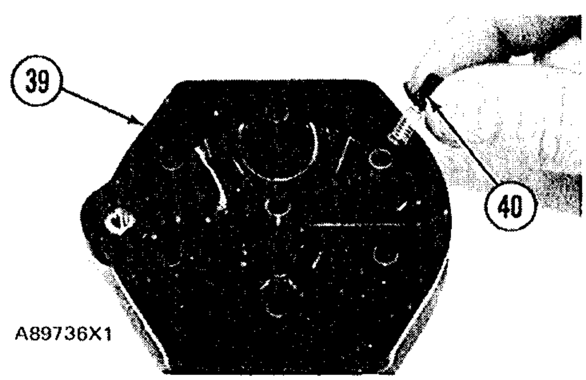
B5598X1

3304

36. Install brush and spring assemblies (40) in block assembly (39). Brushes must move freely in the block.



B5599X1



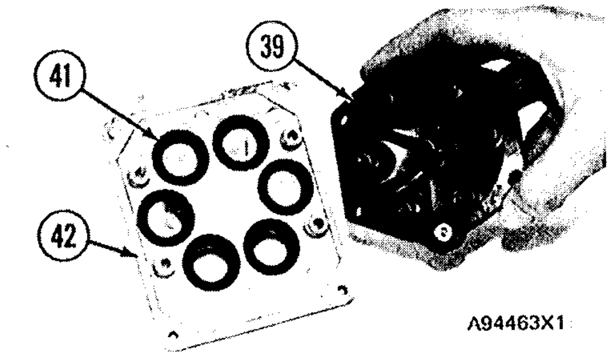
A89736X1

3306

MAGNETO

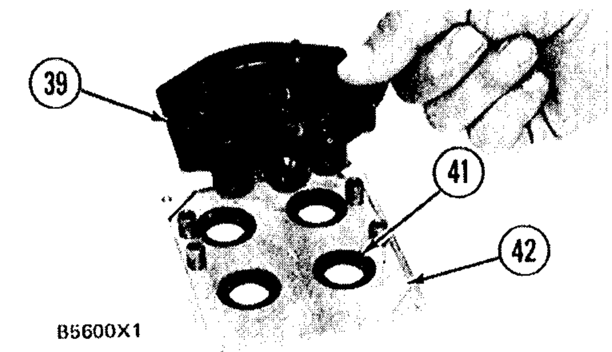
37. Put grommets (41) in position in cover (42).

38. Install block assembly (39) on cover (42) with grounding terminal in a down position as shown.



3306

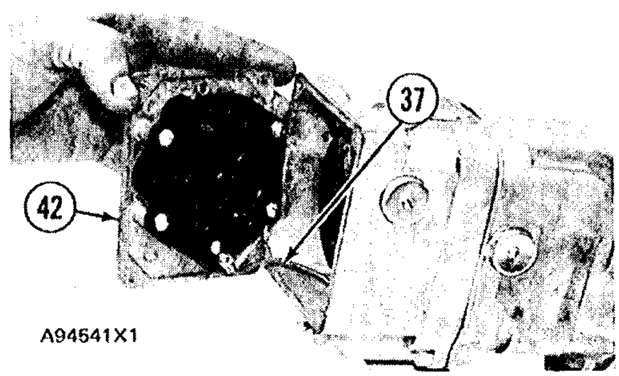
39. Put gasket and cover (42) in position and connect grounding wire (37) to the terminal on block (39). Fasten cap (42) to the end with four lock-washers and screws.



3304

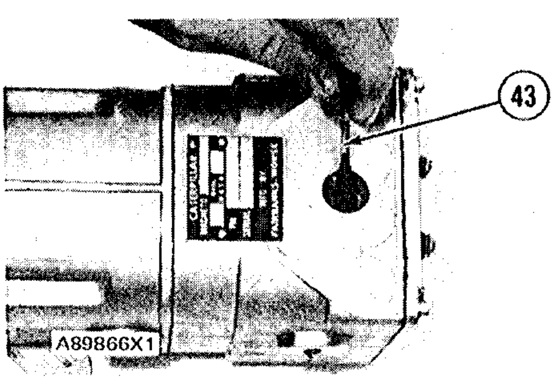
40. Remove the timing nut from the end cap.

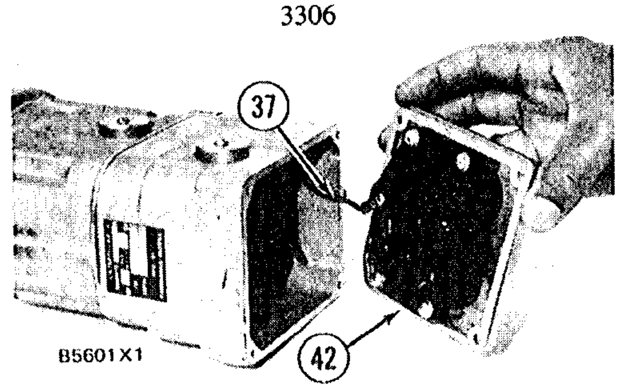
41. Check the brush spring adjustment by a measurement of the clearance between block (39) and the distributor disc with a drill rod (43). The minimum clearance is .156 to .219 in. (3.96 to 5.56 mm). To make an increase in clearance add gaskets under end cap (42). To make a decrease in clearance use number 10 washers between block (39) and end cap (42).



3306

42. The magneto must be checked on a magneto test bench if available.
end by:
a) install magneto





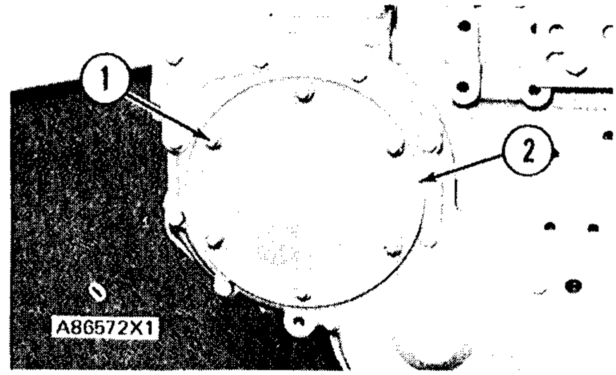
3304

MAGNETO DRIVE

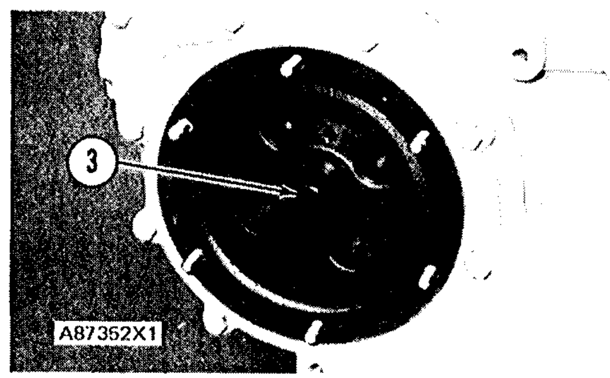
REMOVE MAGNETO DRIVE 1421-11

	Tools Needed	A
8S2264	Puller Group	1
9S9155	Spacer	1
0S1605	Bolt (3/8"-24 NF x 3 1/4 in. long)	2
4B4278	Flat Washer	2

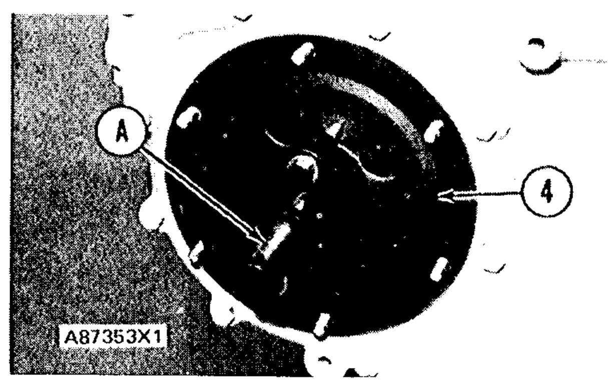
start by:
a) remove magneto
b) remove service meter



1. Remove nuts (1), washers, cover (2) and gasket from the front housing.

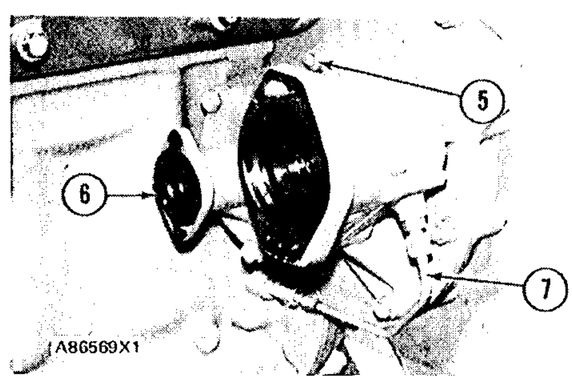


2. Remove bolt (3) and washer.



3. Put tooling (A) in position on drive gear (4). Loosen drive gear (4) from the magneto drive sleeve. Remove tooling (A).

4. Disconnect oil supply line (7) from magneto drive (6).

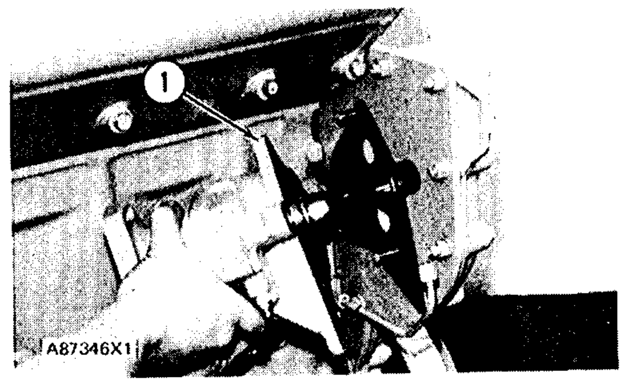


5. Remove nuts (5) and washers that hold magneto drive (6) in place. Remove magneto drive.

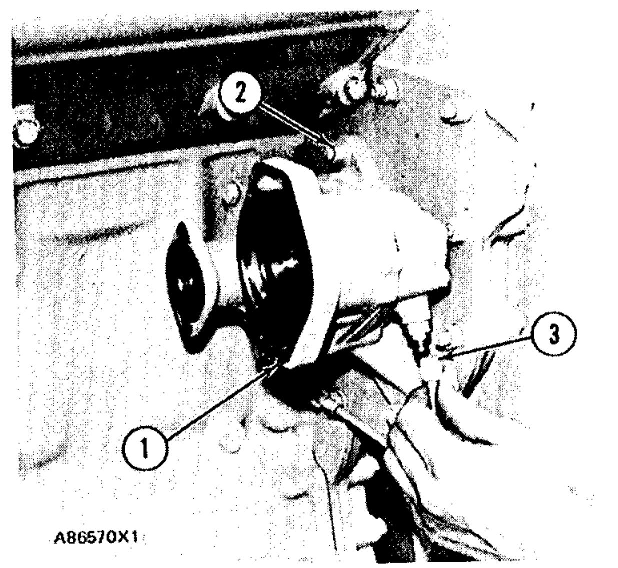
MAGNETO DRIVE

INSTALL MAGNETO DRIVE 1421-12

1. Put magneto drive (1) in position on the front housing plate.

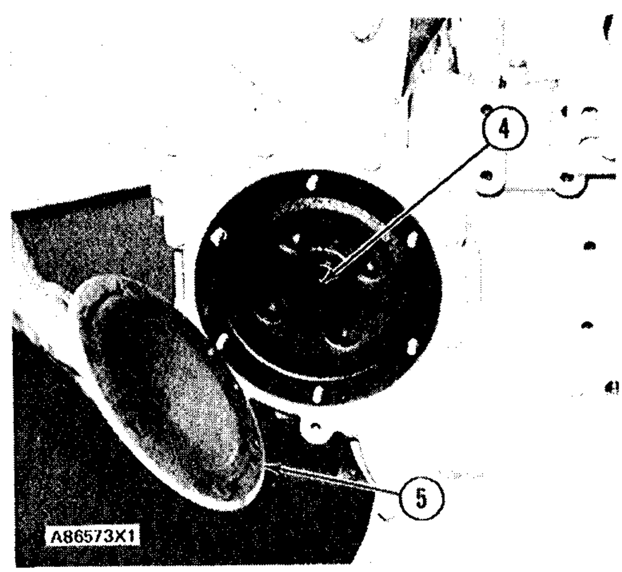


2. Install washers and nuts (2) that hold magneto drive in place.



3. Connect oil supply line (3) to the magneto drive.

4. Install washer and bolt (4). Tighten bolt (4) to a torque of 110 ± 5 lb.ft. (149 ± 7 N·m).



5. Install gasket and cover (5) on the front housing. Tighten the nuts that hold the cover in place to a torque of 20 ± 5 lb.ft. (25 ± 7 N·m).
   end by:
   a) install service meter
   b) install magneto

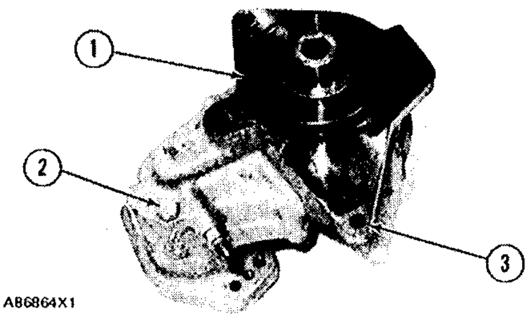
MAGNETO DRIVE

DISASSEMBLE MAGNETO DRIVE 1421-15

	Tools Needed	A	B
1P510	Driver Group	1	
9S9152	Bearing Puller Attachment		1

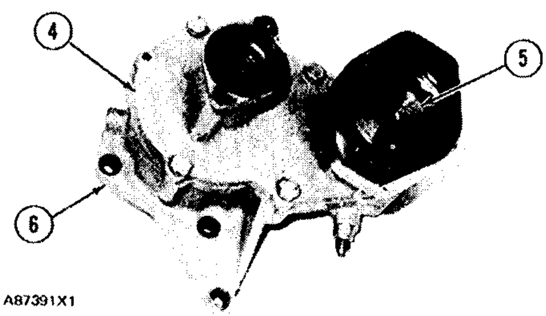
start by:
a) remove magneto drive

1. Remove O-ring seal (1) and bolt (2) from magneto drive (3).



A86864X1

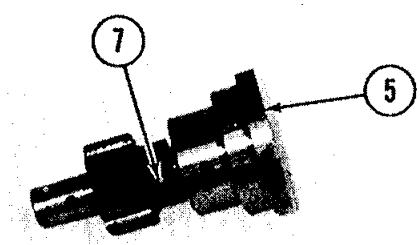
2. Turn magneto drive (3) over and remove magneto drive gear assembly (5).



A87391X1

3. Remove adapter assembly (4) and gasket from housing (6).

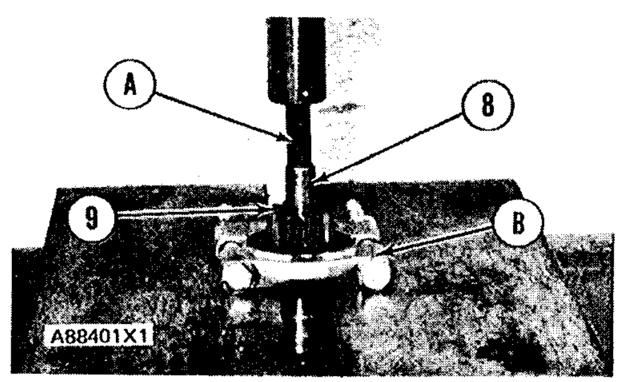
4. Use a hammer and punch and remove taper pin (7) from magneto drive gear assembly (5).



A84394X1

5. Put magneto drive gear assembly (5) and tooling (B) in position in a press as shown.

6. Use tooling (A) and press to push shaft (8) from gear (9).

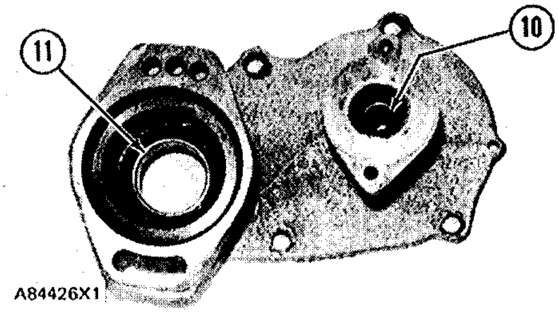


A88401X1

7. Remove key from shaft (8).

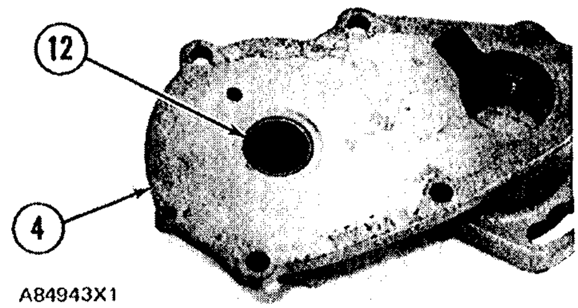
MAGNETO DRIVE

8. Inspect bushing (11) for wear and damage. If a replacement is necessary, bushing (11) must be destroyed to be removed.



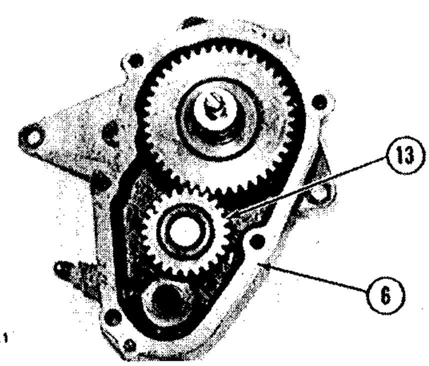
A84426X1

9. Inspect seal (10) for wear and damage. If a replacement is necessary, seal (10) must be destroyed to be removed.



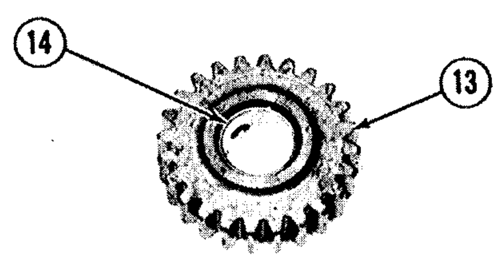
A84943X1

10. Turn adapter assembly (4) over. Inspect bearing (12) for wear and damage. If a replacement is necessary, bearing (12) must be destroyed to be removed.



A84947X1

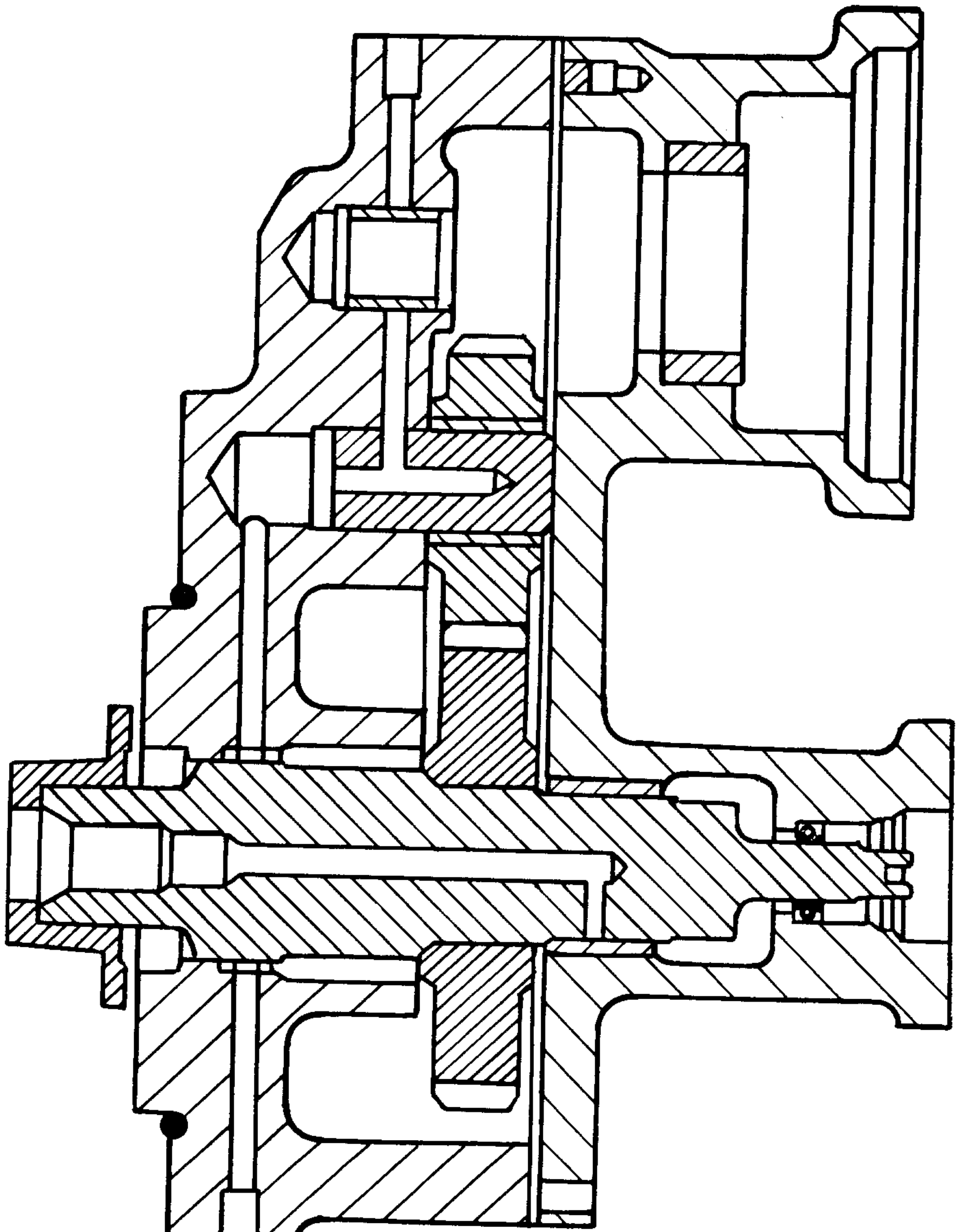
11. Remove idler gear (13) from housing (6).



A88773X1

12. Inspect bearing (14) for wear and damage. Use tooling (A) to remove if necessary.

MAGNETO DRIVE



A91083X1

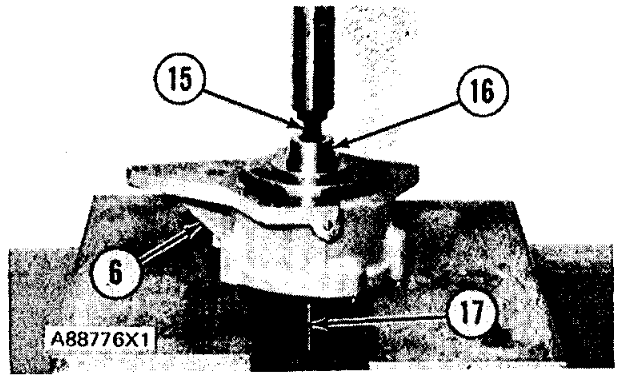
MAGNETO DRIVE

13. Put housing (6) in position on a press.

14. Install a ½"-20 NF x 2" bolt (15) in shaft assembly as shown.

NOTICE

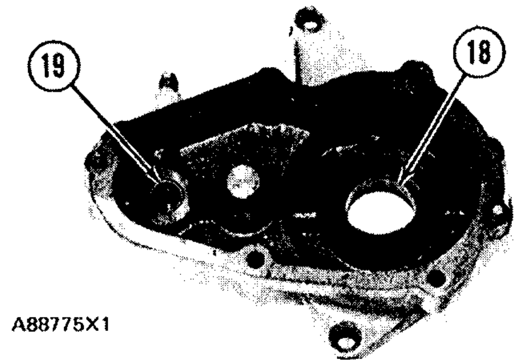
Make sure gear on shaft assembly (17) does not make contact with the press while the shaft assemby is pushed from sleeve (16).



15. Use press to push shaft assembly (17) free of sleeve (16).

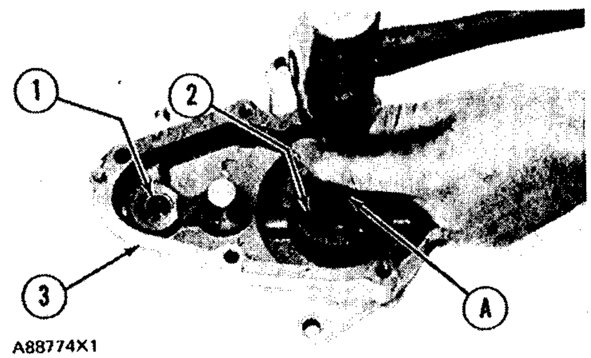
16. Remove shaft assembly (17), bolt (15) and sleeve (16) from housing (6).

17. Inspect bearings (18) and (19) for wear and damage. If a replacement is necessary, bearings (18) and (19) must be destroyed to remove.



ASSEMBLE MAGNETO DRIVE 1421-16

	Tools Needed	A	B	C
1P510	Driver Group	1		
3H467	Washer		1	
9S9152	Bearing Puller Attachment			1

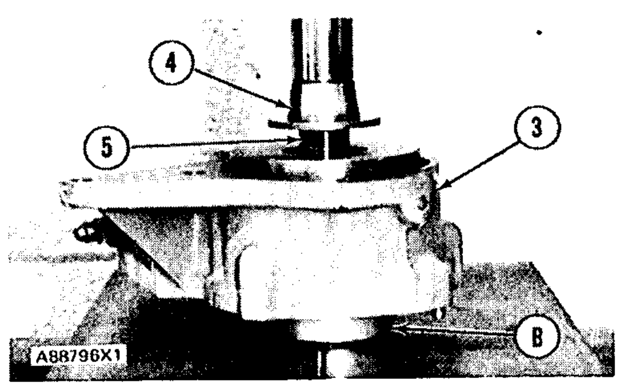


NOTE: Make an alignment of oil holes in bearings (1) and (2) with the oil holes in housing (3).

1. If bearing (1) was removed, use tooling (A) to install the bearing even with the face of the housing.
2. If bearing (2) was removed, use tooling (A) to install the bearing to the bottom of the bearing bore.
3. Put shaft assembly (5) into position in housing (3). Put tool (B) under gear of shaft assembly (5) for support.

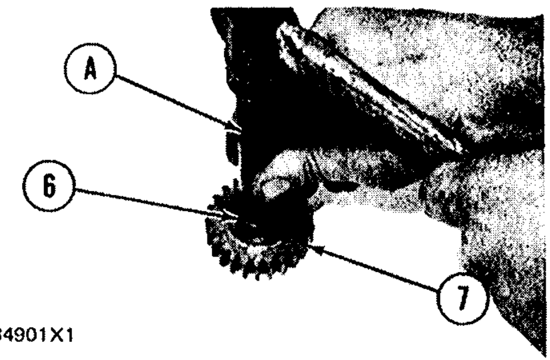
NOTE: A new sleeve must be used each time sleeve (4) is removed.

4. Use a press to install a new sleeve (4) on shaft assembly (5) as shown.



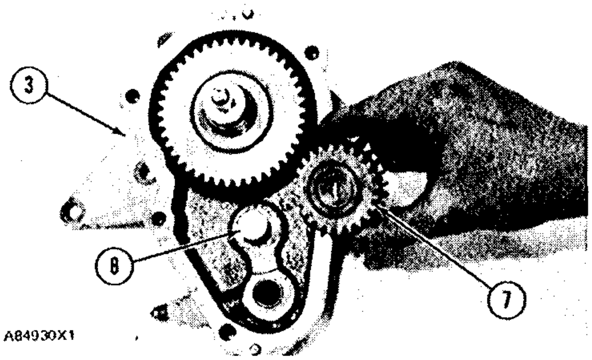
MAGNETO DRIVE

5. If bearing (6) was removed, use tooling (A) to install bearing even with face of gear (7).



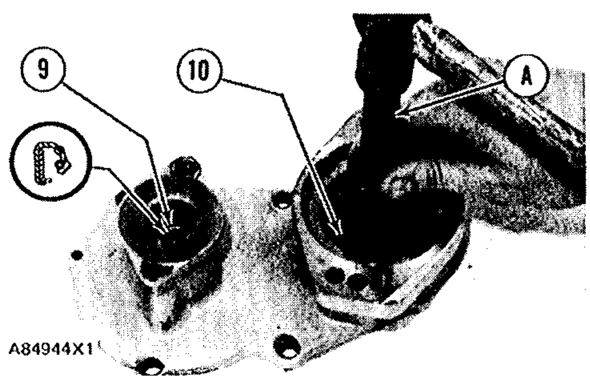
A84901X1

6. Put gear (7) in position over shaft (8) in housing (3).



A84930X1

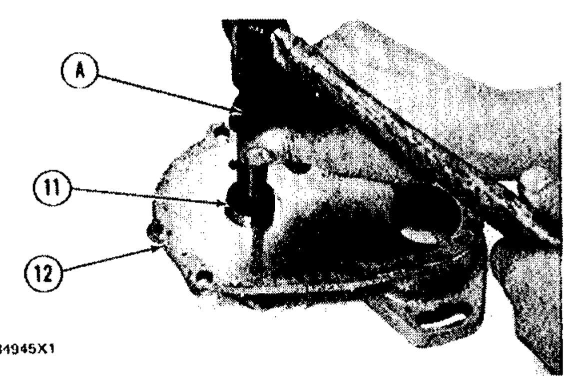
7. If seal (9) was removed, use tooling (A) to install seal to the bottom of the seal bore with the lip of the seal toward the inside. Put a small amount of engine oil on the seal lip.



A84944X1

8. If bushing (10) was removed, use tooling (A) to install the bushing to the bottom of the bushing bore.

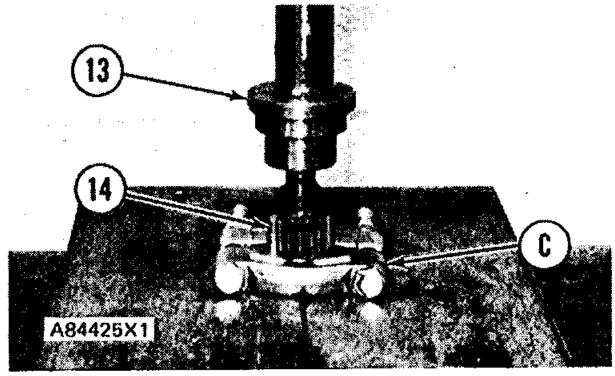
9. If bearing (11) was removed from adapter (12), use tooling (A) to install bearing even with the face of the adapter.



A84945X1

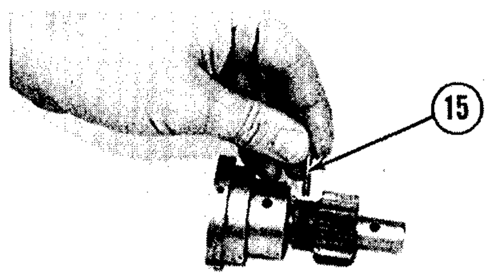
MAGNETO DRIVE

10. Install key on shaft (13).



A84425X1

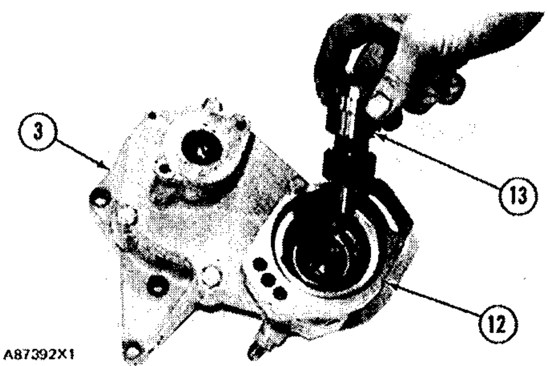
11. Use a press and tooling (C) to push gear (14) on shaft (13) until the holes in the gear and shaft are in alignment.



A88778X1

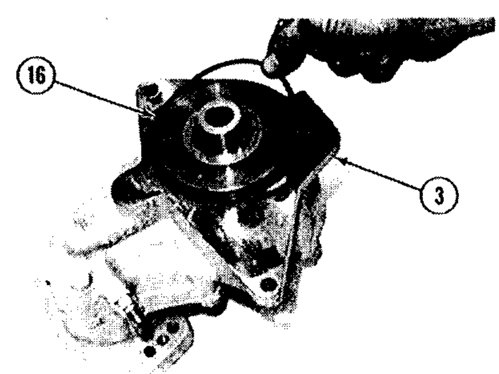
12. Install taper pin (15) that holds gear (14) in place. Move the metal (peen) on the small diameter end of taper pin (15) to hold the taper pin in place.

13. Install a new gasket and adapter (12) on housing (3).



A87392X1

14. Put shaft (13) and gear into position in adapter.

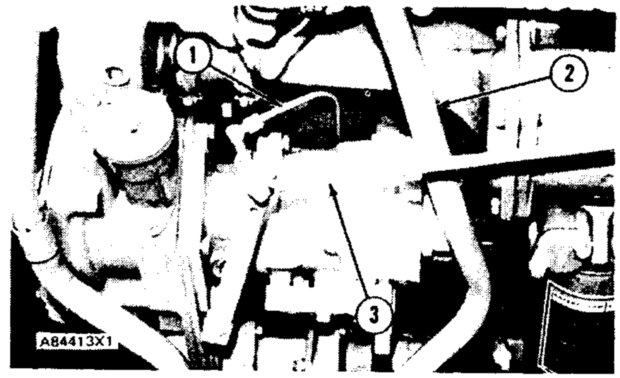


A86863X1

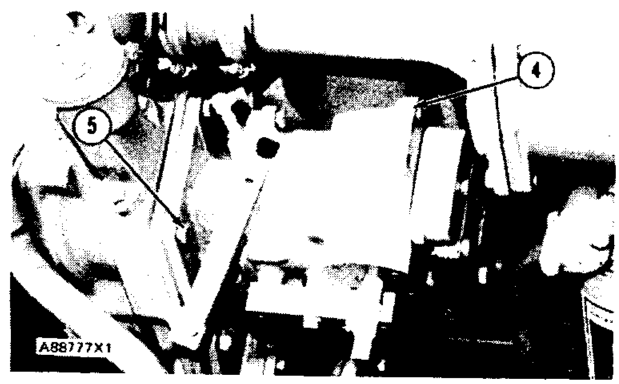
15. Install O-ring seal (16) on housing (3). Put a small amount of engine oil on the O-ring seal.
end by:
a) install magneto drive

GOVERNOR AND GOVERNOR DRIVE

REMOVE GOVERNOR AND GOVERNOR DRIVE 1265 & 1288-11

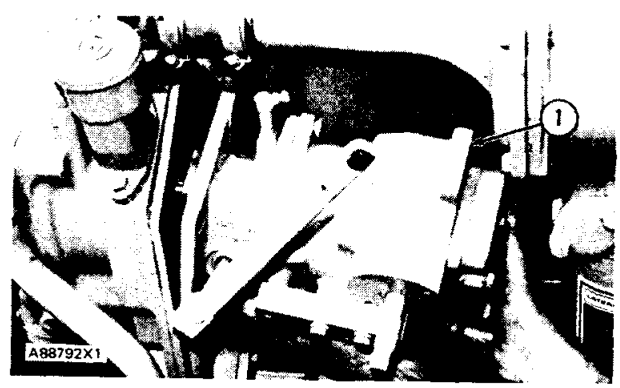


1. Close water supply line to auxiliary water pump.
2. Remove water line (2) from the auxiliary water pump to the aftercooler.
3. Remove oil supply line (1).

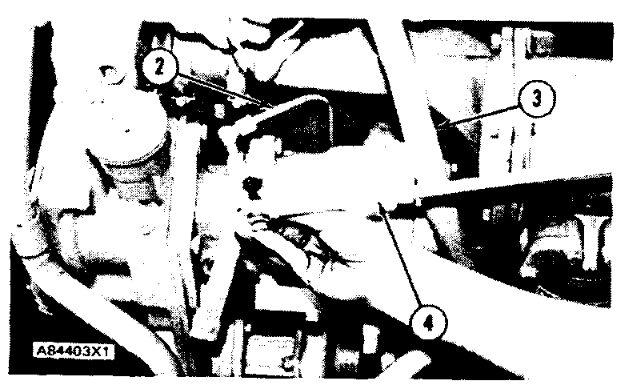


4. Disconnect carburetor control rod (3) from the governor lever.
5. Remove bolts (5) that hold governor (4) and governor drive in place.
6. Remove governor (4), governor drive and gasket.

INSTALL GOVERNOR AND GOVERNOR DRIVE 1265 & 1288-12



1. Put the gasket, governor and governor drive (1) in position. Make sure the governor drive shaft engages with the water pump gear. Install the bolts that hold the governor drive in place.
2. Install oil supply line (2).



3. Install water supply line (3) from the auxiliary water pump to the aftercooler.
4. Connect carburetor control rod (4) to the governor lever.
5. Open water supply line to auxiliary water pump.

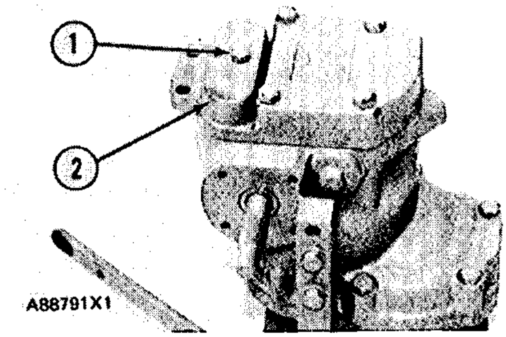
GOVERNOR AND GOVERNOR DRIVE

SEPARATION OF GOVERNOR FROM GOVERNOR DRIVE 1265 & 1288-29

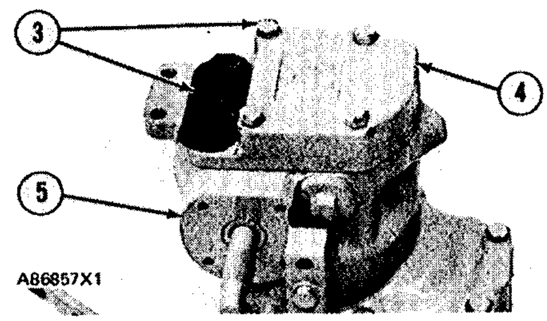
start by:

a) remove governor and governor drive

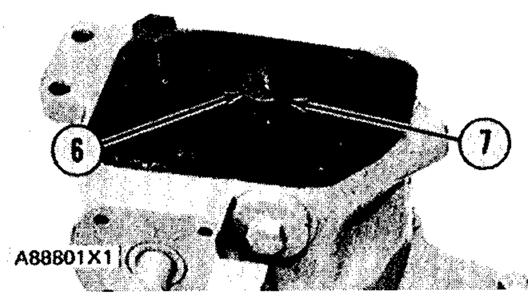
1. Remove bolt (1), washer, cover (2) and gasket.



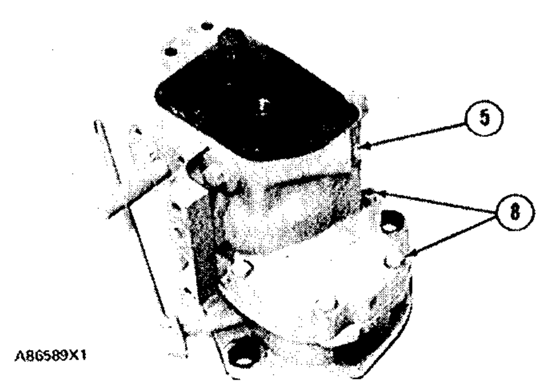
2. Remove bolts (3), cover (4) and gasket from housing (5).



3. Remove screw (7) from stop collar (6).



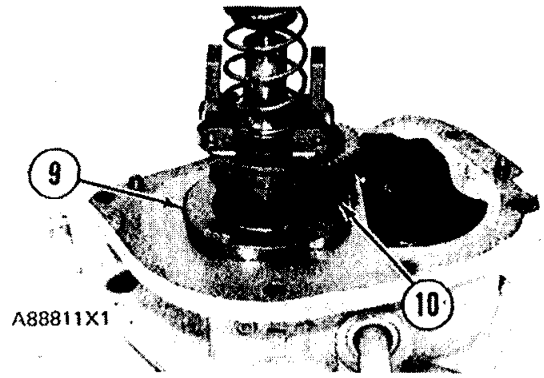
4. Remove stop collar (6).



5. Remove bolts (8) that hold housing (5) in place. Remove housing (5) and gasket from the governor drive.

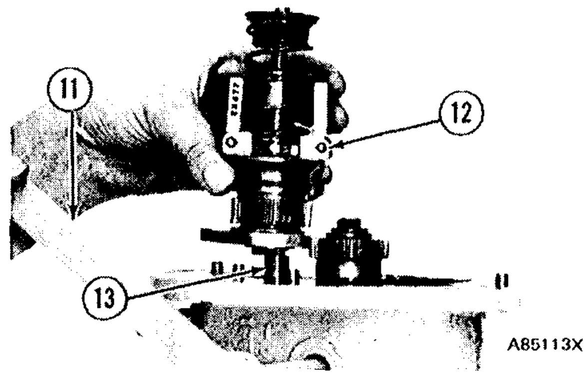
GOVERNOR AND GOVERNOR DRIVE

6. Bend the tabs on lock (9) and remove three bolts (10) and lock (9).



A88811X1

7. Pull cylinder and weight assemblies (12) straight up, while lever (11) is lifted until they are free of the dowels.

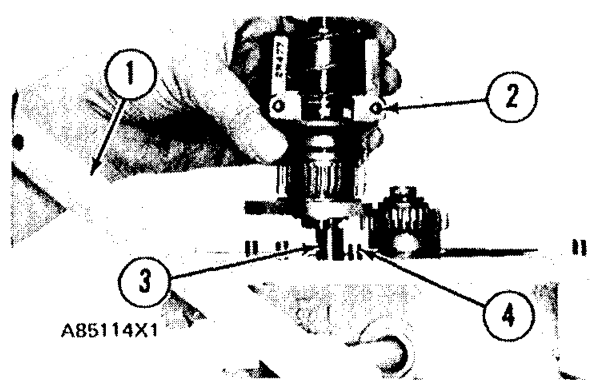


A85113X1

8. Slide the cylinder and weight assemblies to the side to free the piston from shaft (13).

CONNECTION OF GOVERNOR TO GOVERNOR DRIVE 1265 & 1288-29

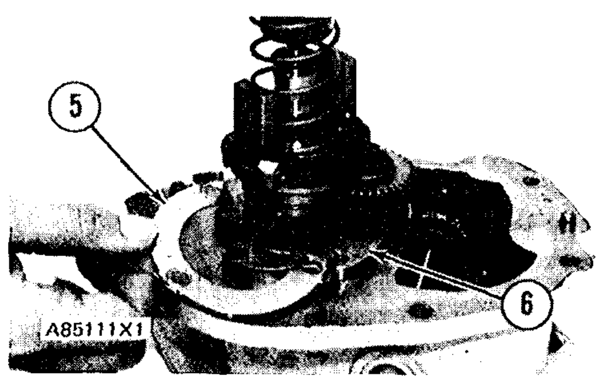
1. Lift lever (1) until shaft (3) is approximately .75 in. (19.1 mm) above the governor drive face.



A85114X1

2. Put cylinder and weight assemblies (2) in position on the governor drive so the piston engages shaft (3).

3. Lower lever (1) and push the cylinder and weight assemblies on to the location dowels (4).



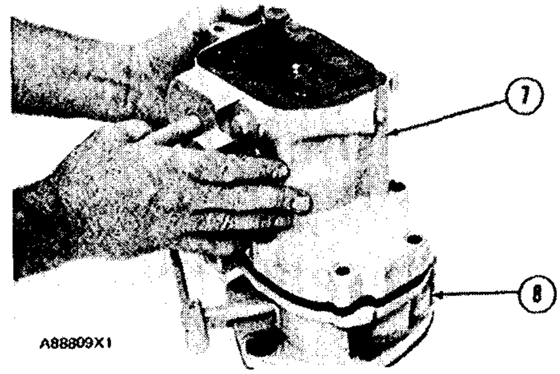
A85111X1

4. Put lock (5) in position on cylinder (6).

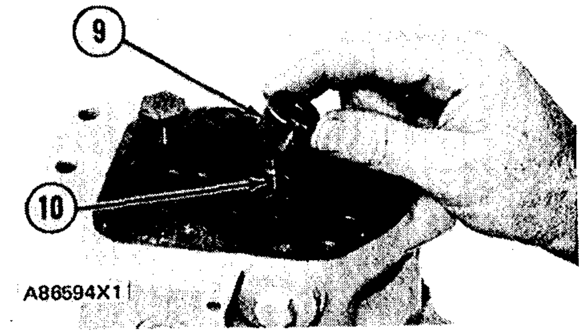
5. Install three bolts that hold cylinder (6) in place. Bend tabs on lock (5) to fasten bolts in place.

GOVERNOR AND GOVERNOR DRIVE

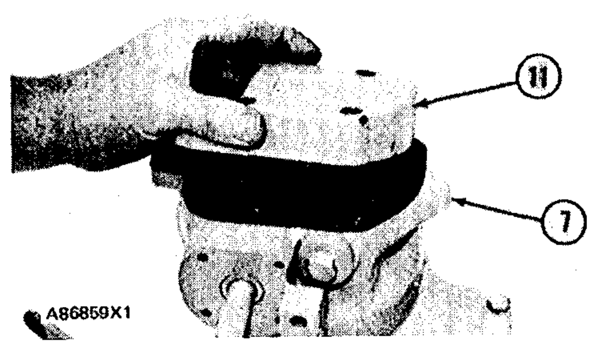
6. Put the gasket and housing (7) in position on governor drive (8) and install the bolts that hold the housing in place.



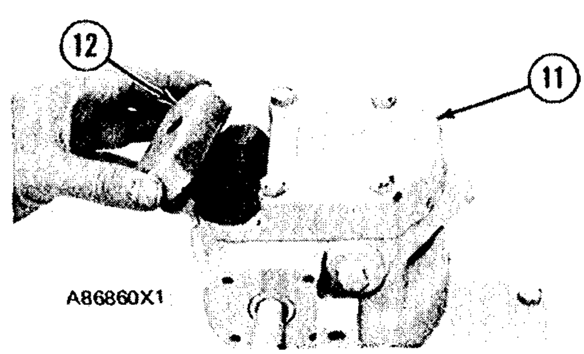
7. Lift the governor drive lever until the stop collar (9) can be installed on bolt (10).



8. Install stop collar (9) on bolt (10) and fasten with the screw.



9. Install gasket and cover (11) on housing (7).



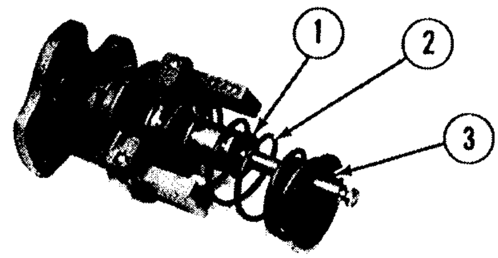
10. Put cover (12) and the gasket in position over the high idle screw and fasten to cover (11).

GOVERNOR

DISASSEMBLE GOVERNOR 1265-15

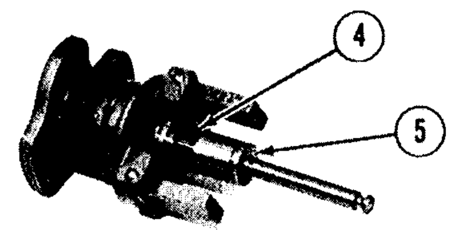
	Tools Needed	A
1P510	Driver Group	1

start by:
a) separation of governor from governor drive



A85097X1

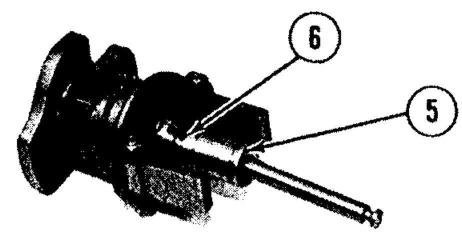
1. Remove seat (3), spring (2) and spring washer (1).



A85096X1

2. Remove retainer ring (4) from seat (5).

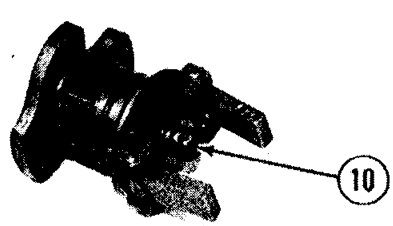
3. Remove dowel (6) and make a separation of seat (5) from the weight assembly.



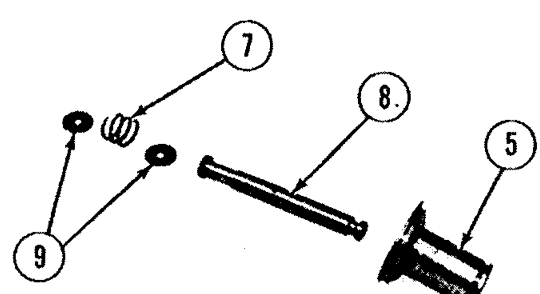
A85095X1

4. Remove washers (9), spring (7) and bolt (8) from seat (5).

5. Remove sleeve (10) and bearing assembly from the cylinder and weight assemblies.



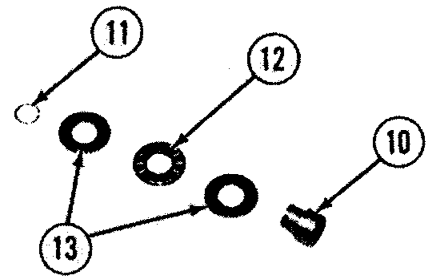
A85092X1



A85094X1

GOVERNOR

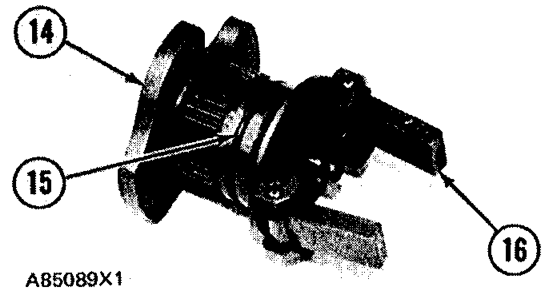
6. Remove ring (11), races (13) and bearing (12) from sleeve (10).



A85091X1

7. Remove lockring (15) that holds weight assembly (16) to cylinder (14).

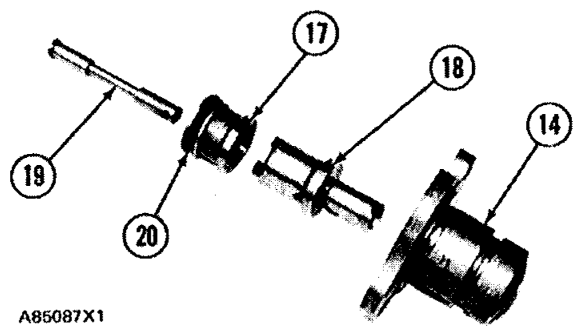
8. Remove weight assembly (16) from cylinder (14).



A85089X1

9. Remove valve (19), piston (18) and sleeve (17) from cylinder (14).

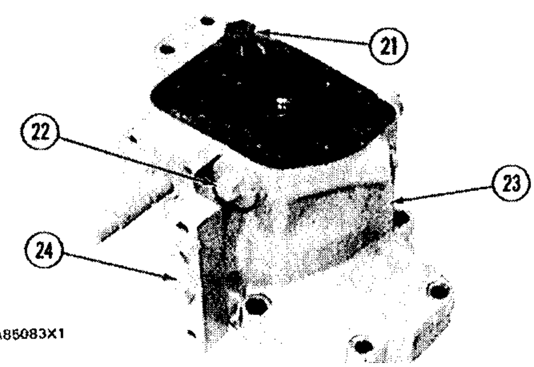
10. Remove O-ring seal (20) from sleeve (17).



A85087X1

11. Remove bracket (24) from housing (23).

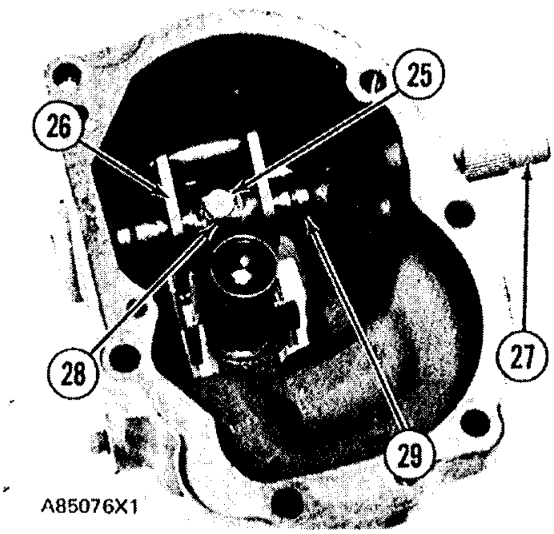
12. Remove high idle screw (21), plug (22) and gasket from housing (23).



A85083X1

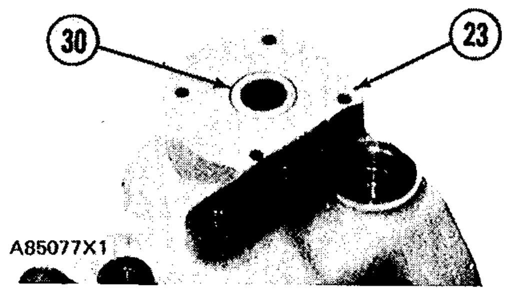
GOVERNOR

13. Bend lock (28) away from bolt (25) and remove the bolt and lock that hold lever (26) to shaft (27).



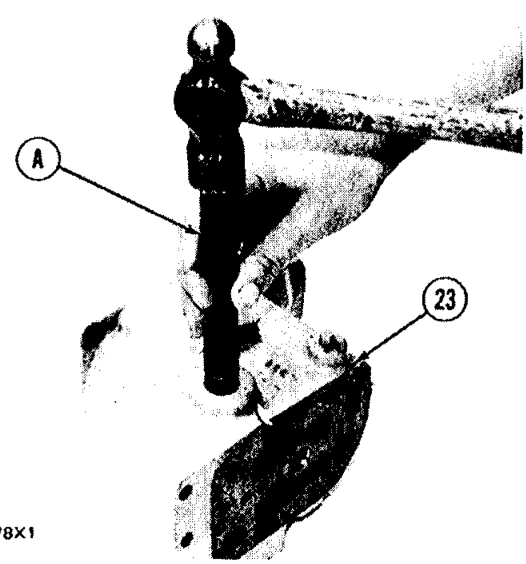
A85076X1

14. Remove lever (26) and shaft (27) from the housing.



A85077X1

15. Remove seal (30) from housing (23).



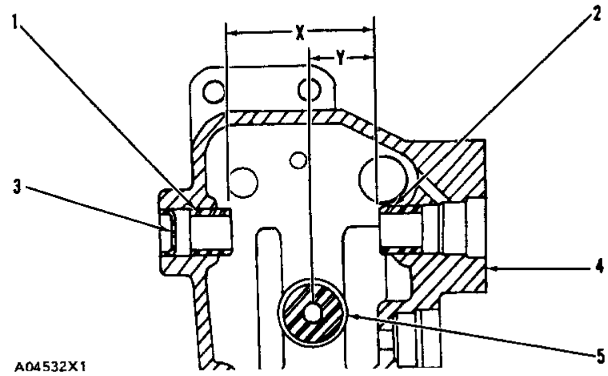
A85078X1

16. Remove plug and bearings (29) from housing (23) with tooling (A).

GOVERNOR

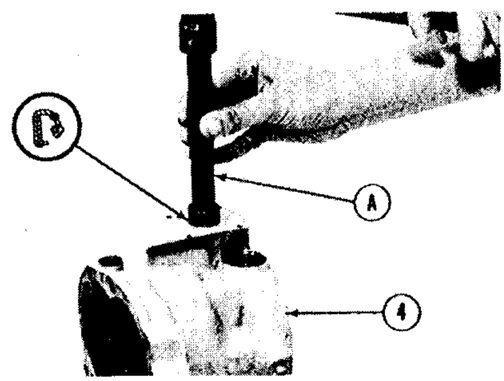
ASSEMBLE GOVERNOR 1265-16

	Tools Needed	A
1P510	Driver Group	1



A04532X1

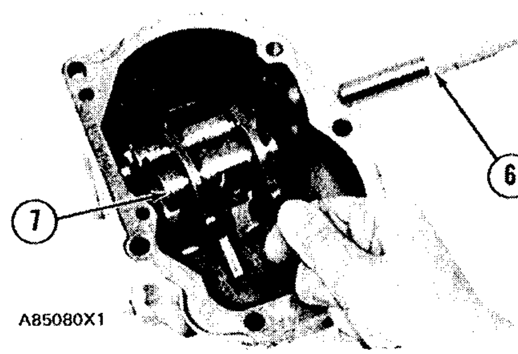
1. Install bearing (2) in housing (4) to dimension (Y), 1.073 in. (27.25 mm) from the center of guide (5) with tooling (A). Install bearing (1) in the housing to dimension (X), 2.385 ± .005 in. (60.58 ± 0.13 mm) from bearing (2) with tooling (A). Install plug (3) in the housing.



A85079X1

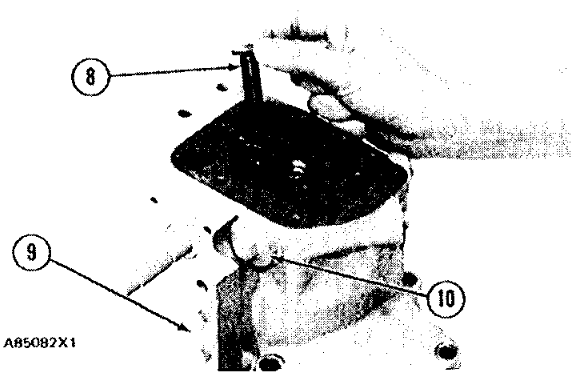
NOTE: Install the seal with the lip toward the inside of the housing.

2. Install the seal in housing (4) with tooling (A) even with the face of the housing. Put a small amount of engine oil on the lip of the seal.



A85080X1

3. Put lever assembly (7) in position in the housing. Install shaft (6) in the housing through the lever. Install the lock and bolt that hold the lever to the shaft.



A85082X1

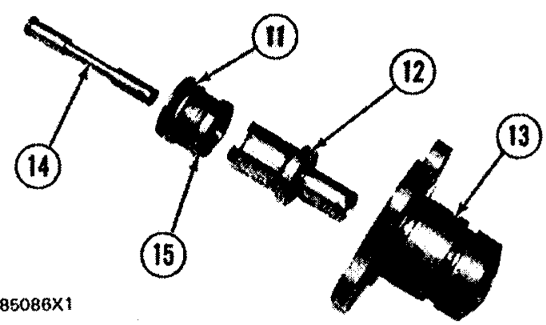
4. Install gasket and plug (10). Tighten the plug to a torque of 27 ± 5 lb.ft. (37 ± 7 N·m).

5. Install bracket (9) on the housing.

6. Install high idle screw (8) in the housing.

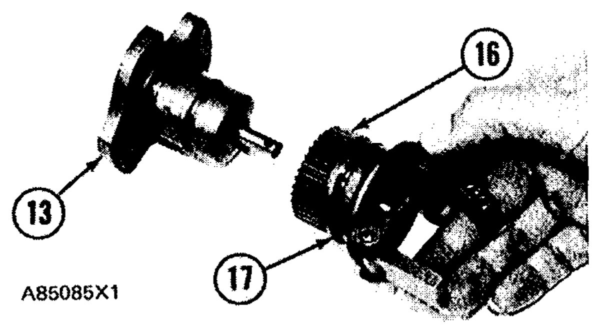
GOVERNOR

7. Install O-ring seal (11) on sleeve (15). Put a small amount of engine oil on seal (11), piston (12) and the inside bore of sleeve (11) and cylinder (13).



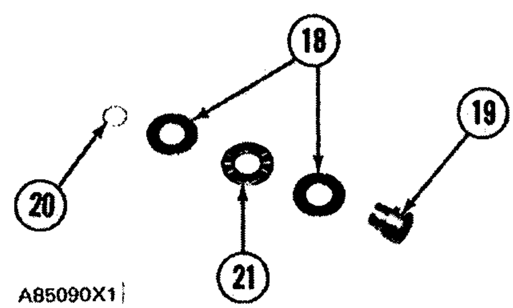
A85086X1

8. Install piston (12), sleeve (11) and valve (14) in cylinder (13).



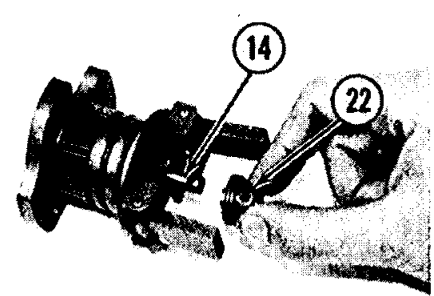
A85085X1

9. Put weight assembly (16) in position on cylinder (13). Install lockring (17) that holds the weight assembly on the cylinder.



A85090X1

10. Put races (18) and bearing (21) in position on sleeve (19). Install ring (20) that holds the races and bearing on the sleeve.

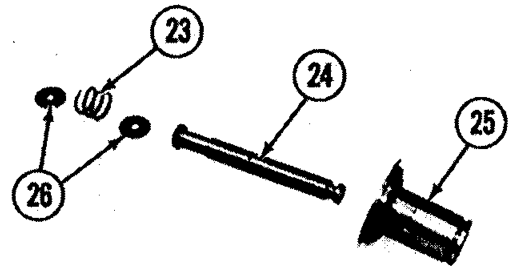


A85084X1

11. Put sleeve assembly (22) in position on valve (14). Make an alignment of the holes in the sleeve and valve.

GOVERNOR

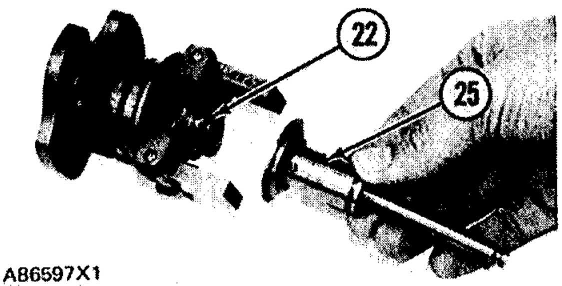
12. Install bolt (24), washers (26) and spring (23) in seat (25).



A85093X1

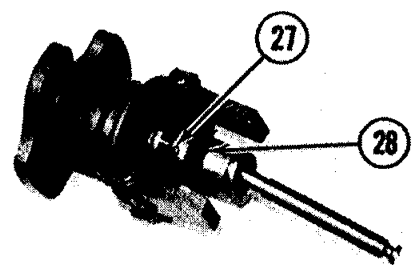
13. Put seat (25) in position on sleeve assembly (22).

14. Make an alignment of the holes in the seat, sleeve assembly and valve. Install dowel (27) that holds the seat, sleeve assembly and valve together.



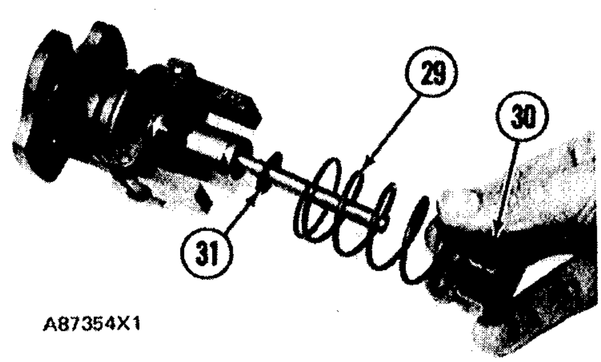
A86597X1

15. Install retainer ring (28) that holds dowel (27) in place.



A86598X1

16. Put spring washer (31) in position on the bolt.



A87354X1

17. Put spring (29) and seat (30) in position on the weight assembly.
    end by:
    a) connection of governor to governor drive

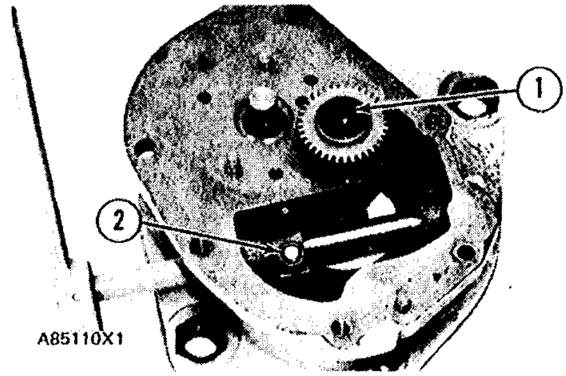
GOVERNOR DRIVE

DISASSEMBLE GOVERNOR DRIVE 1288-15

	Tools Needed	A
1P510	Driver Group	1

start by:
a) separation of governor from governor drive

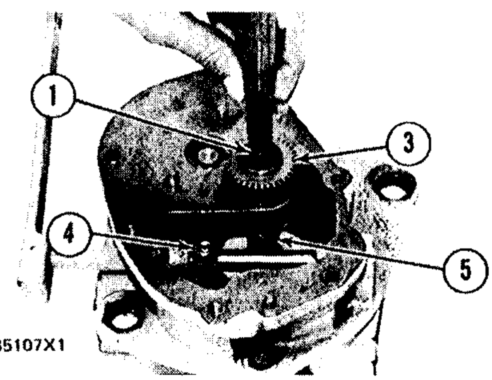
1. Remove locknut (2) and loosen bolt (1) one complete turn.



A85110X1

2. Put the governor drive on wooden blocks. Use a brass punch and hammer to hit (tap) bolt (1) to loosen gear (3) from shaft (5).

3. Install a 5/16''-18 NC jam nut on bolt (4) even with the end of bolt (4). Use a brass punch and hammer to loosen the bolt from the lever.

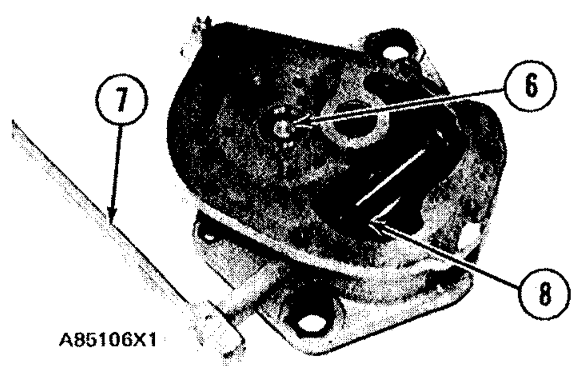


A85107X1

4. Remove bolt (1), washer, jam nut and bolt (4).

5. Remove gear (3) and shaft (5).

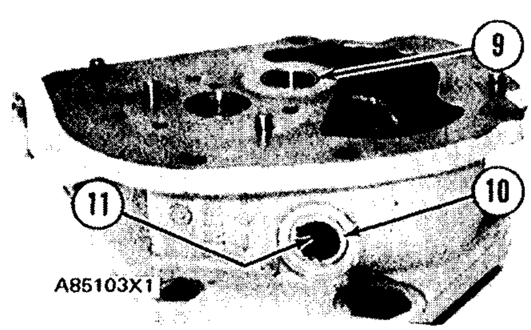
6. Remove lever and shaft assembly (7), lever (8) and shaft (6).



A85106X1

7. Inspect bearing (9) for wear and damage. If a replacement is needed, use tooling (A) to remove it.

8. Inspect seal (10) for wear and damage. If a replacement is needed, the seal must be destroyed to be removed.



A85103X1

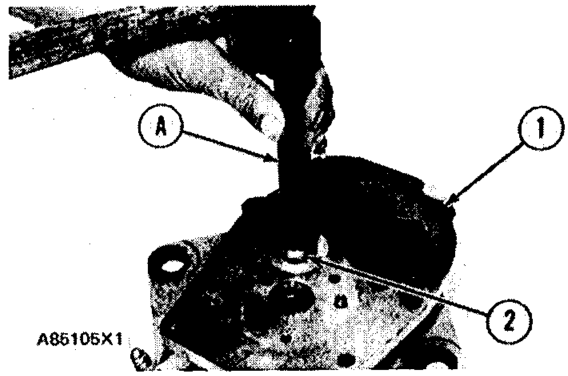
9. Inspect bearings (11) for wear and damage. If replacements are needed, use tooling (A) to remove these.

GOVERNOR DRIVE

ASSEMBLE GOVERNOR DRIVE 1288-16

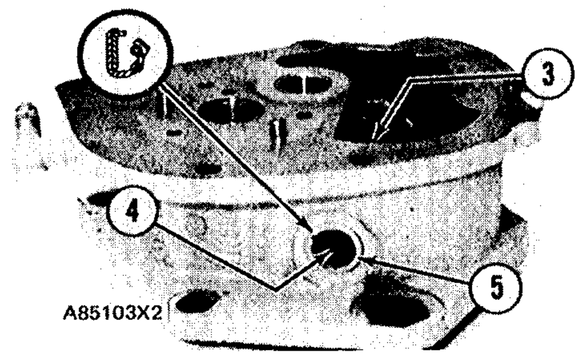
	Tools Needed	A
1P510	Driver Group	1

1. If bearing (2) was removed, make an alignment of the oil holes in the bearing and housing (1). Use tooling (A) to install bearing (2) even with the face of housing (1).



2. If bearing (3) was removed, install the bearing with tooling (A) approximately 0.30 in. (7.6 mm) above the face of housing (1).

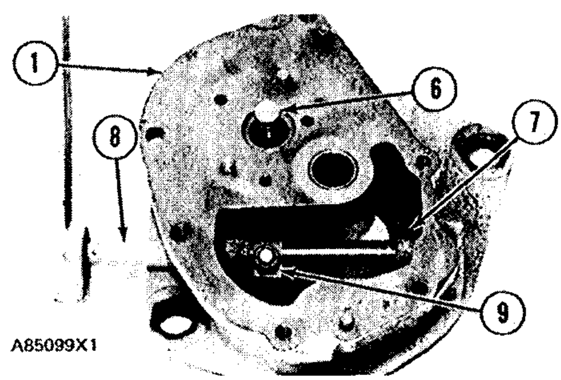
3. If bearing (4) was removed, install the bearing with tooling (A) even with the bottom of the seal counterbore.



4. Install seal (5), with the lips of the seal toward the inside, with tooling (A) to the bottom of the seal counterbore. Put a small amount of engine oil on the lip of seal (5).

5. Put shaft (6) and lever (9) in position in housing (1).

6. Put lever and shaft assembly (8) in position in housing (1) through lever (9). Make sure the end of lever (9) is engaged in the groove of shaft (6).



NOTICE

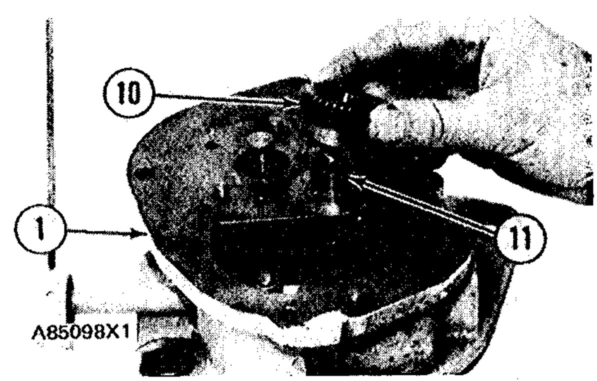
Before dowel (7) is installed make sure the end of shaft (8) does not make contact with the inner face of bearing (3). If the end of shaft (8) makes contact with the inner face of bearing (3), move the bearing away from the end of the shaft.

7. Install dowel (7) that holds shaft (8) in place.

8. Fasten lever (9) to shaft (8) with the taper bolt and locknut.

9. Put shaft (11) in position in housing (1).

10. Install gear (10) on shaft (11).
    end by:
    a) connection of governor to governor drive

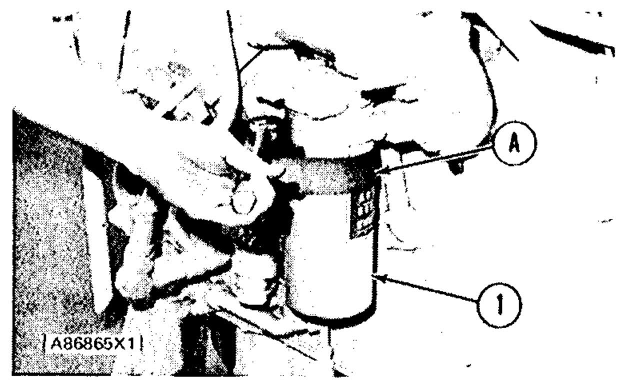


OIL FILTER BASE

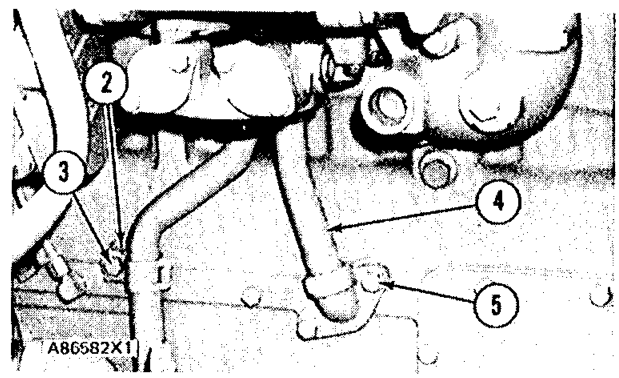
REMOVE OIL FILTER BASE 1306-11

	Tools Needed	A
2P8250	Strap Wrench	1

NOTE: Photos shown are on 3306 engine.

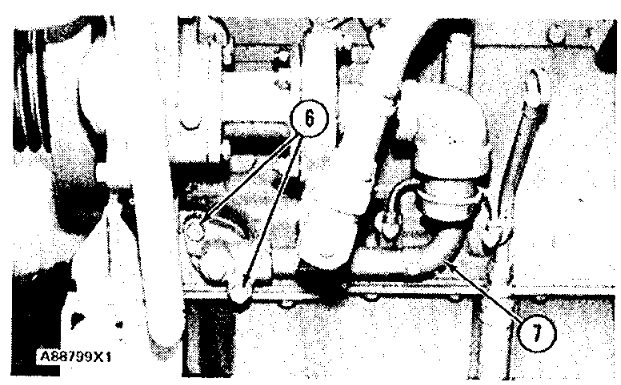


1. Remove oil filter (1) with tool (A).

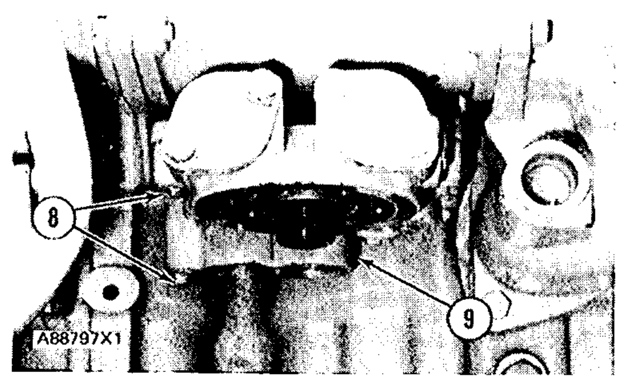


2. Remove bolts (5) and remove outlet tube (4) from the oil filter base.

3. Remove bolt (3) and clip (2) from the inlet tube.



4. Remove bolts (6) and remove inlet tube (7) from the oil filter base.



5. Remove four bolts (8) and oil filter base (9) from the engine oil cooler.

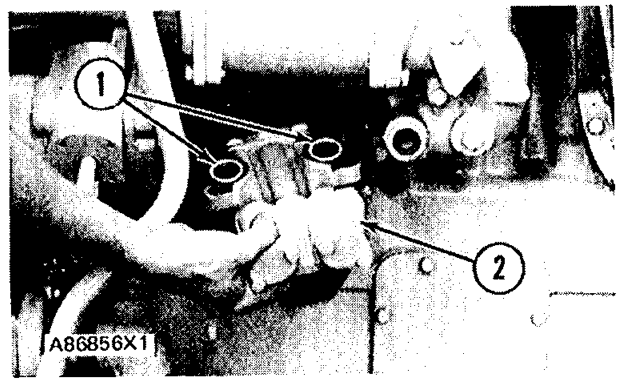
OIL FILTER BASE

INSTALL OIL FILTER BASE 1306-12

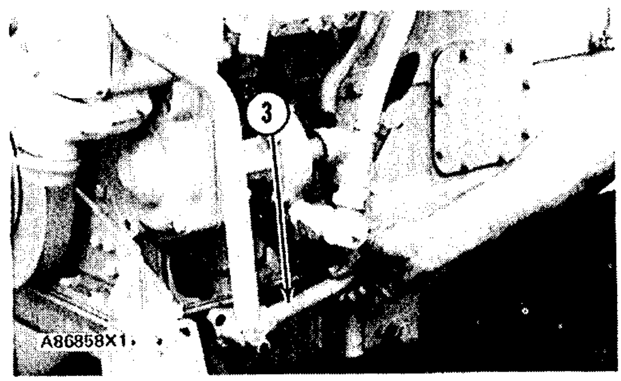
	Tools Needed	A
2P8250	Strap Wrench	1

NOTE: Photos shown are on 3306 engine.

1. Make sure O-ring seals (1) are in position in oil filter base.



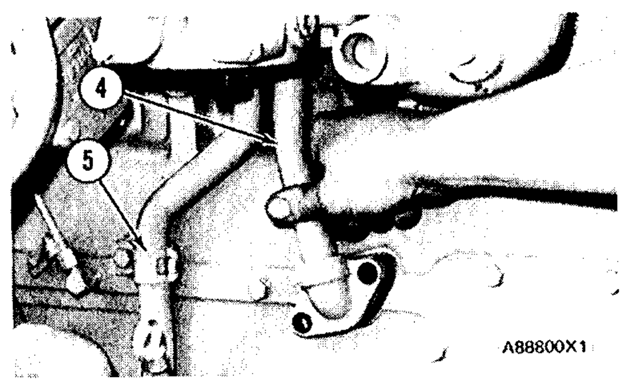
2. Put oil filter base (2) in position and fasten it to the engine oil filter base.



3. Put a thin layer of engine oil on the O-ring seal of inlet tube (3) and outlet tube (4).

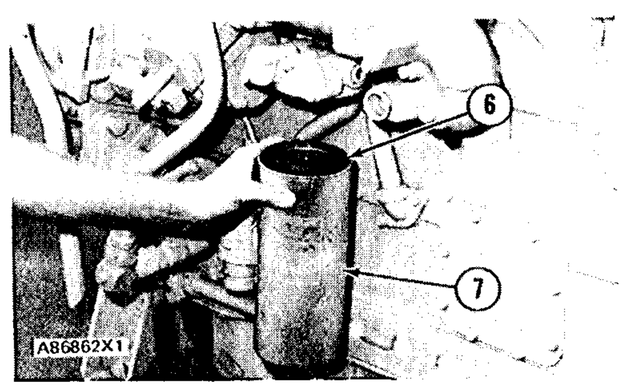
4. Use a new gasket and install inlet tube (3).

5. Install clip (5).



6. Use a new gasket and install outlet tube (4).

7. Put a thin layer of engine oil on gasket seal (6) of the oil filter.



8. Install oil filter (7) until the gasket seal (6) makes contact with the oil filter base.

9. Tighten the oil filter (7) ¾ of a turn more with tool (A).

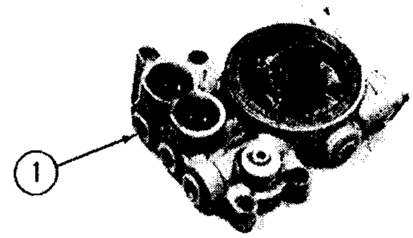
OIL FILTER BASE

DISASSEMBLE OIL FILTER BASE 1306-15

start by:

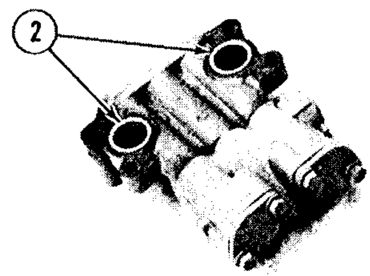
a) remove oil filter and base

1. Remove five plugs (1) from the oil filter base.



A86853X1

2. Remove O-ring seals (2).



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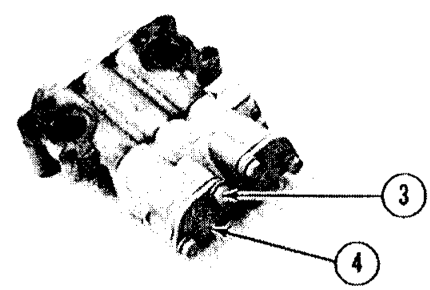
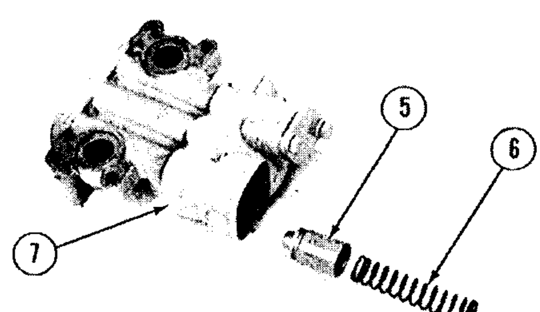
3. Remove bolts (3), washers, cover (4) and gasket.



A86854X1

4. Remove spring (6) and plunger (5) from the oil cooler bypass valve of the oil filter base (7).



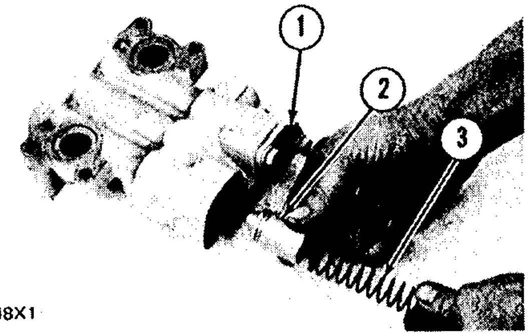
A86849X1

5. Do Steps 3 and 4 for the oil filter bypass valve of the oil filter base (7).

OIL FILTER BASE

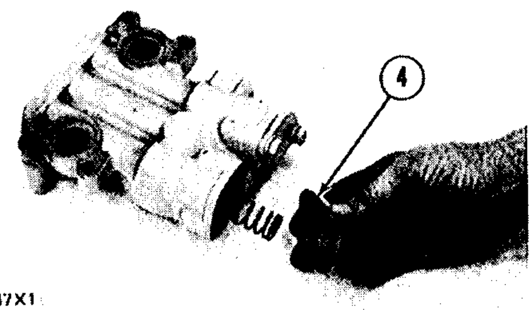
ASSEMBLE OIL FILTER BASE 1306-16

1. Install plunger, spring, gasket, cover (1), washer and bolts for the oil filter bypass valve.



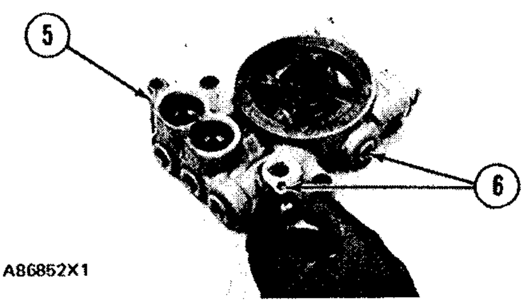
A86848X1

2. Install plunger (2) and spring (3) for the oil cooler bypass valve.



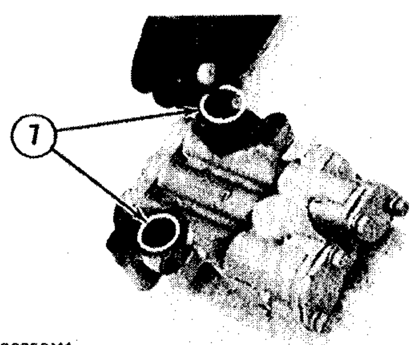
A86847X1

3. Install gasket, cover (4), washers and bolts for the oil cooler bypass valve.



A86852X1

4. Put 5P3413 Pipe Sealant on the threads of the five plugs (6) and install plugs in oil filter base (5).



A86850X1

5. Put O-ring seals (7) in position on the oil filter base.
   end by:
   a) install oil filter and base

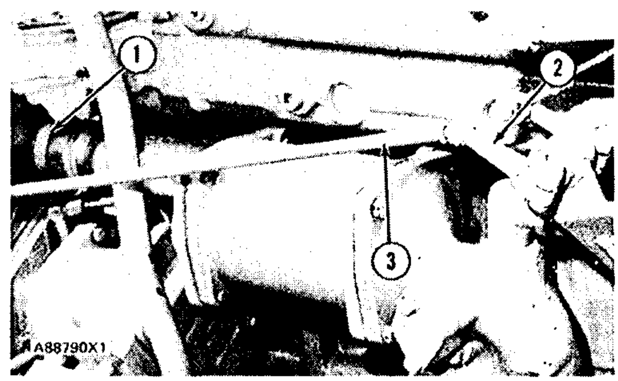
ENGINE OIL COOLER

REMOVE ENGINE OIL COOLER 1378-11

start by:
a) remove oil filter base

1. Drain the coolant from the engine cooling system.

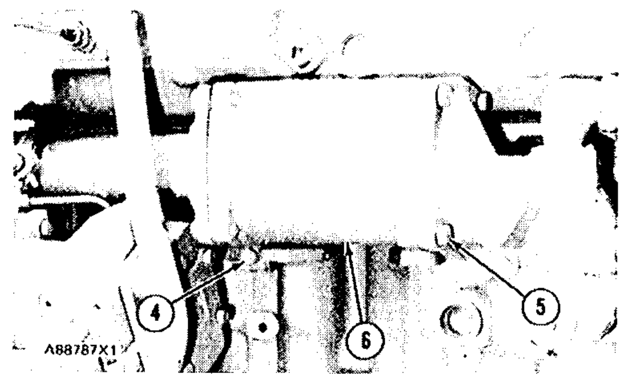
2. Disconnect carburetor control rod (3) from lever (2).



3. Loosen hose clamps (1).

4. Remove bolt (4) and bolts (5) that hold engine oil cooler (6) to the bonnet.

5. Remove engine oil cooler (6), bonnet and hose as a unit.



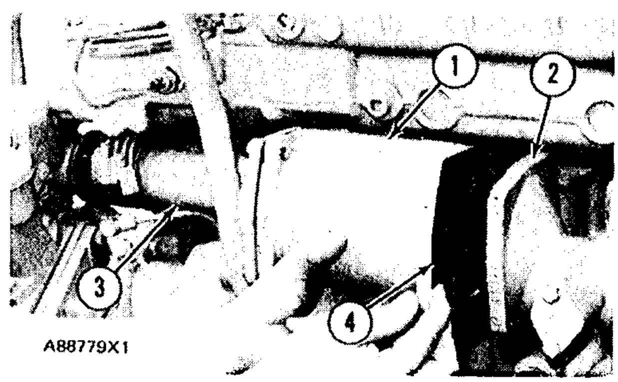
INSTALL ENGINE OIL COOLER 1378-12

1. Put hose, bonnet (3), engine oil cooler (1) and a new gasket (4) in position.

2. Install the bolts that hold engine oil cooler (1) to bonnet (2).

3. Install the bolt that holds bonnet (3) to the engine.

4. Tighten the hose clamps.

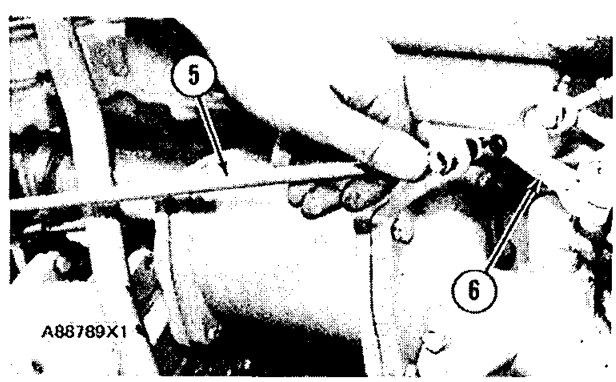


5. Connect carburetor control rod (5) to lever (6).

6. Fill the cooling system with coolant to the correct level.

7. After the end by step is completed, start the engine and check the engine oil level.

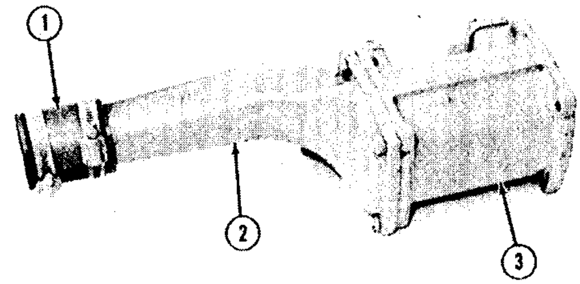
end by:
a) install oil filter base



ENGINE OIL COOLER

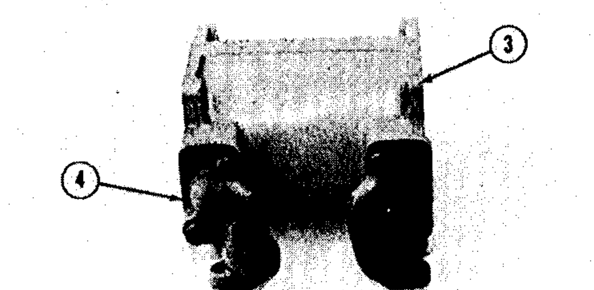
DISASSEMBLE ENGINE OIL COOLER 1378-15

start by:
a) remove engine oil cooler



A88786X1

1. Remove clamps, hose (1), bonnet (2) and gasket from engine oil cooler (3).

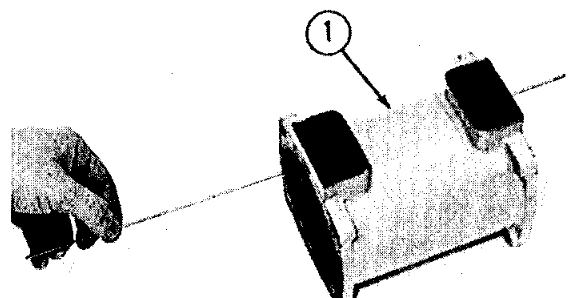


A88784X1

2. Remove elbows (4) and O-ring seals from engine oil cooler (3).

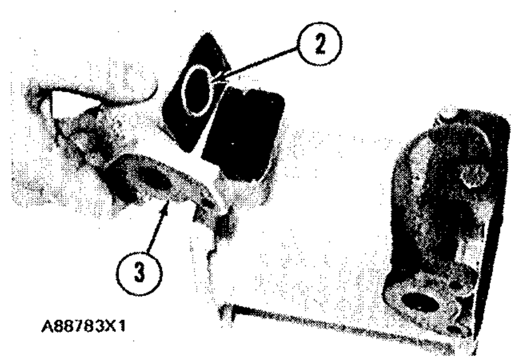
ASSEMBLE ENGINE OIL COOLER 1378-16

1. Clean the core in engine oil cooler (1) with a .125 in. (3.2 mm) diameter rod.



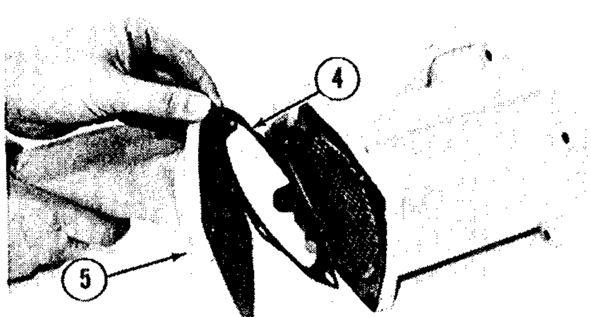
A88780X1

2. Put O-ring seals (2) in position on elbows (3) and install elbows on the engine oil cooler.



A88783X1

3. Install a new gasket (4) and bonnet (5).
end by:
a) install engine oil cooler



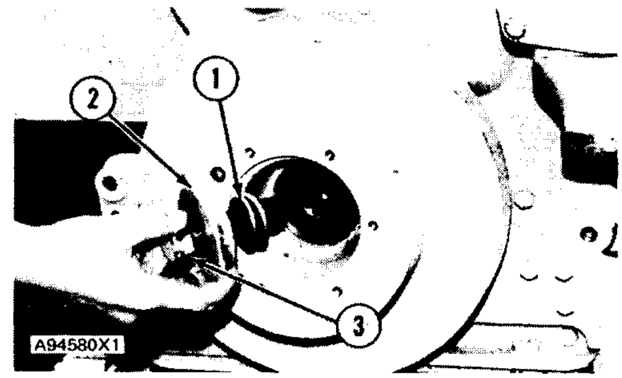
A88785X1

VIBRATION DAMPER AND PULLEY

REMOVE VIBRATION DAMPER AND PULLEY 1205-11

	Tools Needed	A
1P820	Hydraulic Puller	1
3H465	Plate	4
1B4207	Nut	2
8B7550	Leg	2
5F342	Adapter	2
8B7560	Step Plate	1
FT915	Adapter Plate	1
5P3100	Pump Group (or electric)	1

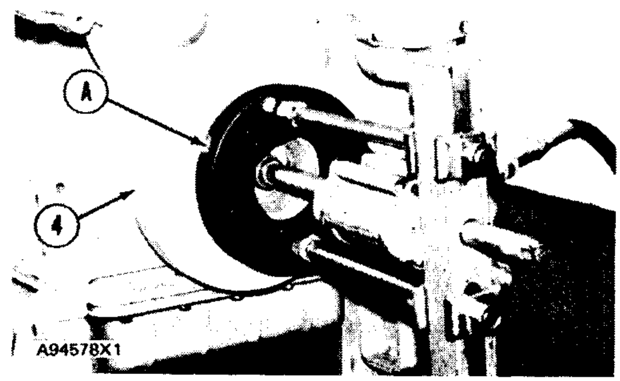
NOTE: Photos shown are on 3306 engine. 3304 engine does not have the vibration damper.



1. Remove bolt and washer (2). Install two ¾" flat washers (1), washer (2) and bolt (3) back into the threaded hole in the crankshaft.

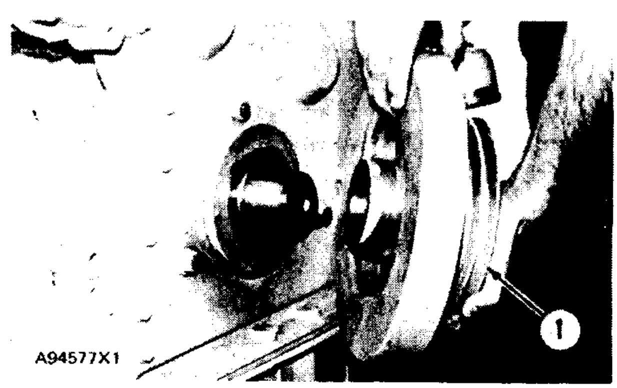
⚠ WARNING

The two flat washers, washer (2) and bolt (3) will keep the pulley on the crankshaft when it is loosened from the taper on the end of the crankshaft with tooling (A).

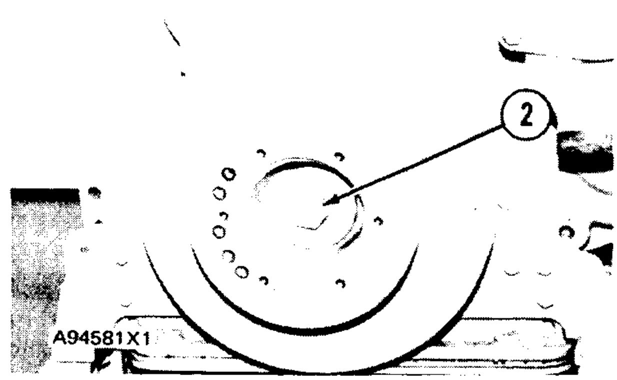


2. Loosen the pulley with tooling (A). Remove tooling (A), bolt (3), washer (2) and two flat washers (1) from the crankshaft. Remove the pulley and vibration damper (4).

INSTALL VIBRATION DAMPER AND PULLEY 1205-12



1. Put the vibration damper and pulley (1) in position on the end of the crankshaft.



2. Install the bolt (2) and the washer that hold the pulley in place. Tighten bolt (2) to a torque of 210 to 250 lb.ft. (284 to 340 N·m). Hit (tap) the head of the bolt with a hammer. Tighten the bolt again to a torque of 210 to 250 lb.ft. (284 to 340 N·m).

CRANKSHAFT FRONT SEAL AND WEAR SLEEVE

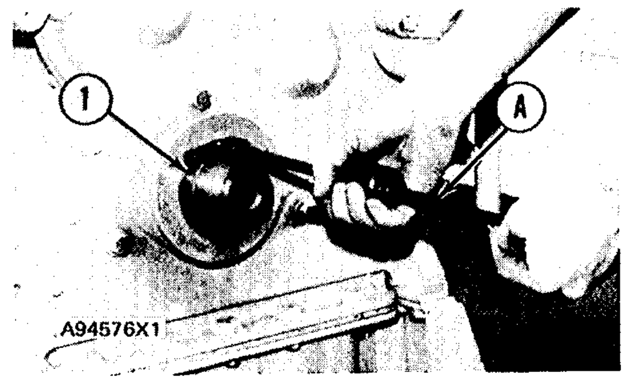
REMOVE CRANKSHAFT FRONT SEAL AND WEAR SLEEVE 1160-11

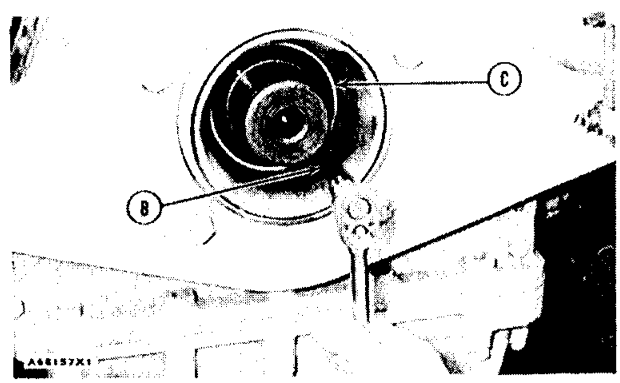
	Tools Needed	A	B	C
1P3075	Puller Group	1		
5P7312	Distorter		1	
5P7315	Ring			1

start by:
a) remove vibration damper and pulley

NOTE: When a replacement of the front seal (1) is made a replacement of the wear sleeve is to be made also.

1. Remove the crankshaft front seal (1) with tooling (A).
2. Install tool (C) into the seal bore.
3. Install tool (B) between tool (C) and the wear sleeve. Turn tool (B) until the edge of the tool makes a flat place (crease) in the wear sleeve. Do this in two or more places until the wear sleeve is loose.
4. Remove tool (C) and the wear sleeve by hand.





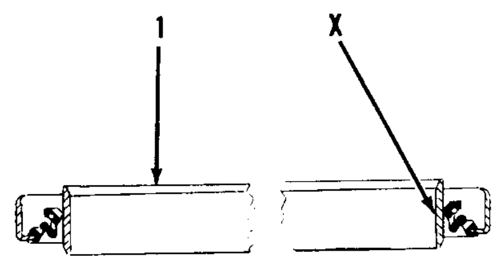
TYPICAL EXAMPLE

INSTALL CRANKSHAFT FRONT SEAL AND WEAR SLEEVE 1160-12

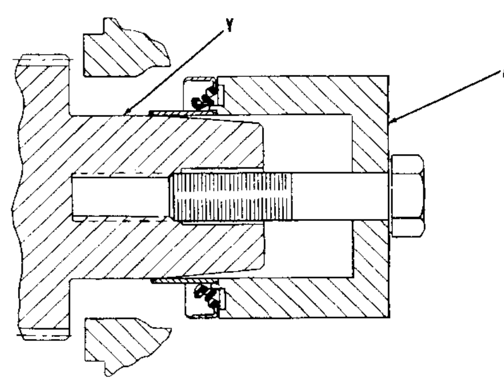
	Tools Needed	A
5P7299	Installer	1
7F8022	Bolt (¾"-16 NF x 3¼" long)	1
4B4283	Flat Washer	1

NOTE: The wear sleeve and seal must be installed together.

1. Put clean engine oil on the seal lip and on the outside diameter of wear sleeve (1). Install the seal on the wear sleeve as shown with the lip of the seal toward the side of the wear sleeve that has the chamfer on the inside diameter.
2. Use 8M8060 Quick Cure Primer to remove any oil from inside diameter "X" of the wear sleeve and surface "Y" of the crankshaft. Make an application of 9S3265 Retaining Compound to surfaces "X" and "Y".
3. Put the wear sleeve and seal on to the crankshaft as shown with the lip of the seal toward the engine.
4. Install tooling (A) as shown and put lubricant between the bolt head and installer.
5. Use tooling (A) to push the wear sleeve and seal on to the crankshaft until the installer is against the end of the crankshaft. The wear sleeve and seal will then be in the correct location.
6. Remove tooling (A).
end by:
a) install vibration damper and pulley



A44158X1

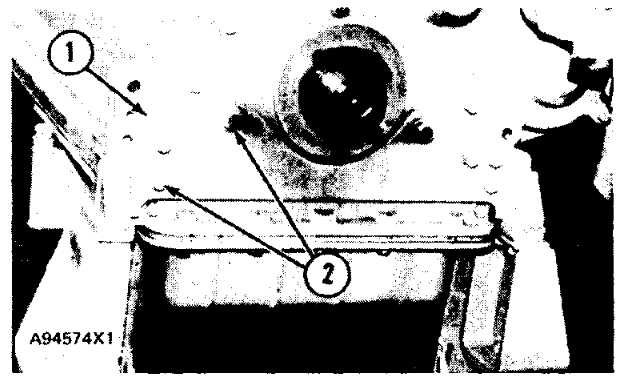


A44172X1

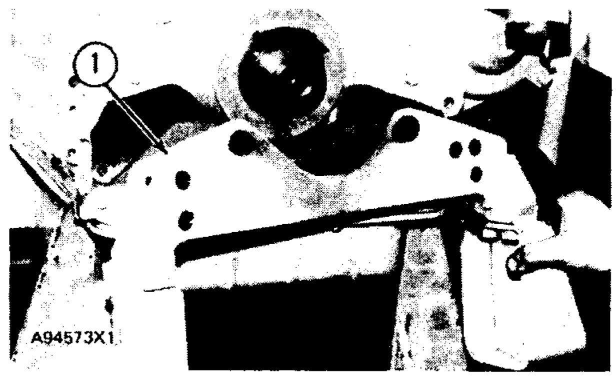
FRONT SUPPORT, TIMING GEAR COVER

REMOVE AND INSTALL FRONT SUPPORT 1153-10

1. Remove bolts (2) that hold front support to the timing cover.



2. Remove the front support (1) from the timing cover.

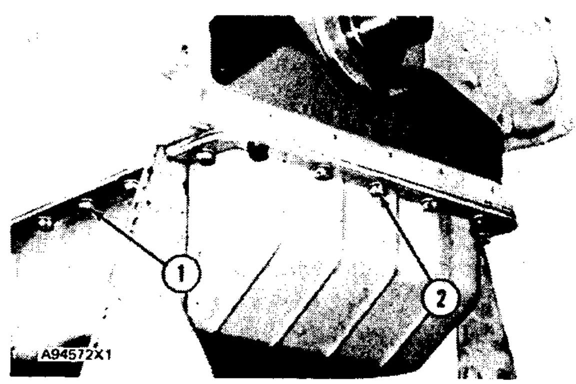


3. Put the engine front support (1) in position on the timing cover. Install the bolts and washers that hold it in place.

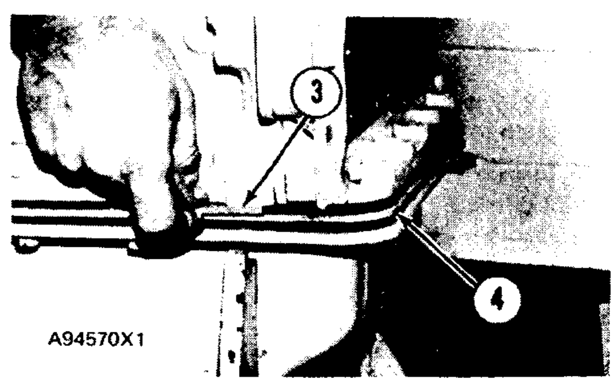
REMOVE TIMING GEAR COVER 1166-11

Tools Needed		A
5P9736	Bracket-Link	2

start by:
a) remove front support
b) remove water pump
c) remove governor drive
d) remove auxiliary water pump (fresh water-3306)
e) remove vibration damper and pulley



1. Remove the seven bolts (2) that hold the oil pan to the timing gear cover.
2. Loosen bolts (1) that hold the oil pan and plate to the cylinder block.
3. Fasten a hoist to the engine and lift the front of the engine.
4. Install two shims (3) between the oil pan plate (4) and the cylinder block on both sides of the engine.

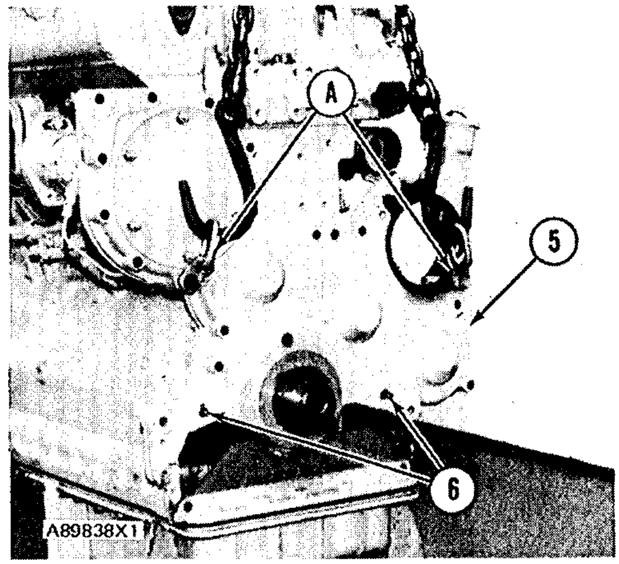


NOTICE

Do not cause damage to the oil pan and oil pan plate gaskets.

TIMING GEAR COVER

5. Remove the bolts and nuts that hold the timing gear cover to the front of the engine.

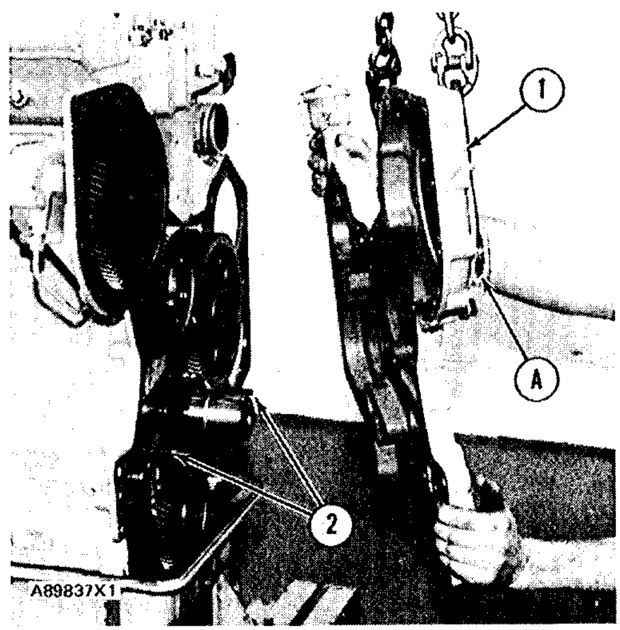


6. Install two 3/8"-16 NC guide bolts (6) in the front of the cylinder block.

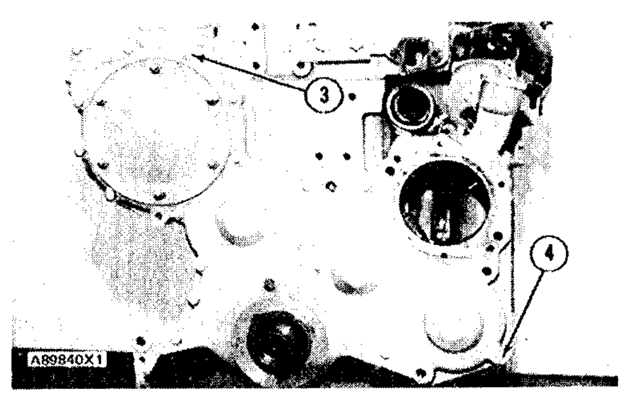
7. Install tooling (A) on the timing gear cover (5) as shown. Fasten a hoist to tooling (A). Move the timing gear cover away from the front of the cylinder block until it is free of the dowels, guide bolts and crankshaft. Remove the timing gear cover. Weight of the timing gear cover is 55 lb. (25 kg).

INSTALL TIMING GEAR COVER 1166-12

	Tools Needed	A
5P9736	Bracket-Link	2



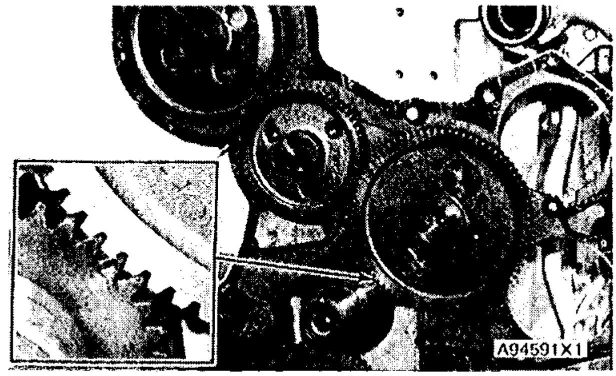
1. Put a new gasket in position on the timing gear plate. Install two 3/8"-16 NC guide bolts in the cylinder block as shown.
2. Install tooling (A) on the timing gear cover (1). Put a small amount of clean engine oil on the lip of the seal in the timing gear cover.
3. Fasten a hoist to tooling (A). Put timing gear cover (1) in position over guide bolts (2) and dowels. Install the bolts and nuts that hold it. Remove tooling (A) and the guide bolts.
4. Tighten bolts (3) and (4) to a torque of 17 ± 3 lb.ft. (23 ± 4 N·m).
5. Fasten a hoist to the engine and lift the front of the engine. Remove the shims from between the oil pan plate and the cylinder block.
6. Tighten the bolts that hold the oil pan and oil pan plate to the cylinder block.
7. Install the seven bolts that hold the oil pan to the timing gear cover.
   end by:
   a) install front support
   b) install water pump
   c) install governor drive
   d) install auxiliary water pump (fresh water-3306)
   e) install vibration damper and pulley



TIMING GEARS

REMOVE TIMING GEARS 1206-11

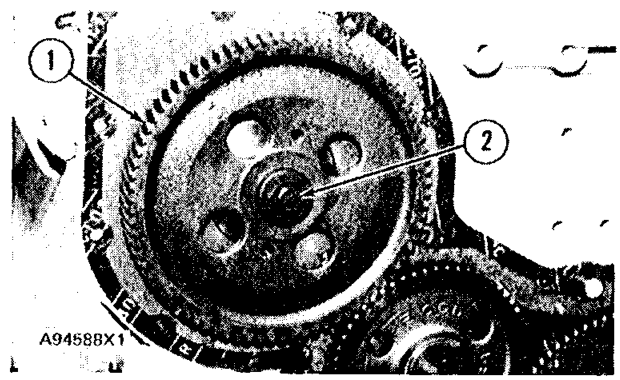
	Tools Needed	A	B	C
8S2264	Puller Group	1		
9S9155	Step Plate	1		
	Bolt (3/8"-24 NF x 3 1/4" long)	2		
	Flat Washer	2		
1P510	Driver Group		1	
1P2321	Puller Assembly			1



start by:

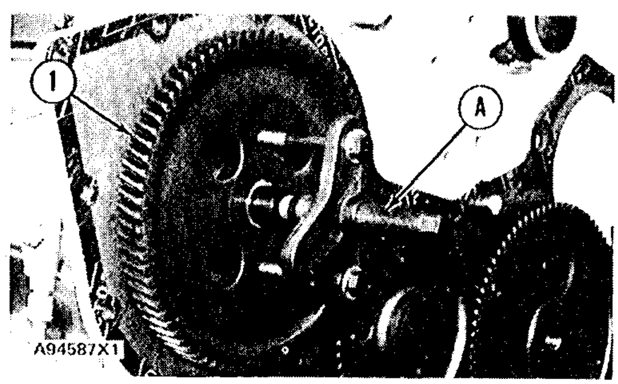
a) remove timing cover

NOTE: Photos shown are on 3306 engine.



1. Turn the crankshaft until No. 1 piston is at top center compression position and the "C" mark on the crankshaft gear is in alignment with the "C" mark on the camshaft gear.

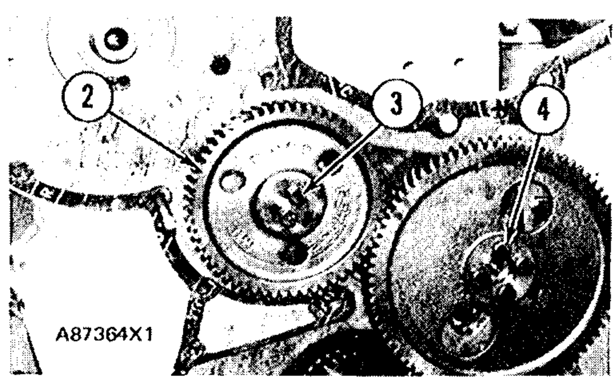
2. Remove bolt (2) and washer from magneto drive gear (1).



⚠ **WARNING**

Hold puller with hand to prevent injury when gear (1) is removed from the shaft.

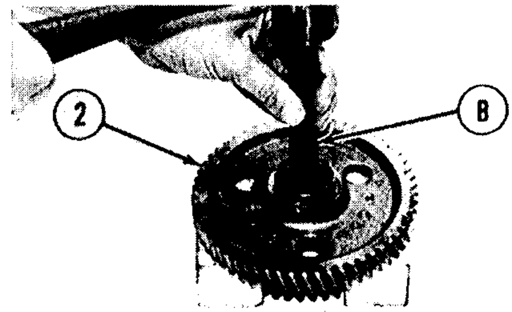
3. Install tooling (A) on gear (1). Remove gear (1) from the magneto drive shaft.



4. Remove bolts (3) and the plate. Remove idler gear (2). Remove bolts (4) from the camshaft gear.

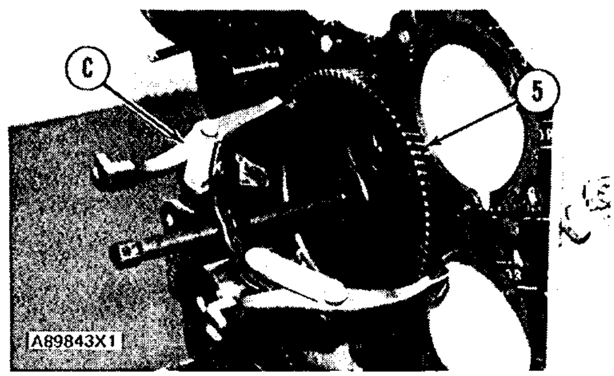
TIMING GEARS

5. Remove the bearing from the idler gear (2) with tooling (B).



A89835X1

6. Install tooling (C) on camshaft gear (5). Remove camshaft gear (5) with tooling (C).

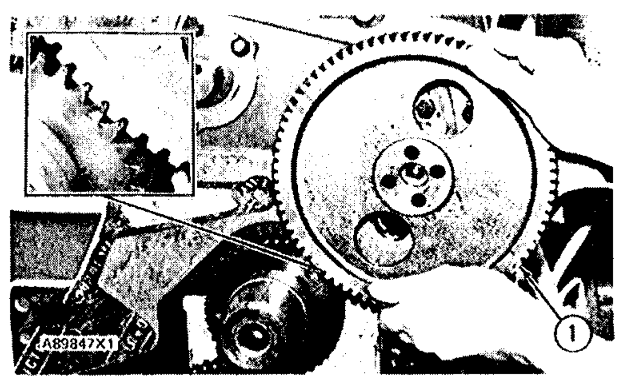


A89843X1

INSTALL TIMING GEARS 1206-12

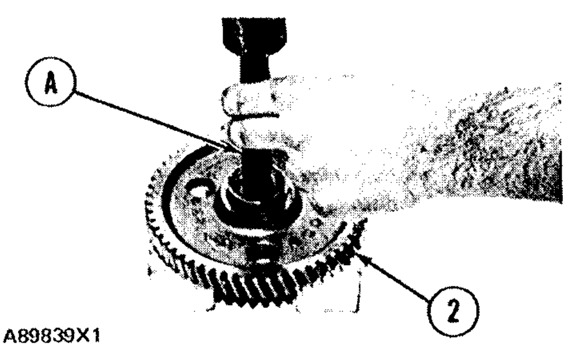
	Tools Needed	A
1P510	Driver Group	1

NOTE: Photos shown are on 3306 engine.



A89847X1

1. Install camshaft drive gear (1). Make sure the "C" mark on the crankshaft gear is in alignment with the "C" mark on the camshaft drive gear. Install the four bolts that hold the camshaft drive gear.

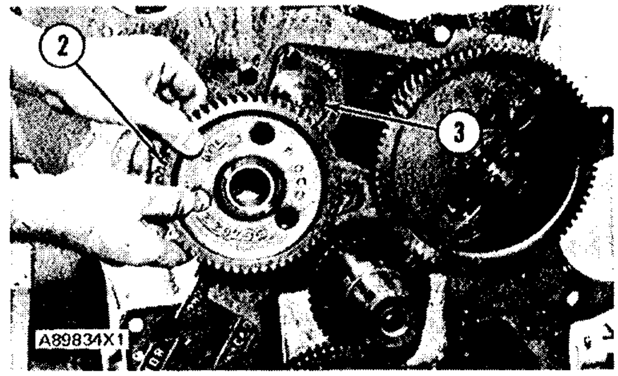


A89839X1

2. Use tool (A) to install the bearing in idler gear (2).

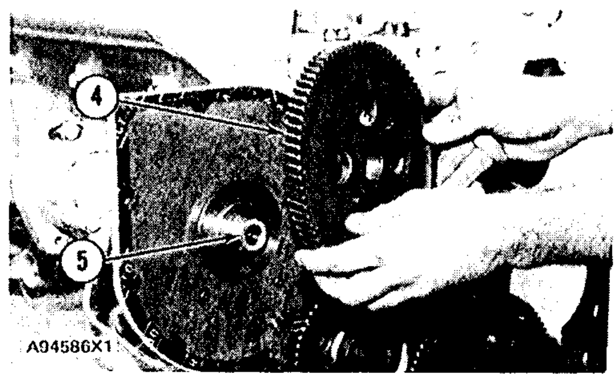
TIMING GEARS, TIMING GEAR PLATE

3. Put idler gear (2) in position on shaft (3). Put machined side of the plate toward the gear and fasten with two bolts.



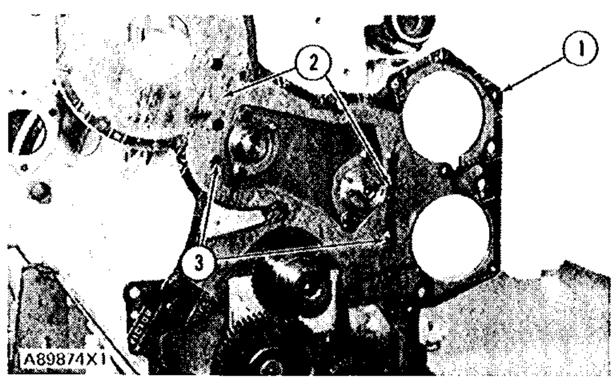
4. Put magneto drive gear (4) in position over magneto drive shaft (5). Install washer with the chamfered edge away from the gear and fasten with the bolt. Tighten the bolt to a torque of 110 ± 5 lb.ft. (149 ± 7 N·m).

   end by:
   a) install timing cover

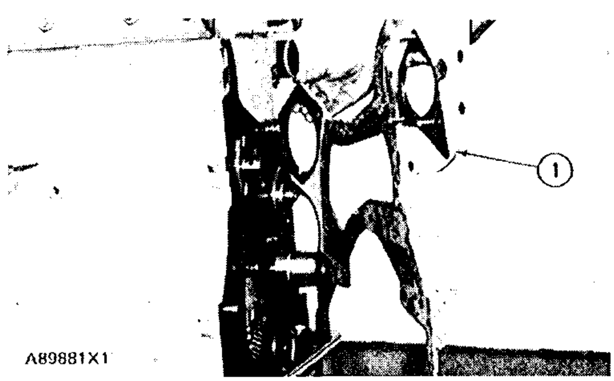


REMOVE AND INSTALL TIMING GEAR PLATE 1206-10

start by:
a) remove timing gears
b) remove magneto drive



1. Remove six bolts (3) and two locks (2) that hold the timing gear plate (1) to the cylinder block. Remove the timing gear plate and gasket.



A89881X1

2. Install timing gear plate (1) and gasket. Install the two locks (2) and six bolts (3).

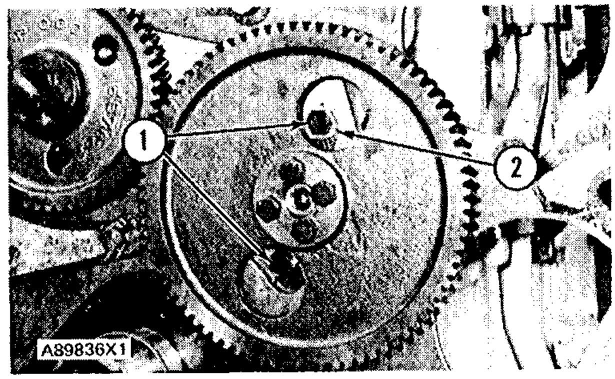
   end by:
   a) install timing gears
   b) install magneto drive

CAMSHAFT

REMOVE CAMSHAFT 1210-11

start by:
a) remove valve lifters
b) remove timing gear cover

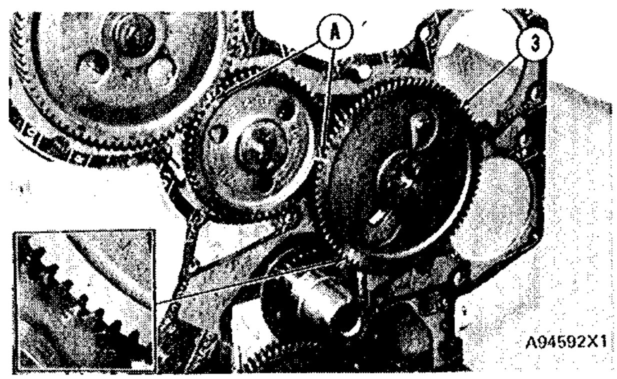
1. Bend lock (tabs) (2) and remove bolts (1).



2. Turn the crankshaft until the "C" mark on the crankshaft gear is in alignment with the "C" mark on the camshaft gear.

NOTE: To keep the engine timing correct during removal and installation of the camshaft, put a mark on the teeth of the idler gear, camshaft gear (3) and magneto drive gear at locations (A).

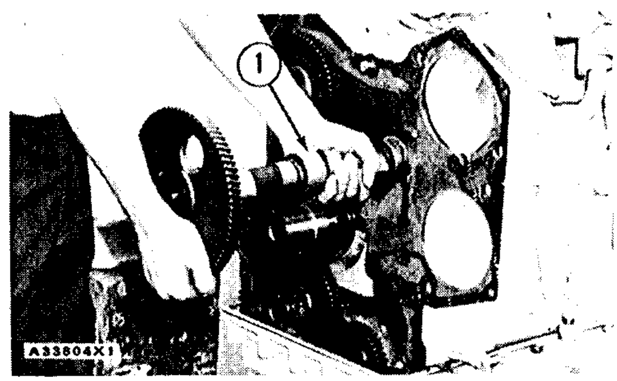
3. Remove the camshaft and gear. Do not cause damage to the lobes or bearings when the camshaft is removed.



4. Remove the bolts that hold the camshaft gear to the camshaft. Remove the camshaft gear (3).

INSTALL CAMSHAFT 1210-12

1. Install the camshaft drive gear on the end of the camshaft. Put clean SAE 30 oil on the lobes and bearing journals of the camshaft.

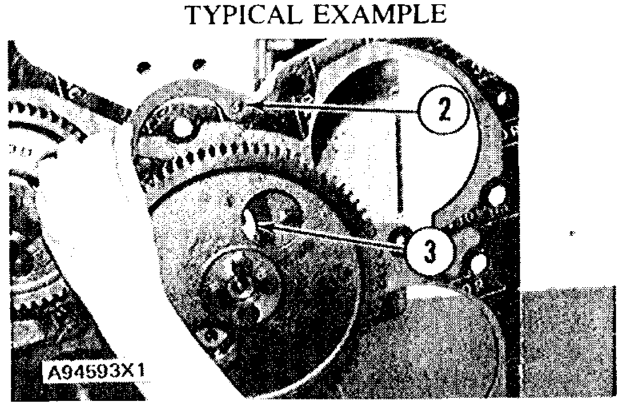


TYPICAL EXAMPLE

NOTICE

Do not cause damage to the lobes or bearing journals when the camshaft is installed.

2. Make an alignment of the "C" marks and marks put on during removal. Install camshaft (1) in the cylinder block.



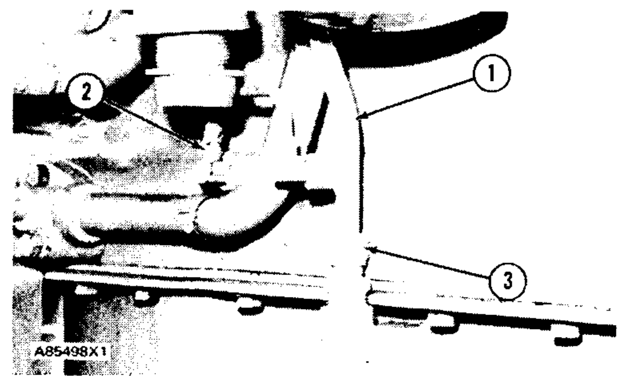
3. Install thrust washer (3), lock (2) and the bolts that hold the camshaft in place.
end by:
a) install valve lifters
b) install timing gear cover

OIL PAN

REMOVE OIL PAN 1302-11

NOTE: Photos shown are on 3306 engine.

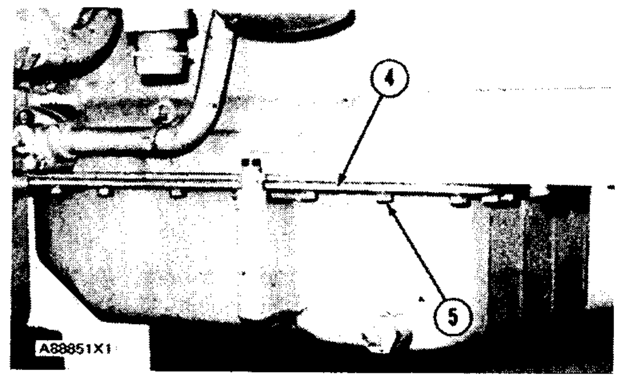
1. Drain the oil from the oil pan.



2. Remove the oil level gauge.

3. Disconnect tube (2) from the engine block.

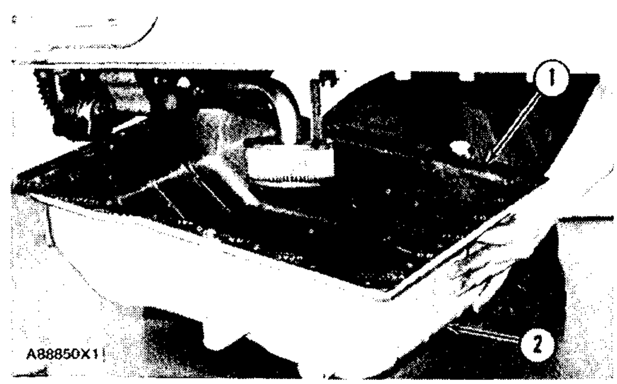
4. Disconnect nut (3) from the oil pan and remove tubes (1) and (2) as a unit.



5. Remove bolts (5) and washers that hold oil pan (4) in position and remove the oil pan. Remove the old gasket from the oil pan.

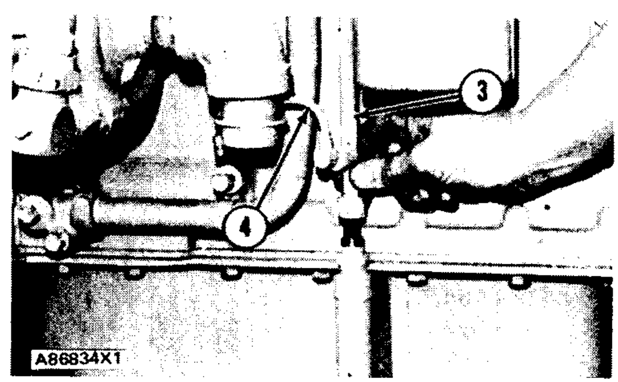
INSTALL OIL PAN 1302-12

1. Install a new gasket (1) on oil pan (2).



2. Put oil pan (2) in position on the engine and install the washers and bolts that hold it.

3. Connect oil gauge tube (3) and tube (4).



4. Fill the crankcase with oil to the correct level. See LUBRICATION AND MAINTENANCE.

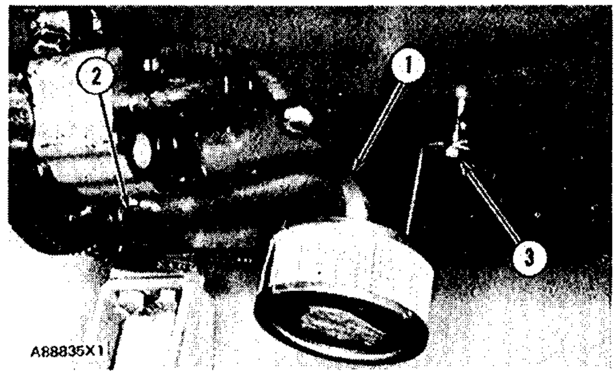
OIL PAN PLATE

REMOVE OIL PAN PLATE 1302-11

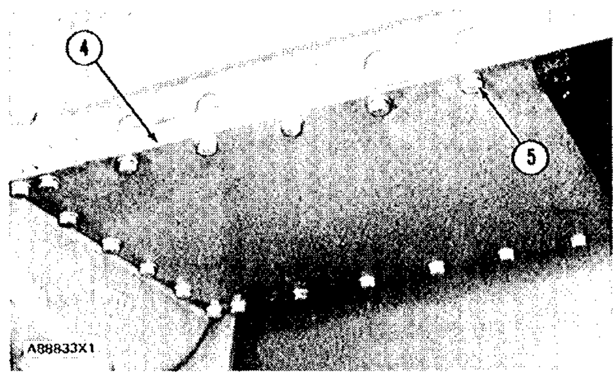
start by:
a) remove oil pan

NOTE: Photos shown are on 3306 engine.

1. Remove bolt (3) and lock. Remove bolts (2) and lock.



2. Remove suction bell and tube (1).

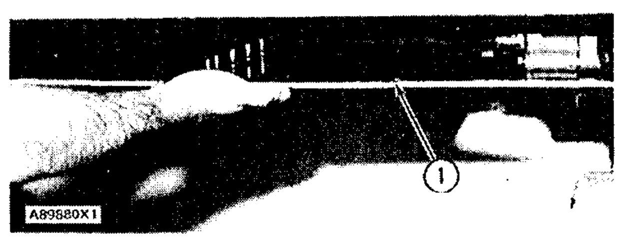


3. Remove the bolts (5) and washers that hold the oil pan plate to the cylinder block. Remove oil pan plate (4) and gasket.

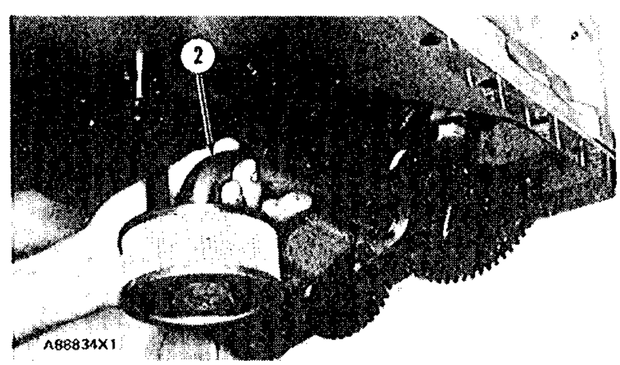
INSTALL OIL PAN PLATE 1302-12

NOTE: Photos shown are on 3306 engine.

1. Put a new gasket and oil pan plate (1) in position and install the bolts and washers that hold it to the cylinder block.



2. Put suction bell and tube (2) in position on the oil pump and install the locks and bolts that hold it in position.
end by:
a) install oil pan

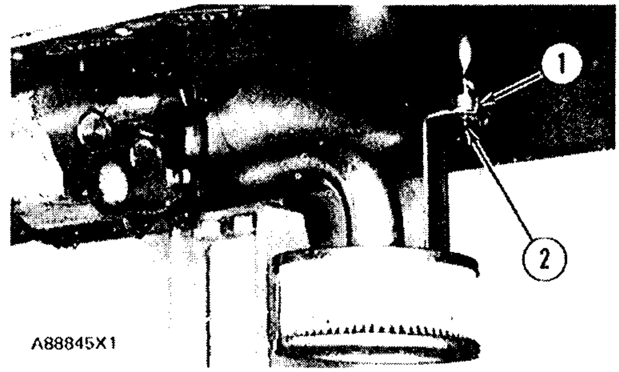


OIL PUMP

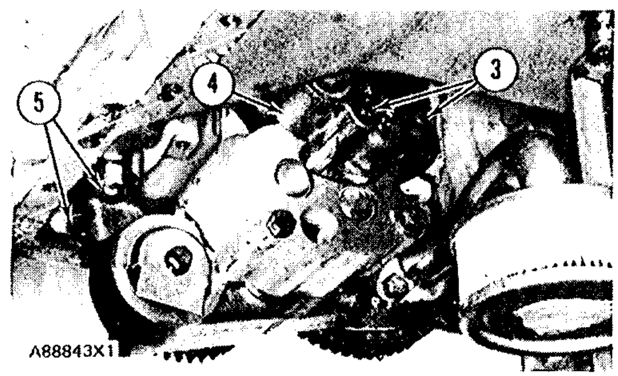
REMOVE OIL PUMP 1304-11

start by:
a) remove oil pan

NOTE: Photos shown are on 3306 engine. Do Step 1 for 3306 only.



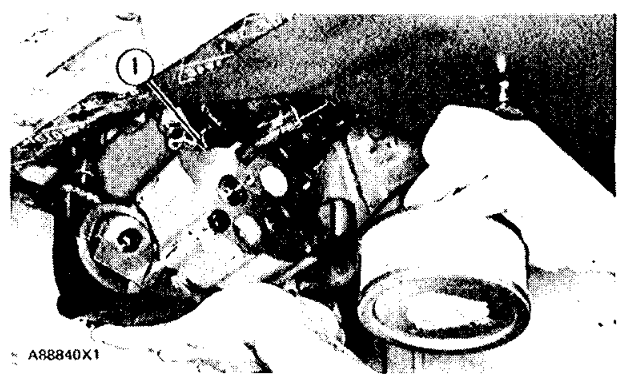
1. Bend the tab on lock (1) away from bolt (2). Remove bolt (2).



2. Remove bolts (3) and disconnect tube assembly (4) from the oil pump.

3. Bend the tabs on the locks away from the bolt and remove the four bolts (5) that hold the oil pump to the cylinder block.

4. Remove the oil pump.

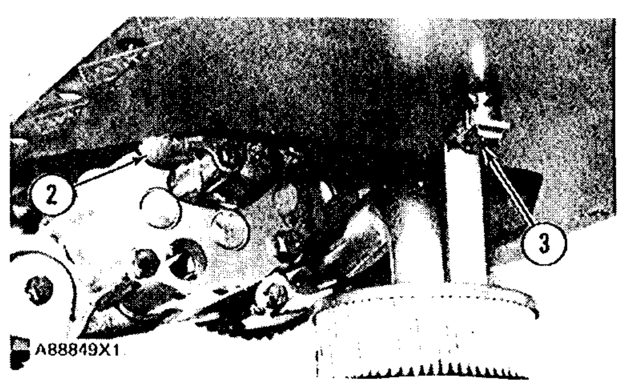


INSTALL OIL PUMP 1304-12

1. Put oil pump (1) in position on the cylinder block and install the locks and bolts that hold it in place.

2. Install gasket and connect tube assembly (2) to the oil pump.

NOTE: Do Step 3 for 3306.



3. Install lock and bolt (3) that hold the suction bell to the oil pan plate.
end by:
a) install oil pan

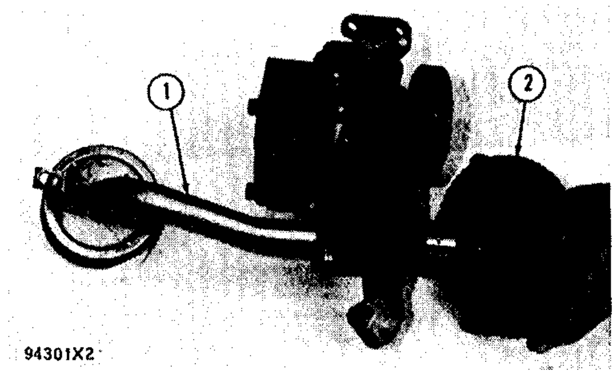
OIL PUMP

DISASSEMBLE OIL PUMP 1304-15

	Tools Needed	A	B	C
1P2320	Puller Assembly	1		
8B7560	Step Plate	1		
1P529	Handle		1	1
1P468	Drive Plate		1	
1P465	Drive Plate		1	
1P462	Drive Plate			1
1P461	Drive Plate			1

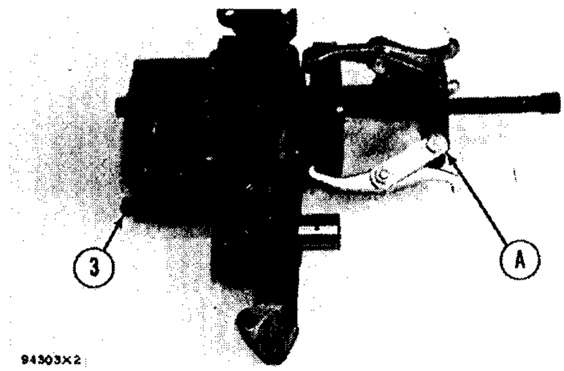
start by:
a) remove oil pump

NOTE: Photos shown are on 3306 engine.



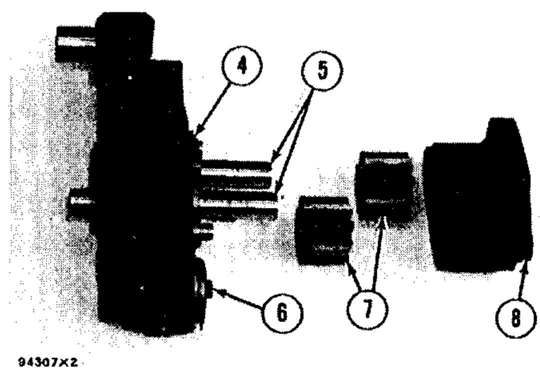
1. Remove idler gear (2). Remove bearing from gear with tooling (B).

2. Remove suction bell (1).



3. Remove the bolt and the washer from the oil pump drive gear.

4. Remove the drive gear from the shaft with tooling (A).

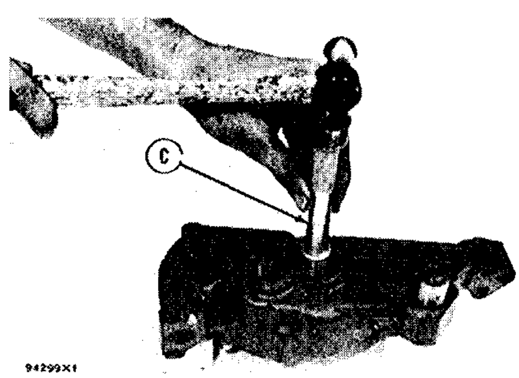


5. Remove the key from the pump shaft.

6. Remove bolts (3) from the pump body.

7. Remove body (8), two gears (7), keys and spacer (4) from the pump.

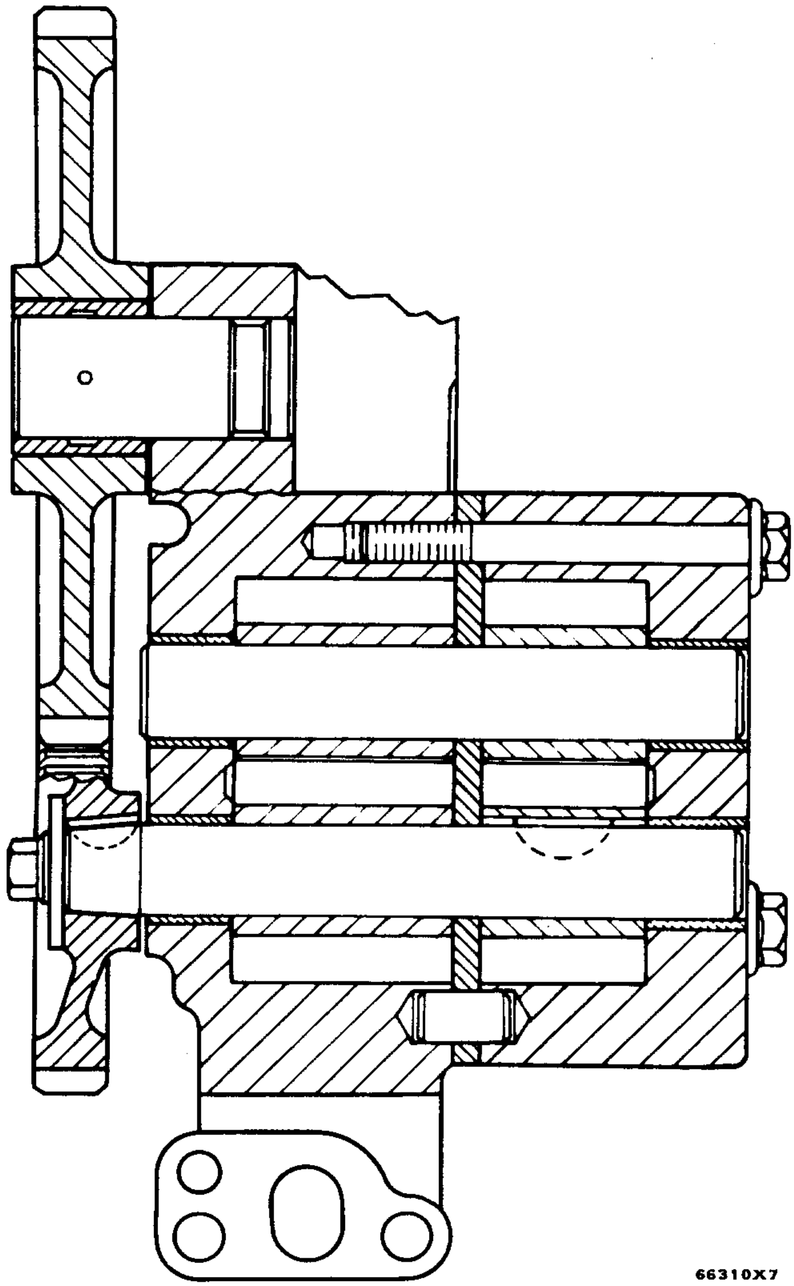
8. Remove two shafts (5) and the gears.



9. Remove bolts (6), the cover and the pressure relief valve from the body.

10. Remove the bearings from the oil pump body assembly and the scavenge pump body assembly with tooling (C).

OIL PUMP



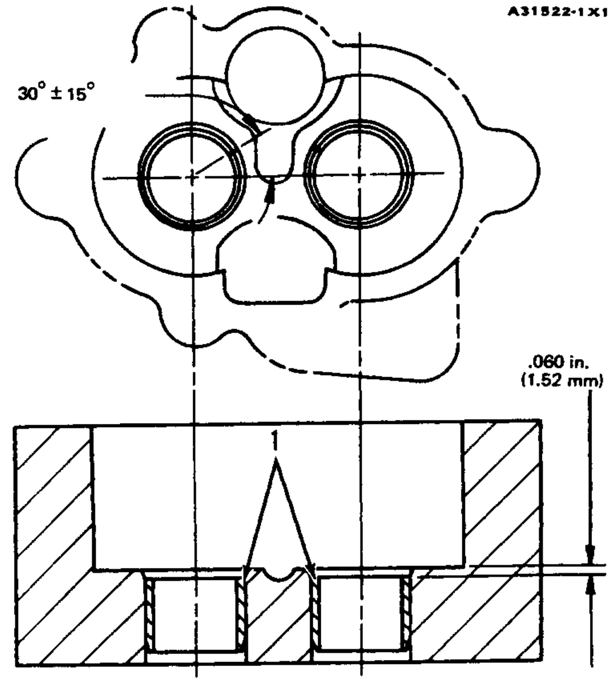
66310X7

OIL PUMP

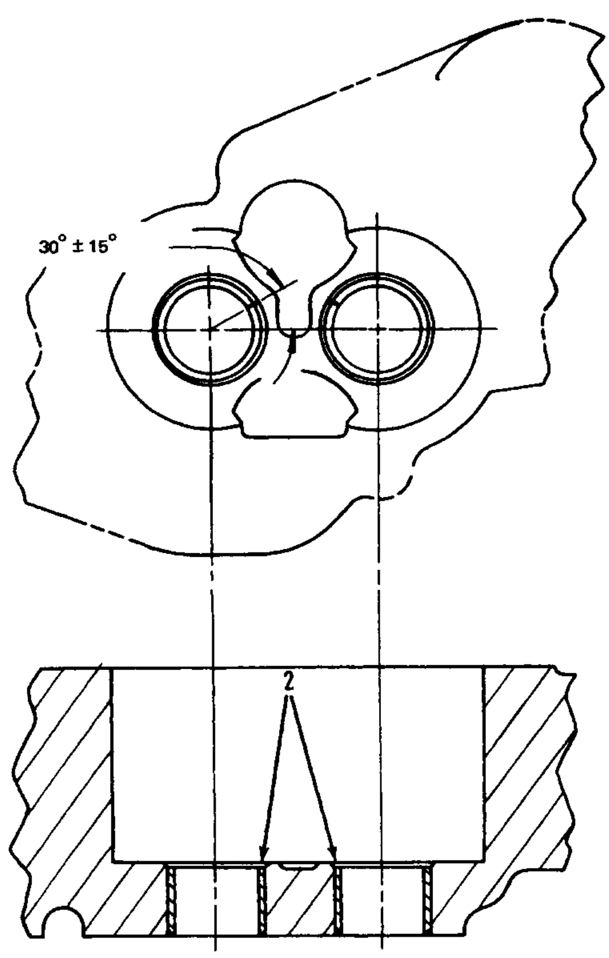
ASSEMBLE OIL PUMP 1304-16

	Tools Needed	A	B
1P529	Handle	1	1
1P461	Drive Plate	1	
1P462	Drive Plate	1	
1P465	Drive Plate		1
1P468	Drive Plate		1

1. Install the bearings in the scavenge pump body assembly with tooling (A) as follows:
   a) Put bearings (1) in position on the inside of the scavenge pump body assembly with the chamfer on the bearing toward the outside of the pump body. Install the bearing until it is .060 in. (1.52 mm) below the inside machined surface of the scavenge pump body assembly. Make sure the joints in the bearings are at an angle of 30° ± 15° from the center line through the bores in the scavenge pump body and toward the outlet passage of the pump. The outlet passage has a cavity between the bearing bores.



2. Install the bearings in oil pump body assembly with tooling (A) as follows:
   a) Put bearings (2) in position on the inside of the oil pump body assembly with the chamfer on the bearings toward the outside of the pump body. Install the bearings until they are even with the outside of the pump body. Make sure the joints in the bearings are at an angle of 30° ± 15° from the centerline through the bearing bores and toward the outlet passage of the pump. The outlet passage has a cavity between the bearing bores.



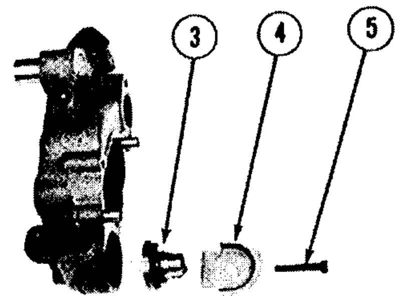
3. Check the condition of the relief valve. Check the condition and specifications for all the parts of the oil pump before it is assembled. See OIL PUMP (2P1785) in SPECIFICATIONS.

OIL PUMP

4. Put clean engine on all of the parts of the oil pump.

5. Install pressure relief valve (3), cover (4) and bolt (5) in the oil pump body assembly.

6. Install gears and shafts (6) in the oil pump body assembly.

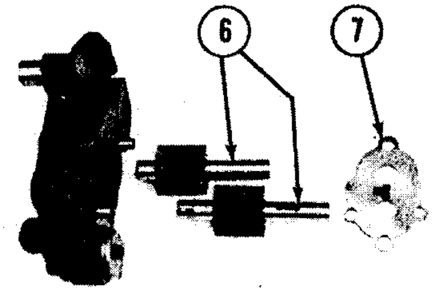


94308X3

7. Install spacer (7) and the two keys in shafts (6).

8. Install two gears and scavenge pump body assembly (8).

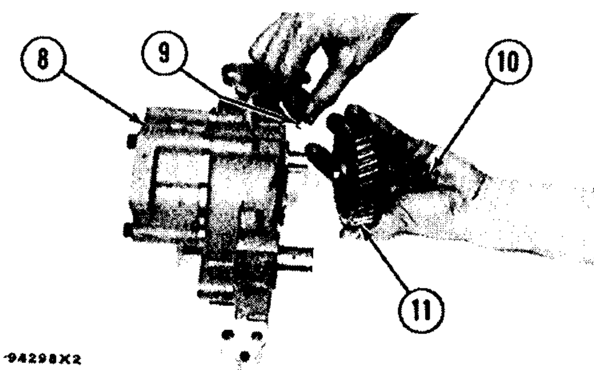
9. Install key (9), drive gear (11), the washer and bolt (10). Tighten the bolt to a torque of 32 ± 5 lb.ft. (43 ± 7 N·m).



94302X3

10. Install the bearing in the idler gear with tooling (B) until it is even with the outside surface of the gear.

11. Install the idler gear.



94298X2

NOTICE
Before installation, lubricant must be in the oil pump and it must turn freely.

end by:
a) install oil pump

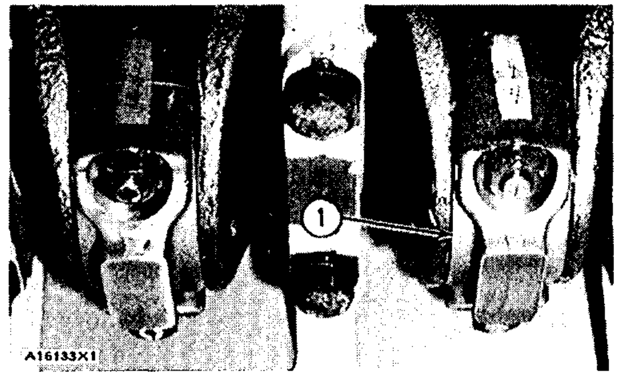
CONNECTING ROD BEARINGS

REMOVE AND INSTALL CONNECTING ROD BEARINGS 1219-10

Tools Needed	A
Plastigage	•

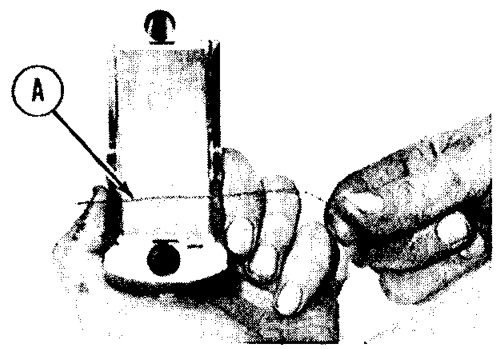
start by:
a) remove oil pan plate
b) remove oil pump

1. Turn the crankshaft until two pistons are at bottom center. Remove connecting rod caps (1) from the two connecting rods. Remove the lower half of the bearings from the caps.



A16133X1

2. Push the connecting rods away from the crankshaft and remove the upper half of the bearings.
3. Clean the surfaces where the bearings fit. Install the upper half of the new bearings in the rods. Put the connecting rods in position on the crankshaft.
4. Clean the surfaces where the bearings fit. Install the lower half of the new bearings in the caps.

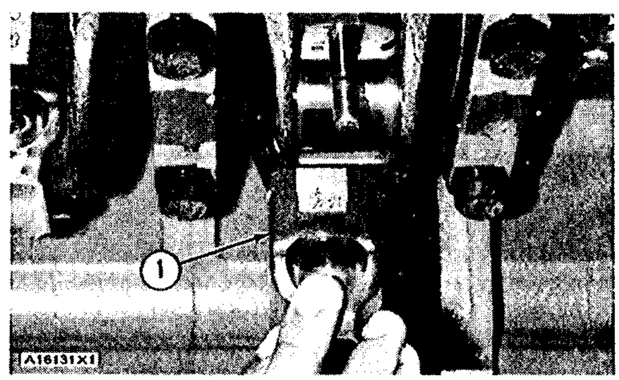


A06678X1

NOTICE

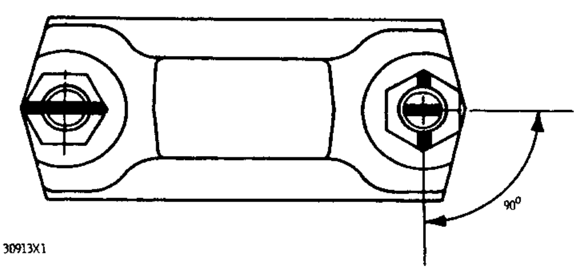
When the connecting rods caps are installed, make sure the number on the side of the cap is next to and respective with the number on the side of the connecting rod.

5. Check the bearing clearance with plastigage (A). Put caps (1) in position on the connecting rods and install the nuts. Tighten the nuts to a torque of 30 ± 3 lb.ft. (40 ± 4 N·m). Put a mark on each nut and the end of each bolt. Tighten the nuts 90° more.



A16131X1

6. Remove the cap. Measure the thickness of the Plastigage. The rod bearing clearance (Plastigage thickness) must be .0030 to .0066 in. (0.076 to 0.168 mm)with new bearings. The maximum permissible clearance is .010 in. (0.25 mm) with used bearings.
7. Put clean engine oil on the bearings, crankshaft journals, bolt threads and contact surfaces of the nuts.
8. Put the caps in position on the connecting rods and install the nuts. Tighten the nuts to a torque of 30 ± 3 lb.ft. (40 ± 4 N·m). Put a mark on each nut and the end of each bolt. Tighten the nuts 90° more.



30913X1

9. Do Steps 1 through 7 again for the other bearings.

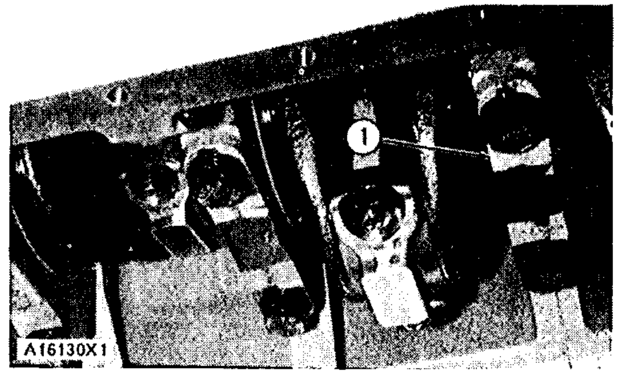
end by:
a) install oil pump
b) install oil pan plate

CRANKSHAFT MAIN BEARINGS

REMOVE AND INSTALL CRANKSHAFT MAIN BEARINGS 1203-10

	Tools Needed	A	B	C
1P5518	Main Bearing Removal Tool	1		
	Plastigage		*	
8S2328	Dial Test Indicator Group			1

start by:
a) remove oil pump
b) remove oil pan plate

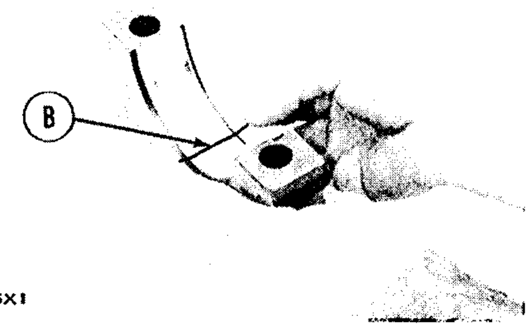


1. Remove the odd number main bearing caps (1) of the crankshaft.

2. Remove the upper halves of main bearings as crankshaft is turned and bearing is moved out of the cylinder block with tool (A). Remove lower halves (2) of main bearings from caps.

3. Put upper halves of main bearings into place with tool (A).

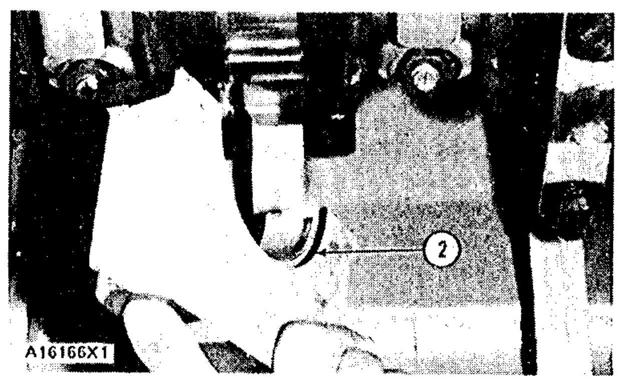
4. Clean the main bearing caps, and install lower halves of bearings in caps.



A16165X1

NOTE: Make sure the crankshaft is held up against the upper main bearings with a force equal to the weight of the crankshaft.

5. Check the bearing clearance with Plastigage (B). Install caps and turn bolts to a torque of 30 ± 3 lb.ft. (40 ± 4 N·m). Put a mark on both bolt heads and bearing caps, then turn each bolt 90° more. Remove the bearing caps, and measure thickness of Plastigage. Main bearing clearance with new bearings must be .0030 to .0065 in. (0.076 to 0.165 mm). Maximum permissible clearance with used bearings is .010 in. (0.025 mm).



6. Put clean engine oil on threads of cap bolts, face of washers and upper and lower halves of main bearings. Put the caps (1) in position on engine with number on cap in direction of respective number on pan face on left side of cylinder block. Install bolts and washers. Turn both bolts to a torque of 30 ± 3 lb.ft. (40 ± 4 N·m). Put a mark on both bolt heads and bearing caps, then turn both bolts 90° more.

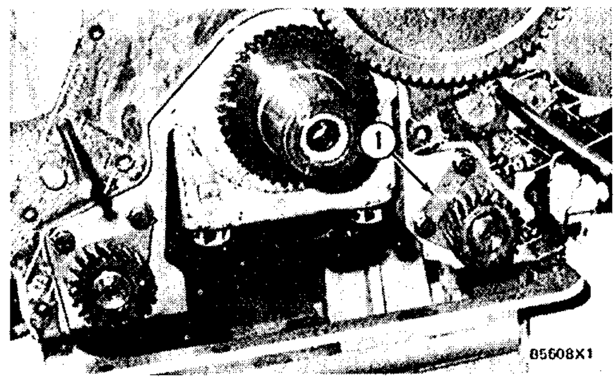
7. Remove the even number main bearing caps. Remove the crankshaft thrust bearings. Put clean engine oil on the new thrust bearings and install them in cylinder block with the tab in the machined area in the cylinder block.

8. Do Step 2 through Step 6 for the remainder of the bearings. Check crankshaft end play with indicator group (C). End play with new bearings must be .0025 to .0145 in. (0.064 to 0.368 mm). Maximum permissible end play with used bearings is .025 in. (0.64 mm).
end by:
a) install oil pan plate
b) install oil pump

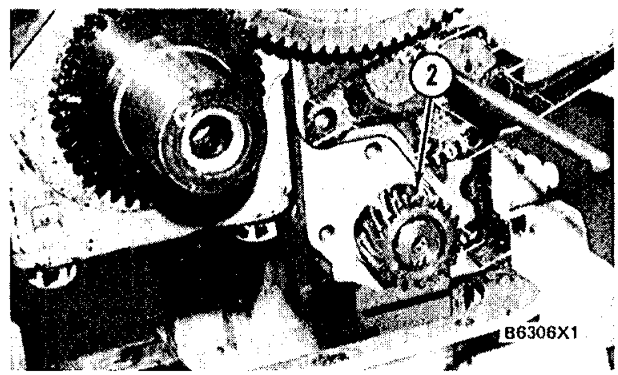
BALANCER SHAFTS (3304)

REMOVE BALANCER SHAFTS (3304) 1220-11

start by:
a) remove timing gear cover
b) remove oil pump



1. Put the engine on top cneter compression stroke. See FINDING TOP CENTER COMPRESSION POSITION FOR NO. 1 PISTON in TESTING AND ADJUSTING.

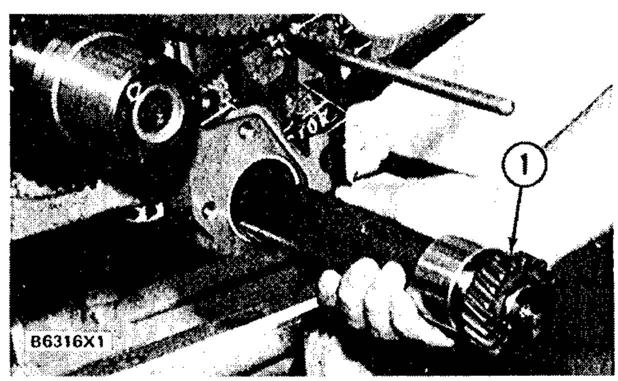


2. Remove bolts, lock and washer (1) that hold the balancer shafts in the cylinder block.

3. Remove balancer shaft (2) from the cylinder block.

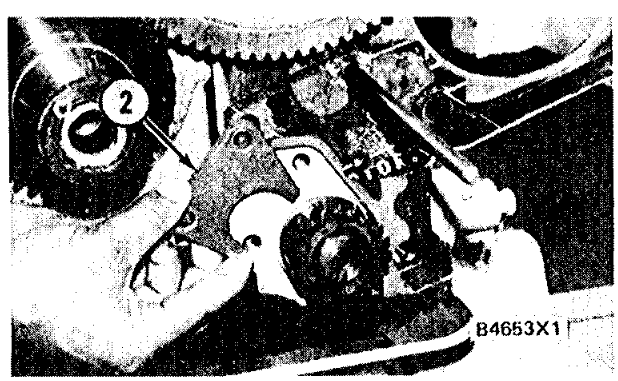
INSTALL BALANCER SHAFTS (3304) 1220-12

1. Put clean engine oil on the balancer shaft. Put balancer shaft (1) in position in the cylinder block. Install washer (2), locks and bolts.



2. Turn both balancer shafts until the flat part on each shaft is away from the oil pan plate. Install two 3/8"-16 NC bolts 1 ½" long through the oil pan plate and into the holes in the balancer shafts. This will make the shafts so they will not turn. Do not tighten the bolts against the bottom of the holes in the shafts.

3. Install oil pump. See INSTALL OIL PUMP.



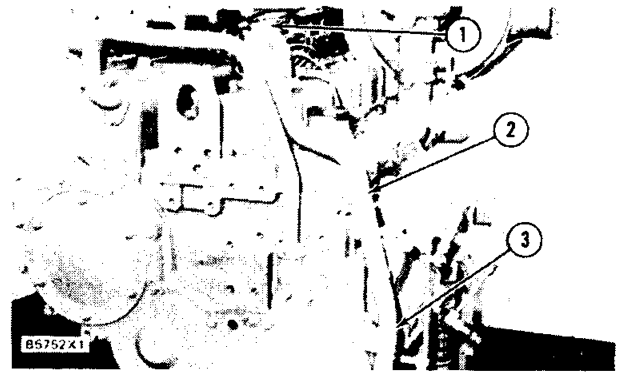
4. Remove the two 3/8"-16 NC bolts from the balancer shafts. Check to see that the balancer shaft timing is correct. The balancer shaft timing is correct when the holes in the balancer shafts are in alignment with the holes in the oil pan plate, and No. 1 piston is at the top center compression position.

end by:
a) install timing gear cover
b) install oil pan

VALVE COVER

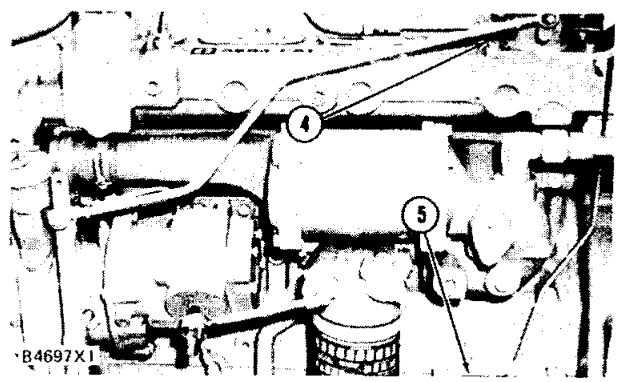
REMOVE VALVE COVER 1107-11

NOTE: Photos shown are on 3304 engine.



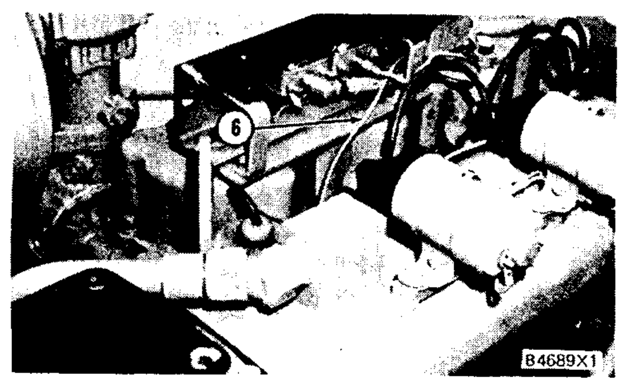
1. Remove bolt (1) and washer that hold breather assembly (2) in place.

2. Remove bolt from clip (3) on the water pump cover.



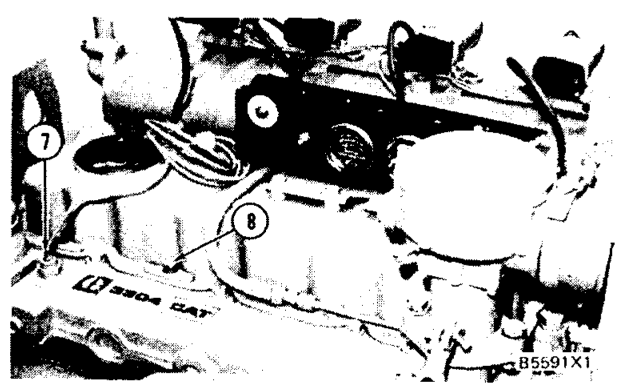
NOTE: Do Steps 3, 4 and 5 only for 3304 engine.

3. Remove bolt from clip (4) and disconnect oil line (5) at the cylinder block.



4. Disconnect wire (6), which is fastened to the magneto and the stop switch, at the stop switch on the instrument panel.

5. Remove the water temperature sending unit (7) from the cylinder head.



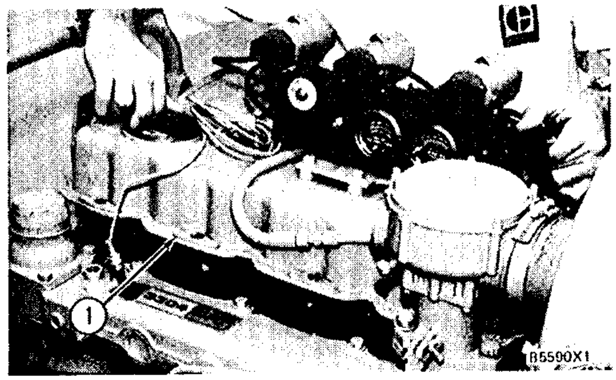
6. Remove bolts (8) and washers from the valve cover.

7. Remove the valve cover and gasket from the cylinder head.

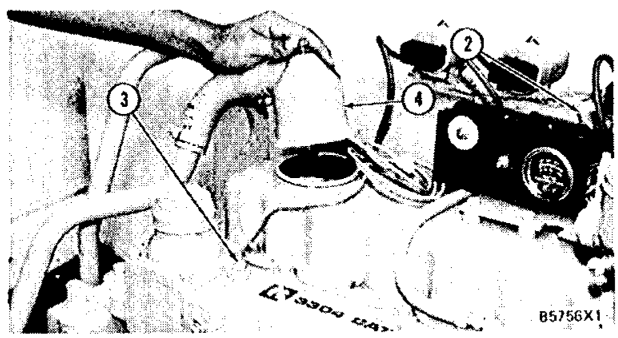
VALVE COVER

INSTALL VALVE COVER 1107-12

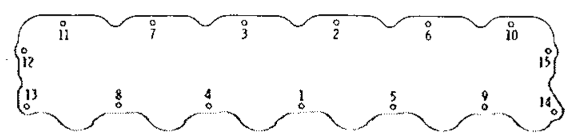
NOTE: Photos shown are on 3304 engine.



1. Install a new valve cover gasket if necessary. Put 5H2471 Cement on gasket and valve cover during installation of new gasket.

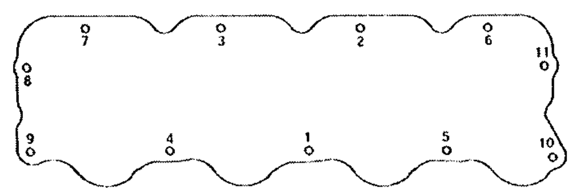


2. Put valve cover (1) in position on the cylinder head and install the bolts. Tighten bolts to a torque of 96 ± 24 lb.in. (10.9 ± 2.8 N·m) in the number sequence shown in illustrations.



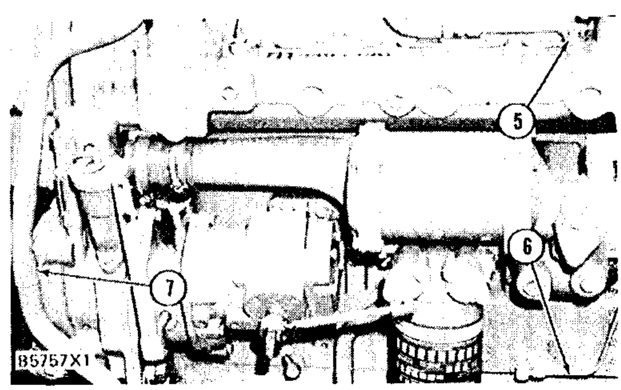
T98227

3. Connect wire (2) to the stop switch. Install water temperature sending unit (3) in the cylinder head.



T98226

4. Install the bolt and washer that hold breather assembly (4) in place. Tighten the bolt to a torque of 120 ± 24 lb.in. (13.6 ± 2.8 N·m).



5. Install bolt in clip (5) on the oil pressure line. Connect oil pressure line (6) to the cylinder block.

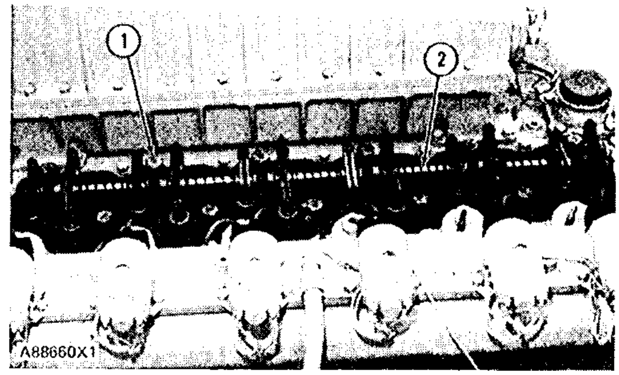
6. Install clip (7) and bolt on the breather assembly tube.

ROCKER SHAFT AND PUSH RODS

REMOVE ROCKER SHAFT AND PUSH RODS 1102 & 1208-11

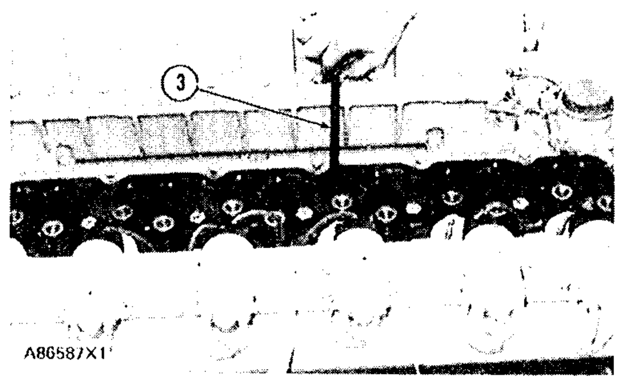
start by:
a) remove valve cover

NOTE: Photos shown are on 3306 engine.



1. Loosen bolts (1) evenly and remove the bolts and washers that hold the rocker shaft in position.
2. Remove rocker shaft (2).
3. Remove the O-ring seal from rear support bracket.

NOTE: A replacement of the O-ring seal must be made each time the head bolt is removed from the rear support bracket.



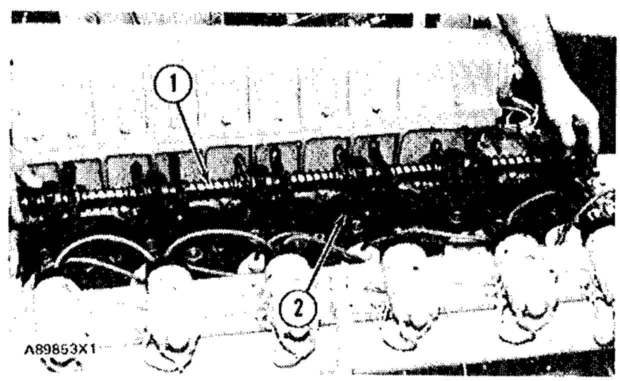
4. Remove push rods (3).

INSTALL ROCKER SHAFT AND PUSH RODS 1102 & 1208-12

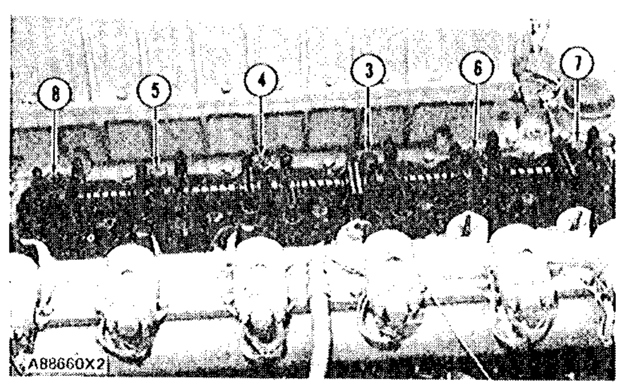
1. Install the push rods (2).

NOTICE

Make an alignment of the dowels in the brackets on each end of the rocker shaft with the holes in the cylinder head.



2. Install a new O-ring seal in the rear support bracket of rocker shaft.
3. Put rocker shaft (1) in position on the cylinder head.
4. Put 2P2506 Anti-Seize Compound on the threads of the bolts that hold the rocker shaft in position.
5. Install the six bolts (four bolts on 3304) and washers that hold the rocker shaft in position.

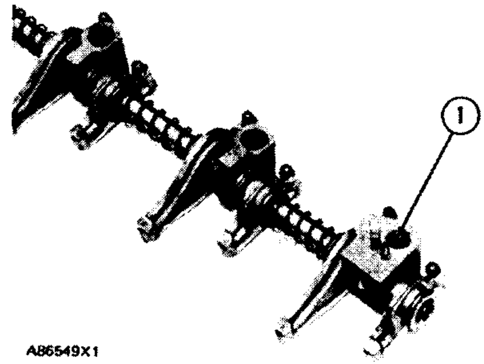


6. Tighten all bolts (3), (4), (5), (6), (7) and (8) in number sequence to a torque of 115 lb.ft. (156 N·m). Tighten four cylinder engine bolts to same torque and in same sequence. Tighten bolts again in number sequence to a torque of 185 ± 13 lb.ft. (250 ± 17 N·m). Last, tighten the bolts again by hand in number sequence to a torque of 185 ± 13 lb.ft. (250 ± 17 N·m).
7. Adjust the intake valves to a clearance of 0.15 in. (0.38 mm) and the exhaust valves to a clearance of .030 in. (0.76 mm). Tighten the locknut on the valve adjustment screw to a torque of 21 ± 5 lb.ft. (26 ± 7 N·m).

ROCKER SHAFT

DISASSEMBLE ROCKER SHAFT 1102-15

start by:
a) remove rocker shaft and push rods



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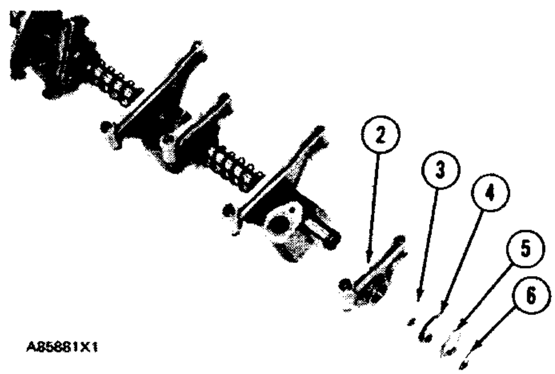
1. Remove O-ring seal (1) from the rear support bracket.

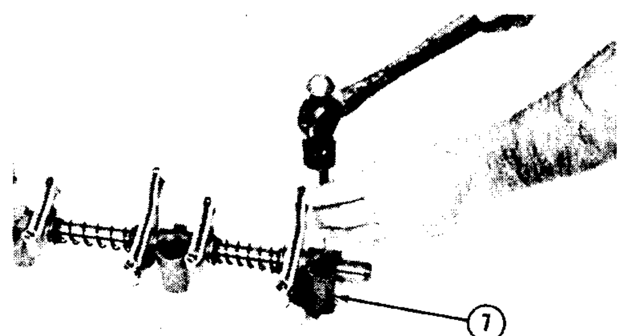
NOTE: A replacement of the O-ring seal must be made each time the head bolt is removed from the rear support bracket.



A85881X1

2. Remove retainer ring (6), washer (5), spring (4) and washer (3) from each end of rocker shaft. Remove rocker arm (2).

3. Remove pin from rear support bracket with a hammer and punch. Remove rear support bracket (7) from shaft.



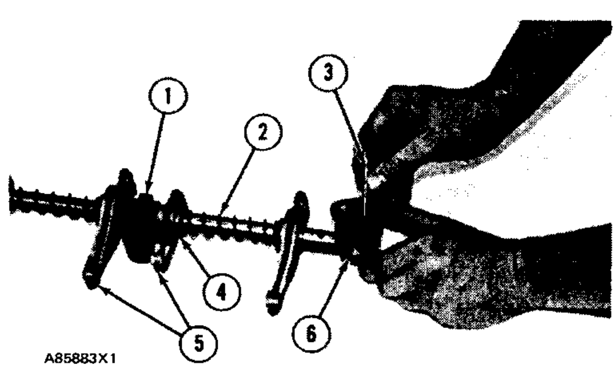
A85882X1

4. Remove the remainder of rocker arms, springs, washers and brackets.

5. Remove plugs from each end of the shaft if necessary.

ASSEMBLE ROCKER SHAFT 1102-16

1. Install rocker arms (5), brackets (1), washers (4) and springs (2) on the rocker shaft.



A85883X1

2. Install rear support bracket (6) on rocker shaft. Make sure hole in rear support bracket is in alignment with hole in rocker shaft.

3. Put pin (3) in position in the bracket.

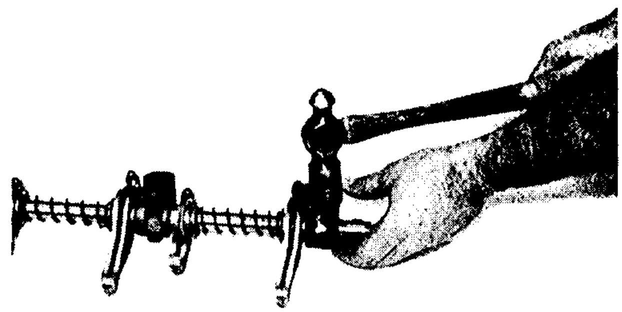
ROCKER SHAFT, EXHAUST MANIFOLD

4. Install pin (3) through bracket and shaft with a hammer.

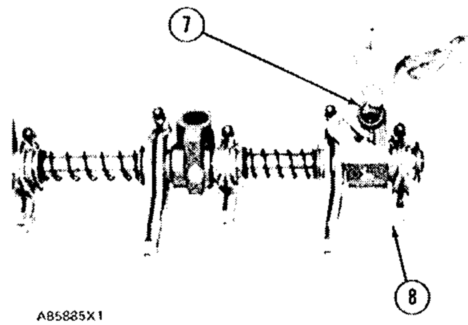
5. Pin (3) must extend .378 in. (9.60 mm) above the bracket.

6. Install O-ring seal (7) in the rear support bracket. Install rocker arm (8), washer, spring, washer and retainer ring on the rocker shaft.

7. Install the plugs in each end of the rocker shaft if they were removed.
   end by:
   a) install rocker shaft and push rods



A85884X1



A85885X1

REMOVE EXHAUST MANIFOLD 1059-11

start by:
a) remove turbocharger (3306)

NOTE: Photos shown are on 3306 engine.

1. Drain the coolant from the engine cooling system.

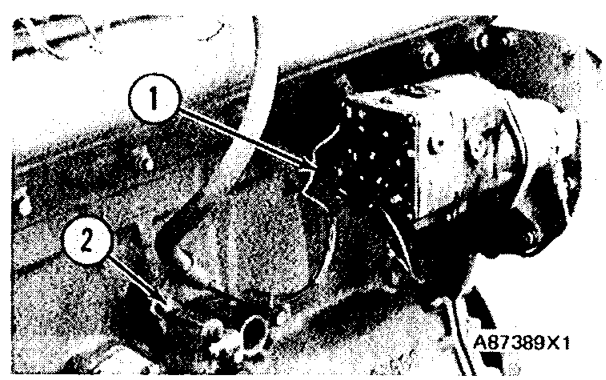
2. Put identification on each wire and screw on the magneto. Remove wires (1) from the magneto.

3. Remove bolt (2) and washer that hold the clip in place.

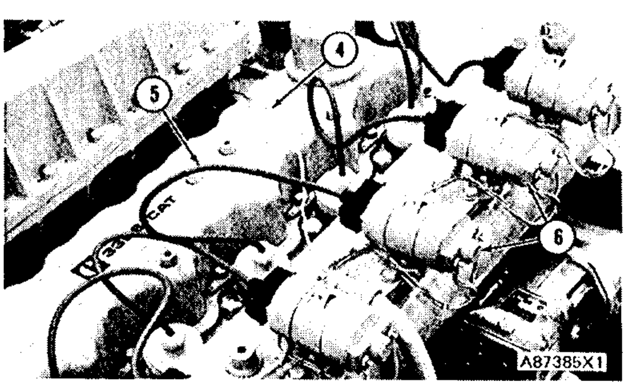
4. Remove tube (3) from the exhaust manifold.

5. Disconnect wire (4) from the reset switch on the instrument panel.

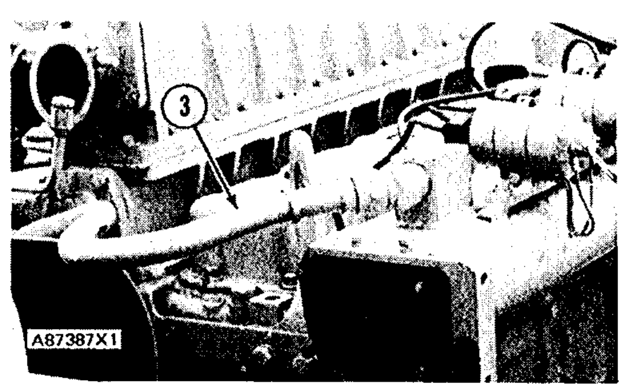
6. Remove spark plug wires (5) from the transformers.



A87389X1



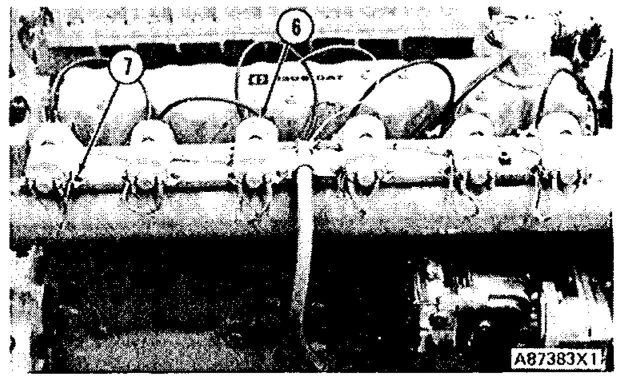
A87385X1



A87387X1

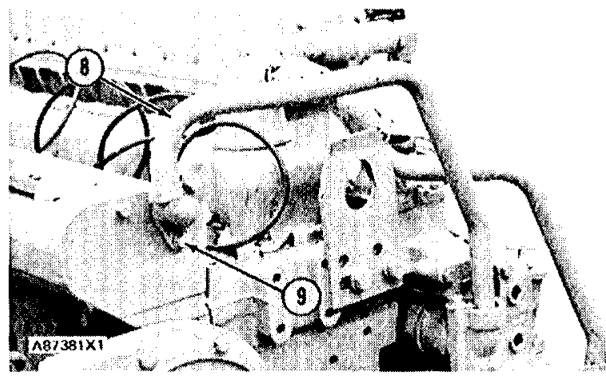
EXHAUST MANIFOLD

7. Remove bolts (7) that hold transformers (6) in place.



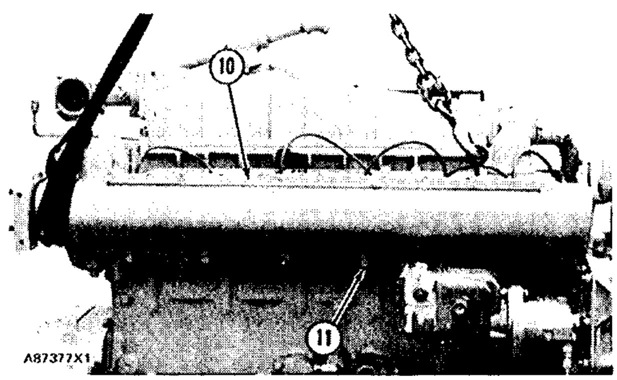
8. Remove the transformers and wiring as a unit.

9. Remove bolts (9) and washers that hold tube (8) in place. Disconnect tube (8) from the exhaust manifold.



10. Install a 5/16"-18 NC forged eyebolt in the exhaust manifold as shown. Fasten a hoist to a nylon strap and the eyebolt as shown.

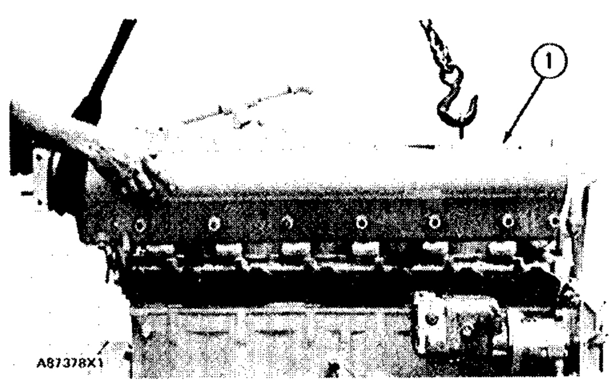
11. Remove bolts (11). Remove the exhaust manifold (10) and gaskets. Weight of the exhaust manifold is 94 lb. (43 kg) on the 3306. The weight on the 3304 is 90 lb. (41 kg).



INSTALL EXHAUST MANIFOLD 1059-12

NOTE: Photos shown are on 3306 engine.

1. Install a 5/16"-18 NC forged eyebolt in the exhaust manifold as shown. Fasten a hoist to a nylon strap and the eyebolt as shown.

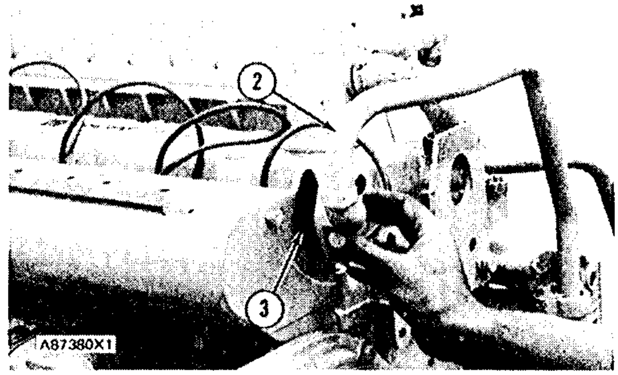


2. Put the gaskets and exhaust manifold (1) into position on the cylinder head.

3. Put 5P3931 Anti-Seize Compound on the threads of the bolts that hold the exhaust manifold in place. Install the exhaust manifold bolts.

EXHAUST MANIFOLD

4. Put gasket (3) in position and connect tube (2) to the exhaust manifold.

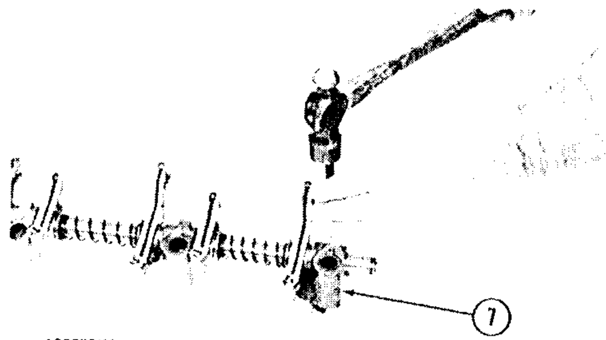


A87380X1

5. Install the transformers (4) and wiring on the exhaust manifold.

6. Connect wire (6) to the reset switch on the instrument panel.

7. Connect the spark plug wires (5) to the transformers.

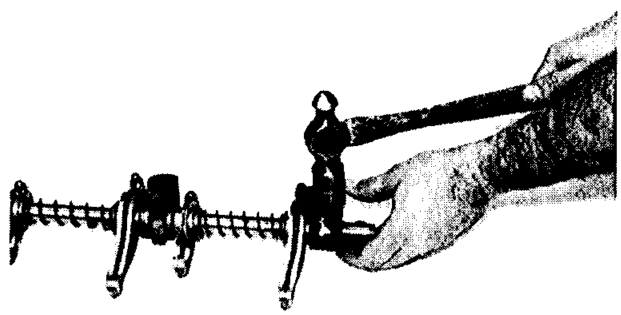


A85882X1

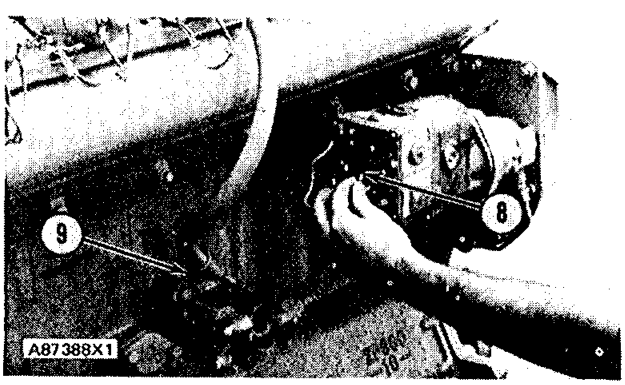
8. Put tube (7) into position and fasten to the fittings on the exhaust manifold and oil cooler.

9. Fasten clip (9) to the engine block.

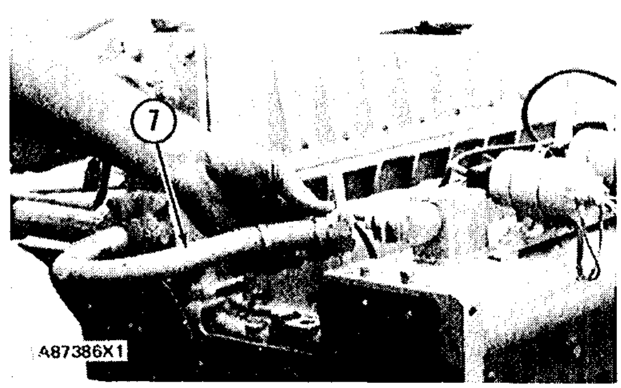
10. Connect wires (8) to the magneto.


A85884X1

11. Fill the cooling system with coolant to the correct level.
    end by:
    a) install turbocharger (3306)



A87388X1



A87386X1

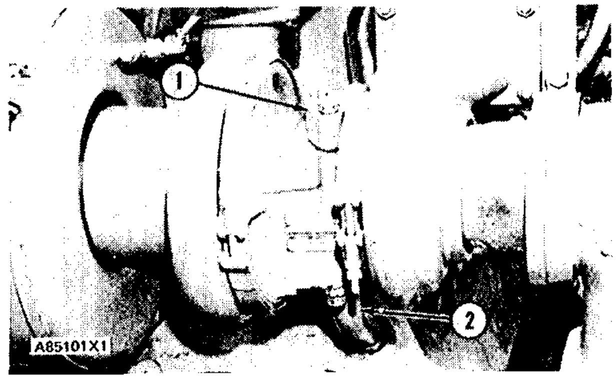
CYLINDER HEAD ASSEMBLY (3306)

REMOVE CYLINDER HEAD ASSEMBLY (3306) 1100-11

	Tools Needed	A
8S9906	Ratchet Puller	1

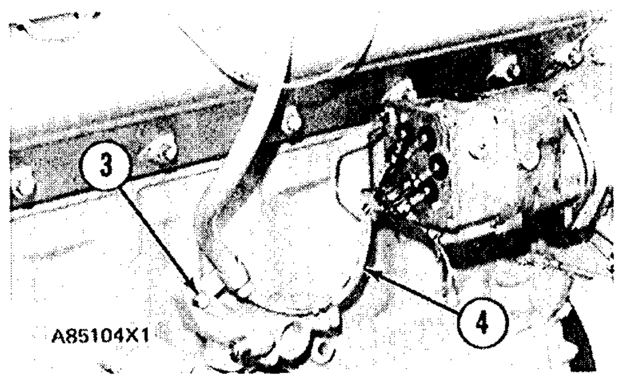
start by:
a) remove rocker shaft and push rods

1. Drain the coolant from the cooling system.



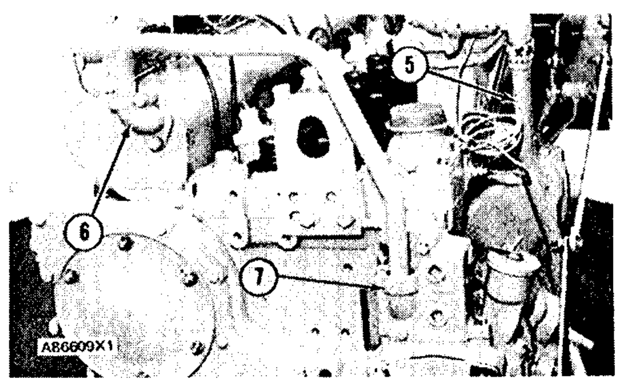
2. Remove oil supply line (1) and oil drain line (2) from the turbocharger.

3. Put identification on each wire and screw on the magneto.



4. Remove bolt (3) and disconnect wires (4) from the magneto.

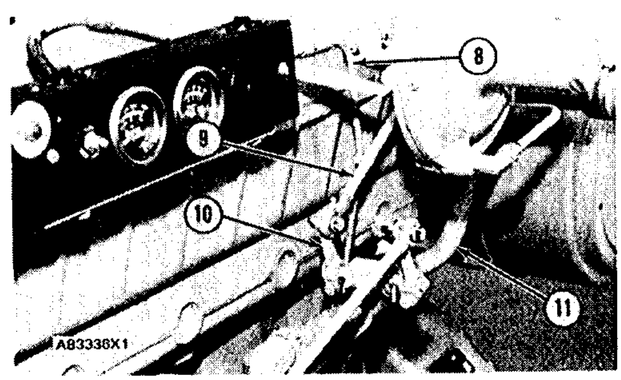
5. Remove tube (5) from the aftercooler to the auxiliary water pump.



6. Remove tube (6) and water pump elbow (7).

7. Disconnect carburetor control rod (9) from lever (10).

8. Remove oil pressure sensing line (8).



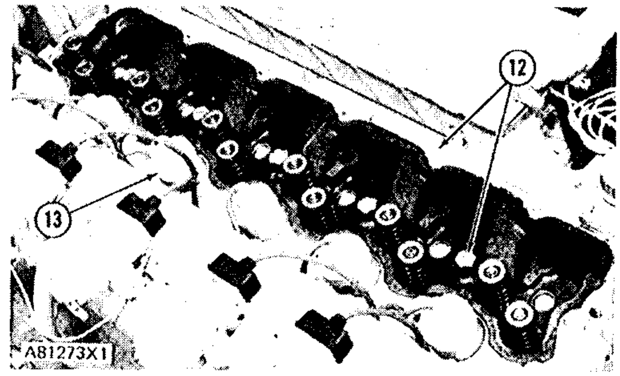
9. Disconnect tube (11) from the engine oil cooler.

10. Disconnect gas supply line to gas pressure regulator.

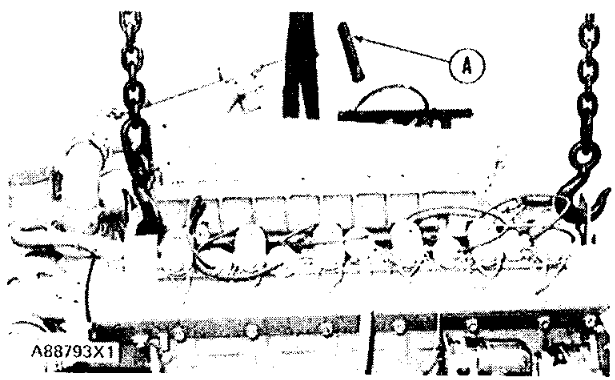
CYLINDER HEAD ASSEMBLY (3306)

11. Remove covers (13) from the spark plugs and adapters.

12. Remove bolts (12) that hold the cylinder head assembly to the cylinder block.



13. Fasten a hoist to the cylinder head assembly. Fasten tool (A) to the gas pressure regulator bracket and the hoist to give balance to the head assembly.



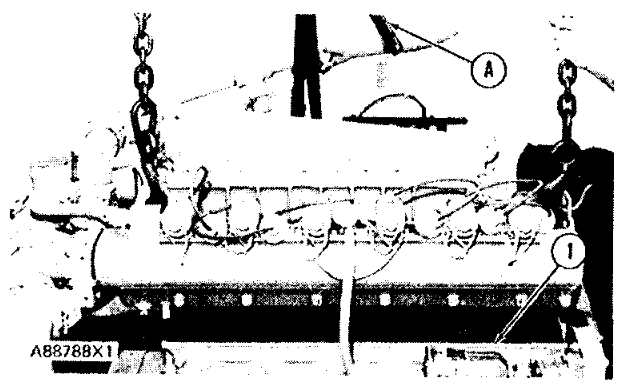
14. Remove the head assembly. The weight of the cylinder head assembly is 510 lb. (229.5 kg).
15. Remove the cylinder head gasket.

INSTALL CYLINDER HEAD ASSEMBLY (3306) 1100-12

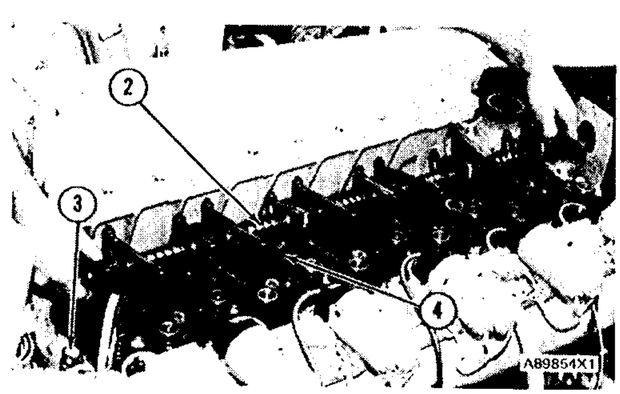
	Tools Needed	A
8S9906	Ratchet Puller	1

1. Thoroughly clean the spacer plate and bottom surface of the cylinder head that make contact with the cylinder head gasket.

NOTE: Be sure a new gasket has been installed between spacer plate and cylinder block. See INSTALL SPACER PLATE.



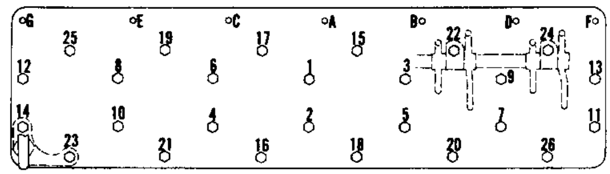
2. Put a new cylinder head gasket (1) in position on the cylinder block. Make sure the holes in the cylinder head gasket are in alignment with the holes in the cylinder block.
3. Fasten a hoist to the cylinder head assembly. Fasten tool (A) to the gas pressure regulator bracket and the hoist. The weight of the cylinder head assembly is 510 lb. (229.5 kg).
4. Put the cylinder head assembly in position on the cylinder block.
5. Put 2P2506 Anti-Seize Compound on the threads of the cylinder head bolts (3). Install the cylinder head bolts and washers loosely.
6. Install push rods (4). Put rocker shaft (2) in position on the cylinder head.



CYLINDER HEAD ASSEMBLY (3306)

NOTICE

Make sure the dowels in the rocker shaft assembly are in alignment with the holes in the cylinder head before the bolts are installed and tightened.



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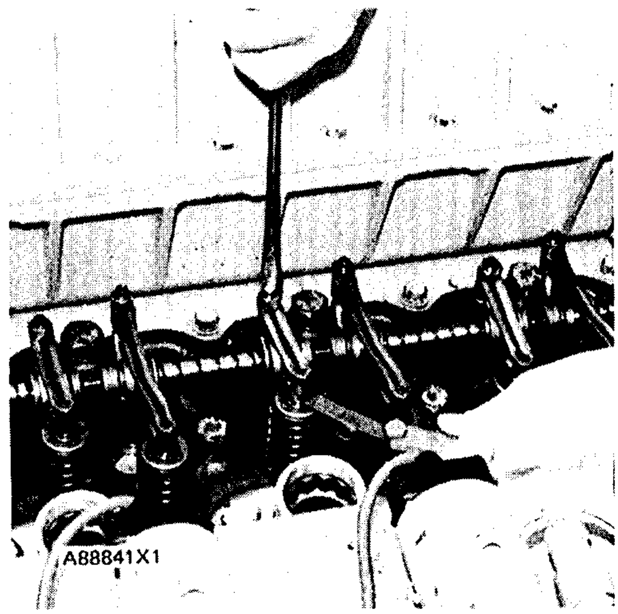
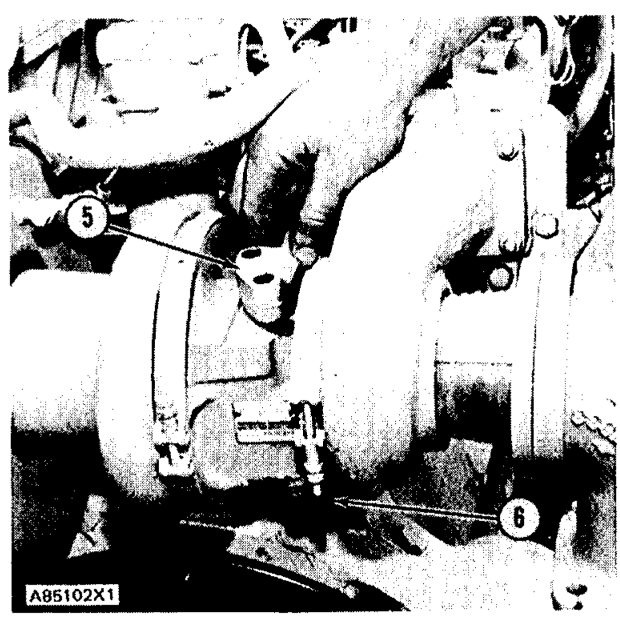
7. Put 2P2506 Anti-Seize Compound on the threads of the rocker shaft bolts and install the rocker shaft bolts and washers. Tighten the cylinder head and rocker shaft as follows:
   a) Tighten all the bolts in number sequence to a torque of 115 lb.ft. (156 N·m).
   b) Tighten all bolts in number sequence to a torque of 185 ± 13 lb.ft. (250 ± 17 N·m).
   c) Tighten all bolts in number sequence (hand turn only) to a torque of 185 ± 13 lb.ft. (250 ± 17 N·m). The minimum amount of torque on these bolts after the engine is warm must be 150 lb.ft. (203 N·m).
   d) Tighten all bolts in letter sequence to a torque of 22 lb.ft. (30 N·m).
   e) Tighten all bolts in letter sequence to a torque of 32 ± 5 lb.ft. (43 ± 7 N·m).
   f) Tighten all bolts in letter sequence (hand turn only) to a torque of 32 ± 5 lb.ft. (43 ± 7 N·m). The minimum amount of torque on these bolts must be 27 lb.ft. (37 N·m) after the engine is warm.



8. Make adjustments until the intake valve clearance is .015 in. (0.38 mm) and the exhaust valve clearance is .030 in. (0.76 mm). See VALVE CLEARANCE SETTING in TESTING AND ADJUSTING.

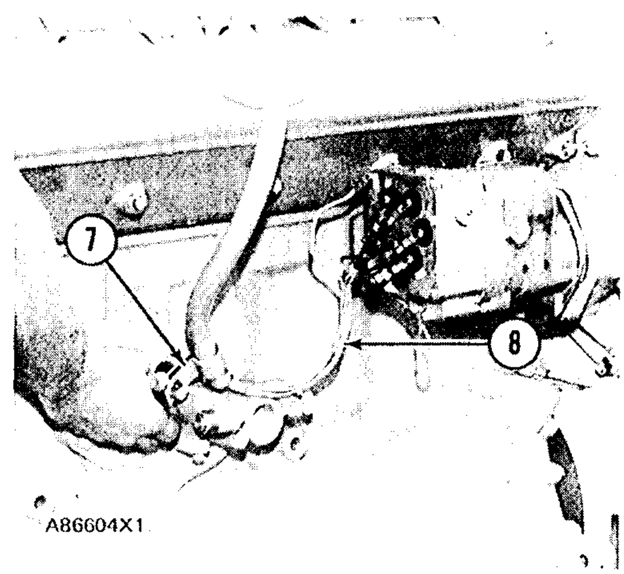
9. Connect the spark plug covers to the adapters and spark plugs.

10. Install the turbocharger drain line (6) and oil supply line (5).



CYLINDER HEAD ASSEMBLY (3306)

11. Connect wires (8) to the magneto. Each wire must be connected to the same terminal from which it was removed. Fasten clip (7) to the engine block.



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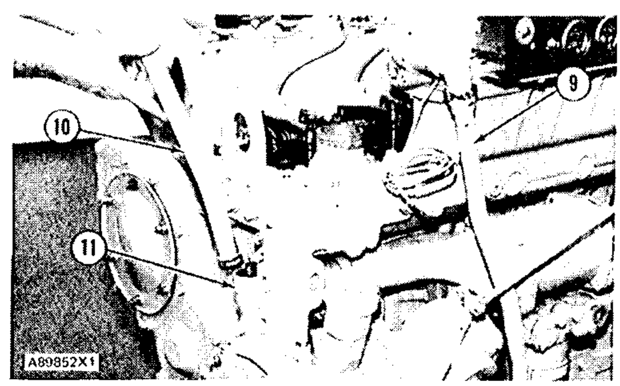
12. Install water pump elbow (11) and tighten the clamp on the hose to the oil cooler.

13. Install tube (9) from the aftercooler to the auxiliary water pump.



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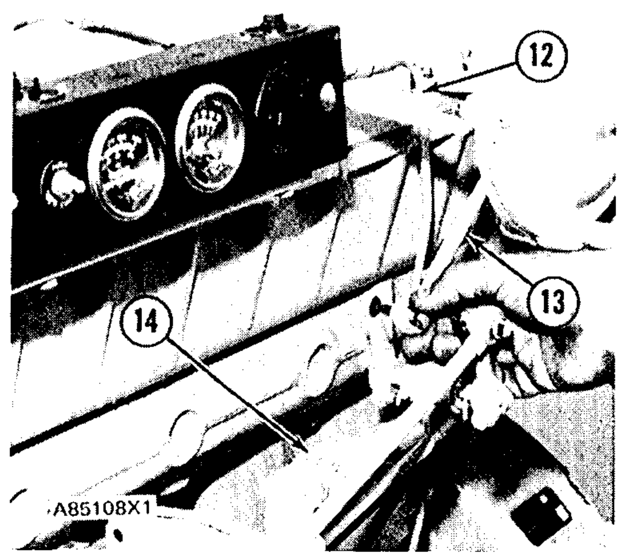
14. Install tube (10) from water pump elbow (11) to the exhaust manifold.

15. Connect tube (14) to the engine oil cooler.



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16. Install oil pressure sensing line (12).

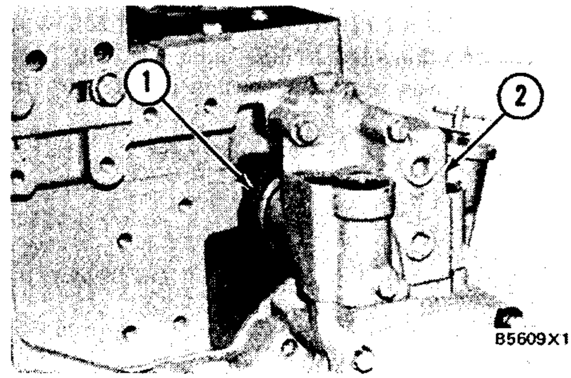
17. Connect carburetor control rod (13) to the lever.

18. Fill the cooling system with coolant to the correct level.
    end by:
    a) install valve cover

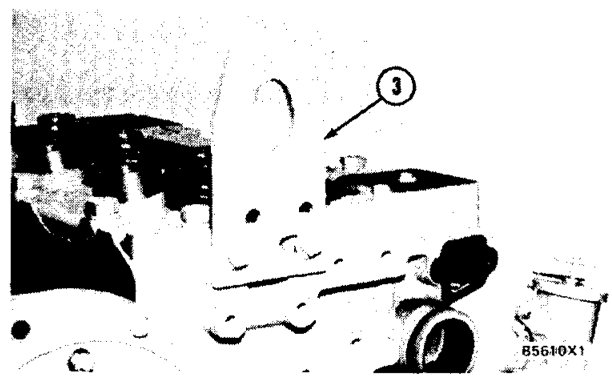
CYLINDER HEAD ASSEMBLY (3304)

REMOVE CYLINDER HEAD ASSEMBLY (3304) 1100-11

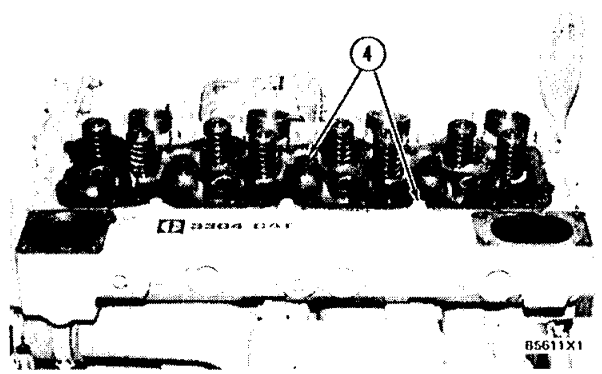
start by:
a) remove air cleaner
b) remove carburetor
c) remove exhaust manifold
d) remove rocker shaft and push rods
e) remove water temperature regulator



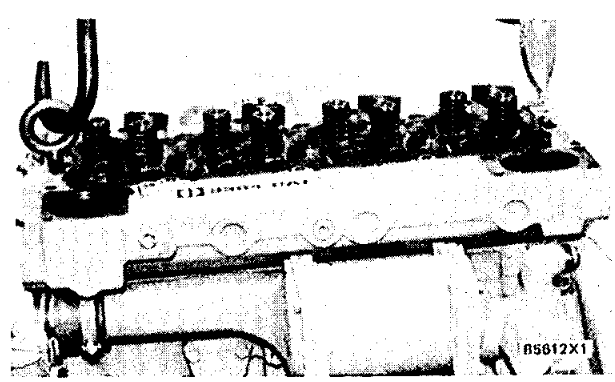
1. Drain the coolant from the cooling system.



2. Loosen clamp (1) on the hose that connects water pump elbow to the engine oil cooler.
3. Remove bolts, gasket and elbow (2) from the cylinder head and water pump.



4. Remove bolts and bracket (3) from the cylinder head.
5. Remove bolts (4) that hold the cylinder head assembly to the cylinder block.

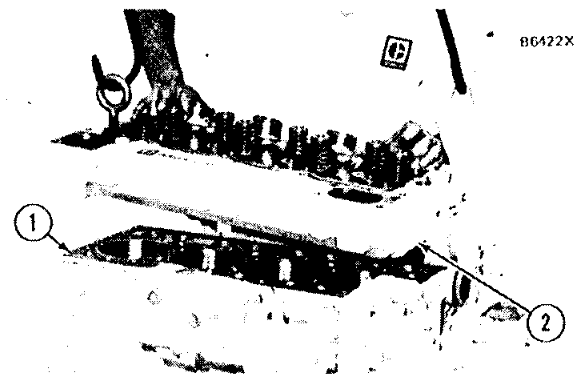


6. Install a ¾"-10 NC eyebolt. Fasten a hoist to the cylinder head assembly.
7. Remove the head assembly. The weight of the cylinder head assembly is 140 lb. (63 kg).
8. Remove the cylinder head gasket.

CYLINDER HEAD ASSEMBLY (3304)

INSTALL CYLINDER HEAD ASSEMBLY (3306) 1100-12

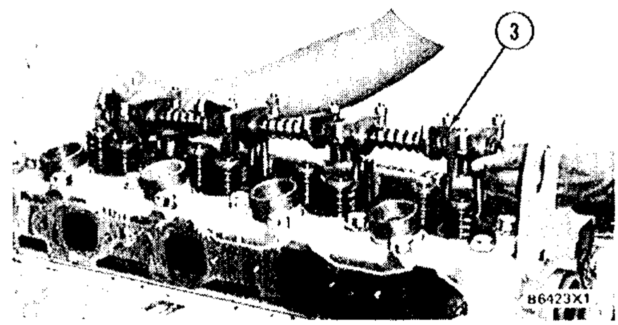
1. Thoroughly clean the spacer plate and the bottom surface of the cylinder head that make contact with the cylinder head gasket.



NOTE: Be sure a new gasket has been installed between spacer plate and cylinder block. See INSTALL SPACER PLATE.

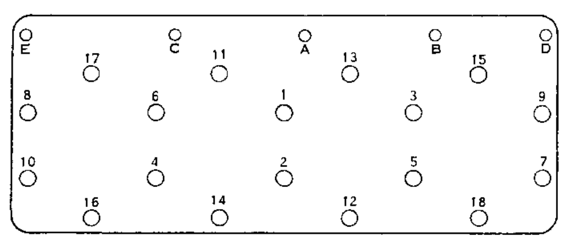
2. Install cylinder head gasket (1).

3. Fasten a hoist and install the cylinder head assembly (2) on the cylinder block.



NOTICE

Make sure the dowels in the rocker shaft assembly are in alignment with the holes in the cylinder head before the bolts are installed and tightened.



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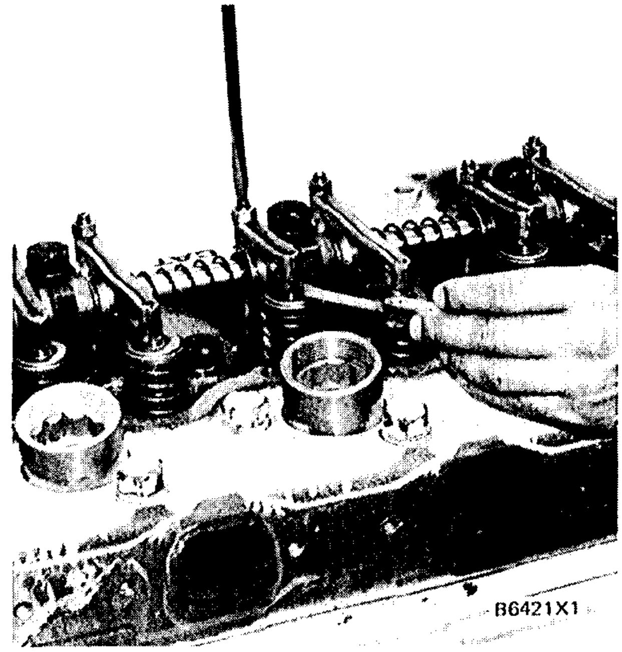
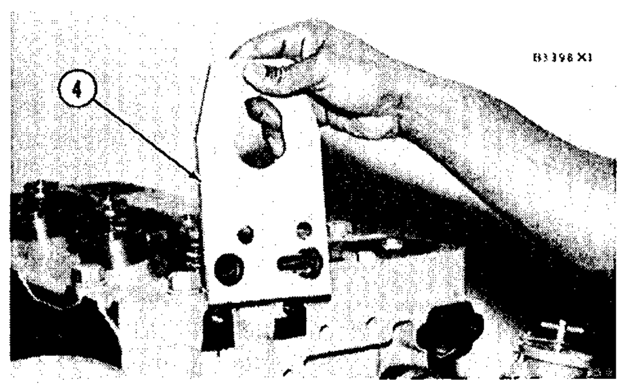
4. Install the push rods and put rocker shaft (3) in position on the cylinder head. Put 2P2506 Anti-Seize Compound on the threads of the cylinder head and rocker shaft bolts. Install the bolts and washers and tighten the bolts as follows:
   - Step 1. Tighten all bolts in number sequence to a torque of 115 lb.ft. (156 N·m).
   - Step 2. Again tighten all bolts in number sequence to a torque of 185 ± 13 lb.ft. (250 ± 17 N·m).
   - Step 3. Again tighten all bolts in number sequence (hand torque only) to a torque of 185 ± 13 lb.ft. (250 ± 17 N·m).
   - Step 4. Tighten all bolts in letter sequence to a torque of 22 lb.ft. (30 N·m).
   - Step 5. Again tighten all bolts in letter sequence to a torque of 32 ± 5 lb.ft. (43 ± 7 N·m).
   - Step 6. Again tighten all bolts in letter sequence to a torque of 32 ± 5 lb.ft. (43 ± 7 N·m).

CYLINDER HEAD ASSEMBLY (3304)

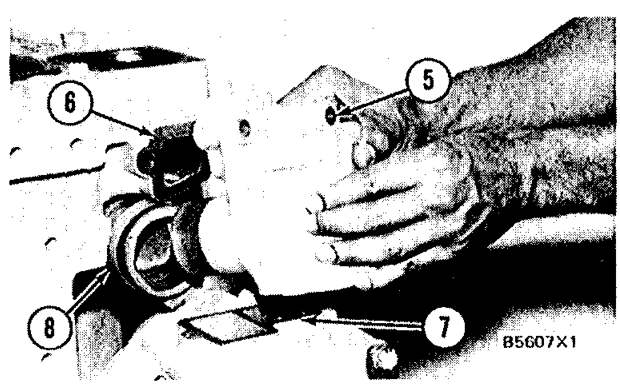
5. Make adjustment of valves to have a clearance of .015 in. (0.38 mm) for intake and .025 in. (0.64 mm) for exhaust. See VALVE CLEARANCE SETTING in TESTING AND ADJUSTING.



6. Install bracket (4) and the bolts which hold it to the cylinder head.



7. Put gaskets (6) and (7) in position. Put elbow (5) in position and install the bolts. Tighten hose clamp (8).
end by:
a) install water temperature regulator
b) install exhaust manifold
c) install carburetor
d) install air cleaner
e) install valve cover



VALVES

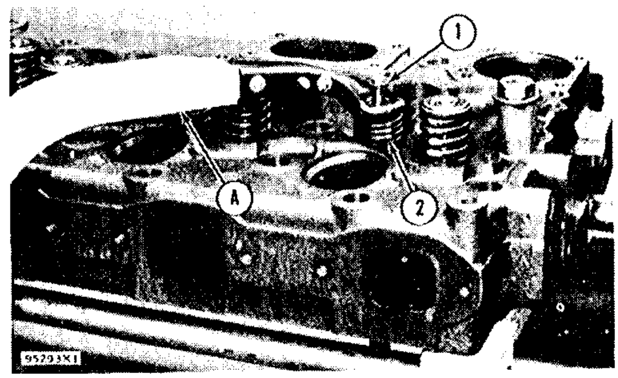
REMOVE VALVES 1105-11

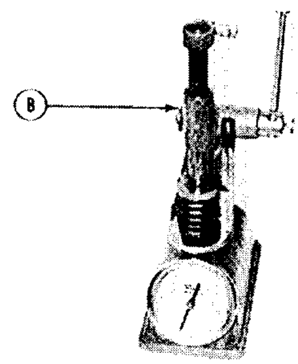
	Tools Needed	A	B
5S1330	Valve Spring Compressor	1	
8S2263	Valve Spring Tester		1

start by:
a) remove cylinder head assembly
b) remove exhaust manifold (3306)
c) remove aftercooler (3306)
d) remove water temperature regulator (3306)

1. Put compression on valve spring (2) with tool (A) and remove locks (1).
2. Remove tool (A), rotocoil, spring and valve. Put identification on valves with respect to their locations in the cylinder head.
3. Check the spring force with tool (B). The minimum spring force (used) is 46.5 lb. (207 N). The length of spring under test force is 1.766 in. (44.86 mm). The free length after test is 2.05 in. (52.1 mm).
4. Do Steps 1 through 3 again for remainder of valves.

NOTE: See GUIDELINE FOR REUSABLE PARTS: VALVES AND VALVE SPRINGS Forms SEBF8002 and SEBF8034.





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INSTALL VALVES 1105-12

	Tools Needed	A	B
5S1322	Valve Keeper Insert	1	
5S1330	Valve Spring Compressor		1

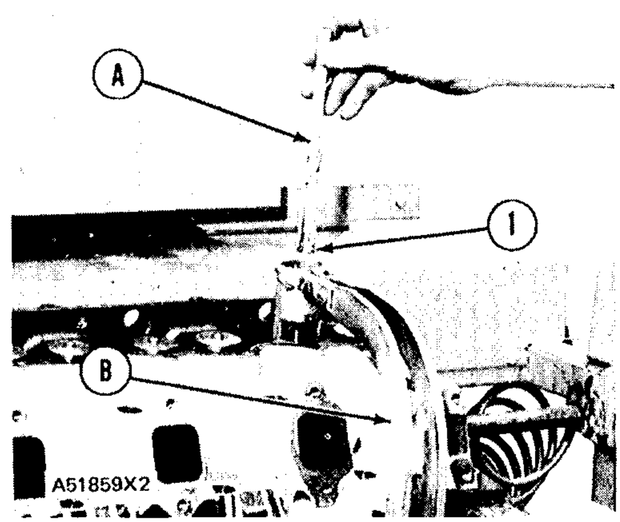
1. Put clean engine oil on valve stems. Install valve, spring and rotocoil in the cylinder head.
2. Put tool (B) in position on valve spring and install the locks (1) with tool (A).

⚠ WARNING

Locks can be thrown from valve when compressor is released, if they are not in their correct position on valve stem.

3. Remove tool (B) and hit the top of the valve with a plastic hammer to be sure the locks are in their correct position on the valve.
4. Do Steps 1 through 3 again for remainder of valves.

end by:
a) install water temperature regulator (3306)
b) install aftercooler (3306)
c) install exhaust manifold (3306)
d) install cylinder head assembly



TYPICAL EXAMPLE

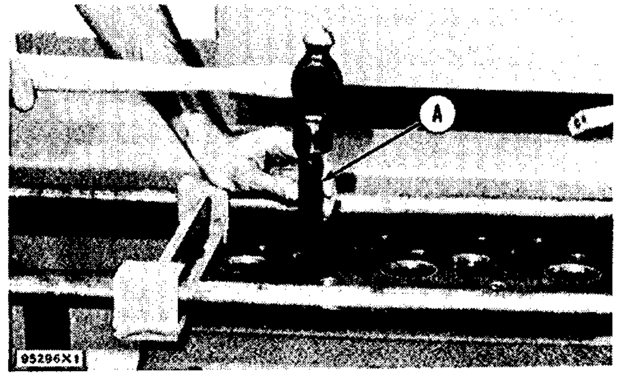
VALVE GUIDES

REMOVE AND INSTALL VALVE GUIDES 1104-10

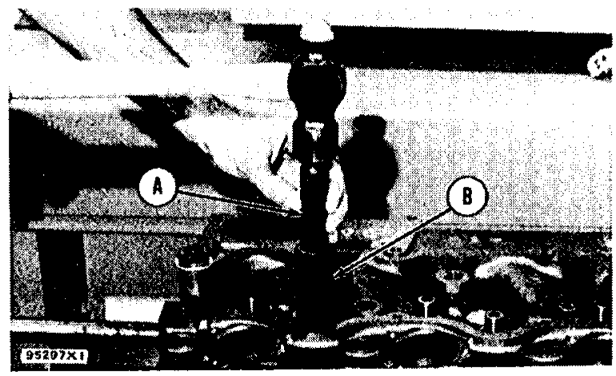
Tools Needed		A	B
7S8859	Guide Driver	1	
7S8858	Bushing		1

start by:
a) remove valves

1. Remove valve guides from the cylinder head with tool (A).



2. Put clean engine oil on outside diameter of guide. Install valve guide with tools (A) and (B).



3. The inside diameter of valve guide after installation must be .3734 ± .0010 in. (9.484 ± 0.025 mm) minimum.

end by:
a) install valves

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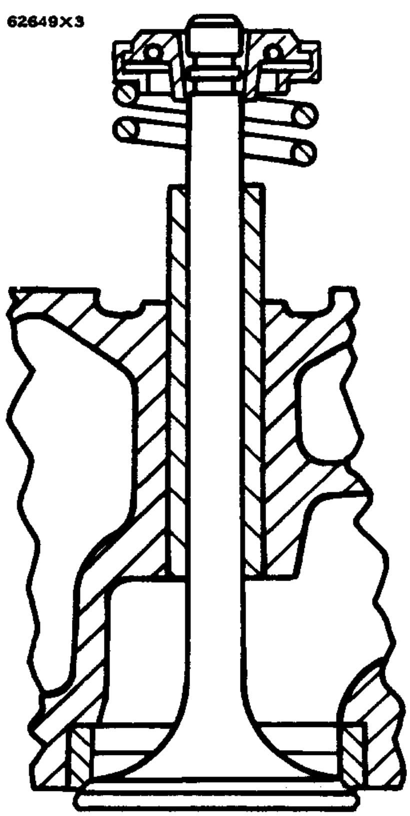


VALVE SEAT INSERTS, WATER DIRECTORS

REMOVE AND INSTALL VALVE SEAT INSERTS 1103-10

Tools Needed		A
9S3080	Valve Seat Insert Group	1

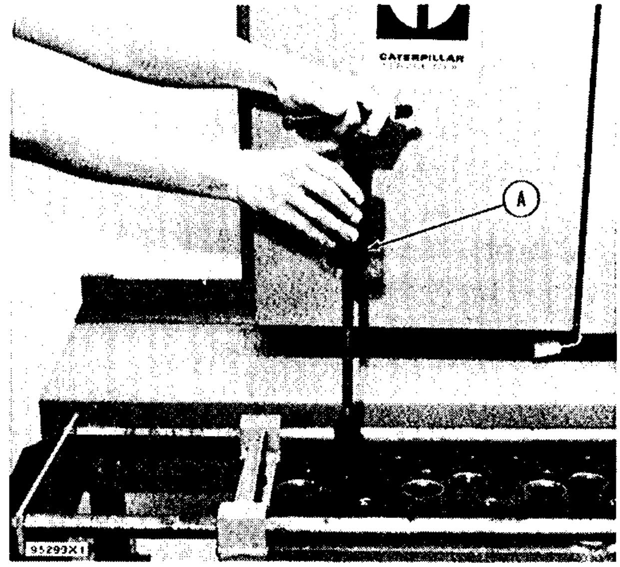
start by:
a) remove valves

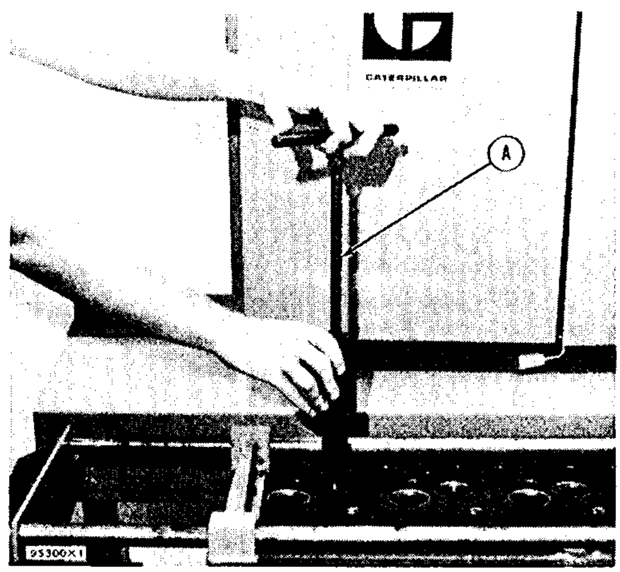
1. Remove valve seat insert with tool group (A).

2. Clean and remove burrs from the valve seat bore.

3. Install the new valve seat insert with tool group (A). Do not increase diameter of extractor in valve seat insert when it is installed in the cylinder head.

4. Grind valve seat insert according to specifications given in SPECIFICATIONS SECTION.





end by:
a) install valves

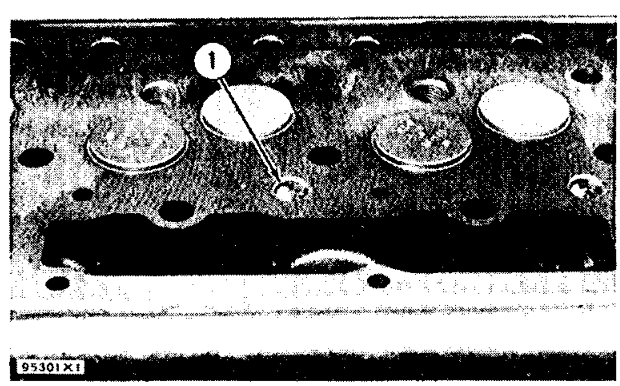
REMOVE AND INSTALL WATER DIRECTORS 1115-10

start by:
a) remove cylinder heads

1. Remove old water directors (1) from the cylinder head.

2. Clean the cylinder head.

3. Install new water directors in the cylinder head. Install the directors so the hole in directors is in alignment with the "V" mark on cylinder head.



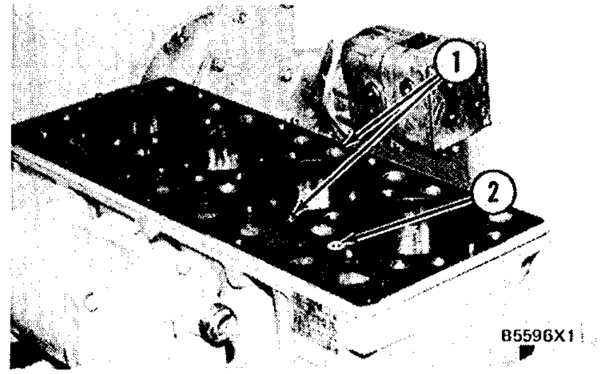
NOTE: For reconditioning of cylinder head see STMG FORM JEG02327.

SPACER PLATE

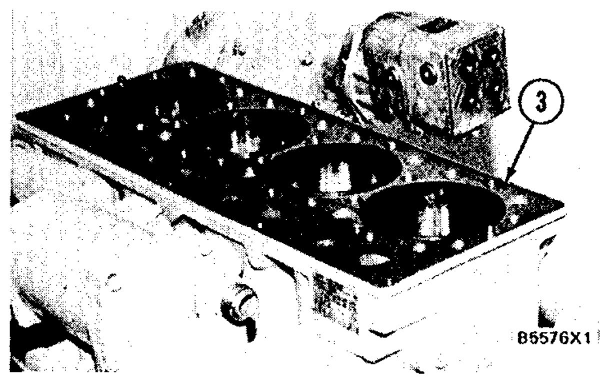
REMOVE SPACER PLATE 1221-11

start by:
a) remove cylinder head

NOTE: Photos shown are on 3304 engine.



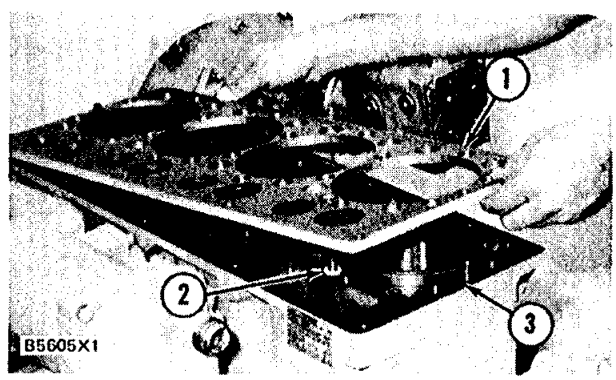
1. Remove large and small water ferrules (1) from the spacer plate.
2. Remove O-ring seal (2) from the hollow dowel.
3. Remove spacer plate (3).



4. Remove O-ring seal from the hollow dowel.
5. Remove spacer plate gasket.

INSTALL SPACER PLATE 1221-12

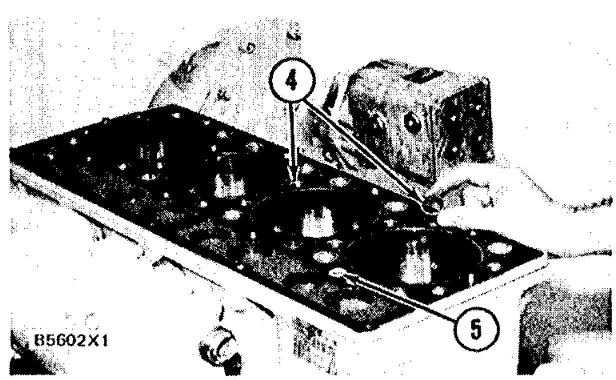
1. Thoroughly clean the spacer plate and cylinder block surface.
2. Install a new spacer plate gasket (3). Install a new O-ring seal (2) on the hollow dowel.
3. Install spacer plate (1).



NOTICE

Both surfaces of spacer plate, top of cylinder block and both sides of spacer plate gasket must be clean and dry. Do not use any gasket adhesives or other substances on these surfaces.

4. Install a new O-ring seal (5) on the hollow dowel.
5. Install new large and small water ferrules (4) in the spacer plates.
6. Check cylinder liner projection. See INSTALL CYLINDER LINERS.
   end by:
   a) install cylinder head



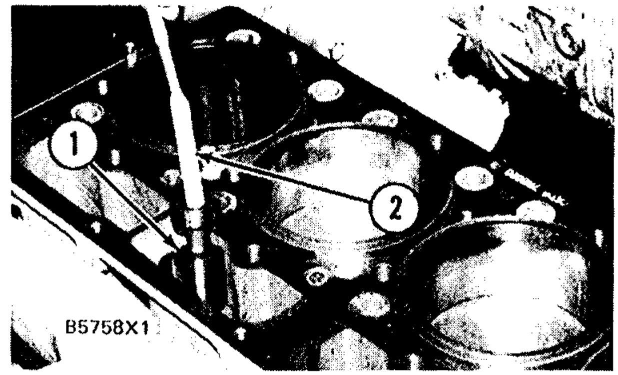
VALVE LIFTERS, PISTONS

REMOVE VALVE LIFTERS 1209-11

start by:
a) remove spacer plate

NOTE: Photos shown are on 3304 engine.

1. Remove valve lifters (1) with magnet (2).
2. Put identification on each lifter for use at installation of the valve lifters.



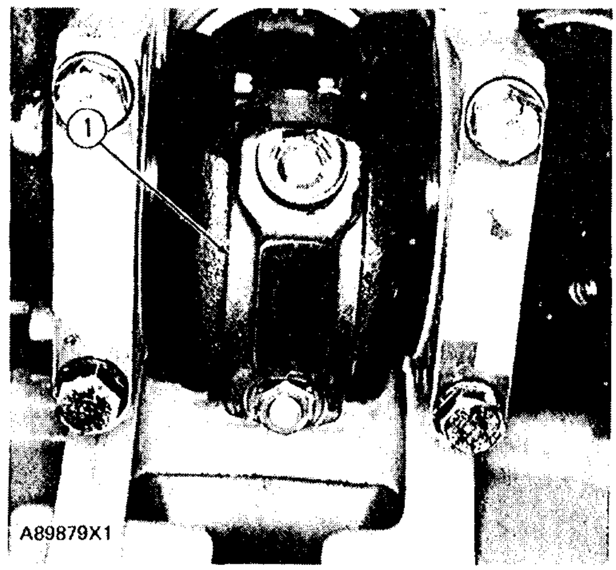
INSTALL VALVE LIFTERS 1209-12

1. Put clean engine oil on the valve lifters and camshaft lobes. Install the valve lifters in their original positions in the cylinder block.
end by:
a) install spacer plate

REMOVE PISTONS 1214-11

start by:
a) remove spacer plate
b) remove oil pan plate

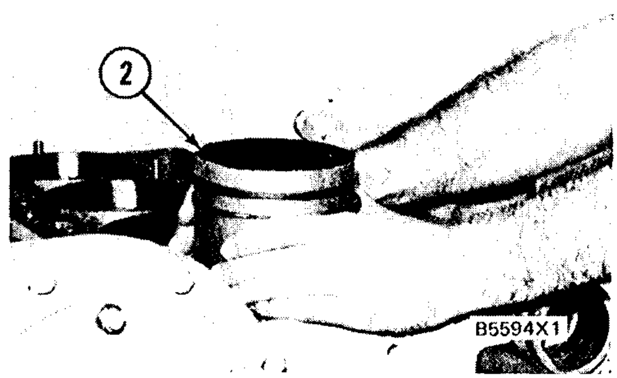
1. Remove the ring of carbon from the top inner surface of the cylinder liners.
2. Turn the crankshaft until two pistons are at bottom center. Remove connecting rod caps (1) from the two connecting rods.



3. Put tape or pieces of rubber hose over the threads of the connecting rod bolts. This will prevent damage to the crankshaft during removal of the pistons.

NOTICE
Do not let the connecting rods hit the bottom of the cylinder liners or crankshaft when the pistons are removed or installed.

4. Push the piston and connecting rod away from the crankshaft until the piston rings are above the cylinder liner. Remove the two pistons (2) and the connecting rods from the engine.



5. Keep each connecting rod cap with its respective connecting rod and piston. Put identification on each connecting rod as to its location in the engine for use at assembly of the engine.
6. Do Steps 2 through 5 for the remainder of the pistons.

PISTONS

INSTALL PISTONS 1214-12

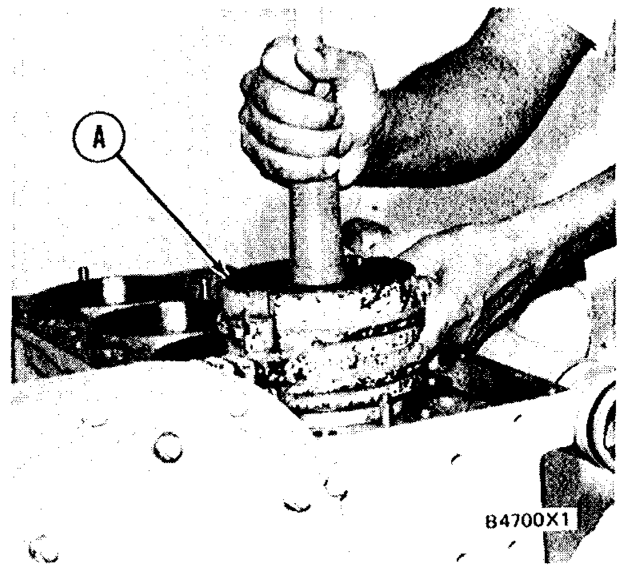
	Tools Needed	A
5P3525	Ring Compressor	1

NOTE: Photos shown are on 3304 engine.

1. Turn the crankshaft until the bearing journals for the pistons to be installed are at bottom center.

2. Put clean engine oil on the crankshaft journals and on the inside of the cylinder liners. Put clean engine oil on the piston rings and connecting rod bearings.

3. Move the piston rings on the piston until the ring openings (gap) are approximately 180° apart.

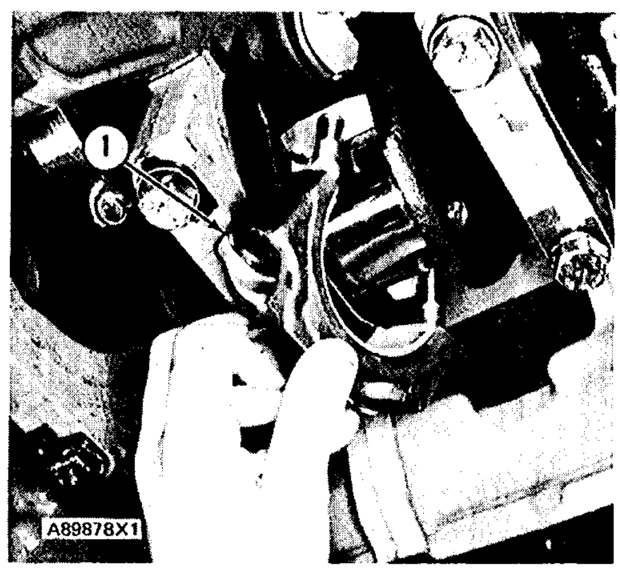


NOTICE

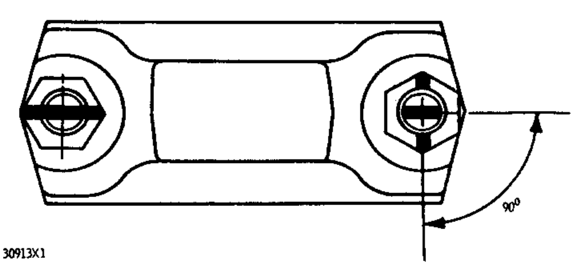
Never install tool (A) (the ring compressor) without the use of the cylinder liner as a guide. Damage to the piston rings can be the result.

4. Put tool (A) in position on the cylinder liner as shown. Put the connecting rod and piston in position in the same cylinder liner from which it was removed and into the ring compressor. Make sure the "V" mark on the piston is in alignment with the "V" mark on the cylinder block.

5. Push the piston into position while the connecting rod is put into position over the crankshaft.



6. Put clean engine oil on bearings, bolt threads and surfaces of the nuts that make contact with the connecting rod caps. Put caps (1) in position on the connecting rods and install the nuts. Tighten the nuts to a torque of 30 ± 3 lb.ft. (40 ± 4 N·m). Put a mark on each nut and the end of each bolt. Tighten the nuts 90° more.



NOTICE

When the connecting rod caps are installed, make sure the number on the side of the cap is next to and respective with the number on the side of the connecting rod.

7. Follow Steps 1 through 6 for the installation of the other pistons.
end by:
a) install spacer plate
b) install oil pump
c) install oil pan plate

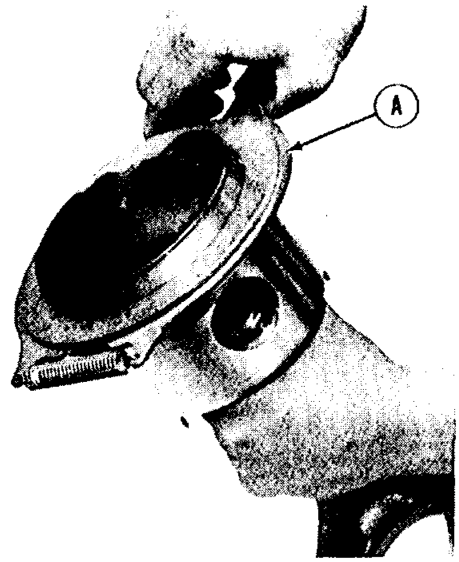
PISTONS

DISASSEMBLE AND ASSEMBLE PISTONS 1214-17

	Tools Needed	A	B
7S9470	Ring Expander	1	
5P8639	Press Group		1
5P8655	Tool Group		1
5P8819	Hydraulic Pump		1
8F24	Hose Assembly		1
1P2375	Coupler Assembly		1
1P2376	Coupler Assembly		1

start by:
a) remove pistons

1. Remove rings from the piston with tool (A).



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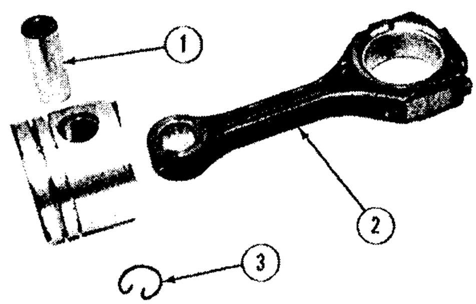
2. Remove retainer ring (3), piston pin (1) and connecting rod (2) from the piston.



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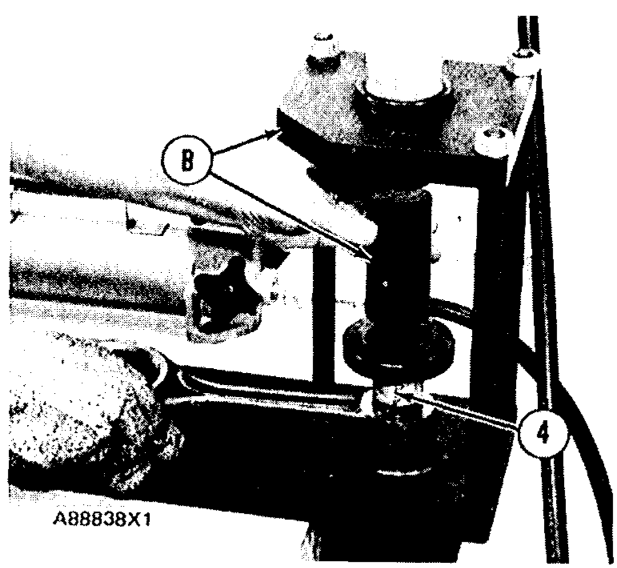
3. Clean the piston ring grooves on the old pistons with an acceptable ring groove tool.

NOTE: For clearances on pistons and rings, see PISTONS AND RINGS in SPECIFICATIONS.

4. See SPECIAL INSTRUCTION, Form SMHS7295 for USE OF PISTON PIN REMOVAL AND INSTALLATION TOOLS.

NOTE: Be sure to remove the bearings from the crankshaft end of the connecting rod.

5. Heat the connecting rod in an oven to a temperature of 350° - 400°F (176° - 204°C). Never use a direct flame to heat a connecting rod.

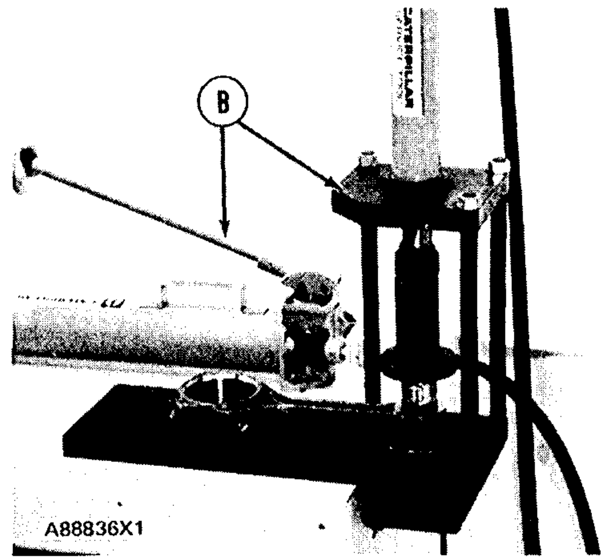


A88838X1

6. Put the connecting rod in position on tooling (B). Put a new rod pin bearing in position. Make sure the rod pin bearing joint (4) is 90° from a center line through crankshaft and pin bearing bores.

PISTONS

7. Use tooling (B) to remove the old rod pin bearing and install the new rod pin bearing with one operation.
8. Use a pin boring machine to make the bearing the correct size. The bore in the bearing (new) must be 1.5017 ± .0003 in. (38.143 ± 0.008 mm). The maximum permissible clearance between the bearing and piston pin (worn) must not be more than .003 in. (0.08 mm).
9. Put the connecting rod in position in the piston with the bearing tab groove (5) and number identification on the same side as the "V" mark on top of the piston.



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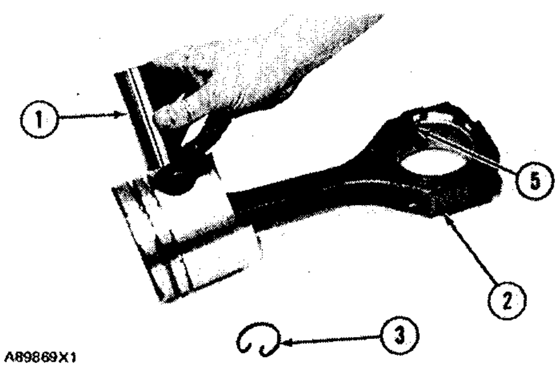
10. Install piston pin (1) and retaining ring (3).
11. Check the clearance between the ends of the piston rings (end gap) with the rings installed in a cylinder liner with a bore size of 4.750 in. (120.65 mm). The clearance of the top ring is .020 ± .003 in. (0.51 ± 0.08 mm) and the clearance for the oil ring is .018 ± .005 in. (0.46 ± 0.13 mm).
12. Install the oil ring spring in the oil ring groove of the piston.



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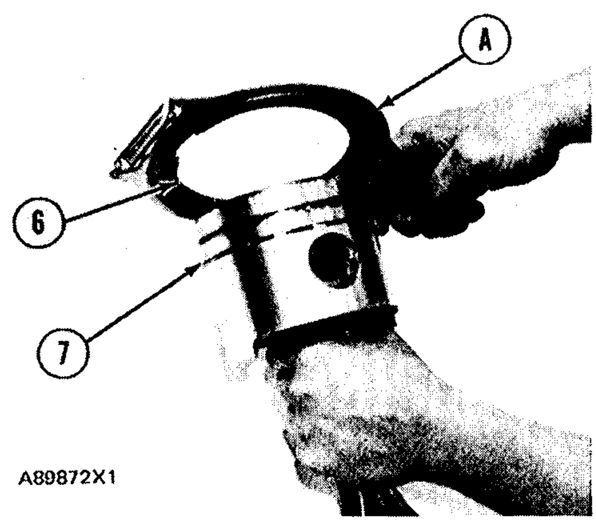
NOTE: The oil ring (7) must be installed on the piston with the ring end gap 180° from the oil ring spring joint.

13. Install the oil ring (7) on the piston with tool (A).
14. Install the top piston ring (6) with the side that has the mark "UP" toward the top of the piston with tool (A).



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15. Check the clearance between the piston ring grooves and the rings. The maximum permissible clearance between all of the rings and piston grooves must not be more than .006 in. (0.15 mm). The clearance between the top ring (new) and groove must be .0028 to .0046 in. (0.071 to 0.117 mm). The clearance between the oil ring (new) and groove must be .0015 to .0035 in. (0.038 to 0.089 mm). Make sure the top piston ring and oil ring end gaps are 180° apart before the pistons are installed.

end by:

a) install pistons

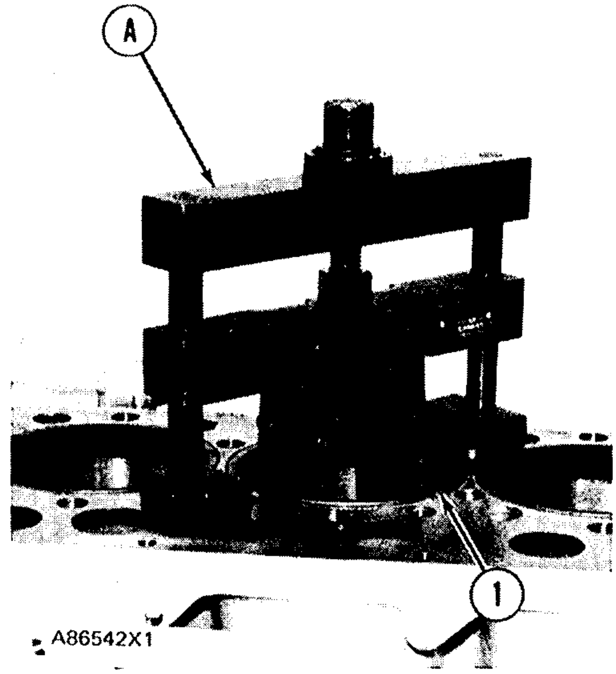
CYLINDER LINERS

REMOVE CYLINDER LINERS 1216—11

	Tools Needed	A
5P8665	Cylinder Liner Puller	1

start by:
a) remove pistons

1. Remove the coolant from the cylinder block.
2. Put covers on journals of crankshaft for protection from dirt or water.
3. Remove cylinder liners (1) with tooling (A).

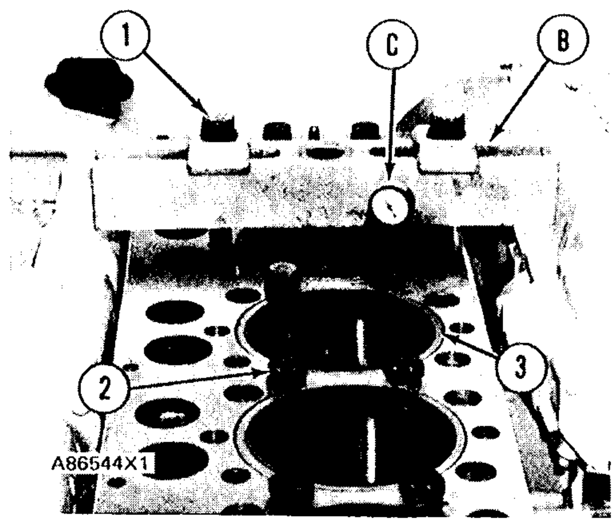


TYPICAL EXAMPLE

INSTALL CYLINDER LINERS 1216—12

	Tools Needed	A	B	C
2P8260	Cylinder Liner Installation Tool	1		
1P5510	Liner Projection Tool			1
8B7548	Puller Crossbar		1	
1P2394	Adapter Plate		1	
3H465	Plate		2	
S1589	Bolt ⅝-11 NC—1.75 in. (44.5 mm) long		12	
1S379	Washer (copper)		12	
1D4595	Bolt ⅝-11 NC—6.00 in. (152.4 mm) long		2	
2S736	Washer		2	

1. Clean the cylinder liners (3) and the liner bores in the cylinder block.
2. Install the cylinder liners in the block without the O-ring seals or filler bands.
3. Check the cylinder liner projection as follows:
   a) Install the S1589 Bolts (2) and 1S379 Washers of tooling (B) on the cylinder block next to each liner. Tighten the bolts evenly, in four steps: 10 lb. ft. (14 N·m), 25 lb. ft. (35 N·m), 50 lb. ft. (70 N·m) and 70 lb. ft. (95 N·m).
   b) Put adapter plate on top of the liner and install the remainder of tooling (B). Tighten the 1D4595 Bolts (1) evenly in four steps: 5 lb. ft. (7 N·m), 15 lb. ft. (20 N·m), 25 lb. ft. (35 N·m) and 50 lb. ft. (70 N·m).



TYPICAL EXAMPLE

CYLINDER LINERS

c) Check to be sure the distance from the bottom edge of the crossbar to the top of the cylinder block is the same on both sides of the liner.

d) Check the cylinder liner projection with tool group (C) at four locations around the liner.

e) Liner projection must be .0013 to .0069 in. (0.033 to 0.175 mm). Measurements on the same liner must not be different by more than .002 in. (0.05 mm). Average measurements between liners next to each other must not be different by more than .002 in. (0.05 mm). The difference in the average cylinder liner projection of all cylinder liners under one cylinder head must not be more than .004 in. (0.10 mm).

NOTE: If the liner is turned in the bore, it can make a difference in the liner projection.

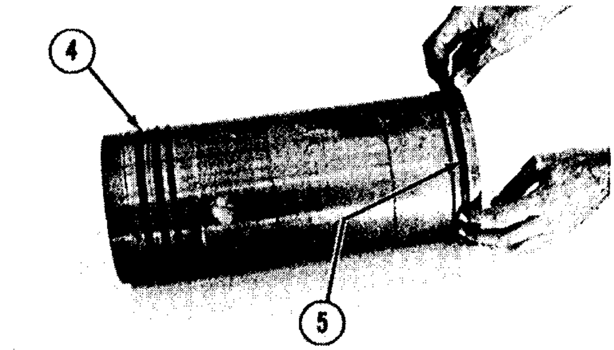
4. If the liner projection is not .0013 to .0069 in. (0.033 to 0.175 mm), check the thickness of the following parts: spacer plate, spacer plate gasket and cylinder liner flange. The thickness of the spacer plate must be .3925 ± .0010 in. (9.970 ± 0.025 mm). The thickness of the spacer plate gasket must be .0082 ± .0010 in. (0.208 ± 0.025 mm). The thickness of the cylinder liner flange must be .4048 ± .0008 in. (10.282 ± 0.020 mm).

NOTE: If the liner projection changes from point to point around the liner, turn the liner to a new position in the bore. If the liner projection is still not to specifications, move the liner to a different bore.

5. When the cylinder projection is correct, put a mark on the liner and block so the liner can be installed in the same position from which it was removed.

NOTE: Cylinder liner projection can be adjusted by the removal of material from (machining) the contact face of the cylinder block with the use of the 8S3140 Cylinder Block Counterboring Tool Arrangement. Machine to a minimum depth of .030 in. (0.76 mm) and to a maximum depth of .045 in. (1.14 mm). The instructions for the use of the tool group are in Special Instruction Form No. FM055228. Shims are available for the adjustment of the liner projection. See CYLINDER LINER PROJECTION in TESTING AND ADJUSTING for the shim thickness and part number.

6. Remove tooling (B) and (C). Remove the liner.



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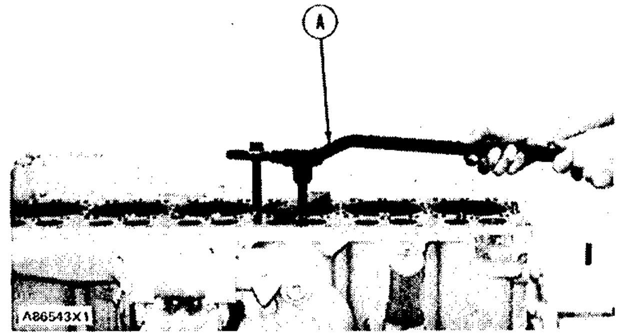


TYPICAL EXAMPLE

7. Put liquid soap on bottom liner bore in block, on grooves in lower liner and on O-ring seals (4). Install O-ring seals on the liner.

8. Put filler band (5) in clean SAE 30 oil for a moment and install on liner. Install cylinder liner immediately in the cylinder block (before expansion of filler band).

9. Make sure the mark on liner is in alignment with the mark on the block. Use tooling (A) to push the liner into position.

10. Do Steps 5 through 9 for the remainder of the cylinder liners.

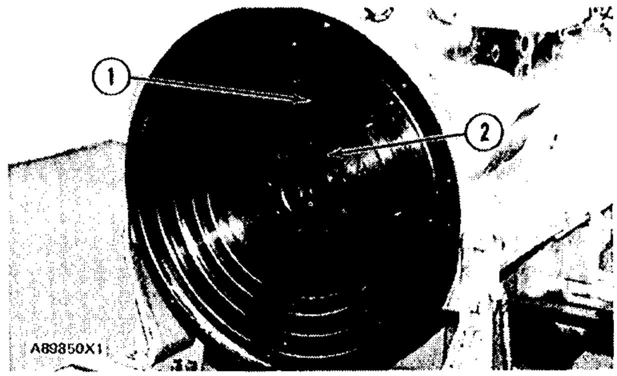
end by:
a) install pistons

FLYWHEEL

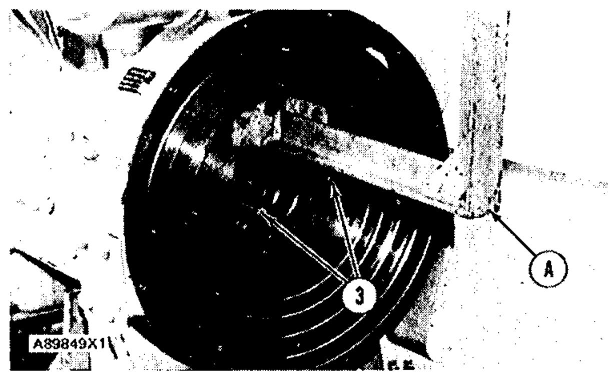
REMOVE FLYWHEEL 1156-11

	Tools Needed	A
FT120	Lifting Bracket	1

1. Turn the flywheel until threaded hole (1) is at the top.

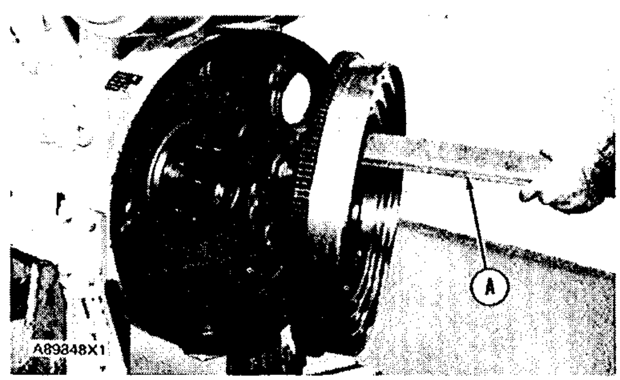


2. Remove upper five bolts (2).



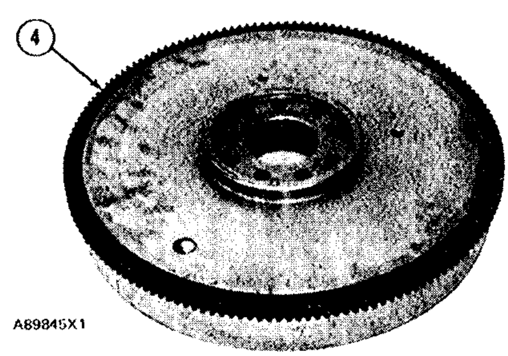
3. Install two 5/8''-18 NF guide bolts (3) as shown.

4. Fasten tool (A) to a hoist and to the flywheel using a ½''-13 NC x 1 ¾'' bolt in threaded hole (1).



5. Remove the other four bolts that hold the flywheel to the crankshaft.

6. Remove the flywheel with tool (A). Weight of the flywheel is 160 lb. (72 kg).



7. Remove gear (4) from the flywheel.

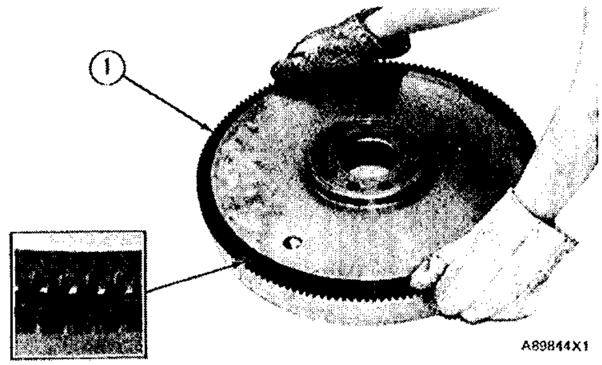
FLYWHEEL

INSTALL FLYWHEEL 1156-12

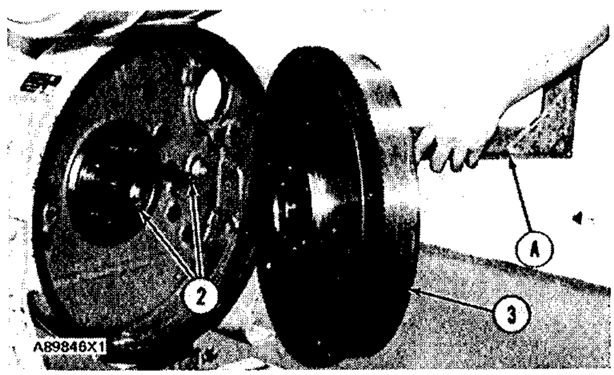
	Tools Needed	A
FT120	Lifting Bracket	1

CAUTION

When flywheel ring gear (1) is installed on the flywheel, the tooth chamfer side must be installed away from the flywheel.



1. Heat the flywheel ring gear (1) to a maximum temperature of 600°F (315°C). Install the flywheel ring gear on the flywheel.



2. Install two 5/8"-18 NF guide bolts (2) in the crankshaft as shown.
3. Fasten tool (A) to the flywheel (3) and a hoist.
4. Use tool (A) to put flywheel (3) in position over guide bolts (2). Weight of the flywheel is 160 lb. (72 kg).

5. Make an alignment of marks (4) on the end of the crankshaft and flywheel.
6. Install the bottom four of nine bolts.
7. Remove tool (A) and the two guide bolts.
8. Install the other five bolts that hold the flywheel in place.

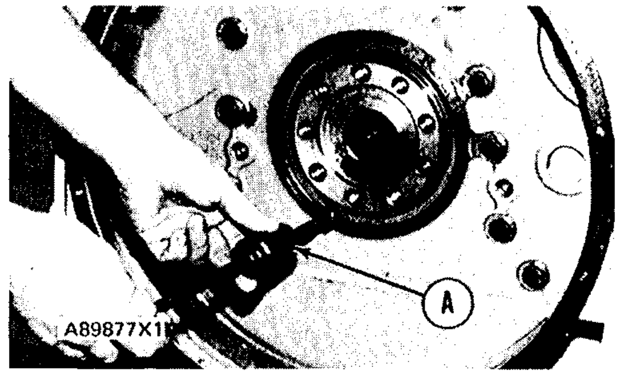
CRANKSHAFT REAR SEAL AND WEAR SLEEVE

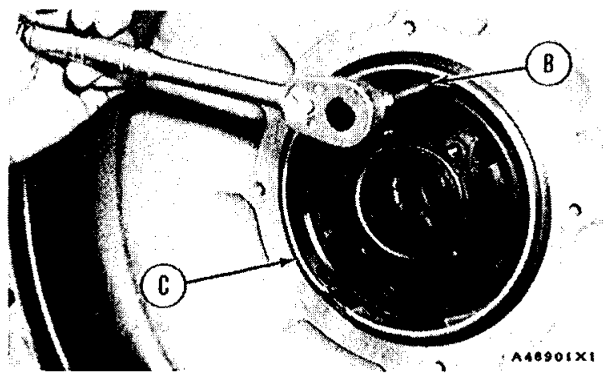
REMOVE CRANKSHAFT REAR SEAL AND WEAR SLEEVE 1161-11

	Tools Needed	A	B	C
1P3075	Puller Group	1		
5P7312	Distorter		1	
5P7313	Ring			1

start by:
a) remove flywheel

1. Use tool (A) to remove the crankshaft rear seal.
2. Install tool (C) in the rear seal bore.
3. Install tool (B) between tool (C) and the wear sleeve. Turn tool (B) until the ends of the tool make a flat piece (crease) in the wear sleeve. Do this in two or more places until the wear sleeve is loose.
4. Remove tool (C) and the wear sleeve by hand.





TYPICAL EXAMPLE

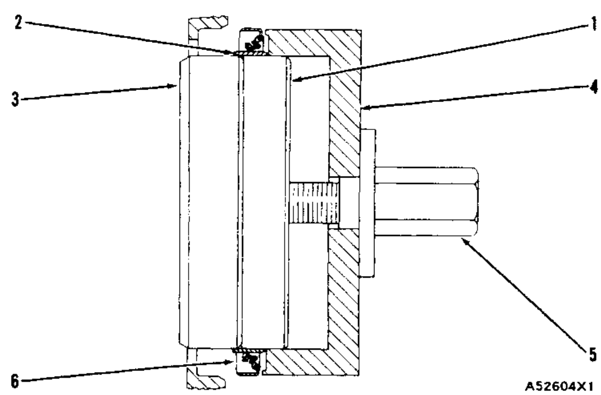
INSTALL CRANKSHAFT REAR SEAL AND WEAR SLEEVE 1161-12

	Tools Needed	A
9S8871	Locator	1
9S8858	Nut	1
9S8890	Bolt	3
5P7298	Installer	1

1. Install the crankshaft rear seal and wear sleeve with tooling (A) as follows:
   a) Put locator (1) in position on the crankshaft and install the three bolts that hold it in place.
   b) Put clean engine oil on the seal lip of seal (6) and on the outside diameter of wear sleeve (2).
   c) Install seal (6) on wear sleeve (2) from the end of the wear sleeve that has the bevel on the outside diameter. Make sure the lip of the seal is toward the inside of the engine and the bevel that is on the outside diameter of the wear sleeve is toward the outside of the engine when installed.
   d) Use 6V1541 Quick Cure Primer to clean the outside diameter of the crankshaft flange (3) and the inside diameter of wear sleeve (2).
   e) Put 9S3265 Retaining Compound on the outside diameter of crankshaft flange (3) and the inside diameter of wear sleeve (2).

NOTE: Make sure the lip of the seal is toward the inside of the engine and the outside diameter bevel of the wear sleeve is toward the outside of the engine.

   f) Put wear sleeve (2) with seal (6) on locator (1). Put installer (4) on locator (1) and install nut (5). Put lubrication on the face of the washer and the nut.



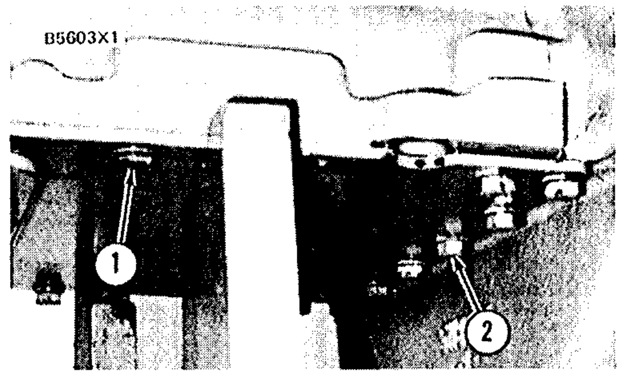
   g) Tighten nut (5) until installer (4) comes in contact with locator (1).
   h) Remove tooling (A) and check the wear sleeve and seal for correct installation.

end by:
a) install flywheel

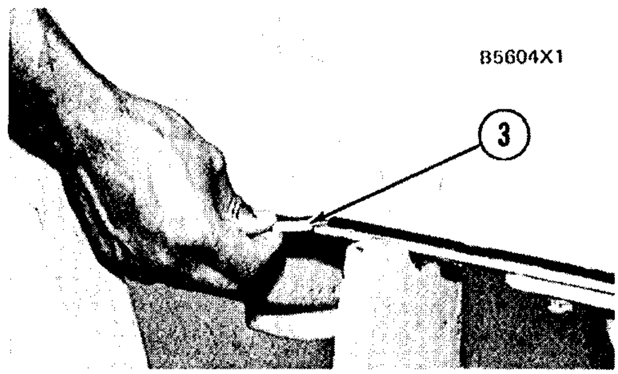
FLYWHEEL HOUSING

REMOVE FLYWHEEL HOUSING 1157-11

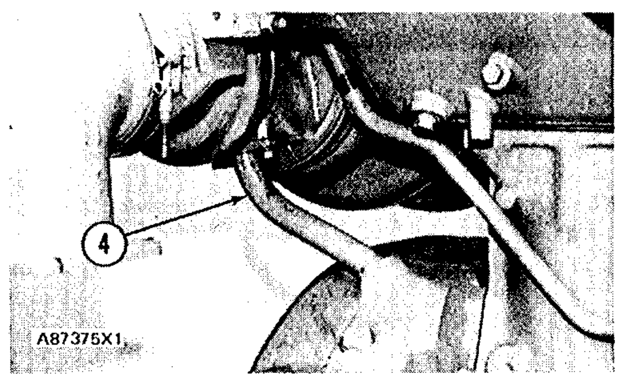
start by:
a) remove starter
b) remove flywheel



1. Remove the bolts (2) and washers that hold the oil pan plate to the flywheel housing. Loosen the bolts (1) that hold the oil pan to the cylinder block.

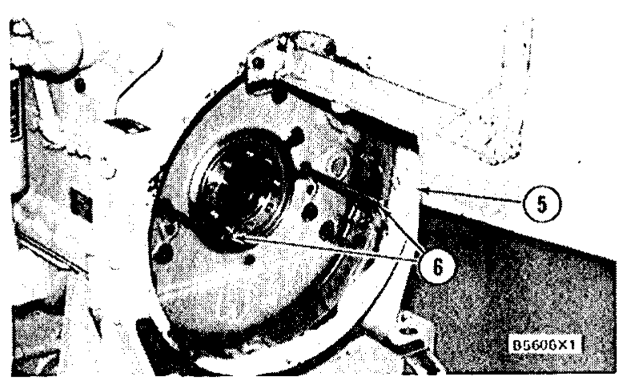


2. Fasten a hoist to the engine. Lift the engine and install shims (3) on each side of the engine between the cylinder block and the oil pan plate.



3. Remove the turbocharger oil drain tube (4) (if equipped with a turbocharger).

4. Fasten an approved lifting bracket to flywheel housing (5) and a hoist.



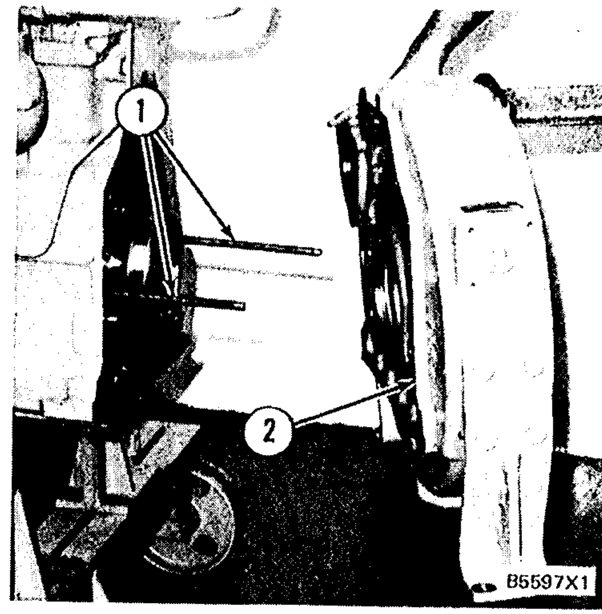
5. Install two ½''-13 NC guide bolts (6) in the cylinder block as shown.

6. Remove the bolts that hold the flywheel housing to the cylinder block. Remove the flywheel housing (5). The weight of the flywheel housing is 160 lb. (72 kg).

FLYWHEEL HOUSING

INSTALL FLYWHEEL HOUSING 1157-12

1. Clean the old gasket from the surfaces of the cylinder block and flywheel housing that make contact with each other. Put a new gasket in position.

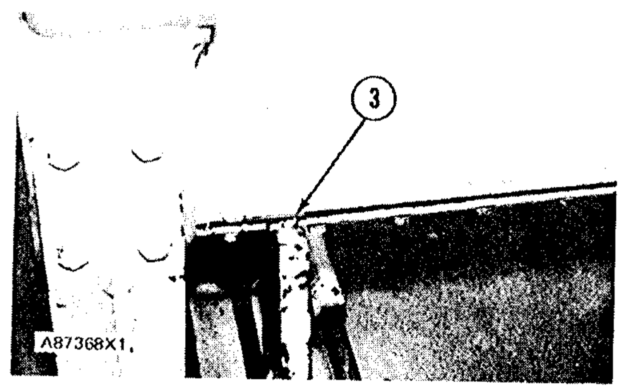


2. Install two ½"-13 NC guide bolts (1) in the cylinder block as shown. Fasten tool (A) to the flywheel housing (2) and a hoist. Weight of the flywheel housing is 160 lb. (72 kg).

3. Put a small amount of clean engine oil on the lip of the seal in the flywheel housing.

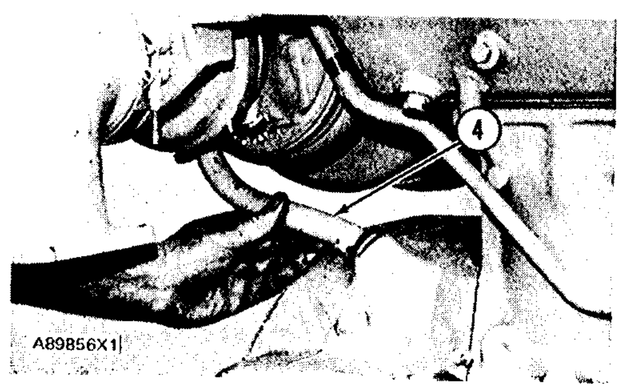
NOTICE

Be careful when the flywheel housing is installed so the seal is not damaged.



4. Put the flywheel housing (2) in position on the guide bolts (1). Install all but two bolts in the flywheel housing. Remove tool (A) and guide bolts (1). Install the other two bolts.

5. Cut the bottom of the gasket off even with the flywheel housing and cylinder block. Put 5H2471 Gasket Cement on the bottom of the gasket where the gasket makes contact with the gasket for the oil pan plate.



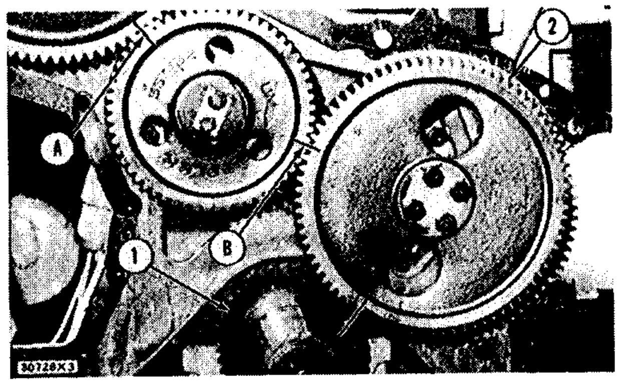
6. Remove shims (3) from each side of the engine. Tighten all of the oil pan bolts. Install the bolts that hold the oil pan plate to the flywheel housing.

7. Install turbocharger oil drain tube (4) (if equipped with a turbocharger).
end by:
a) install flywheel
b) install starting motor

CRANKSHAFT (3306)

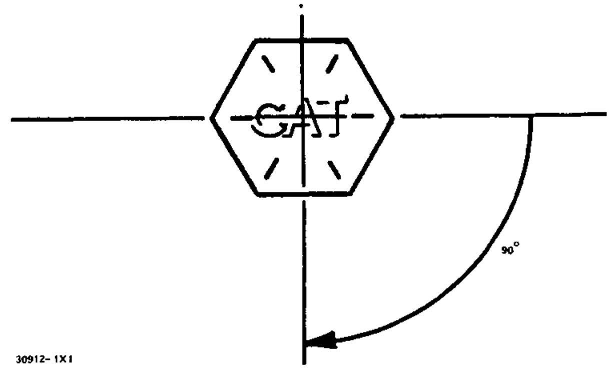
REMOVE CRANKSHAFT (3306) 1201-11

start by:
a) remove flywheel housing
b) remove timing gear cover
c) remove pistons



1. Turn the crankshaft until the timing mark on the crankshaft gear (1) is in alignment with the timing mark on camshaft gear (2).

2. Make a mark on the teeth of the magneto drive gear and the idler gear in their engaged position at location (A). Put a mark of identification on the engaged teeth of idler gear and camshaft gear at location (B). This will give assistance in the correct timing of the camshaft for the magneto drive during crankshaft installation.

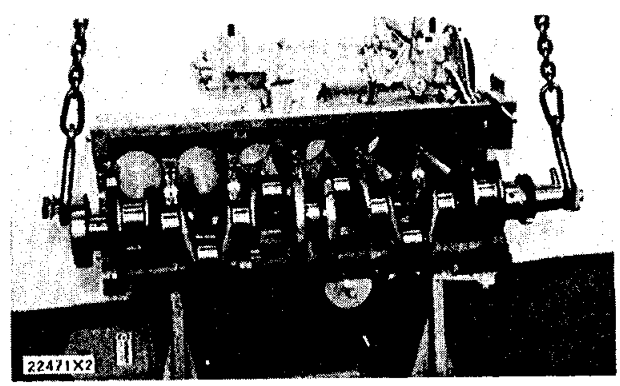


3. Fasten a hoist to the crankshaft.

4. Remove the caps for the main bearings.

5. Remove the crankshaft. Weight of the crankshaft is 210 lb. (95 kg).

6. Remove the crankshaft main bearings from the cylinder block and from the caps.



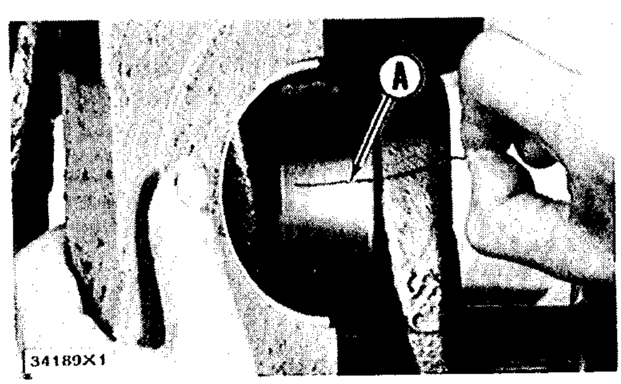
INSTALL CRANKSHAFT (3306) 1201-12

	Tools Needed	A	B
	Plastigage	*	
8S2328	Dial Test Indicator Group		1

1. Clean the surfaces on the cylinder block for the bearings. Install the upper halves of the main bearings in the block.

2. Put the crankshaft in the block with a hoist. Be sure all timing marks are in alignment.

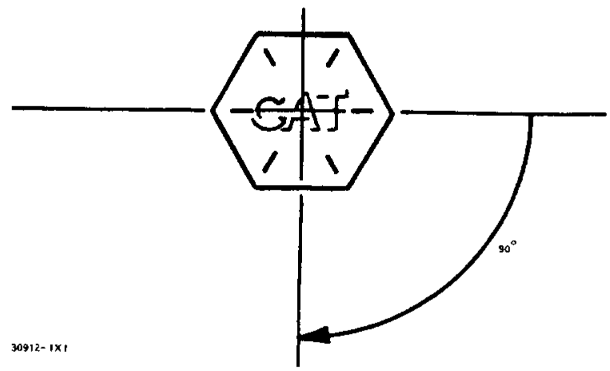
3. Clean the main bearing caps. Install the lower halves of the main bearings in the caps.



4. Check the main bearing clearance with Plastigage (A). Install the caps in their correct places. Be sure the number on the cap is toward the number on the pan surface on the left side of the block.

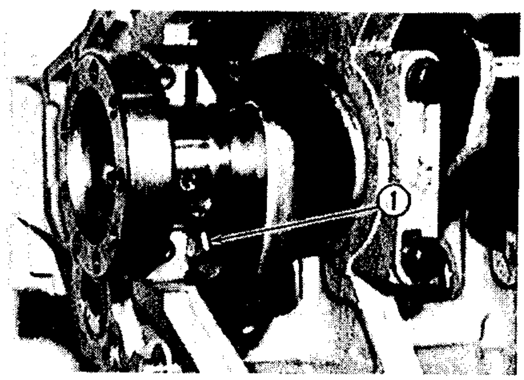
CRANKSHAFT (3306)

5. Put clean oil on the threads of the bolts and on the faces of the washers that hold the main bearing caps. Install the bolts and washers. Tighten both bolts to 30 ± 3 lb.ft. (40 ± 4 N·m). Put a mark on the bolt heads and bearing caps. Tighten the bolts 90° from the mark as shown. Remove bearing caps and measure the thickness of the Plastigage (A). Main bearing clearance (Plastigage thickness) must be .0030 to .0065 in. (0.076 to 0.165 mm). Maximum permissible clearance is .010 in. (0.25 mm).



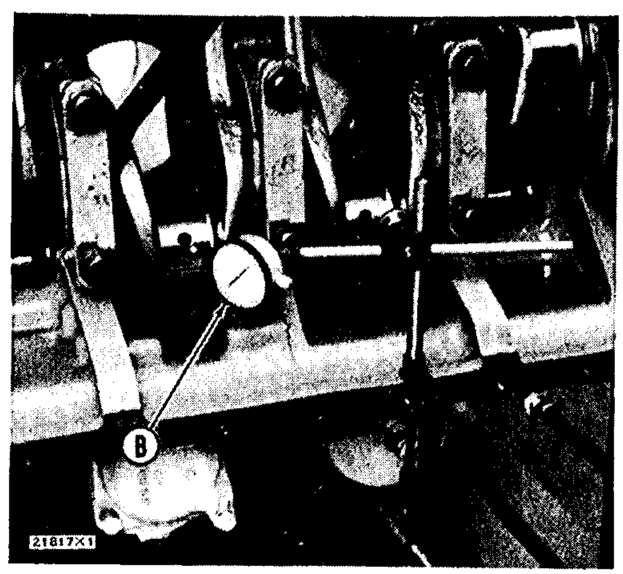
30912-1X1

6. Put clean oil on the upper and lower halves of main bearings. Install the caps in their correct places. Install the bolts and washers. Tighten to 30 ± 3 lb.ft. (40 ± 4 N·m). Put marks on bolt heads and caps. Tighten each bolt 90° from the mark.



22466X1

7. Check the crankshaft end clearance with tool group (B). End clearance is controlled by the thrust bearing (1) on the rear main. When the bearings are installed the tab will fit into the machined area in the cylinder block. End clearance must be .0025 to .0145 in. (0.064 to 0.368 mm). Maximum permissible end clearance is .025 in. (0.64 mm).



8. If the accessory drive gear, idler gear, camshaft gear or crankshaft gear has been removed or a replacement has been made, it is necessary to put the accessory drive shaft into correct timing after the engine is assembled. See TIMING MAGNETO TO ENGINE in TESTING AND ADJUSTING.

end by:

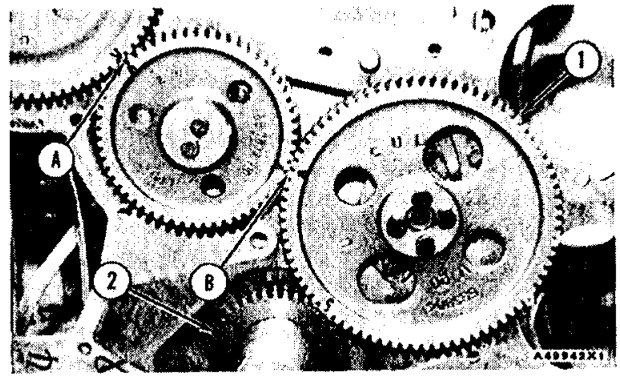
a) install pistons
b) install timing gear cover
c) install flywheel housing

CRANKSHAFT (3304)

REMOVE CRANKSHAFT (3304) 1202-11

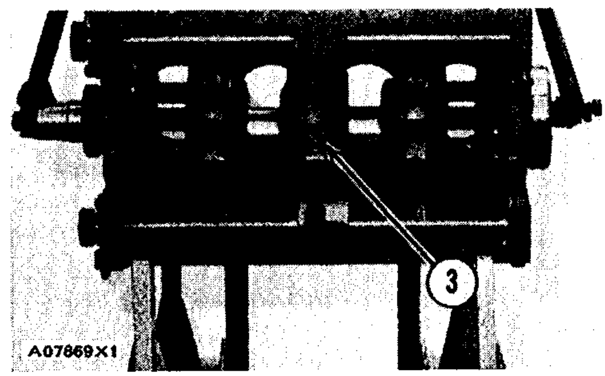
start by:
a) remove flywheel housing
b) remove timing gear cover
c) remove pistons

1. Turn the crankshaft until the "C" mark on crankshaft gear (2) is in alignment with the "C" mark on camshaft gear (1).



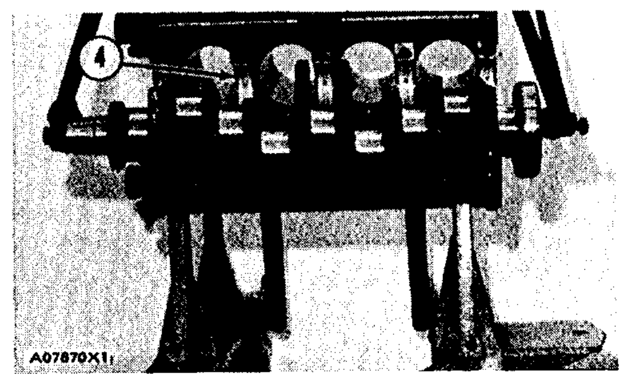
NOTE: To keep the engine timing correct during removal and installation of the crankshaft, put a mark on the teeth of the magneto drive gear and idler gear at location (A). Put a mark on the teeth of the idler gear and camshaft gear at location (B). The engine timing will be correct when the marks at locations (A) and (B) are in alignment and the "C" marks on the crankshaft and camshaft gears are in alignment.

2. Install a ¾"-16 NF bolt in the gear end of the crankshaft. Install two 5/8"-18 NF bolts in the flywheel end of the crankshaft. Fasten a hoist to the crankshaft.



3. Remove main bearing caps (3).

4. Remove the crankshaft from the cylinder block. The weight of the crankshaft is 145 lb. (65 kg).

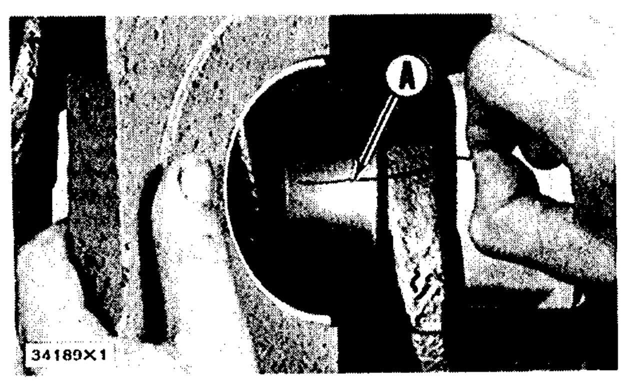


5. Remove main bearings (4) from the block and from the caps. Remove the thrust bearings.

INSTALL CRANKSHAFT (3304) 1202-12

	Tools Needed	A	B
	Plastigage	*	
8S2328	Dial Test Indicator Group		1

1. Clean the surfaces on the cylinder block for the main bearings. Install the upper halves of the main bearings in the block.



2. Put the crankshaft in position in the cylinder block with a hoist. Make sure all of the timing marks are in alignment.

3. Clean the Nos. 1 and 5 main bearing caps. Install new bearings in caps. Temporarily install caps to hold crankshaft in place.

CRANKSHAFT (3304)

NOTICE

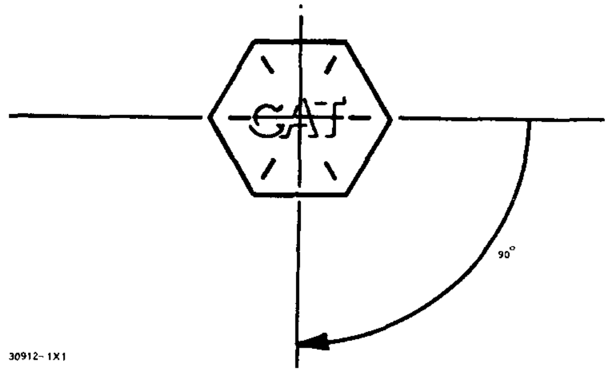
Make sure part number on cap is toward front of engine, and number on bottom of cap is the same as number on block when caps are installed.

4. Clean the Nos. 2, 3 and 4 main bearing caps. Install new bearings in the caps. Put clean engine oil, bolts threads and surfaces of the washers that make contact with the caps.
5. Check the bearing clearance with Plastigage (A). Install the caps and tighten the bolts to a torque of 30 ± 3 lb.ft. (40 ± 4 N·m). Put a mark on each bolt head and the bearing caps. Tighten the bolts 90° more. Remove the bearing caps and measure the thickness of the Plastigage. The main bearing clearance (Plastigage thickness) with new bearings must be .0029 to .0069 in. (0.074 to 0.165 mm). The maximum permissible clearance with used bearings is .010 in. (0.25 mm).
6. Put clean engine oil on the bearings. Put the caps in position on the engine and install the washers and bolts. Tighten the bolts to a torque of 30 ± 3 lb.ft. (40 ± 4 N·m). Put a mark on each bolt head and the bearing caps. Tighten the bolts 90° more.
7. Remove the Nos. 1 and 5 main bearing caps. Follow the procedure in Steps 4 and 5 and check the main bearing clearance for the Nos. 1 and 5 main bearings.
8. Follow the procedure in Step 6 and install the No. 1 main bearing cap.
9. Put clean engine oil on thrust bearings (1). Install the bearings with the tab into the machined area in the cylinder block. Install the No. 5 main bearing cap. Tighten the bolts for the cap with the procedure in Step 6.
10. Check the crankshaft end play with tool group (B). The end play is controlled by the thrust bearings on the No. 5 main. The end play with new bearings must be .0025 to .0145 in. (0.064 to 0.368 mm). The maximum permissible end play with used bearings is .025 in. (0.64 mm).

NOTE: If a replacement has been made for any of the timing gears, it will be necessary to check the engine timing to make sure it is correct. See TIMING MAGNETO TO ENGINE in TESTING AND ADJUSTING.

end by:

a) install pistons
b) install timing gear cover
c) install flywheel housing



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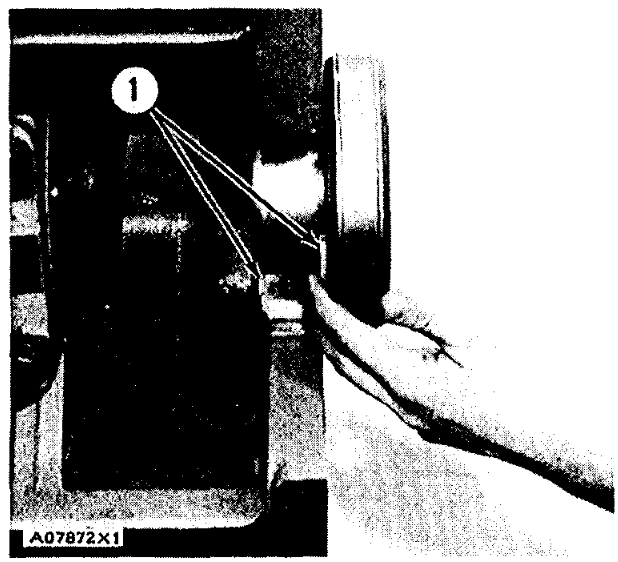

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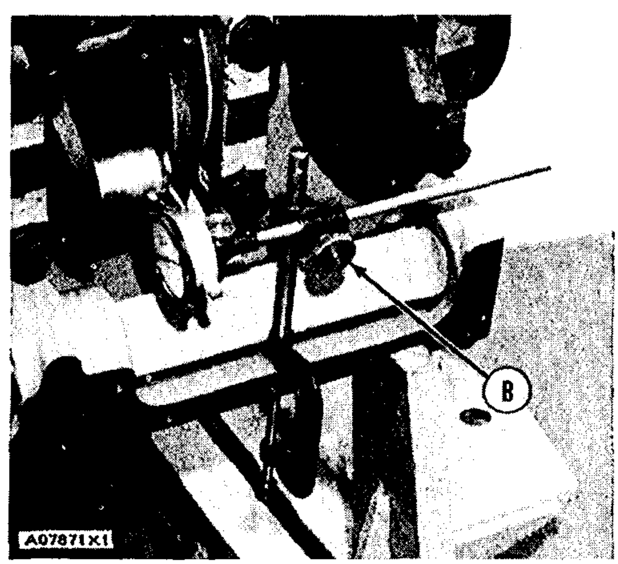

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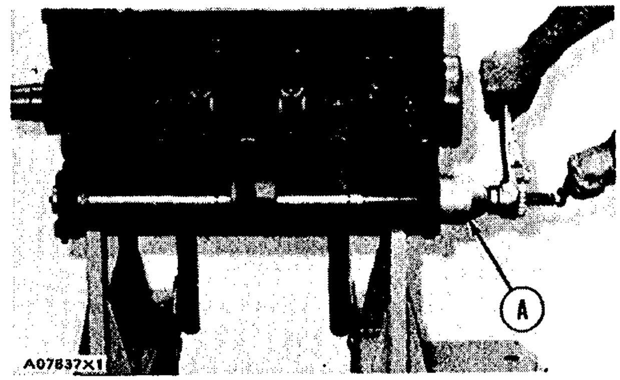
BALANCER SHAFT BEARINGS (3304)

REMOVE BALANCER SHAFT BEARINGS (3304) 1220-28

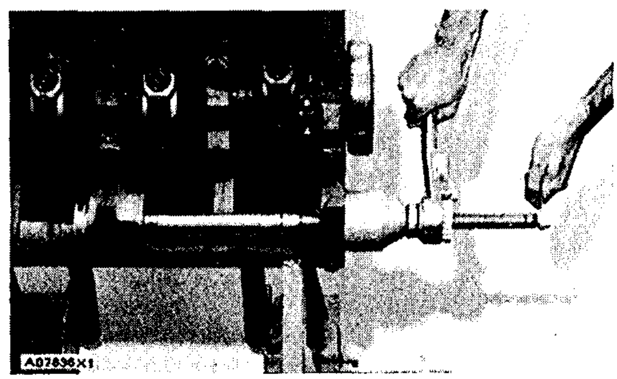
	Tools Needed	A
8S2241	Camshaft Bearing Tool Group	1
8H684	Ratchet Box Wrench	1

start by:
a) remove flywheel housing
b) remove oil pan plate
c) remove oil pump
d) remove balancer shafts



1. Remove the front bearing for the balancer shaft with tooling (A).

2. Remove the center bearing for the balancer shaft with tooling (A).

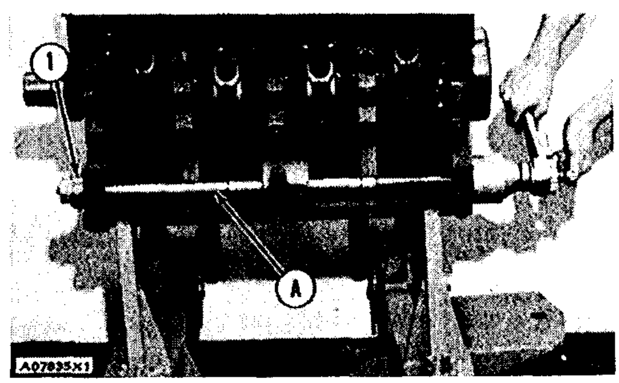


3. Remove the rear bearing for the balancer shaft with tooling (A).

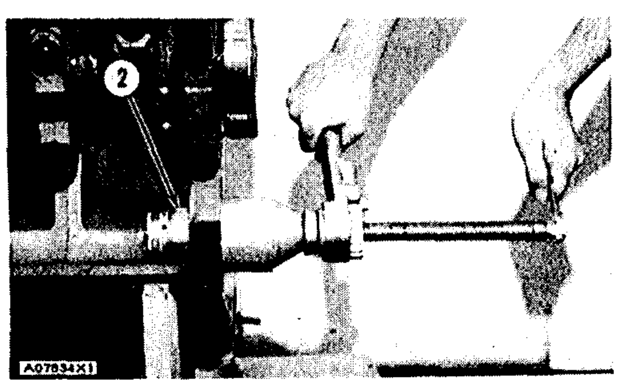
4. Do Steps 1, 2 and 3 again for the other balancer shaft bearings.

INSTALL BALANCER SHAFT BEARINGS (3304) 1220-28

	Tools Needed	A
8S2241	Camshaft Bearing Tool Group	1
8H684	Ratchet Box Wrench	1



1. Install balancer shaft front bearing (1) with tooling (A). Make sure the oil hole in the bearing is in alignment with the oil hole in the cylinder block. The bearing must be .03 ± .02 in. (0.8 ± 0.5 mm) inside the end of the cylinder block after installation.
2. Install the balancer shaft center bearing with tooling (A). Make sure the oil hole in the bearing is in alignment with the oil hole in the cylinder block.



3. Install balancer shaft rear bearing (2) with tooling (A). Make sure the oil hole in the bearing is in alignment with the oil hole in the cylinder block. The bearing must be .03 ± .02 in. (0.8 ± 0.5 mm) inside the end of the cylinder block after installation.
end by:
a) install balancer shafts
b) install oil pump
c) install oil pan plate
d) install flywheel housing

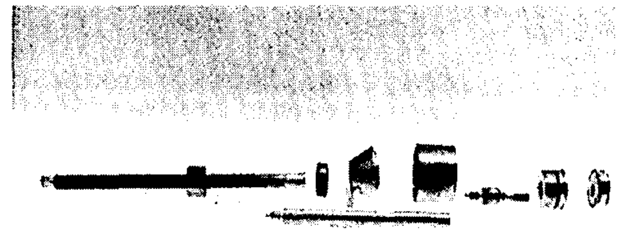
CAMSHAFT BEARINGS

REMOVE CAMSHAFT BEARINGS 1211-11

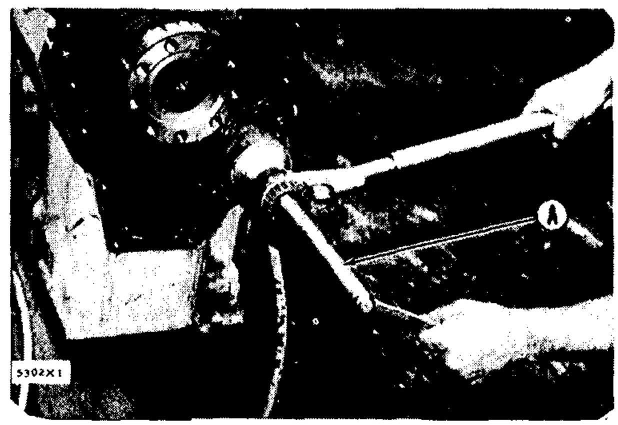
	Tools Needed	A
8S2241	Camshaft Bearing Tool Group	1
8H684	Ratchet Box Wrench	1

start by:
a) remove oil pan plate
b) remove timing gears and plate
c) remove flywheel housing
d) remove camshaft

NOTE: Photos shown are on 3306 engine.



1. Remove the camshaft bearings with tooling (A).



INSTALL CAMSHAFT BEARINGS 1211-12

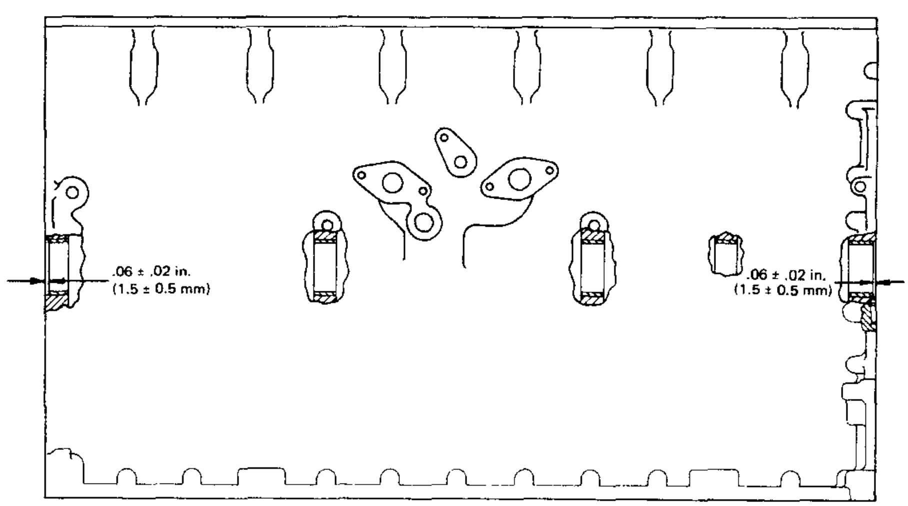
	Tools Needed	A
8S2241	Camshaft Bearing Tool Group	1
8H684	Ratchet Box Wrench	1

1. Install the camshaft bearings in the cylinder block with tooling (A).

NOTE: Install all bearings with oil hole in bearing in alignment with oil hole in cylinder block.

2. The front and rear bearings are to be .06 in. (1.5 mm) inside the ends of the cylinder block after installation.

end by:
a) install camshaft
b) install flywheel housing
c) install timing gears and plate
d) install oil pan plate

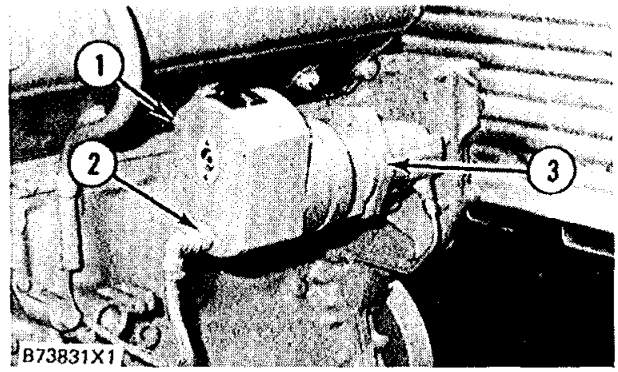


ALTRONIC IGNITION SYSTEM D & A (Section 6)

ALTRONIC MAGNETO

REMOVE MAGNETO 1552-11

1. Disconnect connector (2) at magneto (1).
2. Give support to magneto (1) and remove the bolts that hold magneto (1) to magneto drive (3).
3. Remove magneto (1).



INSTALL MAGNETO 1552-12

1. Put a new gasket on the magneto flange and install the bolts that hold the magneto to the magneto drive.
2. Connect connector (2) to magneto (1).
3. Refer to the topic MAGNETO TIMING for correct magneto timing procedure.

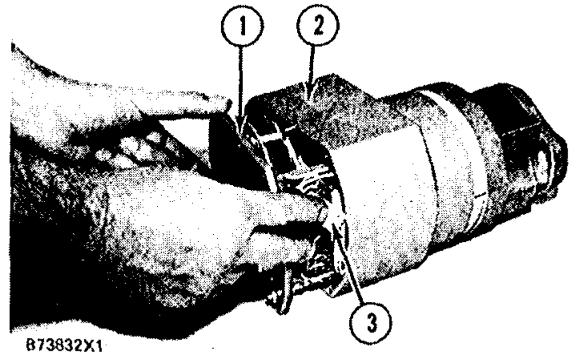
ALTRONIC MAGNETO

DISASSEMBLE MAGNETO 1552-15

	Tools Needed	A	B	C
8H663	Bearing Puller Attachment	1		
5P5265	Bolt		1	
1P510	Driver			1

start by:
a) remove magneto

1. Remove four screws that hold cover (1) to intermediate housing (2) and unplug connector (3).



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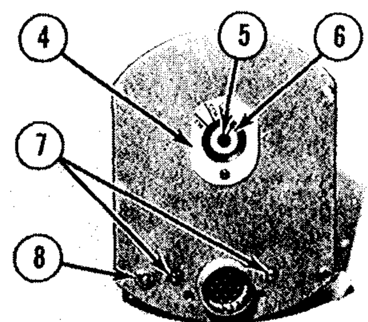
NOTICE

Put a mark for alignment on the connector halves. Hold both halves of the connector. Do not pull the wires to separate the connector.

2. Remove timing cover (4), screw (5) and timing label (6).
3. Remove screws (7) and nut (8) for the diode.
4. Remove driven gear (9).
5. Tilt circuit board (10) away from pick-up coils and unplug the wires from the pick-up coils at the circuit board pin connectors. Do not lose plastic brace when circuit board is moved away from pick-up coils.



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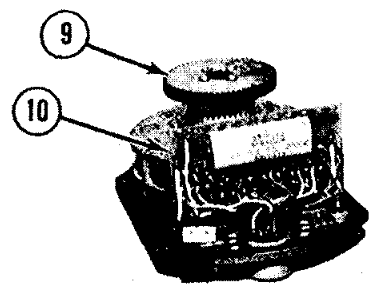
NOTICE

Use needle nose pliers to unplug the receptacles at the pin connectors. Do not pull the wires to disconnect the pin connectors.



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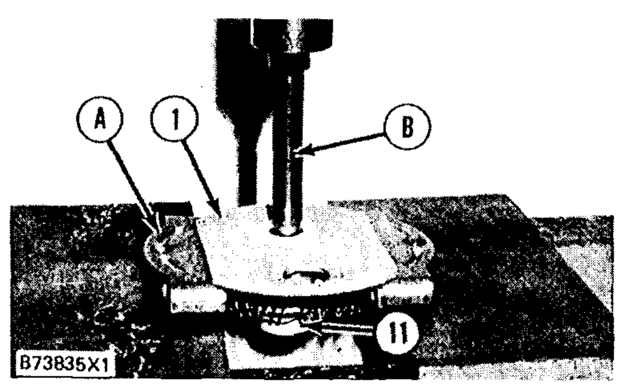
6. Use tool (A) to give support to end cover (1) in a press.
7. Use tool (B), or rod of same dimension, in a press to move distributor shaft, bearing and timer arm assembly (11) out of end cover (1).
8. Use tool (A) to hold timer arm assembly (11) so shaft bearing can be pressed out of aluminum hub in timer arm assembly (11).



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ALTRONIC MAGNETO

9. Remove spring pin (12) and drive coupling (13).

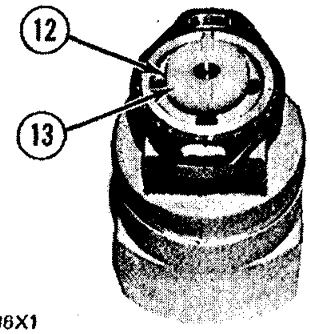
NOTICE

Put identification on flange (14) and housing (15) so flange (14) can be installed in the same position.

10. Remove flange (14) from front housing (15).
11. Give support to flange (14) with tool (A) in a press and use tool (C) to remove seal (16) from the flange.
12. Disconnect stator wires from clamp (18).
13. Remove three screws that hold intermediate housing (17) to stator and front housing (15) and remove intermediate housing (17). use a soft hammer to separate intermediate housing (17) from the stator.

NOTICE

Intermediate housing (17) fits on a bearing rubber cover on the rotor assembly.



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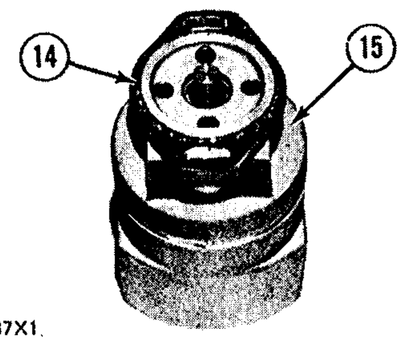

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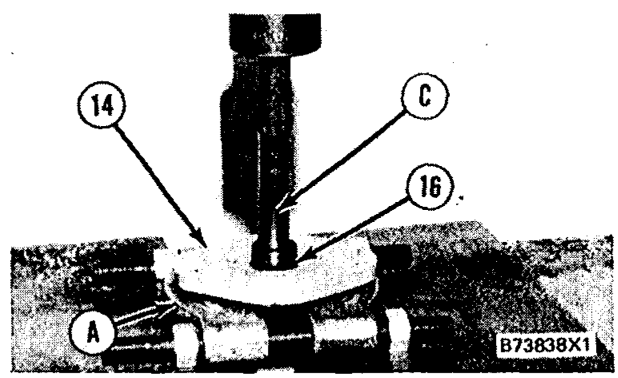

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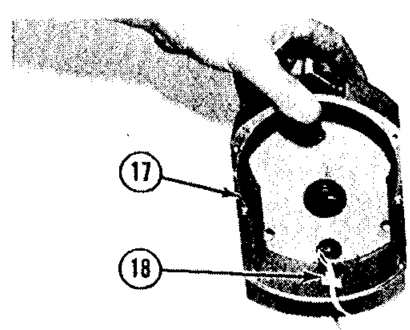

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ALTRONIC MAGNETO

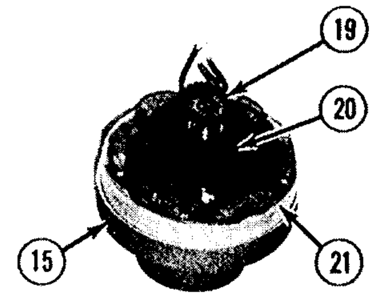
NOTICE

Put a mark for alignment on stator (21) and front housing (15).

14. Remove drive gear (19), bearing rubber cover (20) and stator (21).
15. Put front housing (15) in tool (A) in a press shaft and rotor assembly out of front housing (15).

NOTICE

Do not let the shaft and rotor assembly fall after it is clear of the bearing.



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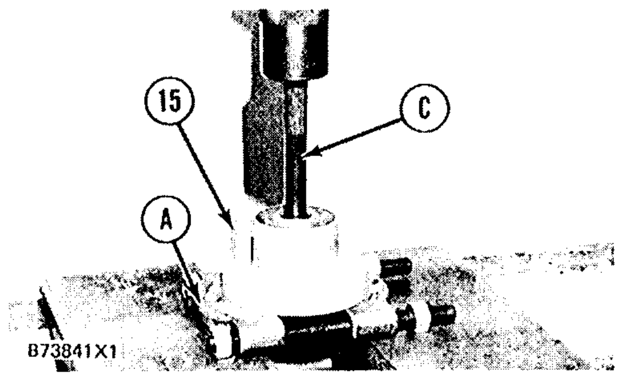

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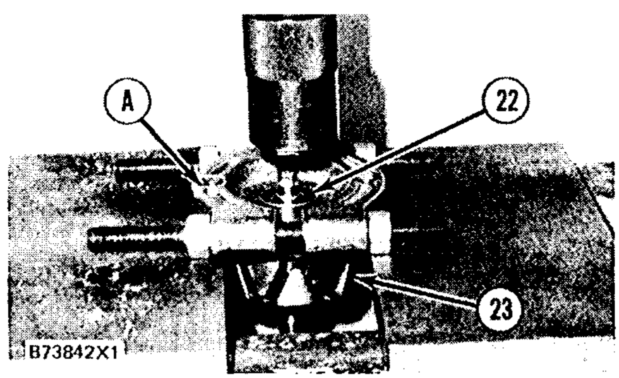
16. Put front housing (15) on tool (A) in a press and use tool (C) to remove the bearing from the front housing.
17. Use tool (A) to hold bearing (22) in a press. Press shaft and rotor assembly (23) out of bearing (22).

NOTICE

Do not let the shaft and rotor assembly fall after it is clear of the bearing.

18. Replace all parts contained in the repair kit.
19. Clean all parts and remove metal filings from the magnet-rotor.



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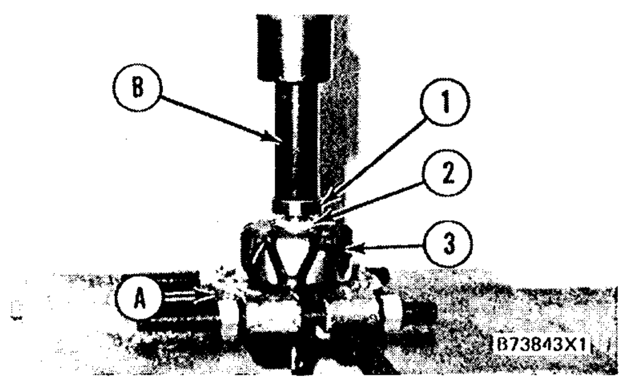
ASSEMBLE MAGNETO 1552-16

	Tools Needed	A	B	C	D	E
8H663	Bearing Puller Attachment	1				
2P2314	Bushing		1			
8S5578	Spacer			1		
1P510	Driver				1	
8S7219	Spacer					1

1. Put spacer (2) in position on the drive gear end of shaft and rotor assembly (3).
2. Give support to the shaft and rotor assembly (3) with tool (A) in a press.
3. Use tool (B) to press bearing (1) against spacer (2).



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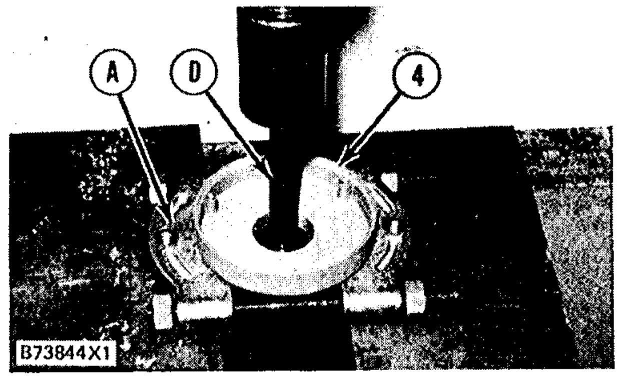
ALTRONIC MAGNETO

4. Give support to front housing (4) with tool (A) in a press. Use tool (D) to install the bearing into front housing (4).



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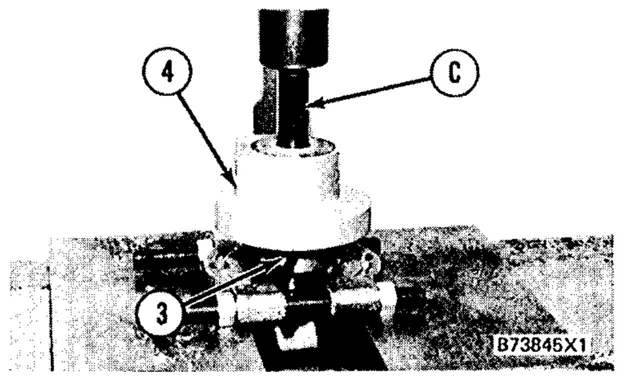
5. Use tool (A) in a press to hold the rotor of shaft and rotor assembly (3).
6. Use tool (C) with a 11.1125 mm (.4375 in.) hardened washer to install front housing (4) and bearing onto the coupling end of the shaft of shaft and rotor assembly (3).



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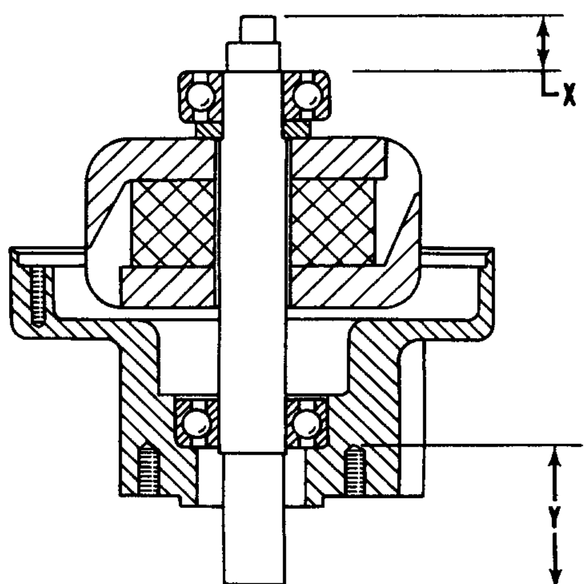
7. Before further assembly check dimensions (X) and (Y) of the shaft and rotor and front housing.

   Dimension (X) from the drive gear end of the bearing is 15.6 mm (.615 in.). Be sure the rotor is against spacer (2).

   Dimension (Y) from the coupling end of the shaft to the bearing is 38.7 mm (1.524 in.).
8. Put stator (6) in position in front housing (4). Use the mark put on at disassembly for alignment reference. Be sure the screw holes are in alignment. Do not damage the teflon wrapping.



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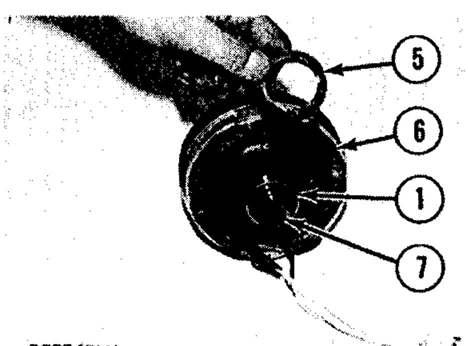
9. Install bearing rubber cover (5) on bearing (1).
10. Install drive gear (7) on shaft.



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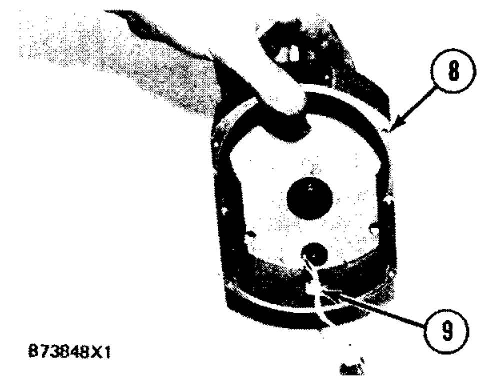
ALTRONIC MAGNETO

NOTICE

Put vaseline petroleum jelly in the base for the bearing in intermediate housing (8).

11. Put intermediate housing (8) in position on stator (G). Be sure the wires are on the same side as the flat base on front housing (8). Put wires in clamp (9).
12. Install three screws through intermediate housing (8), stator (6) into front housing (4). Tighten the screws evenly to bring the housings together over the stator.



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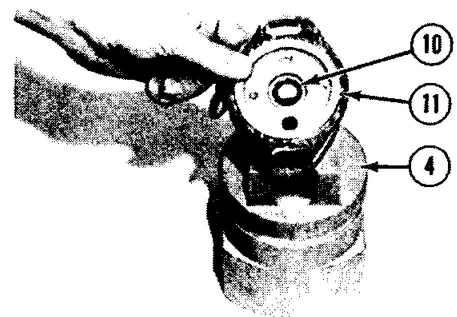
NOTICE

Do not damage the teflon wrapping on stator (6).

13. Put 9S3263 Sealant on the outside of seal (10) and use tool (D) to install seal (10) into flange (11). The lip of the seal faces out.
14. Install the gasket between flange (11) and front housing (4). Align the mark and install the four screws.
15. Install coupling (12) and spring pin (13).
16. Give support to end cover (16) in a press.
17. Use tool (E) and a press to install shaft and bearing (14) into its bore in the end cover. Be sure shaft and bearing is bottomed in its bore.
18. Support end of shaft (arrow) and use tool (E) and a press to install timer assembly (15) onto shaft (14). Install timer assembly until dimension (Z) between the pick-up arm and pick-up coil is 0.25 to 0.46 mm (.010 to .018 in.).
19. The timer arm (15) must rotate freely. If there is interference between the timer arm and the pick-up coils or magnet remove shaft and bearing (14) and timer arm from end cover (16). Remove timer arm (15) from shaft and bearing (14). Repeat Step 18. Dimension (Z) must not exceed 0.46 mm (.018 in.).



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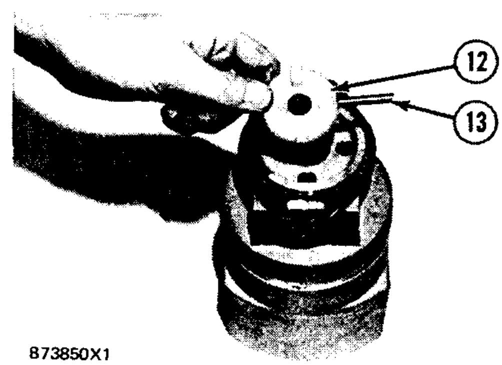

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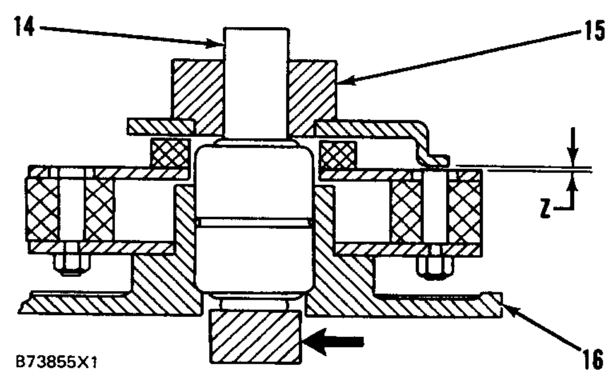

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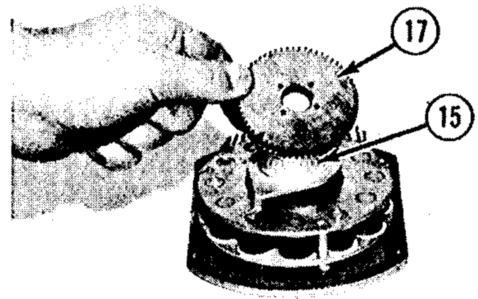
ALTRONIC MAGNETO

20. Install gear (17) on timer arm (15).
21. Put circuit board (18) into position in end cover (16). Connect the wire receptacles to the circuit board pins. The wires are held in order by the wire guide. Do not change the order of the wires. Be sure the pick-up coil wire receptacles seat all the way on the circuit board pins. Use American Pamcer Inc. No. 90204-1 Crimping Tool to crimp the receptacles.
22. Install the screws to hold the circuit board (18) to end cover (16). Install the nut on the diode stud.
23. Install plastic brace (19).
24. Install shaft timing label (20) but do not tighten the screw.
25. Put timer arm (15) over the center of pick-up coil [(A) painted red].
26. Set the mark on the shaft timing label (20) between the "CCW" and "CW" marks and tighten the screw. Be sure the timing label is clean. Check again Steps 24 and 25.
27. Install the timing cover and gasket.
28. Put the gasket in place on end cover (16).
29. Align the mark on connector (21) and engage the halves of the connector.
30. Guide the wiring into intermediate housing (8) and engage end cover (16) onto the dowels on intermediate housing (8). Install and tighten the screws that hold end cover (16).

end by:
a) install magneto



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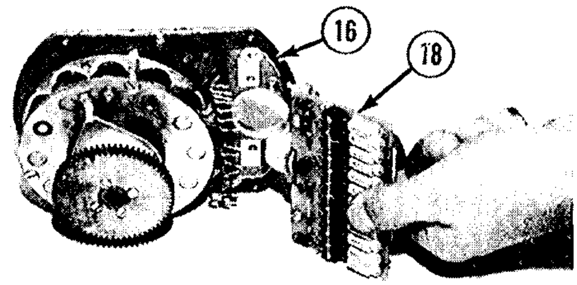

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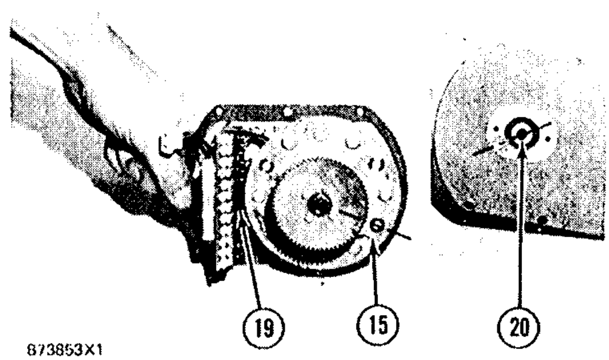

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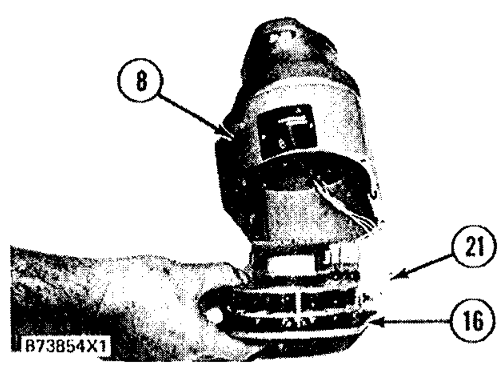

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