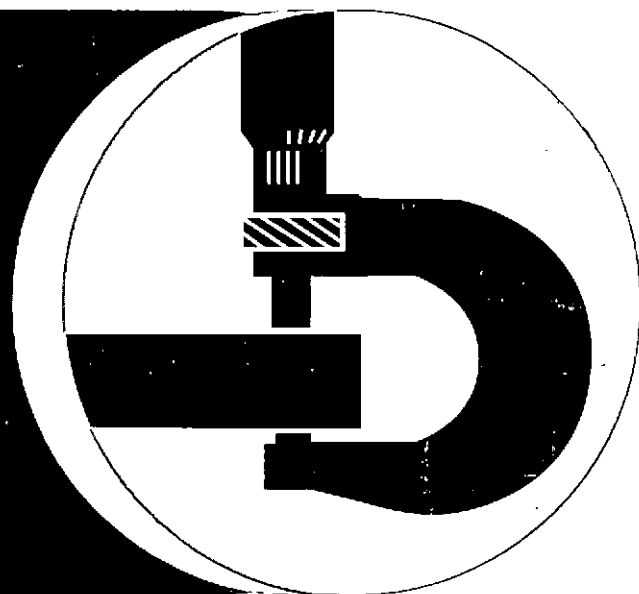


**POWERTECH 4.5 L & 6.8 L
4045 and 6068
Diesel Engines**

**COMPONENT
TECHNICAL
MANUAL**



**Deere Power Systems Group
CTM104 (01JUN96)**

LITHO IN U.S.A.
ENGLISH



DEERE
POWER

Introduction

FOREWORD

This manual is written for an experienced technician. Essential tools required in performing certain service work are identified in this manual and are recommended for use.

Live with safety: Read the safety messages in the introduction of this manual and the cautions presented throughout the text of the manual.



CAUTION: This is the safety-alert symbol. When you see this symbol on the machine or in this manual, be alert to the potential for personal injury.

Use this component technical manual in conjunction with the machine technical manual. An application listing in the introduction identifies product-model/component type-model relationship. See the machine technical manual for information on component removal and installation, and gaining access to the components.

This manual is divided in two parts: repair and operation and tests. Repair sections contain necessary instructions to repair the component. Operation and tests sections help you identify the majority of routine failures quickly.

Information is organized in groups for the various components requiring service instruction. At the beginning of each group are summary listings of all applicable essential tools, service equipment and tools, other materials needed to do the job, service parts kits, specifications, wear tolerance, and torque values.

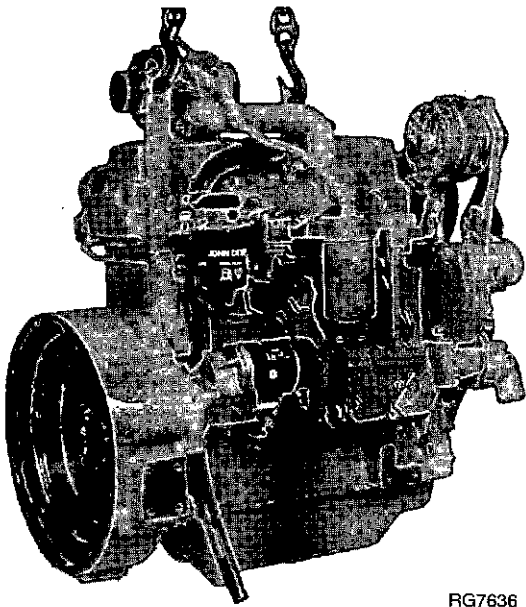
Component Technical Manuals are concise service guides for specific components. Component technical manuals are written as stand-alone manuals covering multiple machine applications.

Fundamental service information is available from other sources covering basic theory of operation, fundamentals of troubleshooting, general maintenance, and basic type of failures and their causes.

CALIFORNIA PROPOSITION 65 WARNING

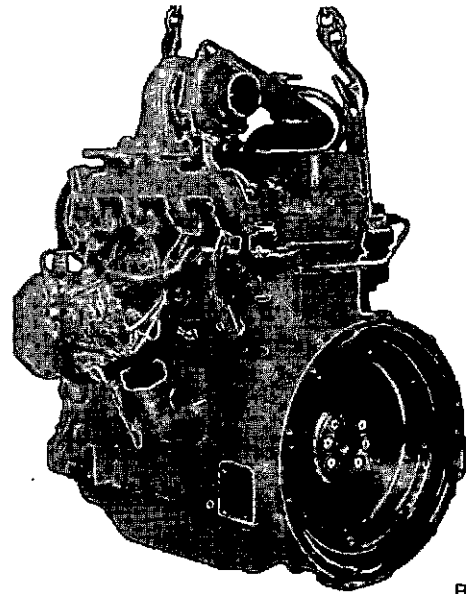
Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects and other reproductive harm.

POWERTECH 4.5 L ENGINE



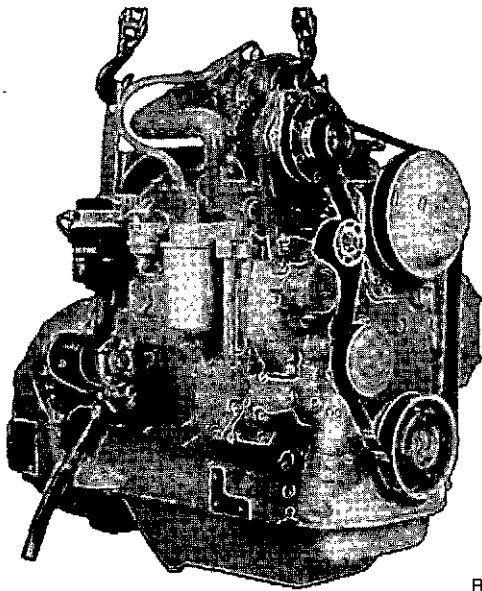
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3/4 Right Rear View



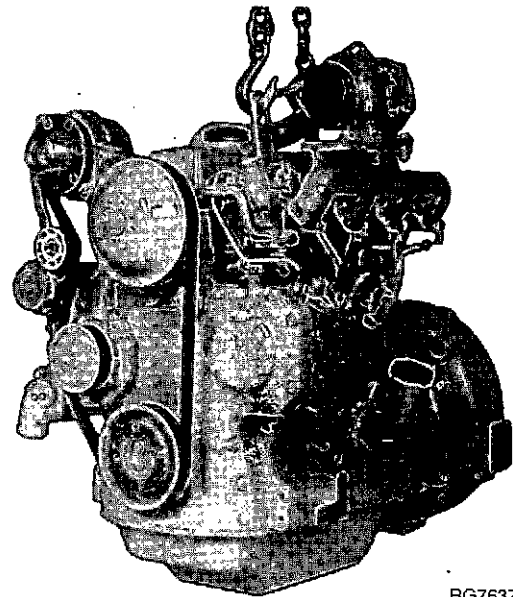
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3/4 Left Rear View



RG7639

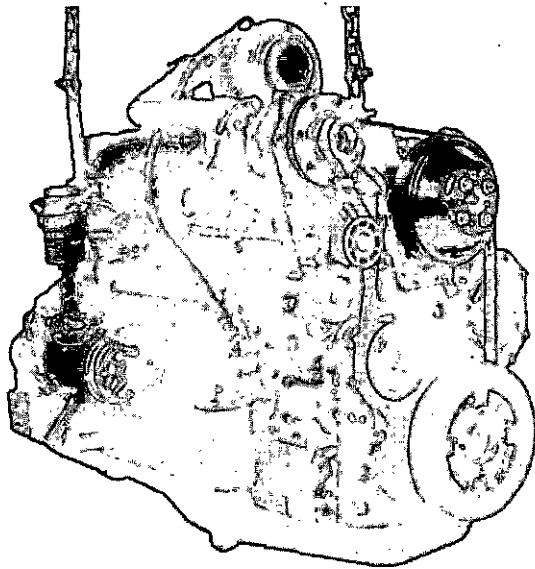
3/4 Right Front View



RG7637

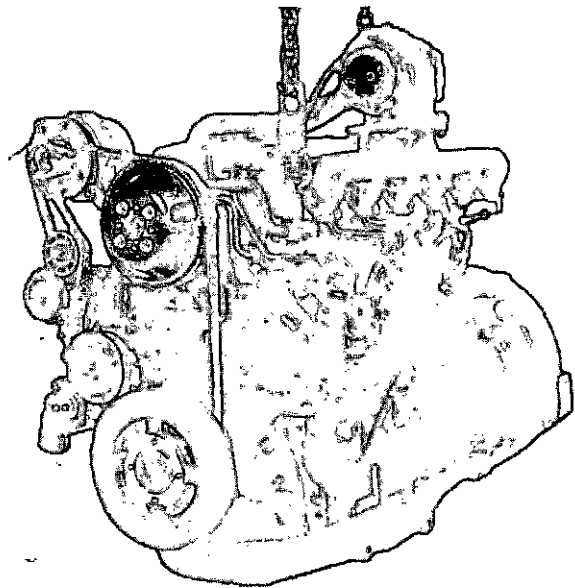
3/4 Left Front View

POWERTECH 6.8 L ENGINE



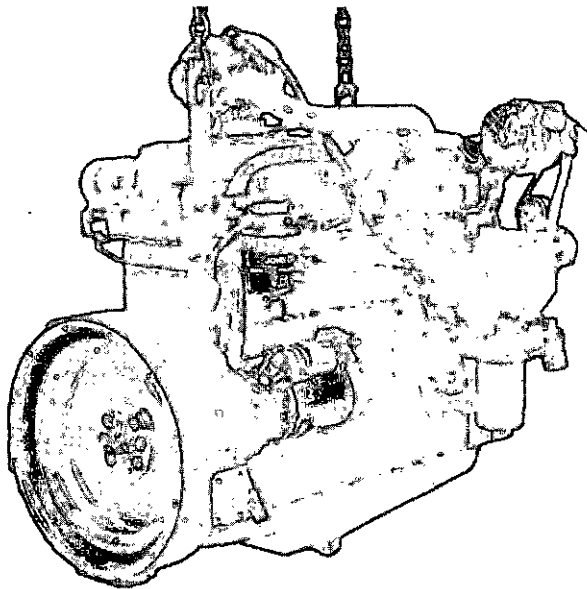
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3/4 Right Front View



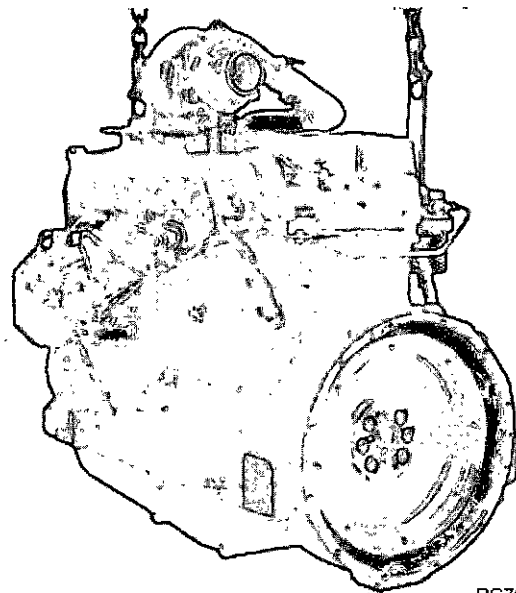
RG7640

3/4 Left Front View



RG7643

3/4 Right Rear View



RG7642

3/4 Left Rear View

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All information, illustrations, and specifications in this manual are based on the latest information available at the time of publication. The right is reserved to make changes at any time without notice.

CTM104 (01JUN96)

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A John Deere ILLUSTRATION® Manual

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HANDLE FLUIDS SAFELY—AVOID FIRES

When you work around fuel, do not smoke or work near heaters or other fire hazards.

Store flammable fluids away from fire hazards. Do not incinerate or puncture pressurized containers.

Make sure machine is clean of trash, grease, and debris.

Do not store oily rags; they can ignite and burn spontaneously.



TS227

PREVENT BATTERY EXPLOSIONS

Keep sparks, lighted matches, and open flame away from the top of battery. Battery gas can explode.

Never check battery charge by placing a metal object across the posts. Use a voltmeter or hydrometer.

Do not charge a frozen battery; it may explode. Warm battery to 16°C (60°F).



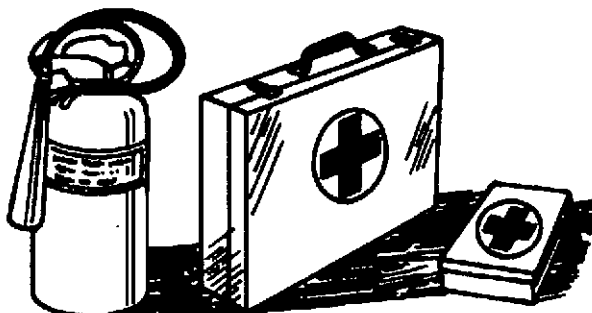
TS204

PREPARE FOR EMERGENCIES

Be prepared if fire starts.

Keep a first aid kit and fire extinguisher handy.

Keep emergency numbers for doctors, ambulance service, hospital, and fire department near your telephone.



TS291

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2

PREVENT ACID BURNS

Sulfuric acid in battery electrolyte is poisonous. It is strong enough to burn skin, eat holes in clothing, and cause blindness if splashed into eyes.

Avoid the hazard by:

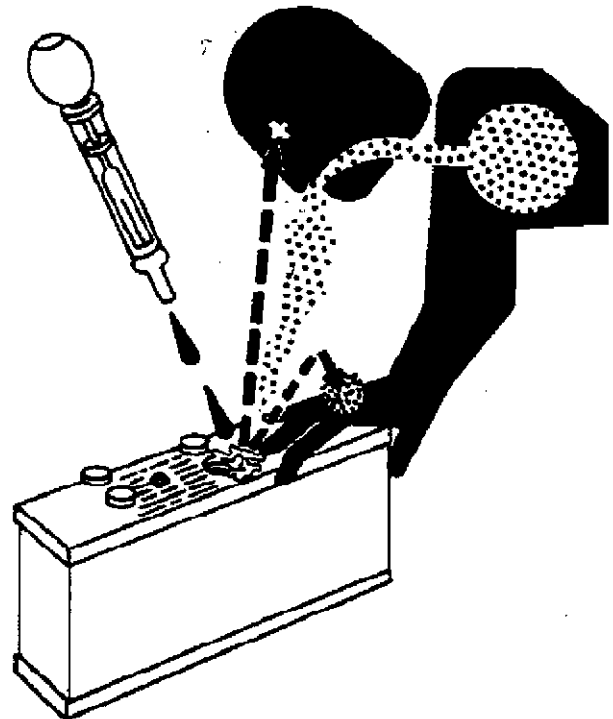
1. Filling batteries in a well-ventilated area.
2. Wearing eye protection and rubber gloves.
3. Avoiding breathing fumes when electrolyte is added.
4. Avoiding spilling or dripping electrolyte.
5. Use proper jump start procedure.

If you spill acid on yourself:

1. Flush your skin with water.
2. Apply baking soda or lime to help neutralize the acid.
3. Flush your eyes with water for 15—30 minutes. Get medical attention immediately.

If acid is swallowed:

1. Do not induce vomiting.
2. Drink large amounts of water or milk, but do not exceed 2 L (2 quarts).
3. Get medical attention immediately.



.TS203

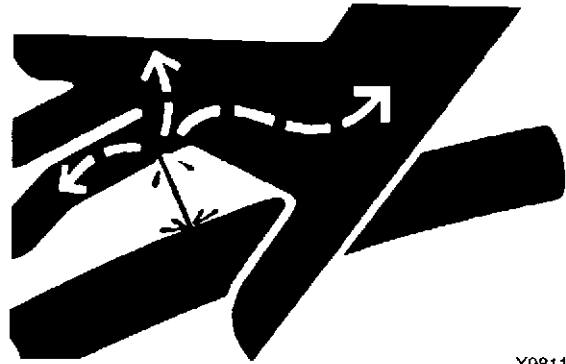
AVOID HIGH-PRESSURE FLUIDS

Escaping fluid under pressure can penetrate the skin causing serious injury.

Avoid the hazard by relieving pressure before disconnecting hydraulic or other lines. Tighten all connections before applying pressure.

Search for leaks with a piece of cardboard. Protect hands and body from high pressure fluids.

If an accident occurs, see a doctor immediately. Any fluid injected into the skin must be surgically removed within a few hours or gangrene may result. Doctors unfamiliar with this type of injury should reference a knowledgeable medical source. Such information is available from Deere & Company Medical Department in Moline, Illinois, U.S.A.



X9811

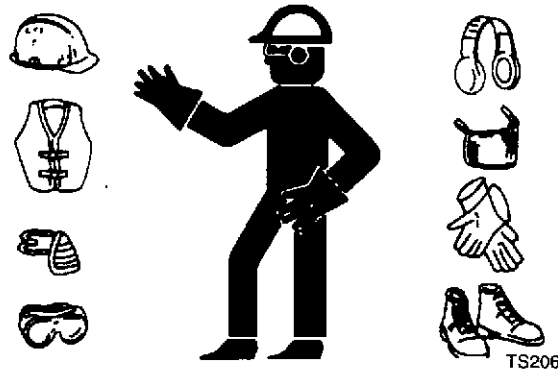
WEAR PROTECTIVE CLOTHING

Wear close fitting clothing and safety equipment appropriate to the job.

Prolonged exposure to loud noise can cause impairment or loss of hearing.

Wear a suitable hearing protective device such as earmuffs or earplugs to protect against objectionable or uncomfortable loud noises.

Operating equipment safely requires the full attention of the operator. Do not wear radio or music headphones while operating machine.

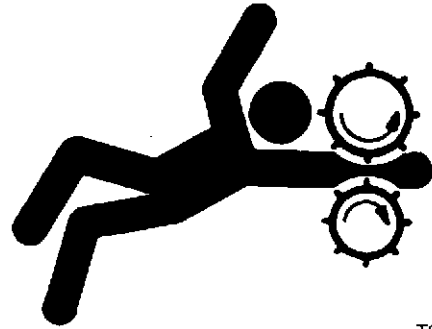


TS206

SERVICE MACHINES SAFELY

Tie long hair behind your head. Do not wear a necktie, scarf, loose, or necklace when you work near machine tools or moving parts. If these items were to get caught, severe injury could result.

Remove rings and other jewelry to prevent electrical shorts and entanglement in moving parts.

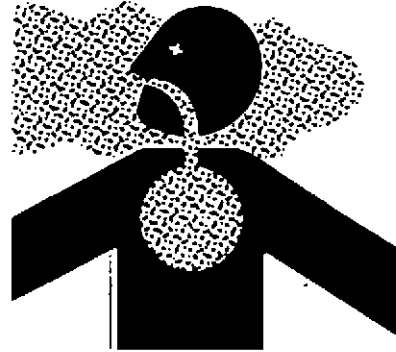


TS228

WORK IN VENTILATED AREA

Engine exhaust fumes can cause sickness or death. If it is necessary to run an engine in an enclosed area, remove the exhaust fumes from the area with an exhaust pipe extension.

If you do not have an exhaust pipe extension, open the doors and get outside air into the area.

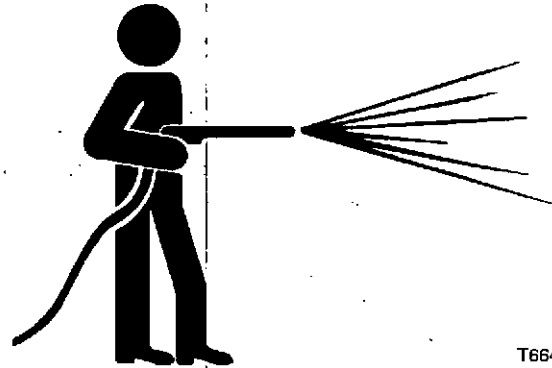


TS220

WORK IN CLEAN AREA

Before starting a job:

- Clean work area and machine.
- Make sure you have all necessary tools to do your job.
- Have the right parts on hand.
- Read all instructions thoroughly; do not attempt shortcuts.



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REMOVE PAINT BEFORE WELDING OR HEATING

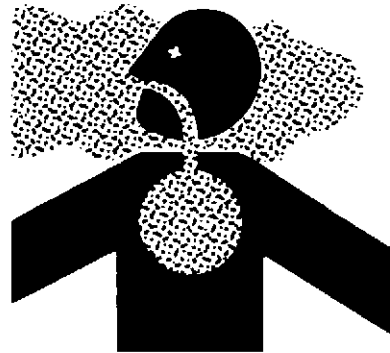
Avoid potentially toxic fumes and dust.

Hazardous fumes can be generated when paint is heated by welding, soldering, or using a torch.

Do all work outside or in a well ventilated area. Dispose of paint and solvent properly.

Remove paint before welding or heating:

- If you sand or grind paint, avoid breathing the dust. Wear an approved respirator.
- If you use solvent or paint stripper, remove stripper with soap and water before welding. Remove solvent or paint stripper containers and other flammable material from area. Allow fumes to disperse at least 15 minutes before welding or heating.



TS220

AVOID HEATING NEAR PRESSURIZED FLUID LINES

Flammable spray can be generated by heating near pressurized fluid lines, resulting in severe burns to yourself and bystanders. Do not heat by welding, soldering, or using a torch near pressurized fluid lines or other flammable materials. Pressurized lines can be accidentally cut when heat goes beyond the immediate flame area.



TS953

ILLUMINATE WORK AREA SAFELY

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Illuminate your work area adequately but safely. Use a portable safety light for working inside or under the machine. Make sure the bulb is enclosed by a wire cage. The hot filament of an accidentally broken bulb can ignite spilled fuel or oil.

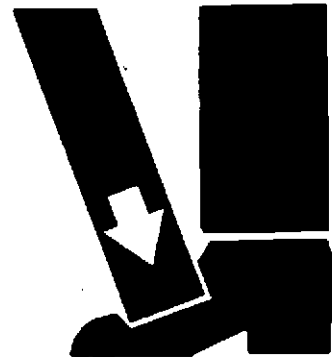


TS223

USE PROPER LIFTING EQUIPMENT

Lifting heavy components incorrectly can cause severe injury or machine damage.

Follow recommended procedure for removal and installation of components in the manual.



TS226

PRACTICE SAFE MAINTENANCE

Understand service procedure before doing work. Keep area clean and dry.

Never lubricate, service, or adjust machine while it is moving. Keep hands, feet, and clothing from power-driven parts. Disengage all power and operate controls to relieve pressure. Lower equipment to the ground. Stop the engine. Remove the key. Allow machine to cool.

Securely support any machine elements that must be raised for service work.

Keep all parts in good condition and properly installed. Fix damage immediately. Replace worn or broken parts. Remove any buildup of grease, oil, or debris.

Disconnect battery ground cable (-) before making adjustments on electrical systems or welding on machine.



TS218

USE PROPER TOOLS

Use tools appropriate to the work. Makeshift tools and procedures can create safety hazards.

Use power tools only to loosen threaded parts and fasteners.

For loosening and tightening hardware, use the correct size tools. DO NOT use U.S. measurement tools on metric fasteners. Avoid bodily injury caused by slipping wrenches.

Use only service parts meeting John Deere specifications.



TS779

DISPOSE OF WASTE PROPERLY

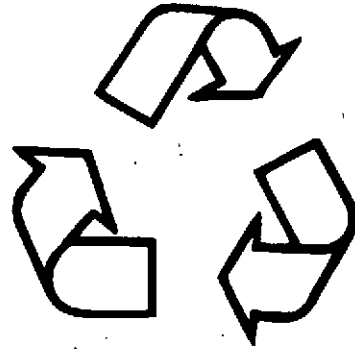
Improperly disposing of waste can threaten the environment and ecology. Potentially harmful waste used with John Deere equipment include such items as oil, fuel, coolant, brake fluid, filters, and batteries.

Use leakproof containers when draining fluids. Do not use food or beverage containers that may mislead someone into drinking from them.

Do not pour waste onto the ground, down a drain, or into any water source.

Air conditioning refrigerants escaping into the air can damage the Earth's atmosphere. Government regulations may require a certified air conditioning service center to recover and recycle used air conditioning refrigerants.

Inquire on the proper way to recycle or dispose of waste from your local environmental or recycling center, or from your John Deere dealer.



TS1133







LIVE WITH SAFETY

Before returning machine to customer, make sure machine is functioning properly, especially the safety systems. Install all guards and shield.



TS231

UNIFIED INCH BOLT AND CAP SCREW TORQUE VALUES

SAE Grade and Head Markings	1 or 2 ^b NO MARK 	5 5.1 5.2 	8 8.2 
SAE Grade and Nut Markings	2 NO MARK 	5 	8 

01
1

Size	Grade 1				Grade 2 ^b				Grade 5, 5.1, or 5.2				Grade 8 or 8.2			
	Lubricated ^a		Dry ^a		Lubricated ^a		Dry ^a		Lubricated ^a		Dry ^a		Lubricated ^a		Dry ^a	
	N·m	lb-ft	N·m	lb-ft	N·m	lb-ft	N·m	lb-ft	N·m	lb-ft	N·m	lb-ft	N·m	lb-ft	N·m	lb-ft
1/4	3.7	2.8	4.7	3.5	6	4.5	7.5	5.5	9.5	7	12	9	13.5	10	17	12.5
5/16	7.7	5.5	10	7	12	9	15	11	20	15	25	18	28	21	35	26
3/8	14	10	17	13	22	16	27	20	35	26	44	33	50	36	63	46
7/16	22	16	28	20	35	26	44	32	55	41	70	52	80	58	100	75
1/2	33	25	42	31	53	39	67	50	85	63	110	80	120	90	150	115
9/16	48	36	60	45	75	56	95	70	125	90	155	115	175	130	225	160
5/8	67	50	85	62	105	78	135	100	170	125	215	160	240	175	300	225
3/4	120	87	150	110	190	140	240	175	300	225	375	280	425	310	550	400
7/8	190	140	240	175	190	140	240	175	490	360	625	450	700	500	875	650
1	290	210	360	270	290	210	360	270	725	540	925	675	1050	750	1300	975
1-1/8	400	300	510	375	400	300	510	375	900	675	1150	850	1450	1075	1850	1350
1-1/4	570	425	725	530	570	425	725	530	1300	950	1650	1200	2050	1500	2600	1950
1-3/8	750	550	950	700	750	550	950	700	1700	1250	2150	1550	2700	2000	3400	2550
1-1/2	1000	725	1250	925	990	725	1250	930	2250	1650	2850	2100	3600	2650	4550	3350

DO NOT use these values if a different torque value or tightening procedure is given for a specific application. Torque values listed are for general use only. Check tightness of fasteners periodically.

Shear bolts are designed to fail under predetermined loads. Always replace shear bolts with identical grade.

Fasteners should be replaced with the same or higher grade. If higher grade fasteners are used, these should only be tightened to the strength of the original.

Make sure fasteners threads are clean and that you properly start thread engagement. This will prevent them from failing when tightening.

Tighten plastic insert or crimped steel-type lock nuts to approximately 50 percent of the dry torque shown in the chart, applied to the nut, not to the bolt head. Tighten toothed or serrated-type lock nuts to the full torque value.

^a "Lubricated" means coated with a lubricant such as engine oil, or fasteners with phosphate and oil coatings. "Dry" means plain or zinc plated without any lubrication.

^b Grade 2 applies for hex cap screws (not hex bolts) up to 152 mm (6-in.) long. Grade 1 applies for hex cap screws over 152 mm (6-in.) long, and for all other types of bolts and screws of any length

METRIC BOLT AND CAP SCREW TORQUE VALUES

Property Class and Head Markings	4.8		8.8		9.8		10.9		12.9	
Property Class and Nut Markings	5		10		10		10		12	

Size	Class 4.8				Class 8.8 or 9.8				Class 10.9				Class 12.9			
	Lubricated ^a		Dry ^a		Lubricated ^a		Dry ^a		Lubricated ^a		Dry ^a		Lubricated ^a		Dry ^a	
	N·m	lb-ft	N·m	lb-ft	N·m	lb-ft	N·m	lb-ft	N·m	lb-ft	N·m	lb-ft	N·m	lb-ft	N·m	lb-ft
M6	4.8	3.5	6	4.5	9	6.5	11	8.5	13	9.5	17	12	15	11.5	19	14.5
M8	12	8.5	15	11	22	16	28	20	32	24	40	30	37	28	47	35
M10	23	17	29	21	43	32	55	40	63	47	80	60	75	55	95	70
M12	40	29	50	37	75	55	95	70	110	80	140	105	130	95	165	120
M14	63	47	80	60	120	88	150	110	175	130	225	165	205	150	260	190
M16	100	73	125	92	190	140	240	175	275	200	350	255	320	240	400	300
M18	135	100	175	125	260	195	330	250	375	275	475	350	440	325	560	410
M20	190	140	240	180	375	275	475	350	530	400	675	500	625	460	800	580
M22	260	190	330	250	510	375	650	475	725	540	925	675	850	625	1075	800
M24	330	250	425	310	650	475	825	600	925	675	1150	850	1075	800	1350	1000
M27	490	360	625	450	950	700	1200	875	1350	1000	1700	1250	1600	1150	2000	1500
M30	675	490	850	625	1300	950	1650	1200	1850	1350	2300	1700	2150	1600	2700	2000
M33	900	675	1150	850	1750	1300	2200	1650	2500	1850	3150	2350	2900	2150	3700	2750
M36	1150	850	1450	1075	2250	1650	2850	2100	3200	2350	4050	3000	3750	2750	4750	3500

DO NOT use these values if a different torque value or tightening procedure is given for a specific application. Torque values listed are for general use only. Check tightness of fasteners periodically.

Shear bolts are designed to fail under predetermined loads. Always replace shear bolts with identical class.

Fasteners should be replaced with the same or higher grade. If higher grade fasteners are used, these should only be tightened to the strength of the original.

Make sure fasteners threads are clean and that you properly start thread engagement. This will prevent them from failing when tightening.

Tighten plastic insert or crimped steel-type lock nuts to approximately 50 percent of the dry torque shown in the chart, applied to the nut, not to the bolt head. Tighten toothed or serrated-type lock nuts to the full torque value.

^a "Lubricated" means coated with a lubricant such as engine oil, or fasteners with phosphate and oil coatings. "Dry" means plain or zinc plated without any lubrication.

ENGINE MODEL DESIGNATION

John Deere Engine Model—4045 and 6068 Engines.

John Deere engine model designation includes number of cylinders, displacement in liters, aspiration, user code, and application code. For example:

4045TF150 Engine

4..... Number of cylinders
4.5..... Liter designation
 T..... Aspiration code
 F..... User code
 1..... Internal engine configuration type
 50..... **POWERTECH** application code

Aspiration Code

D..... Naturally aspirated
T..... Turbocharged

User Factory Code

F..... OEM

Model Designation

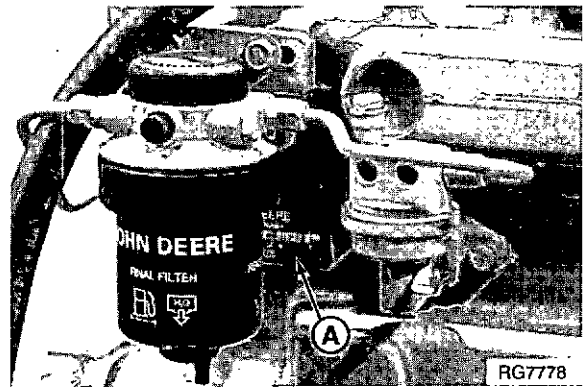
1 or 2..... Indicates different internal engine components

Application Code

50 or above..... **POWERTECH** code for specific application

ENGINE SERIAL NUMBER PLATE INFORMATION

IMPORTANT: The engine serial number plate (A) can be easily destroyed. Before "hot tank" cleaning the block, remove the plate.



1. Engine Serial Number (B)

Each engine has a 13-digit John Deere engine serial number identifying the producing factory, engine model designation, and a 6-digit sequential number. The following is an example:

T04045T000000

T0 Factory producing engine
 4045T Engine model designation
 000000 Sequential serial number

Factory Code

T0 Dubuque, Iowa
 CD Saran, France

Engine Model Designation

4045T Definition explained previously. (See ENGINE MODEL DESIGNATION earlier in this group.)

Sequential Number

000000 6-digit sequential serial number

2. Engine Application Data (C)

The second line of information on the serial number plate identifies the engine/machine or OEM relationship. See ENGINE APPLICATION CHART later in this group.

3. Coefficient of Absorption (D) – (Saran-built engines only)

The second line of information on Saran serial number plate also contains the coefficient of absorption value for smoke emissions.



RG7936

Dubuque Engine Serial Number Plate



RG7935

Saran Engine Serial Number Plate

- A—Engine Serial Number Plate
- B—Engine Serial Number
- C—Engine Application Data
- D—Coefficient of Absorption

ENGINE APPLICATION CHART—OEM APPLICATIONS

4045DF150
4045TF150
4045TF250
6068DF150
6068TF150
6068TF250

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General Information

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6

DIESEL FUEL

Consult your local fuel distributor for properties of the diesel fuel available in your area.

In general, diesel fuels are blended to satisfy the low temperature requirements of the geographical area in which they are marketed.

Diesel fuels specified to EN 590 or ASTM D975 are recommended.

In all cases, the fuel shall meet the following properties:

- **Fuel Lubricity** should pass a minimum of 3100 gram load level as measured by the BOCLE scuffing test.
- **Sulfur Content**
 - Sulfur content should not exceed 0.5%. Sulfur content less than 0.05% is preferred.
 - If diesel fuel with sulfur content greater than 0.5% sulfur content is used, reduce the service interval for engine oil and filter by 50%.
 - DO NOT use diesel fuel with sulfur content greater than 1.0%.
- **Cetane Number of 40 minimum.** Cetane number greater than 50 is preferred, especially for temperatures below -20°C (-4°F) or elevations above 1500 m (5000 ft).
- **Cold Filter Plugging Point (CFPP)** below the expected low temperature OR **Cloud Point** at least 5°C (9°F) below the expected low temperature.

Bio-diesel fuels with properties meeting DIN 51606 or equivalent specification may be used.

DO NOT mix used engine oil or any other type of lubricant with diesel fuel.

LUBRICITY OF DIESEL FUELS

Diesel fuel must have adequate lubricity to ensure proper operation and durability of fuel injection system components.

Diesel fuels for highway use in the United States and Canada now require sulfur content less than 0.05%. Diesel fuel in the European Union will require sulfur content less than 0.05% by 1 October 1996.

Experience shows that some low sulfur diesel fuels may have inadequate lubricity and their use may reduce performance in fuel injection systems due to inadequate lubrication of injection pump components. The lower concentration of aromatic compounds in these fuels also adversely affects injection pump seals and may result in leaks.

Use of low lubricity diesel fuels may also cause accelerated wear, injection nozzle erosion or corrosion, engine speed instability, hard starting, low power, and engine smoke.

Fuel lubricity should pass a minimum of 3100 gram load level as measured by the BOCLE scuffing test.

ASTM D975 and EN 590 specifications do not require fuels to pass a fuel lubricity test.

If fuel of low or unknown lubricity is used, add John Deere PREMIUM DIESEL FUEL CONDITIONER (or equivalent) at the specified concentration. John Deere PREMIUM DIESEL FUEL CONDITIONER is available in winter and summer formulas. Consult your John Deere engine distributor or servicing dealer for more information.

ENGINE BREAK-IN OIL

New engines are filled at the factory with John Deere ENGINE BREAK-IN OIL. During the break-in period, add John Deere ENGINE BREAK-IN OIL as needed to maintain the specified oil level.

Change the oil and filter after the first 100 hours of operation of a new or rebuilt engine.

After engine overhaul, fill the engine with John Deere ENGINE BREAK-IN OIL.

If John Deere ENGINE BREAK-IN OIL is not available, use a diesel engine oil meeting one of the following during the first 100 hours of operation:

- API Service Classification CE
- ACEA Specification E1
- CCMC Specification D4

After the break-in period, use John Deere PLUS-50® or other diesel engine oil as recommended in this manual.

IMPORTANT: Do not use John Deere PLUS-50 oil or engine oils meeting API CG4, API CF4, ACEA E3, ACEA E2, or CCMC D5 performance levels during the first 100 hours of operation of a new or rebuilt engine. These oils will not allow the engine to break-in properly.

DIESEL ENGINE OIL

Use oil viscosity based on the expected air temperature range during the period between oil changes.

The following oil is preferred.

- John Deere PLUS-50®

If John Deere PLUS-50 engine oil and a John Deere oil filter are used, the service interval for oil and filter changes may be extended by 50 hours.

The following oil is also recommended:

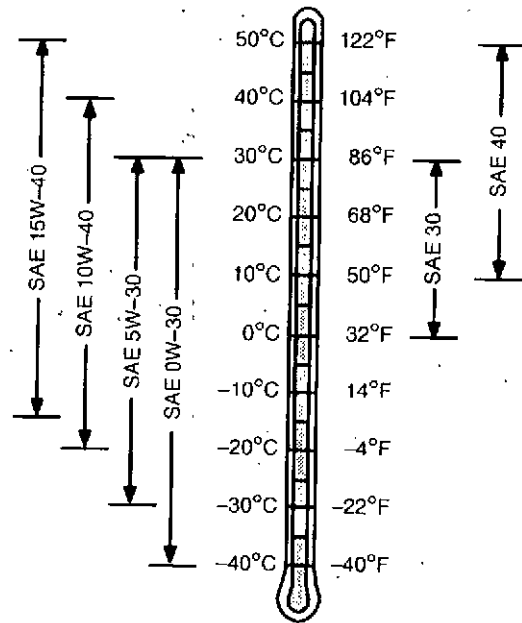
- John Deere TORQ-GARD SUPREME®

Other oils may be used if they meet one or more of the following:

- John Deere UNI-GARD™
- API Service Classification CG-4
- API Service Classification CF-4
- ACEA Specification E3
- ACEA Specification E2
- CCMC Specification D5
- CCMC Specification D4

Multi-viscosity diesel engine oils are preferred.

If diesel fuel with sulfur content greater than 0.5% is used, reduce the service interval by 50%.



TS1647

ALTERNATIVE AND SYNTHETIC LUBRICANTS

Conditions in certain geographical areas may require lubricant recommendations different from those printed in this manual.

Some John Deere brand coolants and lubricants may not be available in your location.

Consult your John Deere dealer to obtain information and recommendations.

Synthetic lubricants may be used if they meet the performance requirements as shown in this manual.

The temperature limits and service intervals shown in this manual apply to both conventional and synthetic oils.

Re-refined base stock products may be used if the finished lubricant meets the performance requirements.

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MIXING OF LUBRICANTS

In general, avoid mixing different brands or types of oil. Oil manufacturers blend additives in their oils to meet certain specifications and performance requirements.

Mixing different oils can interfere with the proper functioning of these additives and degrade lubricant performance.

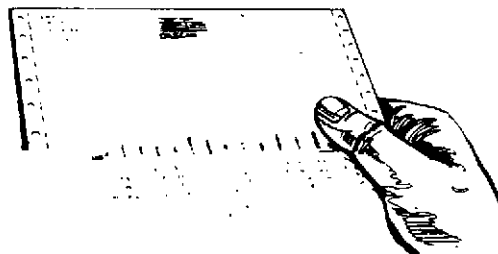
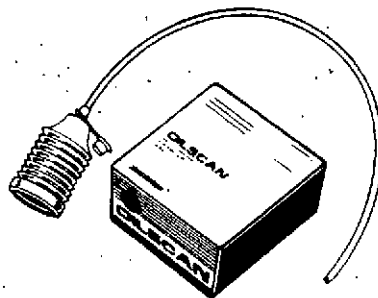
Consult your John Deere engine distributor or servicing dealer to obtain specific information and recommendations.

OILSCAN® AND COOLSCAN™

OILSCAN and COOLSCAN are John Deere sampling programs to help you monitor machine performance and identify potential problems before they cause serious damage.

Oil and coolant samples should be taken from each system prior to its recommended change interval.

Check with your John Deere dealer for the availability of OILSCAN and COOLSCAN kits.



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GREASE

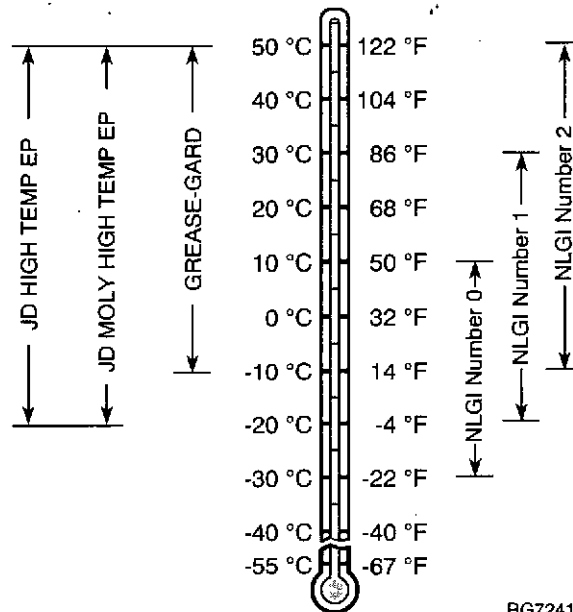
Use grease based on NLGI consistency numbers and the expected air temperature range during the service interval.

The following greases are preferred:

- John Deere HIGH TEMPERATURE EP GREASE
- John Deere MOLY HIGH TEMPERATURE EP GREASE
- John Deere GREASE-GARD™

Other greases may be used if they meet one of the following:

- NLGI Performance Classification GC-LB



RG7241

DIESEL ENGINE COOLANT RECOMMENDATIONS

Contact your engine distributor or servicing dealer to determine what the cooling system of this engine is filled with and the winter freeze protection level.

Solutions of antifreeze and supplemental coolant additives **MUST** be used year-round for freeze protection, boil-over protection, and to provide a stable, noncorrosive environment for seals, hoses and metal engine parts.

The following engine coolant is preferred for service:

- John Deere PREDILUTED ANTIFREEZE/
SUMMER COOLANT
- John Deere COOL-GARD, where available

The following engine coolant is also recommended:

- John Deere ANTIFREEZE/SUMMER COOLANT CONCENTRATE in a 40 to 60 percent mixture of concentrate with quality water

- **JOHN DEERE PREDILUTED ANTIFREEZE/
SUMMER COOLANT**

This product contains all the necessary ingredients that make up the proper coolant solution: chemically pure water, ethylene glycol (low silicate antifreeze), and supplemental coolant additives (SCAs). It is ready to use; no mixing is required.

John Deere Prediluted Antifreeze/Summer Coolant permits extended service life to 3000 hours or 36 months of operation.

- **JOHN DEERE COOL-GARD™**

In certain geographical areas, John Deere COOL-GARD is marketed for use in the engine cooling system. This product contains all the necessary ingredients that make up the proper coolant solution: chemically pure water, ethylene glycol (low silicate antifreeze), and supplemental coolant additives (SCAs). It is ready to add to cooling system as is; no mixing or supplemental coolant additives required. Contact your John Deere Parts Network for local availability.

John Deere COOL-GARD has a service life of 2000 hours or 24 months of operation.

- **JOHN DEERE ANTIFREEZE/SUMMER
COOLANT CONCENTRATE**

This product contains ethylene glycol (low silicate antifreeze) and supplemental coolant additives (SCAs). It must be mixed with quality water, as described later in this section, before adding to the engine cooling system. The proportion of water to be used depends upon the lowest freeze protection temperature desired according to the following table:

% CONCENTRATE	FREEZE PROTECTION LIMIT
40	-24° C (-12° F)
50	-37° C (-34° F)
60	-52° C (-62° F)

John Deere Antifreeze/Summer Coolant Concentrate has a service life of 2000 hours or 24 months of operation.

ENGINE COOLANT SPECIFICATIONS

Engine coolants are a combination of three chemical components: ethylene glycol (antifreeze), inhibiting coolant additives, and quality water.

Coolant solutions of quality water, ethylene glycol concentrate (antifreeze), and supplemental coolant additives (SCAs) **MUST** be used year-round to protect against freezing, boil-over, liner erosion or pitting, and to provide a stable, noncorrosive environment for seals, hoses, and metal engine parts.

Some products, including John Deere PREDILUTED ANTIFREEZE/SUMMER COOLANT and John Deere COOL-GARD, are fully formulated coolants that contain all three components in their correct concentrations. Do not add an initial charge of supplemental coolant additives to these fully formulated products.

Some coolant concentrates, including John Deere ANTIFREEZE/SUMMER COOLANT CONCENTRATE, contain both ethylene glycol antifreeze and inhibiting coolant additives. Mix these products and quality water, but do not add an initial charge of supplemental coolants additives.

Coolants meeting ASTM D5345 (prediluted coolant) or ASTM D4985 (coolant concentrate) require an initial charge of supplemental coolant additives.

Water Quality:

Water quality is important to the performance of the cooling system. Distilled, deionized, or demineralized water is recommended for mixing with ethylene glycol base engine coolant concentrate. All water used in the cooling system should meet the following minimum specifications for quality:

Water Quality Specifications

Item	Parts Per Million	Grains Per U.S. Gallon
Chlorides (maximum)	40	2.5
Sulfates (maximum)	100	5.9
Total Dissolved Solids (maximum)	340	20
Total Hardness (maximum)	170	10
pH Level	5.5—9.0	

Ethylene Glycol Concentrate (Antifreeze):

IMPORTANT: Do not use cooling system sealing additives or antifreeze that contains sealing additives.

The use of John Deere coolant products, as outlined on the previous page, is **strongly recommended**.

If John Deere coolant products are not used, other low silicate ethylene glycol base coolants for heavy-duty diesel engines may be used when mixed with quality water and supplemental coolant additives (SCAs), if they meet one of the following specifications:

- ASTM-D5345 (prediluted coolant)
- ASTM D4985 (coolant concentrate) in a 40% to 60% mixture of concentrate with quality water.

Coolants meeting these specifications require addition of supplemental coolant additives (SCAs), formulated for heavy-duty diesel engines, for protection against corrosion and cylinder liner erosion and pitting.

IMPORTANT: Never use automotive-type coolants (such as those meeting ASTM D3306 or ASTM D4656). These coolants do not contain the correct additives to protect heavy-duty diesel engines. They often contain a high concentration of silicates and may damage the engine or cooling system.

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8

ENGINE COOLANT SPECIFICATIONS—CONTINUED

Supplemental Coolant Additives (SCAs):

IMPORTANT: DO NOT over-inhibit antifreeze solutions, as this can cause silicate-dropout. When this happens, a gel-type deposit is created which retards heat transfer and coolant flow causing engine to overheat.

NOTE: John Deere Prediluted Antifreeze/Summer Coolant, John Deere Antifreeze/Summer Coolant Concentrate, and John Deere COOL-GARD contain supplemental coolant additives (SCAs). However, as the coolant solution loses its effectiveness, additives will need to be added.



John Deere Liquid Coolant Conditioner

Operating without proper coolant additive will result in increased corrosion, cylinder liner erosion and pitting, and other damage to the engine and cooling system. A simple mixture of ethylene glycol and water WILL NOT give adequate protection.

The use of supplemental coolant additives reduces corrosion, erosion, and pitting. These chemicals reduce the number of vapor bubbles in the coolant and help form a protective film on cylinder liner surfaces. This film acts as a barrier against the harmful effects of collapsing vapor bubbles.

Inhibit the antifreeze-coolant mix with a non-chromate inhibitor. John Deere Liquid Coolant Conditioner is recommended as a supplemental coolant additive in John Deere engines.

IMPORTANT: Check inhibitors between drain intervals every 600 hours or 12 months of operation. Replenish inhibitors by the addition of a supplemental coolant additive as necessary.

DO NOT use soluble oil.

Additives eventually lose their effectiveness and must be recharged with additional supplemental coolant additives available in the form of liquid coolant conditioner. See TESTING DIESEL ENGINE COOLANT and REPLENISHING SUPPLEMENTAL COOLANT ADDITIVES (SCAs) BETWEEN COOLANT CHANGES, as described later in this group.

TESTING DIESEL ENGINE COOLANT

Maintaining adequate concentrations of glycol and inhibiting additives in the coolant is critical to protect the engine and cooling system against freezing, corrosion, and cylinder liner erosion and pitting.

Test the coolant solution at 600 hours or 12 month intervals and whenever excessive coolant is lost through leaks or overheating to ensure the necessary protection.



02 Coolant Test Strips

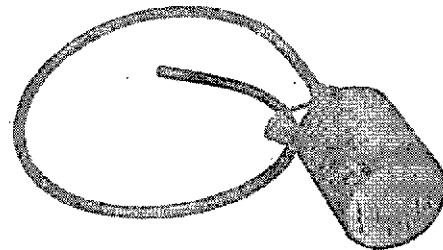
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Coolant test strips are available from your John Deere dealer. These test strips provide a simple, effective method to check the freeze point and additive levels of your engine coolant.

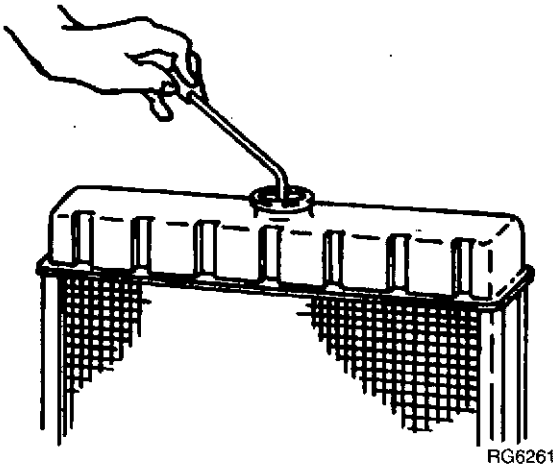
Compare the results to the supplemental coolant additive (SCA) chart to determine the amount of inhibiting additives in your coolant and whether more John Deere Liquid Coolant Conditioner should be added.

COOLSCAN

For a more thorough evaluation of your coolant, perform a COOLSCAN analysis, where available. See your John Deere engine distributor or servicing dealer for information about COOLSCAN.



REPLENISHING SUPPLEMENTAL COOLANT ADDITIVES (SCA'S) BETWEEN COOLANT CHANGES



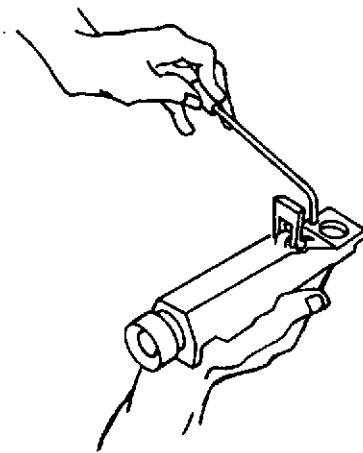
IMPORTANT: Do not add supplemental coolant additives when the cooling system is drained and refilled with John Deere ANTIFREEZE/SUMMER COOLANT or John Deere COOL-GARD.

Through time and use, the concentration of coolant additives is gradually depleted during engine operation. Periodic replenishment of inhibitors is required, even when John Deere ANTIFREEZE/SUMMER COOLANT or John Deere COOL-GARD is used. The cooling system must be recharged with additional supplemental coolant additives available in the form of liquid coolant conditioner.

Maintaining the correct coolant conditioner concentration (SCAs) and freeze point is essential in your cooling system to protect against rust, liner pitting and corrosion, and freeze-ups due to incorrect coolant dilution.

John Deere LIQUID COOLANT CONDITIONER is recommended as a supplemental coolant additive in John Deere engines.

Test the coolant solution at 600 hours or 12 months of operation using either John Deere coolant test strips or a CoolScan analysis. If a CoolScan analysis is not available, recharge system per instructions printed on label of John Deere Liquid Coolant Conditioner.



IMPORTANT: ALWAYS maintain coolant at correct level and concentration. DO NOT operate engine without coolant for even a few minutes.

If frequent coolant makeup is required, the glycol concentration should be checked with JT05460 Refractometer to assure that the desired freeze point is maintained. Follow manufacturer's instructions provided with refractometer.

Add the manufacturer's recommended concentration of supplemental coolant additive. DO NOT add more than the recommended amount.

The use of non-recommended supplemental coolant additives may result in additive drop-out and gelation of the coolant.

If other coolants are used, consult the coolant supplier and follow the manufacturer's recommendation for use of supplemental coolant additives.

See ENGINE COOLANT SPECIFICATIONS earlier in this group for proper mixing of coolant ingredients before adding to the cooling system.

OPERATING IN WARM TEMPERATURE CLIMATES

John Deere engines are designed to operate using glycol base engine coolants.

Always use a recommended glycol base engine coolant, even when operating in geographical areas where freeze protection is not required.

IMPORTANT: Water may be used as coolant *in emergency situations only*.

Foaming, hot surface aluminum and iron corrosion, scaling, and cavitation will occur when water is used as the coolant, even when coolant conditioners are added.

Drain cooling system and refill with recommended glycol base engine coolant as soon as possible.

02
12

FLUSH AND SERVICE COOLING SYSTEM



TS281



CAUTION: Explosive release of fluids from pressurized cooling system can cause serious burns.

Shut off engine. Only remove filler cap when cool enough to touch with bare hands. Slowly loosen cap to first stop to relieve pressure before removing cap completely.

IMPORTANT: Air must be expelled from cooling system when system is refilled. Follow procedure given in your operator's manual.

The ethylene glycol base (antifreeze) can become depleted of SCAs allowing various acids to form that will damage engine components. In addition, heavy metals, such as lead, copper and zinc, accumulate in the ethylene glycol base. The heavy metals come from corrosion that occurs to some degree with in a cooling system. When a coolant is saturated to the point where it can no longer hold heavy metals and other dissolved solids, they settle out and act as abrasives on engine parts.

NOTE: Refer to your operator's manual for a specific service interval.

FLEETGUARD® is a registered trademark of Cummins Engine Company.

RESTORE™ and RESTORE PLUS™ are trademarks of FLEETGUARD.

Flush cooling system and replace thermostats as described in your operator's manual. Clean cooling system with clean water and TY15979 John Deere Heavy-Duty Cooling System Cleaner or an equivalent cleaner such as FLEETGUARD® RESTORE™ or RESTORE PLUS™. Follow the instructions provided with the cleaner. Refill cooling system with the appropriate coolant solution. See ENGINE COOLANT SPECIFICATIONS, earlier in this group.

IMPORTANT: NEVER overfill the system. A pressurized system needs space for heat expansion without overflowing at the top of the radiator. Coolant level should be at bottom of radiator filler neck.

Air must be expelled from cooling system when system is refilled. Loosen temperature sending unit fitting at rear of cylinder head or plug in thermostat housing to allow air to escape when filling system. Retighten fitting or plug when all the air has been expelled.

After adding new coolant solution, run engine until it reaches operating temperature. This mixes the coolant solution uniformly and circulates it through the entire system. After running engine, check coolant level and entire cooling system for leaks.

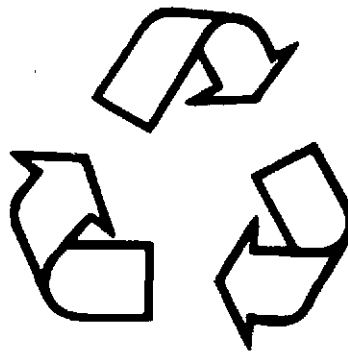
Contact your authorized servicing dealer or engine distributor, if there are further questions.

DISPOSING OF COOLANT

Improperly disposing of engine coolant can threaten the environment and ecology.

Use leakproof containers when draining fluids. Do not use food or beverage containers that may mislead someone into drinking from them.

Do not pour waste onto the ground, down a drain, or into any water source.

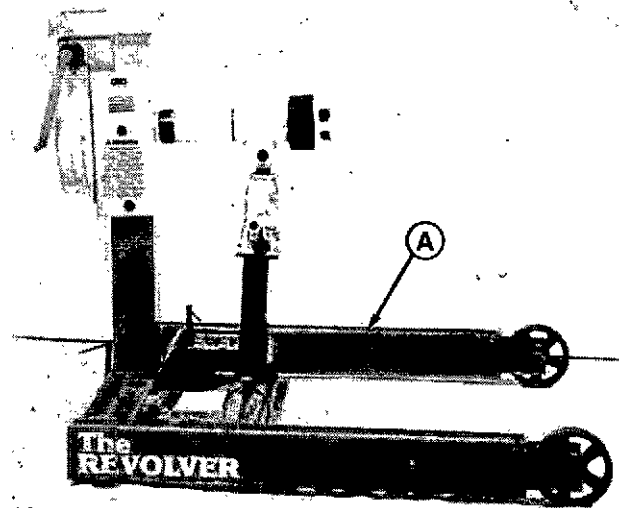


TS1133

02 Inquire on the proper way to recycle or dispose of
14 waste from your local environmental or recycling center,
or from your John Deere dealer.

ENGINE REPAIR STAND

NOTE: Only the 2722 kg (6000 lb) heavy-duty engine repair stand (A) No. D05223ST manufactured by Owatonna Tool Co., Owatonna, Minnesota is referenced in this manual. When any other repair stand is used, consult the manufacturer's instructions for mounting the engine.



RG4929

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1

SAFETY PRECAUTIONS

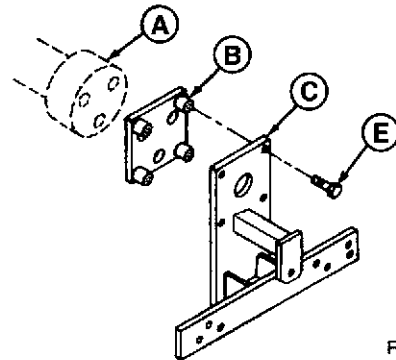
- The engine repair stand should be used only by qualified service technicians familiar with this equipment.
- To maintain shear strength specifications, alloy steel SAE Grade 8 or higher socket head cap screws must be used to mount adapters or engine. Use LOCTITE® 242 Thread Lock and Sealer on cap screws when installing lifting straps on engine. Tighten cap screws to 170 N·m (125 lb-ft).
- For full thread engagement, be certain that tapped holes in adapters and engine blocks are clean and not damaged. A thread length engagement equal to 1-1/2 screw diameters minimum is required to maintain strength requirements.
- To avoid structural or personal injury, do not exceed the maximum capacity rating of 2722 kg (6000 lb). Maximum capacity is determined with the center of the engine located not more than 330 mm (13 in.) from the mounting hub surface of the engine stand.
- To avoid an unsafe off-balance load condition, the center of balance of an engine must be located within 51 mm (2 in.) of the engine stand rotating shaft. Engine center of balance is generally located a few millimeters above the crankshaft.
- To prevent possible personal injury due to engine slippage, recheck to make sure engine is solidly mounted before releasing support from engine lifting device.
- Never permit any part of the body to be positioned under a load being lifted or suspended. Accidental slippage may result in personal injury.
- The lifting jack is to be used when it is necessary to lift the engine for rotation. When working on the engine, the jack should be at its lowest position to keep the center of gravity low and the possibility of tipping low.
- To prevent possible personal injury due to sudden engine movement, lower engine by operating jack release valve slowly. Do not unscrew release valve knob more than two turns from its closed position.

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2

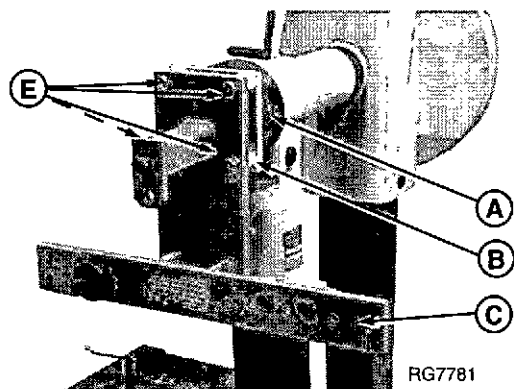
INSTALL ADAPTERS ON ENGINE REPAIR STAND

1. Attach the D05226ST Special Adapter (B) to mounting hub (A) of the engine repair stand using SAE Grade 8 socket-head screws (D). Tighten screws to 135 N·m (100 lb-ft).
2. Attach the 62835* Engine Adapter (C) to the special adapter, using four 5/8 -11 x 2 in. SAE Grade 8 cap screws (E). Tighten screws to 135 N·m (100 lb-ft).

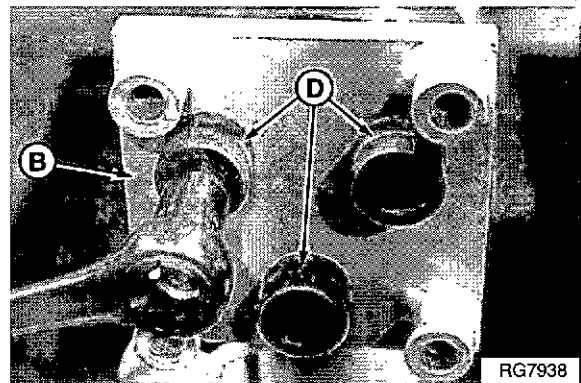


RG7783

- A—Mounting Hub
- B—D05226ST Special Adapter
- C—62835 Engine Adapter
- D—Cap Screws
- E—Cap Screws



RG7781



RG7938

* Part of JT07268 Engine Adapter Kit

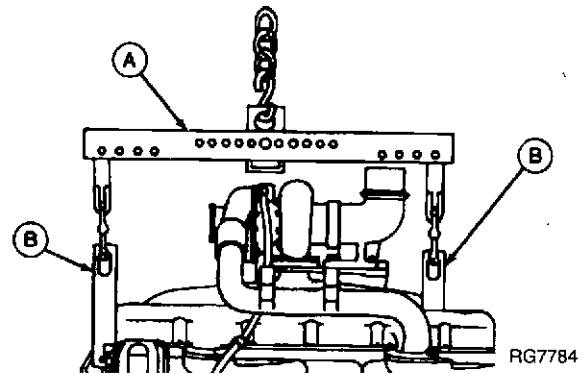
ENGINE LIFTING PROCEDURE



CAUTION: Use extreme caution when lifting and NEVER permit any part of the body to be positioned under an engine being lifted or suspended.

Lift engine with longitudinal loading on lift sling and lifting brackets only. Angular loading greatly reduces lifting capacity of sling and brackets.

1. Attach JDG23 Engine Lifting Sling (A, or other suitable sling) to engine lifting straps (B) and overhead hoist on floor crane.



NOTE: If engine does not have lifting straps, they can be procured through service parts. Use of an engine lifting sling (as shown) is the ONLY APPROVED method for lifting engine.

2. Carefully lift engine to desired location.

03
4

CLEAN ENGINE

1. Cap or plug all openings on engine. If electrical components (starter, alternator, etc.) are not removed prior to cleaning, cover with plastic and tape securely to prevent moisture from entering.
2. Steam-clean engine thoroughly.

IMPORTANT: Never steam clean or pour cold water on an injection pump while it is still warm. To do so may cause seizure of pump parts.

DISCONNECT TURBOCHARGER OIL INLET LINE

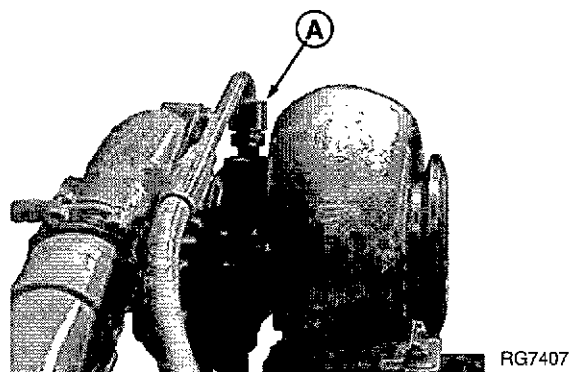
1. Drain all engine oil and coolant, if not previously done.

IMPORTANT: When servicing turbocharged engines on a rollover stand, disconnect turbocharger oil inlet line (A) from oil filter housing or turbocharger before rolling engine over. Failure to do so may cause a hydraulic lock upon starting engine. Hydraulic lock may cause possible engine failure.

Hydraulic lock occurs when trapped oil in the oil filter housing drains through the turbocharger, the exhaust and intake manifolds, and then into the cylinder head.

After starting the engine, the trapped oil in the manifold and head is released into the cylinder(s) filling them with oil causing hydraulic lock and possible engine failure.

2. Disconnect turbocharger oil inlet line.



MOUNT ENGINE ON REPAIR STAND



CAUTION: NEVER remove the overhead lifting equipment until the engine is securely mounted onto the repair stand and all mounting hardware is tightened to specified torque. Always release the overhead lifting equipment slowly.

On engines equipped with a low-profile turbocharger, remove turbocharger before attaching engine to repair stand.

On engines with a left-hand oil fill tube, remove tube before mounting engine to repair stand

NOTE: See next module for illustration of an engine that has been mounted on repair stand.

1. Mount the engine to 62835* Engine Adapter as described below. A label (H) is affixed to the engine adapter for aid in explaining spacer used for each engine model.

NOTE: No. 221668* Spacer (G) is used on the outside of the engine adapter for the 4045 Engines and on the inside (next to engine) on 6068 Engines.

• 4045 Engines

- Hole A—(2) No. 214490* (M12 x 1.75 x 35 mm)
- Hole B—(1) No. 221664* (M14 x 2.00 x 35 mm)
- Hole C—(1) No. 221665* (M14 x 2.00 x 60 mm) with No. 221668* Spacer

• 6068 Engines

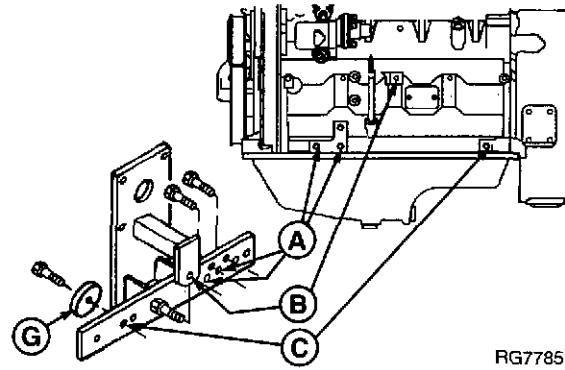
- Hole D— (2) No. 214490* (M12 x 1.75 x 35 mm)
- Hole E—(1) No. 221664* (M14 x 2.00 x 35 mm)
- Hole F— (1) No. 221665* (M14 x 2.00 x 60 mm) with No. 221668* Spacer

NOTE: Four threaded holes in engine mounting adapter are for storing mounting hardware.

TORQUE SPECIFICATIONS

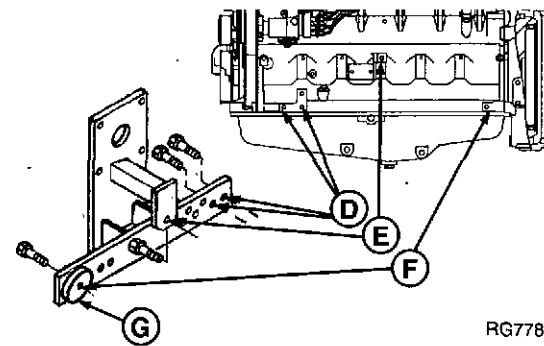
M12 Cap Screws	140 N·m (105 lb-ft)
M14 Cap Screws	225 N·m (165 lb-ft)

* Part of JT07268 Engine Adapter Kit



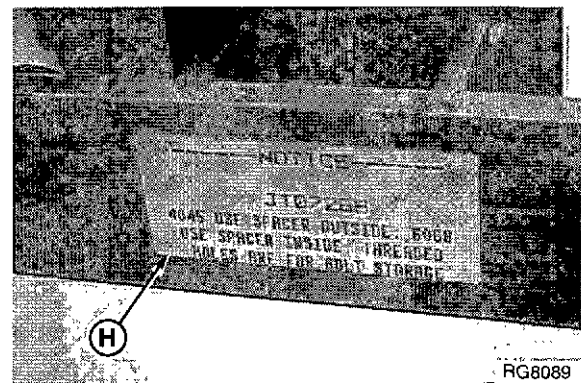
4045 Engine

RG7785



6068 Engine

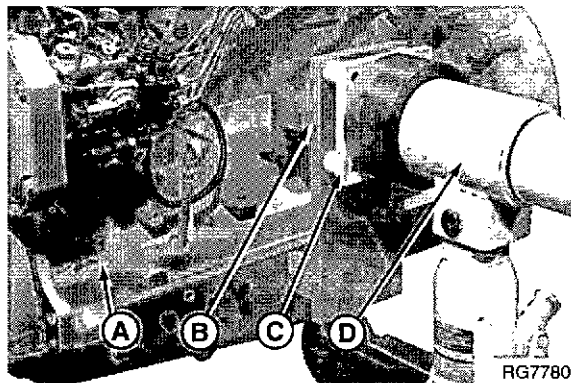
RG7787



RG8089

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6

ENGINE MOUNTED ON REPAIR STAND



6068 Engine

- A—Engine
- B—62835 Engine Adapter
- C—D05226ST Special Adapter
- D—Engine Repair Stand.

03
8

ENGINE DISASSEMBLY SEQUENCE

The following sequence is suggested when complete disassembly for overhaul is required. Refer to the appropriate repair group when removing individual engine components.

1. Mount engine on a safety approved repair stand. (Group 03)
2. Drain coolant and oil. Perform John Deere OILSCAN and COOLSCAN analysis. (Group 02)
3. Remove fan belts, fan, belt tensioner, and alternator. (Group 25)
4. Remove turbocharger (if equipped) and exhaust manifold. (Group 30)
5. Remove rocker arm cover and vent tube. If option code label is located on rocker arm cover, be careful not to damage label. (Group 05)
6. On applications where the water manifold is not an integral part of cylinder head, remove water manifold or thermostat housing. (Group 25)
7. Remove oil cooler piping and water pump. (Groups 20 and 25)
8. Remove dipstick, oil filter, oil cooler, and adapter housing (if equipped). (Group 20)
9. Remove oil pressure regulating valve assembly. (Group 20)
10. Remove fuel filter, fuel supply pump, and fuel line. (Group 35)
11. Remove injection lines, injection pump, and injection nozzles. (Group 35)
12. Remove starting motor.
13. Remove rocker arm assembly and push rods. Keep rods in order (Group 05). Check for bent push rods and condition of wear pad contact surfaces on rockers.
14. Remove cylinder head. Check piston protrusion. (Groups 05 and 10)
15. Remove cam followers. Keep followers in order. (Groups 05 and 16)
16. Remove flywheel and flywheel housing. (Group 15)
17. Remove oil pan. (Group 20)
18. Remove crankshaft pulley. (Group 15)
19. Remove timing gear cover. (Group 16)
20. Remove oil pump drive gear, outlet tube, and pump body. (Group 20)
21. Remove timing gears and camshaft. Perform wear checks. (Group 16)
22. Remove balancer shafts (4045 engines). (Group 16)
23. Remove engine front plate. (Group 16)
24. Remove oil by-pass valve. (Group 20)
25. Stamp cylinder number on connecting rod. Remove pistons and rods. Perform wear checks with PLASTIGAGE®. (Group 10)
26. Remove crankshaft and main bearings. Perform wear checks with PLASTIGAGE. (Group 15)
27. Remove cylinder liners and mark each one with cylinder number. (Group 10)
28. Remove piston cooling orifices. (Groups 10 and 15)
29. Remove balancer shaft bushings (4045 engines) and camshaft bushing. (Group 16)
30. Remove cylinder block plugs and serial number plate when block is to be put in a "hot tank". (Group 10)
31. Clean upper and lower liner bores with nylon brush. (Group 10)
32. Measure cylinder block. (Groups 10, 15, and 16)

PLASTIGAGE® is a trademark of the Perfect Circle Division of DANA Corporation.

SEALANT APPLICATION GUIDELINES

Listed below are sealants which have been tested and are used by the John Deere factory to control leakage and assure hardware retention. **ALWAYS** use the following recommended sealants when assembling your John Deere Diesel Engine to assure quality performance.

LOCTITE® thread sealants are designed to perform to sealing standards with machine oil residue present. If excessive machine oil or poor cleanliness quality exists, clean with solvent. Refer to John Deere Merchandise and Parts Sales Manual for ordering information.

IMPORTANT: LOCTITE gasket materials are NOT designed to work with oil residue present. Oil residues must be cleaned from surfaces before applying gasket material.

• LOCTITE 242—Thread Lock & Sealer (Medium Strength) (blue):

TY9370 6 ml tube /T43512 50 ml tube

- Plugs and fittings: fuel filter base, fuel transfer pump, cylinder block (oil galley), and oil filter base housing.
- Cap screws: vibration damper/pulley, injection pump access cover, electronic tachometer cover, oil filler inlet, flywheel, fuel transfer pump, oil cooler housing-to-cylinder block (open holes only) and timing hole cover.
- Oil pressure sending unit.

• LOCTITE 271—Thread Lock & Sealer (High Strength) (red):

TY9371 6 ml tube/T43513 50 ml bottle

- Studs: water pump-to-cylinder block, injection pump-to-front plate, exhaust manifold-to-turbocharger.
- Oil filter nipple

• LOCTITE 277—Rigid Form-In-Place Gasket (High Strength) (red):

T43514 50 ml bottle

- Steel cap plugs: cylinder block and cylinder head.
- O-ring adapter for oil pump outlet tube.
- Nipples and elbows which are pressed into place, water pump housing, and oil cooler cover.

• LOCTITE 515—Flexible Form-In-Place Gasket (General Purpose) (purple):

TY6304 50 ml bottle

- Flywheel housing-to-cylinder block
- Flywheel housing-to-oil pan
- Front and rear face of cylinder block
- Front plate/timing gear cover-to-oil pan

04
2

SEALANT APPLICATION GUIDELINES—CONTINUED

- **LOCTITE 592—Pipe Sealant with Teflon® (white):**
TY9374 6 mL tube/TY9375 50 mL tube
 - Pipe plugs: cylinder block (water manifold), thermostat housing, water pump, flywheel housing (drain).
 - Injection pump governor cover fitting (fuel return)
 - Temperature sending unit.
 - Oil pan (drain hose, drain valve, and elbow drain fitting).
 - Connectors: turbo line, turbo drain, and water return-to-cylinder block.
 - Adapter fitting and plug for turbo lube on dual oil filter base.
- **PT569 NEVER-SEEZ® COMPOUND:**
PT569 227g brush/PT506 453g spray
 - Cap Screws: exhaust manifold and turbine housing-to-center housing.
- **RTV Silicone Sealant Form-In-Place Gasket* (clear):**
TY15130 3 oz. tube
 - Injection pump cover and pump timing gear cover **ONLY** when traditional gasket is not available.
- **LOCTITE 680—Retaining Compound-Maximum Strength (green):**
TY15969 50 mL bottle
 - Service part wear ring-to-crankshaft
 - Dipstick tube

**Use DD14928 Sealing Compound Kit when servicing an engine within the European Market/Service Area. Follow manufacturer's directions on package when using and storing sealant.*

LOCTITE® is a registered trademark of Loctite Corporation.

NEVER-SEEZ® is a registered trademark of the Emhart Chemical Group.

TEFLON® is a registered trademark of DuPont Co.

ENGINE ASSEMBLY SEQUENCE

The following assembly sequence is suggested when engine has been completely disassembled. Be sure to check run-out specifications, clearance tolerances, torques, etc. as engine is assembled. Refer to the appropriate repair group when assembling engine components.

1. Install all plugs and serial number plate in cylinder block (if removed). (Groups 10 and 15)
2. Install piston cooling orifices. (Group 10)
3. Install new balancer shaft bushings (4045 engines) and a new camshaft bushing. (Group 16)
4. Install cylinder liners without O-rings. Measure liner height. Install liners with O-rings. (Group 10)
5. Install main bearings and crankshaft. PLASTIGAGE bearings. (Group 15)
6. Install flywheel housing, rear oil seal, and flywheel. (Group 15)
7. Install pistons and rods. Measure piston protrusion. (Group 10)
8. Install oil by-pass valve. (Group 20)
9. Install front plate. (Group 16)
10. Install balancer shafts (4045 engines). Check end play. (Group 16)
11. Install oil outlet tube, O-ring in block, and oil pump. (Group 20)
12. Install injection pump. (Group 35)
13. Install camshaft and timing gears. (Group 16)
14. Time all gears with No. 1 cylinder at TDC compression stroke. (Group 16)
15. Install timing gear cover. Install new front seal. (Group 16)
16. Install oil pan. (Group 20)
17. Install oil pressure regulating valve. (Group 20)
18. Install cam followers in same order as removed. (Group 16)
19. Install cylinder head gasket, cylinder head, push rods, and rocker arm assembly. (Group 05)
20. Install starting motor.
21. Install injection nozzles (with new seals) and injection lines. (Group 35)
22. Install fuel filter, fuel supply pump, and fuel lines. (Group 35)
23. Install oil cooler, new oil filter, and dipstick. (Group 20)
24. Install water manifold or thermostat housing and thermostats. (Group 25)
25. Install exhaust manifold and turbocharger. Prelube the turbocharger. (Group 30)
26. Install water pump and hoses. (Group 25)
27. Install crankshaft pulley or vibration damper. (Group 15)
28. Install alternator, belt tensioner, fan, and fan belts. (Group 25)
29. Adjust valves and install rocker arm cover. (Group 05)
30. Install vent tube.
31. Fill engine with clean oil and proper coolant. (Group 02)
32. Perform engine break-in and standard performance checks. (Group 105)

SPECIAL OR ESSENTIAL TOOLS

NOTE: Order tools according to information given in the U.S. SERVICEGARD™ Catalog or in the European Microfiche Tool Catalog (MTC).

Dial Indicator (English, in.) D17526C1
or (Metric, mm) D17527C1

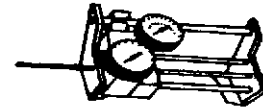
Use with JDG451 to measure valve recess and cylinder liner height-to-cylinder block top deck.



RG6246

Spring Compression Tester D01168AA

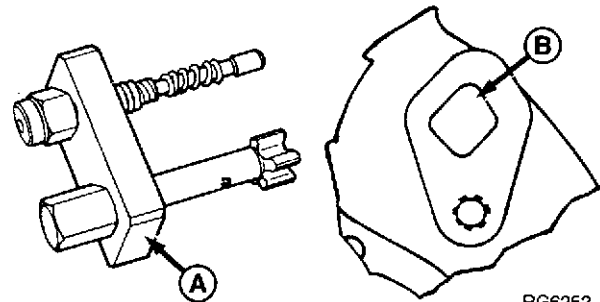
Test valve spring compression.



RG5061

Flywheel Turning Tool (A) JD281A

Used on engines with 142 -tooth flywheel ring gear and a diamond-shaped tool guide bore (B) in flywheel housing. Tool has it's own spring loaded timing pin which threads into flywheel housing.



RG6252

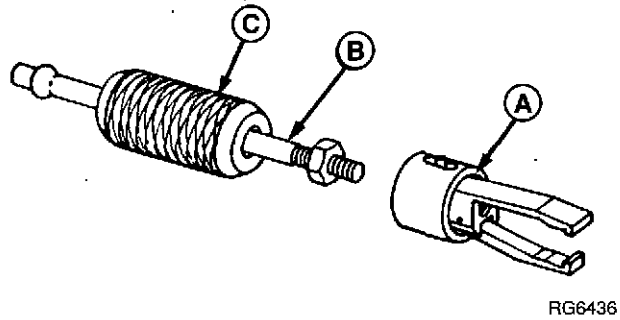
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Injection Nozzle Puller JDE38B

Remove Stanadyne 9.5 mm injection nozzles.

NOTE: If JDE38A Nozzle Puller is available, order JDG716 Adapter and use with slide handle from JDE38 or JDE38A to remove 9.5 mm injection nozzles without removing the rocker arm cover.

NOTE: JDG716-1 Repair Kit is available if leg of JDG716 Adapter is damaged.



A—JDG716 Adapter
B—JDE38-2 Shank
C—JDE38-4 Hammer

RG6436

Nozzle Bore Cleaning Tool JDE39

Clean injection nozzle bores in cylinder head.



RG5084

05
2

Timing Pin JDE81-4

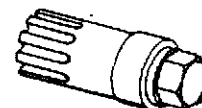
Lock engine at TDC when installing injection pump or timing valve train. Use with JDG820, JDE81-1, or JDE83 Flywheel Turning Tool.



RG5068

Flywheel Turning Tool JDE83

Used to rotate flywheel on engines with 142 tooth flywheel ring gear and a 26.5 mm (1.04 in.) ID flywheel housing guide bore diameter. Use with JDE81-4 Timing Pin.

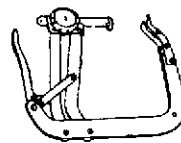


RG6251

Cylinder Head and Valves

Valve Spring Compressor JDE138

Use to compress valve springs when removing and installing valves.

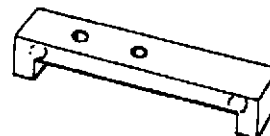


RG5070

Piston and Liner Height Gauge JDG451

Measure piston and liner heights.

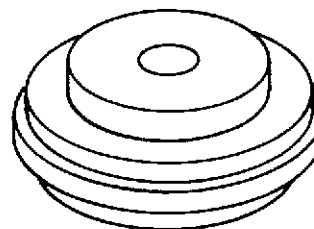
NOTE: A dial indicator is not supplied with JDG451. Use D17526CI (English, in.) or D17527CI (Metric, mm) Dial Indicator with JDG451.



RG7029

Valve Seat Insert Installing Adapter JDG675

Use with JDG676 Pilot Driver to install intake and exhaust valve seat inserts.



RG5240

Valve Seat Driver JDG676

Use with JDG675 Adapter to install intake and exhaust valve seat inserts in cylinder head.



RG5065

Valve Stem Seal Installer JDG678

Use to install valve stem seals.



RG5612

05
3

Cylinder Head and Valves

Tap JDG680

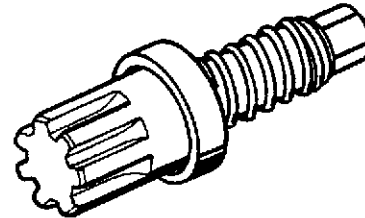
Used to restore threaded holes in cylinder block for cylinder head cap screws.



RG5100

Flywheel Turning Tool JDG820

Used to rotate flywheel on engine, with 129-tooth flywheel ring gear and a 29.9 mm (1.18 in.) ID flywheel housing guide bore diameter, to check damper radial runout and time engine. JDE81-1 may be used also if JDG820 is not available.



RG7056

Valve Guide Knurler Kit JT05949

Knurl valve guides.



RG5064

05
4

SERVICE EQUIPMENT AND TOOLS

NOTE: Order tools from the U.S. SERVICEGARD™ Catalog or from the European Microfiche Tool Catalog (MTC). Some tools may be available from a local supplier.

Name	Use
D05012ST Precision "Bevelled Edge" Straightedge	Check cylinder head flatness.
Plastic Brush	Clean valve guides.
Eccentrimeter	Measure valve seat runout.
JT05893 Heavy-Duty Seat Grinder	Grind valve seats.
D17024BR End Brush	Remove carbon on valve seats.
JDG714 Valve Guide Cutting Tool	Machine exhaust valve towers.
JT05993 Torque Angle Gauge	Tighten flanged-head cylinder head cap screws.
Valve Inspection Center	Check valves for out of round.
JDG966 Crankshaft Front/Rear Rotation Adapter	Rotate crankshaft from front and rear with flywheel removed.

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OTHER MATERIAL

Number	Name	Use
AR44402	Valve Stem Lubricant	Lubricate valve stems.
PT569	NEVER-SEEZ Compound	Apply to exhaust manifold cap screws.

CYLINDER HEAD AND VALVES SPECIFICATIONS

ITEM	SPECIFICATION	WEAR LIMIT
Thickness of New Cylinder Head	104.87—105.13 mm (4.129—4.139 in.)	104.24 mm (4.104 in.)
Maximum Material Removal for Resurfacing Head	0.76 mm (0.030 in.)	—
Maximum Acceptable Head Out-of-Flat:		
For Entire Length or Width	0.08 mm (0.003 in.)	—
For Every 150 mm (5.90 in.) Length or Width	0.03 mm (0.001 in.)	—
Combustion Face Surface Finish (surface grind only) (AA)	0.7—3.2 micrometers (31—125 micro-in.)	—
Maximum Wave Depth	0.012 mm (0.0005 in.)	—
Standard Valve Stem OD:		
Intake Valve	7.864—7.884 mm (0.3096—0.3104 in.)	—
Exhaust Valve	7.848—7.874 mm (0.3090—0.3100 in.)	—
Oversize Valve Stems Available	0.38 mm (0.015 in.) 0.76 mm (0.030 in.)	—
Valve Guide ID	7.912—7.938 mm (0.312—0.313 in.)	—
Valve Stem-to-Guide Clearance	0.05—0.10 mm (0.002—0.004 in.)	0.15 mm (0.006 in.)
Valve Seat Angle (intake and exhaust)	30°	—
Valve Face Angle (intake and exhaust)	29.25° ± 0.25°	—
Maximum Valve Seat Runout	0.08 mm (0.003 in.)	—
Maximum Valve Face Runout (intake and exhaust)	0.038 mm (0.0015 in.)	—
Valve Recess in Cylinder Head:		
Intake Valve	0.61—1.11 mm (0.024—0.044 in.)	1.63 mm (0.064 in.)
Exhaust Valve	1.22—1.72 mm (0.048—0.068 in.)	2.26 mm (0.089 in.)
Valve Seat Width (intake and exhaust)	1.50—2.00 mm (0.059—0.079 in.)	—

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CYLINDER HEAD AND VALVES SPECIFICATIONS—CONTINUED

ITEM	SPECIFICATION	WEAR LIMIT
Valve Head OD:		
Intake Valve	46.47—46.73 mm (1.830—1.840 in.)	_____
Exhaust Valve	42.37—42.63 mm (1.668—1.678 in.)	_____
Cylinder Firing Order:		
4-Cylinder Engines	1-3-4-2	_____
6-Cylinder Engines	1-5-3-6-2-4	_____
Valve Clearance (Engine Cold):		
Rocker Arm-to-Valve Tip		
Intake Valve	0.35 mm (0.014 in.)	_____
Exhaust Valve	0.45 mm (0.018 in.)	_____
Valve Lift at 0.00 mm (in.) Clearance:		
Intake Valve	11.56—12.37 mm (0.455—0.487 in.)	11.13 mm (0.438 in.)
Exhaust Valve	11.28—12.12 mm (0.444—0.477 in.)	10.85 mm (0.427 in.)
Rocker Arm Shaft OD	19.99—20.02 mm (0.787—0.788 in.)	19.94 mm (0.785 in.)
Rocker Arm Bore ID	20.07—20.12 mm (0.790—0.792 in.)	20.17 mm (0.794 in.)
Rocker Arm Shaft Spring Compressed Height	46 mm @ 18—27 N (1.81 in. @ 4—6 lb-force)	_____
Rocker Arm Shaft Support ID (Maximum)	20.17 mm (0.794 in.)	_____
Valve Spring Free Length*	54.0 mm (2.125 in.)	_____
Valve Spring Compressed Height:		
Valve Closed	46.0 mm @ 240—280 N (1.81 in. @ 54—62 lb-force)	_____
Valve Open	34.5 mm @ 590—680 N (1.36 in. @ 133—153 lb-force)	_____
Liner Height Above Block	0.030—0.100 mm (0.0010—0.0040 in.)	_____
Maximum Permissible Height Difference at Nearest Point of Two Adjacent Liners		
	0.051 mm (0.0020 in.)	_____
Cam Follower OD	31.61—31.64 mm (1.245—1.246 in.)	_____
Fuel Supply Pump Push Rod OD	9.891—9.917 mm (0.3894—0.3904 in.)	_____
Fuel Supply Pump Push Rod Bore	10.00—10.05 (0.3937—0.3957 in.)	_____

* Free Length may vary slightly between springs.

CYLINDER HEAD AND VALVES SPECIFICATIONS—CONTINUED

TORQUES

Rocker Arm Support Studs	80 N·m (59 lb-ft)
Rocker Arm Lock Nuts	27 N·m (20 lb-ft)
Rocker Arm Cover Stud Nuts	35 N·m (26 lb-ft)
Cylinder Head Cap Screws:	
Step 1	100 N·m (75 lb-ft)
Step 2	150 N·m (110 lb-ft)
Step 3	Wait 5 Minutes and Verify 150 N·m (110 lb-ft)
Step 4	Tighten Additional 60° ± 10°
Fuel Injection Nozzles-to-Cylinder Head Clamp	40 N·m (30 lb-ft)
Fuel Line Nuts-to-Injection Nozzle	27 N·m (20 lb-ft)
Fuel Line Nuts-to-Injection Pump	34 N·m (25 lb-ft)
Air Inlet Manifold-to-Cylinder Head	70 N·m (52 lb-ft)
Exhaust Manifold-to-Cylinder Head	70 N·m (52 lb-ft)*
Alternator Strap-to-Timing Gear Cover	70 N·m (52 lb-ft)
Alternator Pulley Nut	80 N·m (59 lb-ft)

* See REMOVE, INSPECT, AND INSTALL EXHAUST MANIFOLD in Group 30 for cap screw tightening sequence.

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8

CHECK AND ADJUST VALVE CLEARANCE

IMPORTANT: Valve clearance **MUST BE** checked and adjusted with engine **COLD**.



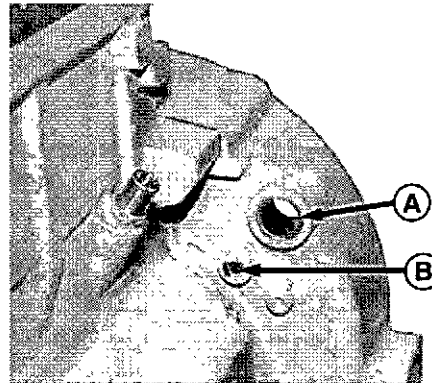
CAUTION: To prevent accidental starting of engine while performing valve adjustments, always disconnect **NEGATIVE (-)** battery terminal.

1. Remove rocker arm cover and crankcase ventilator tube.

IMPORTANT: Visually inspect contact surfaces of valve tips and rocker arm wear pads. Check all parts for excessive wear, breakage, or cracks. Replace parts that show visible damage.

Rocker arms that exhibit excessive valve clearance should be inspected more thoroughly to identify damaged parts.

2. Remove plastic plug or cover plate from engine timing hole (A).
3. Remove plug from timing hole (B).

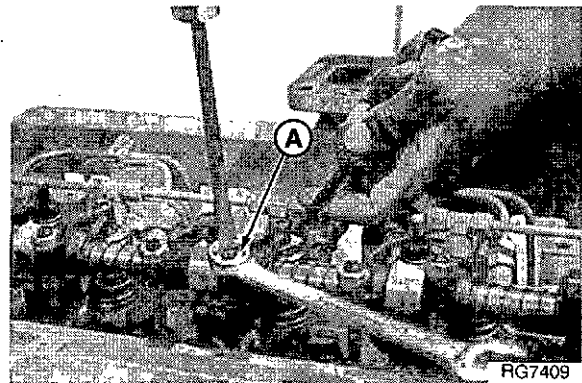


RG7408

- Using engine rotation tool, rotate engine flywheel in running direction (clockwise viewed from front) until No. 1 cylinder is at "TDC" Compression stroke.

NOTE: Some engines are equipped with flywheel housings which do not allow use of an engine flywheel rotation tool. These engines may be rotated from front nose of engine, using JDG966 Crankshaft Rotation Tool.

If No.1 cylinder rocker arms are loose, the engine is at No. 1 "TDC" Compression". If No. 1 cylinder rocker arms are not loose, rotate engine one full revolution (360°) to No. 1 "TDC" Compression.



- Check and adjust valve clearance to specifications, as directed in the following procedures for 4 or 6-cylinder engines.

**VALVE CLEARANCE SPECIFICATION
(ROCKER ARM-TO-VALVE TIP)**

Intake Valve	0.35 mm (0.014 in.)
Exhaust Valve	0.45 mm (0.018 in.)

- If rocker arm is equipped with adjusting screw and jam nut (A), tighten jam nut to 27 N·m (20 lb-ft) after adjusting valve clearance.

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10

• **4-Cylinder Engine:**

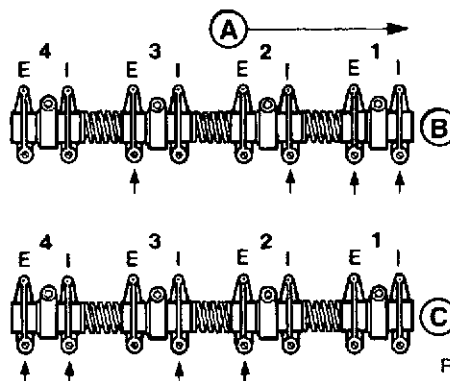
NOTE: Firing order is 1-3-4-2.

Lock No. 1 piston at TDC compression stroke (B).

Adjust valve clearance on No. 1 and 3 exhaust valves and No. 1 and 2 intake valves.

Turn crankshaft 360°. Lock No. 4 piston is at TDC compression stroke (C).

Adjust valve clearance on No. 2 and 4 exhaust valve and No. 3 and 4 intake valves.



RG4776

- A—Front of Engine
- B—No. 1 Piston TDC Compression
- C—No. 4 Piston TDC Compression
- E—Exhaust Valve
- I—Intake Valve

• **6-Cylinder Engine:**

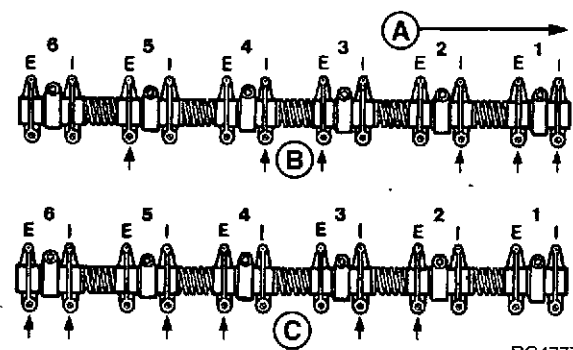
NOTE: Firing order is 1-5-3-6-2-4.

Lock No. 1 piston at TDC compression stroke (B).

Adjust valve clearance on No. 1, 3 and 5 exhaust valves and No. 1, 2, and 4 intake valves.

Turn crankshaft 360°. Lock No. 6 piston is at TDC compression stroke (C).

Adjust valve clearance on No. 2, 4 and 6 exhaust valve and No. 3, 5, and 6 intake valves.



RG4777

- A—Front of Engine
- B—No. 1 Piston TDC Compression
- C—No. 6 Piston TDC Compression
- E—Exhaust Valve
- I—Intake Valve

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11

MEASURE VALVE LIFT

IMPORTANT: For a more accurate measurement, measure valve lift at 0.00 mm (in.) rocker arm-to-valve tip clearance and with engine COLD.

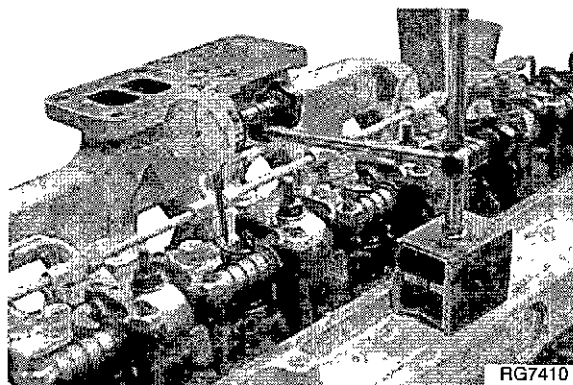
NOTE: Measuring valve lift provides an indication of wear on camshaft lobes and cam followers or push rods.

1. Remove rocker arm cover.
2. Set No. 1 piston at TDC compression stroke and install JDE81-4 Timing Pin in flywheel.
3. Set rocker arm-to-valve tip clearance to 0.00 mm (in.) for:
 - No. 1 and 3 exhaust and No. 1 and 2 intake valves on 4-cylinder engines.
 - No. 1, 3, and 5 exhaust and No. 1, 2, and 4 intake valves on 6-cylinder engines.
4. Place dial indicator tip on top of valve spring cap (retainer) or rotator. Preload indicator tip and set dial at 0.0 mm (in.).
5. Remove timing pin from flywheel and manually rotate engine one full revolution (360°) in running direction using appropriate flywheel turning tool.
6. Observe dial indicator reading as valve is moved to full open. Record maximum reading and compare with specifications given below.

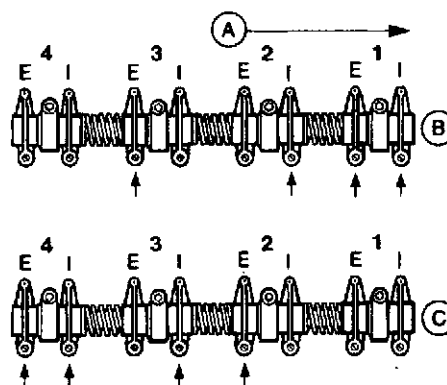
VALVE LIFT SPECIFICATION [at 0.00 mm (in.) Valve Clearance]

Intake Valves	11.56—12.37 mm (0.455—0.487 in.)
Wear Limit	11.13 mm (0.438 in.)
Exhaust Valves	11.28—12.12 mm (0.444—0.477 in.)
Wear Limit	10.85 mm (0.427 in.)

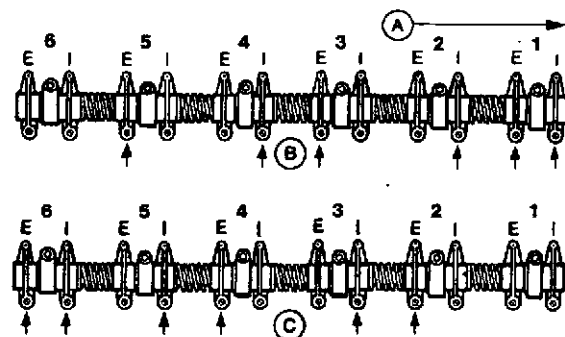
7. Follow same procedure for all remaining valves and record readings.



RG7410



4-Cylinder Engine



6-Cylinder Engine

- A—Front of Engine
- B—No. 1 Piston TDC Compression
- C—No. 4 Piston or No. 6. Piston TDC Compression
- E—Exhaust Valve
- I—Intake Valve

If valve lift on all valves is within specifications, adjust valve lash to specified clearance. (See CHECK AND ADJUST VALVE CLEARANCE earlier in this group.)

If valve lift on one or more valves is not within specification, remove and inspect entire valve train and camshaft.

8. Rotate engine one full revolution (360°). Lock engine at:
 - TDC No. 4 compression stroke for 4-cylinder engines.
 - TDC No. 6 compression stroke for 6-cylinder engines.
9. Set rocker arm-to-valve tip clearance to 0.0 mm (in.) for:
 - No. 2 and 4 exhaust and No. 3 and 4 intake valves on 4-cylinder engines.
 - No. 2, 4, and 6 exhaust and No. 3, 5, and 6 intake valves on 6-cylinder engines.
10. Repeat steps 4—7.

REMOVE CYLINDER HEAD

In some applications, it may be necessary to remove engine from machine to service cylinder head. Refer to your Machine Technical Manual for engine removal procedure.



CAUTION: After operating engine, allow exhaust system to cool before working on engine.

Do NOT drain coolant until the coolant temperature is below operating temperature. Only remove radiator filler cap only when the cap is cool enough to touch with bare hands. Slowly loosen cap to first stop to relieve pressure before removing completely.

1. Drain engine oil and coolant.

NOTE: On engines equipped with a low-profile turbocharger, remove turbocharger before attaching engine to repair stand.

2. Remove air inlet elbow. (See Group 30.)

NOTE: Turbocharger and exhaust elbow may be removed from engine while assembled to exhaust manifold, if desired.

3. On turbocharged engines, disconnect turbocharger oil inlet line (A) at turbocharger (B). Remove turbocharger and exhaust elbow (shown removed).

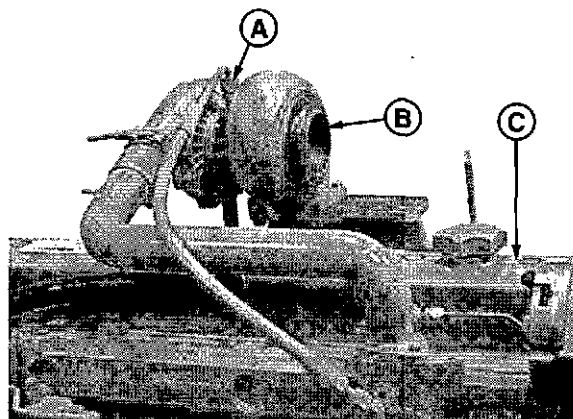
4. Remove rocker arm cover (C).

IMPORTANT: Rocker arm cover sealing ring (D) can be reused if there is no evidence of physical damage. Remove sealing ring from groove for replacement only.

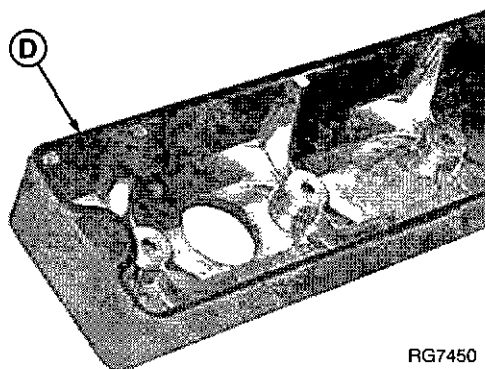
5. Using guide studs, remove exhaust manifold (E).

NOTE: On some engines, the thermostat housing/water manifold (F) is part of the cylinder head.

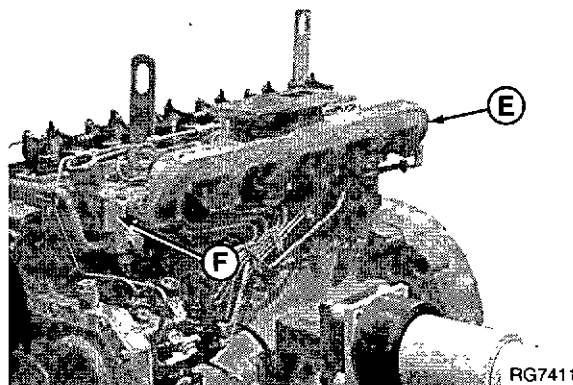
6. Remove thermostat housing/water manifold.



RG7454



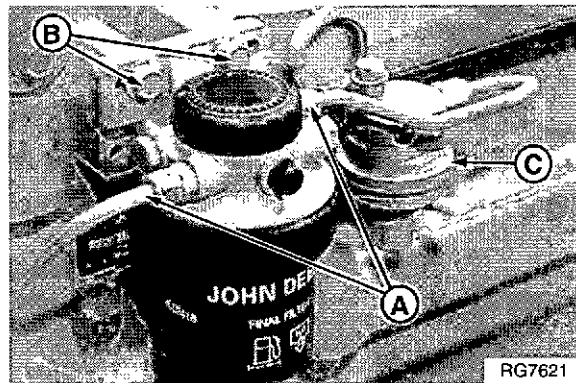
RG7450



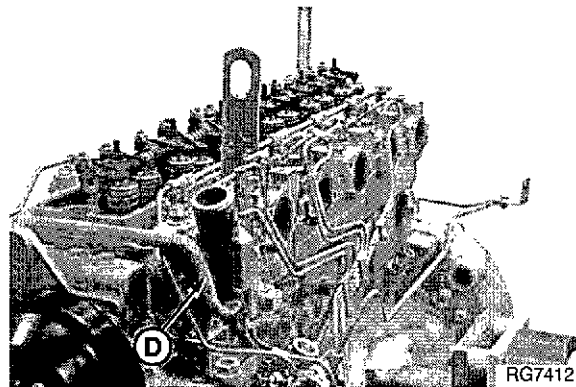
RG7411

- A—Turbocharger Oil Inlet Line
- B—Turbocharger
- C—Rocker Arm Cover
- D—Rocker Arm Cover Sealing Ring
- E—Exhaust Manifold
- F—Thermostat Housing/Water Manifold

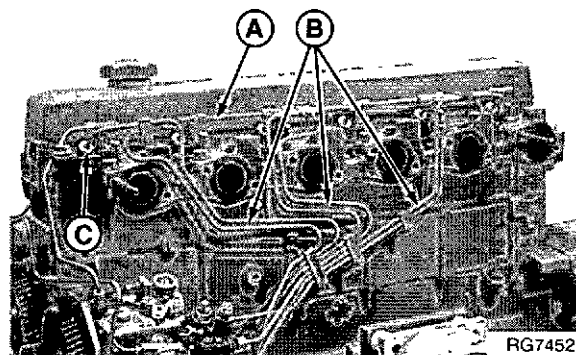
7. Disconnect fuel lines (A) from fuel filter.
8. Remove fuel filter and mounting bracket (B).
9. Remove fuel supply pump (C). Inspect face of pump lever for wear. If worn flat or concave, replace supply pump.
10. Remove alternator if desired.
11. Remove thermostat housing-to-water pump tube (D).



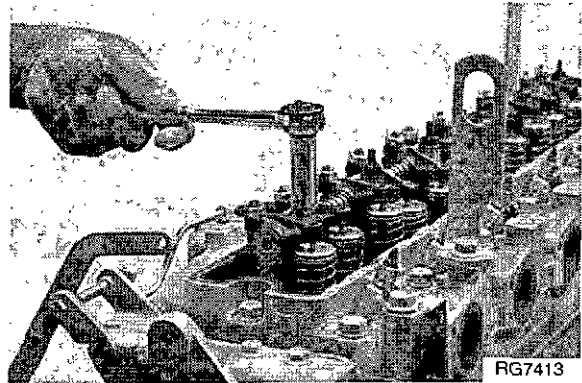
- A—Fuel Lines
- B—Mounting Bracket
- C—Fuel Supply Pump
- D—Thermostat Housing-to-Water Pump Tube



12. Remove fuel leakoff line (A) and fuel delivery lines (B) as an assembly. Remove fuel injection nozzles (C). (See Group 35.)

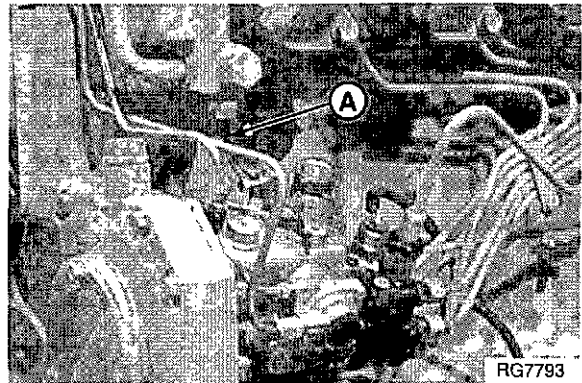


13. Remove rocker arm assembly.



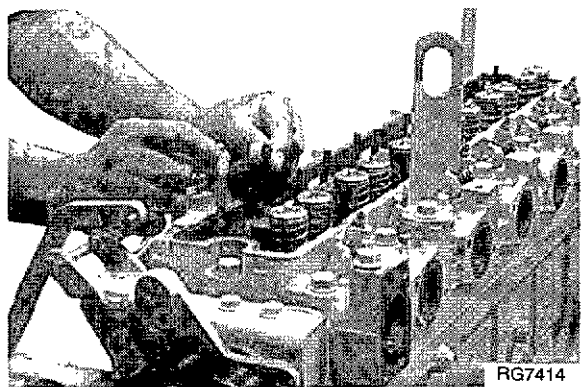
RG7413

14. Disconnect coolant temperature connector (A) from injection pump wiring harness.



RG7793

15. Remove all push rods and identify for reassembly in the same location. Clean and inspect push rods.



RG7414

16. If a cylinder head gasket failure has occurred, check and record torque on each cylinder head cap screw before removing.

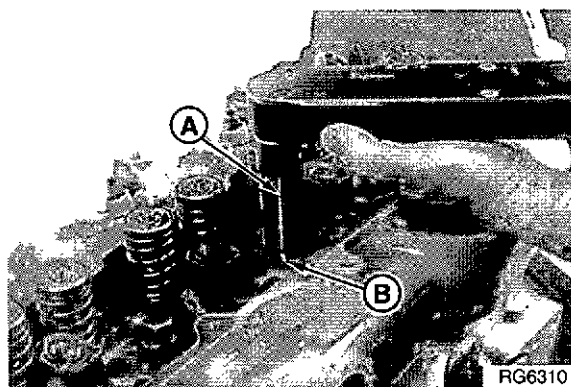
To check cylinder head cap screw torque:

A—Make a reference mark (in-line) on socket (A) and cylinder head surface (B).

B—Loosen cap screw at least 1/2 turn.

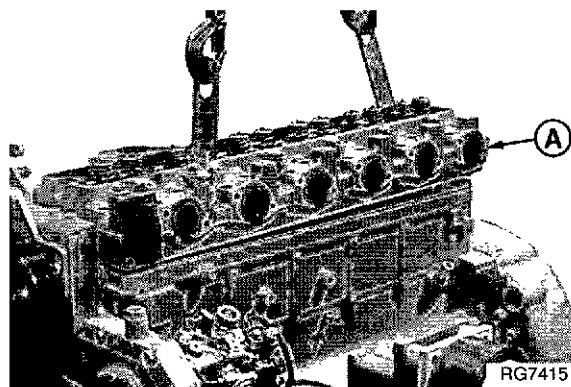
C—Retighten cap screw (using a torque wrench) until reference marks align and record torque.

4. Remove all cylinder head cap screws.

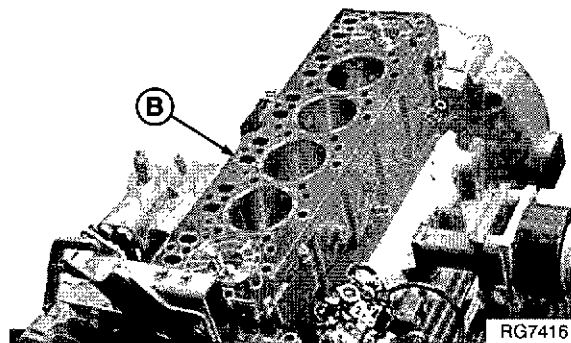


IMPORTANT: DO NOT use screwdrivers or pry bars between cylinder block and head to loosen head gasket seal. Screwdrivers or prybars can damage cylinder head and block gasket surfaces.

5. Lift cylinder head (A) from block. If cylinder head sticks, use a soft hammer to tap cylinder head.
6. Remove cylinder head gasket (B). Inspect for possible oil, coolant, or combustion chamber leaks. Also, check for evidence of incorrect head gasket being used.

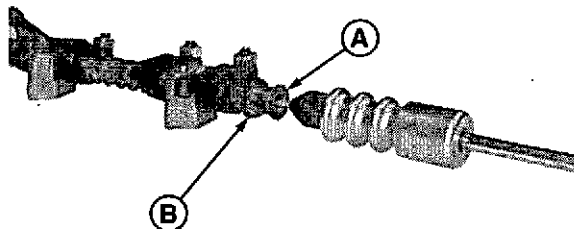


NOTE: Do not rotate crankshaft with cylinder head removed unless cylinder liners are secured with cap screws and large flat washers. (See MEASURE CYLINDER LINER STANDOUT [HEIGHT ABOVE BLOCK], later in this group.)



DISASSEMBLE AND INSPECT ROCKER ARM SHAFT ASSEMBLY

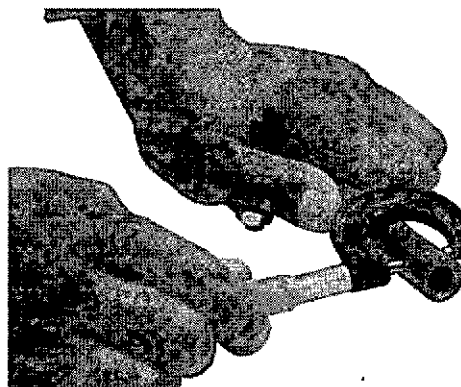
1. Remove plugs (A) and bowed washers (B) from rocker arm shaft.
2. Disassemble and inspect all parts for wear or damage. Replace any parts that are damaged or not within specifications.



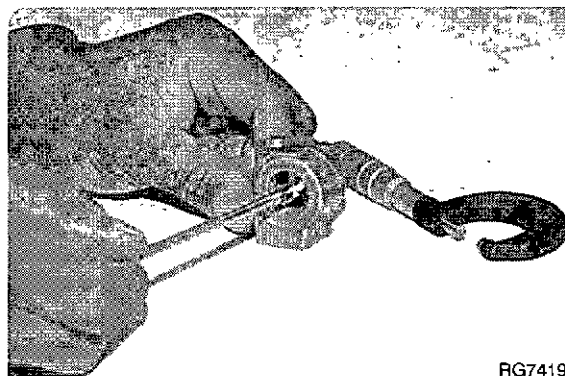
RG7417

ROCKER ARM, SHAFT, SPRING, AND SUPPORT SPECIFICATIONS

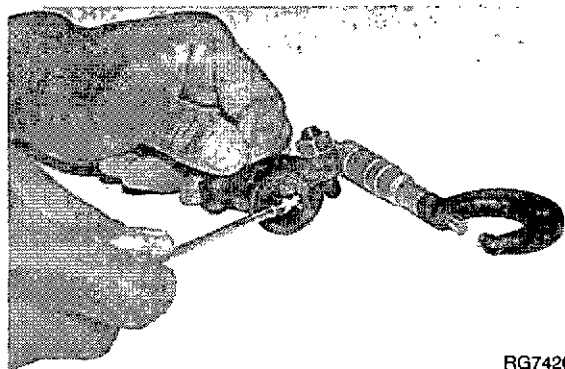
Spring tension at 46 mm (1.81 in.) compressed height.....	18—27 N (4—6 lb-force)
Rocker Arm Shaft OD	19.99—20.02 mm (0.787—0.788 in.)
Wear Limit	19.94 mm (0.785 in.)
Shaft Support ID (maximum)	20.17 mm (0.794 in.)
Rocker Arm Bore ID	20.07—20.12 mm (0.790—0.792 in.)
Wear Limit	20.17 mm (0.794 in.)



RG7418



RG7419



RG7420

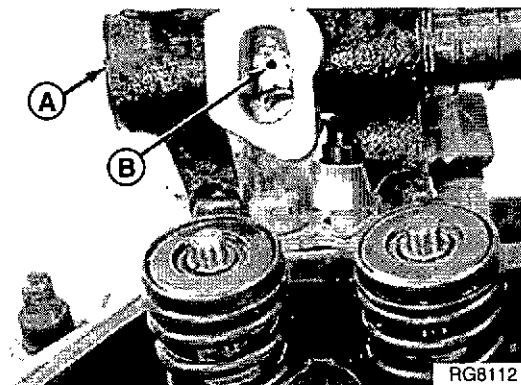
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18

ASSEMBLE ROCKER ARM ASSEMBLY

1. Lubricate shaft OD, rocker arm bores, and rocker arm supports with clean engine oil.

IMPORTANT: The oil supply hole (B) on the rocker arm shaft must be toward the flywheel end of the engine.

2. Assemble springs, rocker arms, and rocker arm supports onto shaft in the same location as removed from.
3. Install bowed washers and new end plugs (A) firmly in end of shaft.

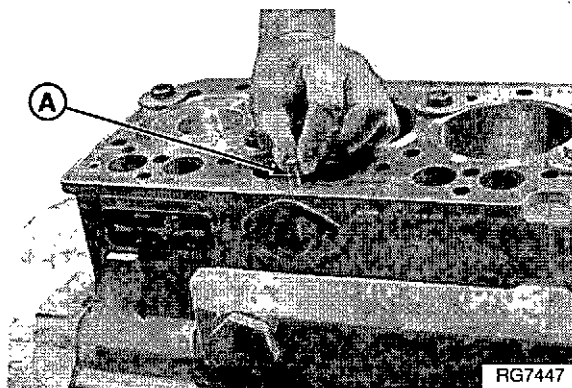


INSPECT, MEASURE, AND INSTALL FUEL SUPPLY PUMP PUSH ROD—IF APPLICABLE

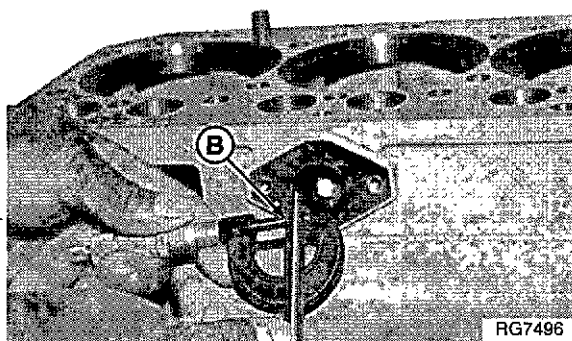
1. Remove and clean push rod (A). Label end(s) for reassembly in same orientation.
2. Measure push rod OD (B). If OD is less than 9.891—9.917 mm (0.3894—0.3904 in.), install a new push rod.
3. Check crown on push rod ends. If flat or concave, replace push rod and check camshaft lobe for wear. (See Group16).
4. Measure push rod bore ID (C) in block. Bore specification is 10.00—10.05 mm (0.3937—0.3957 in.)

Repair or replace block as necessary.

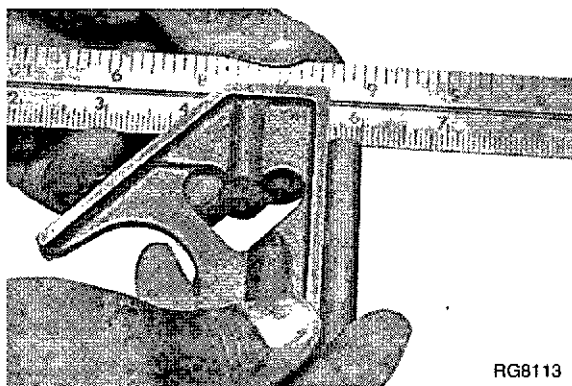
5. Lubricate push rod with clean engine oil and install in bore with same end orientation as removed.



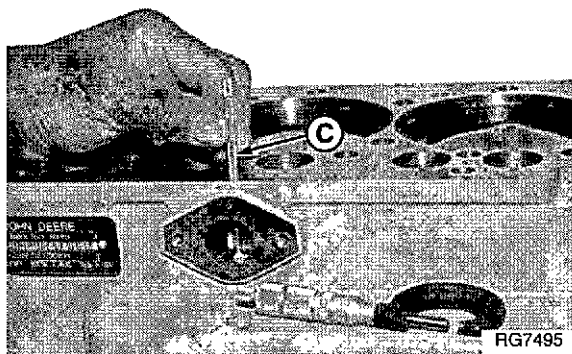
RG7447



RG7496



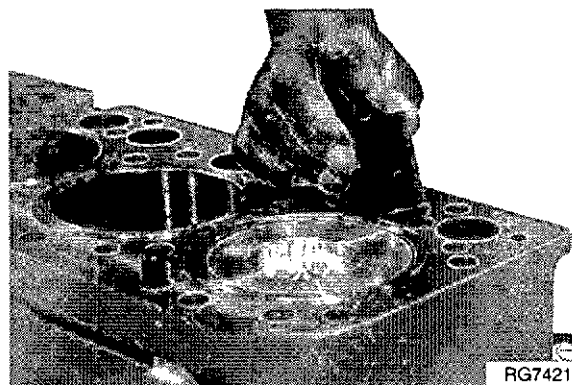
RG8113



RG7495

INSPECT, MEASURE, AND ASSEMBLE CAMSHAFT FOLLOWERS

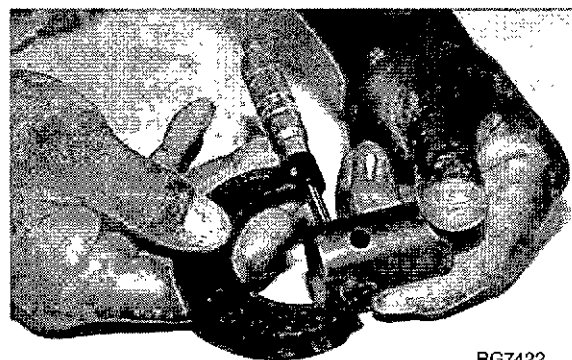
1. Remove and clean camshaft followers. Label for reassembly in same location.



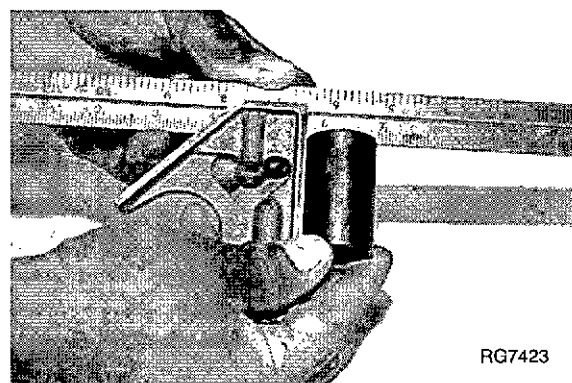
2. Measure camshaft follower OD. If camshaft follower OD is less than specified, install a new follower.

CAMSHAFT FOLLOWER SPECIFICATIONS

Camshaft Follower OD 31.61—31.64 mm
(1.245—1.246 in.)

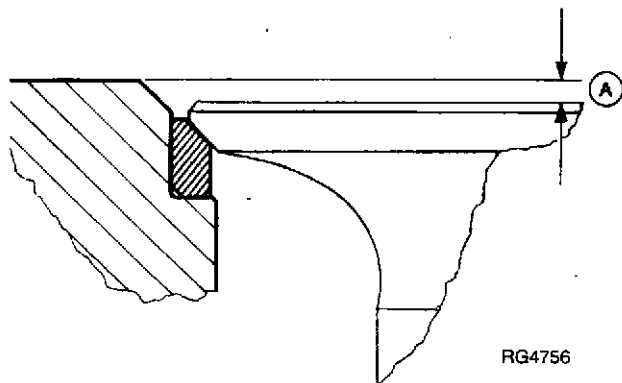


3. Check crown on follower face. If flat or concave, replace follower and check camshaft lobes for wear. (See Group 16.)
4. Measure camshaft follower bore in block and determine if clearance is within specification. (See Group 10.)
5. Lubricate camshaft followers in clean engine oil and install in same bore from which removed.



MEASURE VALVE RECESS IN CYLINDER HEAD

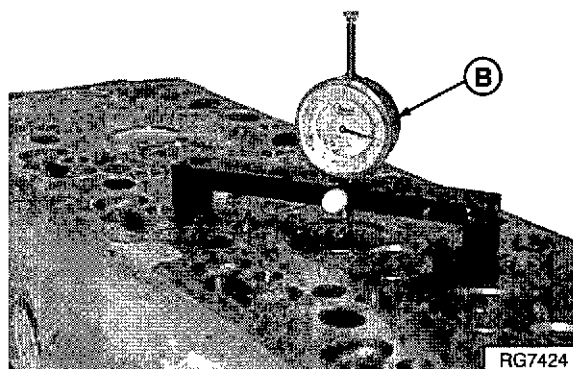
Measure and record valve recess (A) using a depth micrometer or magnetic base dial indicator (B). Measurements must be made a maximum of 3.0 mm (0.12 in.) in from edge of valve head.



VALVE RECESS SPECIFICATIONS

Intake Valve	0.61—1.11 mm (0.024—0.044 in.)
Worn Limit	1.63 mm (0.064 in.)
Exhaust Valve	1.22—1.72 mm (0.048—0.068 in.)
Worn Limit	2.26 mm (0.089 in.)

Install new valves, inserts, or grind existing valves and inserts, as necessary, to obtain proper valve recess. Grind valve seat inserts as required. (See REMOVE VALVE SEAT INSERTS later in this group.)



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PRELIMINARY CYLINDER HEAD AND VALVE CHECKS

Make preliminary inspection of cylinder head and valve assembly during disassembly.

Look for the following conditions:

- **Sticking Valves:**

Carbon deposits on valve stem.
Worn valve guides.
Scored valve stems.
Warped valve stems.
Misaligned or broken valve springs.
Worn or distorted valve seats.
Insufficient lubrication.

- **Warped, Worn, or Distorted Valve Guides:**

Lack of lubrication.
Cylinder head distortion.
Excessive heat.
Unevenly tightened cylinder head cap screws.

- **Distorted Cylinder Head and Gasket Leakage:**

Loss of cylinder head cap screw torque.
Broken cylinder head cap screw.
Overheating from low coolant level operation.
Insufficient liner stand-out.
Coolant leakage into cylinder causing hydraulic failure of gasket.
Leaking aftercooler.
Cracked cylinder head.
Cracked cylinder liner.
Damaged or incorrect gasket.
Overpowering or overfueling.
Damaged cylinder head or block surfaces.
Improper surface finish on cylinder head.
Improperly tightened cylinder head cap screws.
Faulty gasket installation (misaligned).

- **Worn or Broken Valve Seats:**

Misaligned valves.
Distorted cylinder head.
Carbon deposits on seats due to incomplete combustion.
Valve spring tension too weak.
Excessive heat.
Improper valve clearance.
Improper valve timing. Incorrect valve or seat installed.

- **Burned, Pitted, Worn, or Broken Valves:**

Worn or distorted valve seats.
Loose valve seats.
Worn valve guides.
Insufficient cooling.
Cocked or broken valve springs.
Improper engine operation.
Improper valve train timing.
Faulty valve rotators.
Warped or distorted valve stems.
"Stretched" valves due to excessive spring tension.
Warped cylinder head.
Bent push rods.
Carbon build-up on valve seats.
Rocker arm failure.
Incorrect valve or seat installed.
Incorrect piston-to-valve clearance.

- **Improper Valve Clearance:**

Inefficient use of fuel.
Engine starts harder.
Maximum engine power will not be achieved.
Shorter service life of valve train.
Greater chance for engine to overheat.

- **Excessive Recession:**

Worn valve guides.
Bent valves.
Debris passed through valve train.

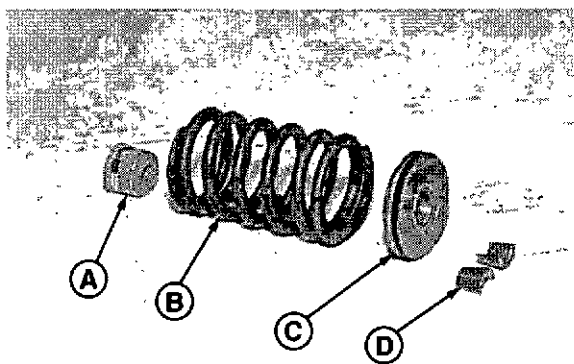
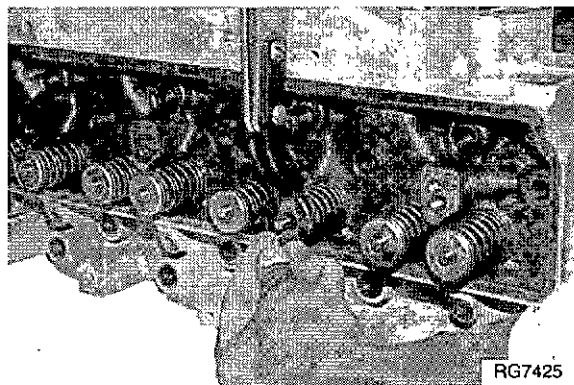
REMOVE VALVE ASSEMBLY

NOTE: A small magnet may be used to aid removal of valve retainer locks.

1. Using JDE138 Valve Spring Compressor, compress valve springs far enough to remove retainer locks (D).
2. Release spring tension and remove valve rotator (C) and valve spring (B).
3. Remove valves from cylinder head.

NOTE: Identify all parts for assembly in same location.

4. Remove valve stem seals (A) (if equipped) from valve guide tower.



- A—Valve Stem Seal
- B—Valve Spring
- C—Valve Rotator
- D—Retainer Locks

INSPECT AND MEASURE VALVE SPRINGS

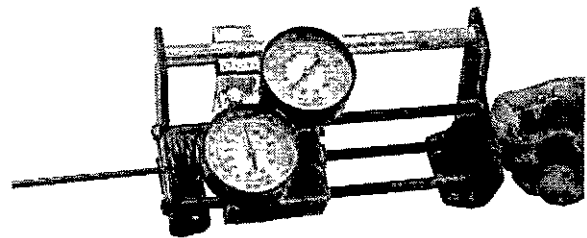
1. Inspect valve springs for alignment, wear, and damage.
2. Using D01168AA Spring Compression Tester, check valve spring tension. Compressed height must be within specification given below.



RG2732

VALVE SPRING SPECIFICATIONS

Compression	Height
Free Length*	
0 N (0 lb-force)	54.0 mm (2.125 in.)
240—280 N (54—62 lb-force)	46.0 mm (1.81 in.)
590—680 N (133—153 lb-force)	34.5 mm (1.36 in.)



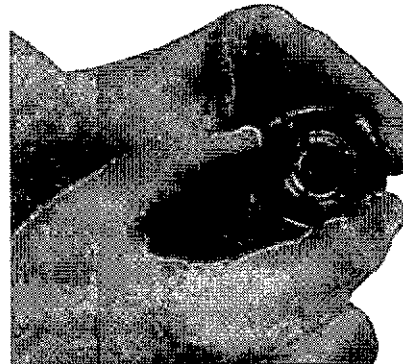
RG7427

*Free length of springs may vary slightly between springs

INSPECT VALVE ROTATORS

Valve rotators cannot be repaired. Replace valve rotators when valves are replaced or reground.

1. Insure that valve rotators turn freely in both directions. Replace if defective.



RG7428

CLEAN VALVES

1. Hold each valve firmly against a soft wire wheel on a bench grinder.

IMPORTANT: Any carbon left on the stem will affect alignment in valve refacer. **DO NOT** use a wire wheel on plated portion of valve stem. Polish the valve stem with steel wool or crocus cloth to remove any scratch marks left by the wire brush.

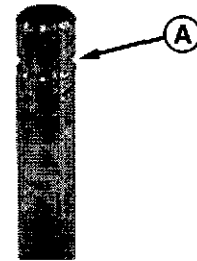
2. Make sure all carbon is removed from valve head, face and unplated portion of stem.

INSPECT AND MEASURE VALVES

1. Clean and inspect valves, valve stems, stem tips, and retainer lock groove (A). Replace valves that are worn or damaged.

NOTE: Intake valve has a larger head OD and is also identified with a dimple (B) on valve head.

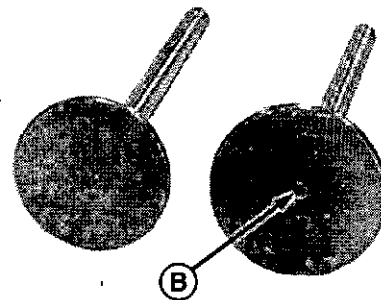
2. Measure valve stem OD. Record measurements and compare with valve guide ID. (See MEASURE VALVE GUIDES later in this group.)



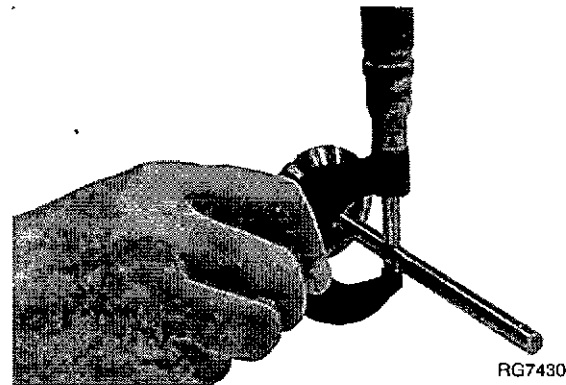
RG7429

VALVE STEM OD SPECIFICATIONS

Intake Valve	7.864—7.884 mm (0.3096—0.3104 in.)
Exhaust Valve	7.848—7.874 mm (0.3090—0.3100 in.)



RG7759

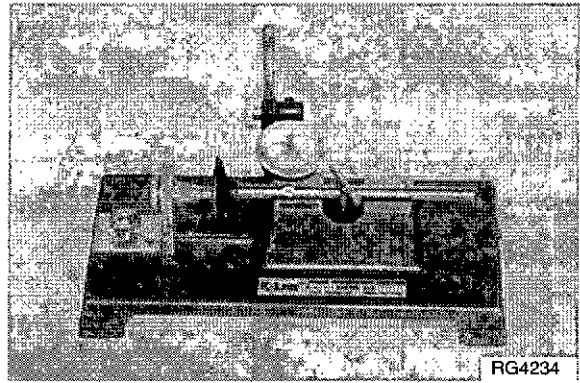


RG7430

- Using a valve inspection center, determine if valves are out of round, bent, or warped.

VALVE FACE RUNOUT SPECIFICATIONS

Maximum valve face runout. 0.038 mm
(intake and exhaust) (0.0015 in.)

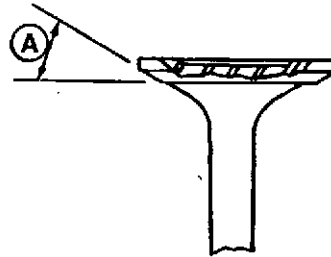


RG4234

GRIND VALVES

- Resurface serviceable valves to specified angle (A).
Face angle on intake and exhaust valves is $29.25^\circ \pm 0.25^\circ$.

IMPORTANT: DO NOT nick valve head-to-stem radius when grinding valves. A nick could cause the valve to break. Break all sharp edges after grinding.



RG4755

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INSPECT AND CLEAN CYLINDER HEAD

1. Inspect combustion face for evidence of physical damage, oil or coolant leakage, or gasket failure prior to cleaning the cylinder head. Repair or replace cylinder head if there is evidence of physical damage; such as cracking, abrasion, distortion, or valve seat "torching". Inspect all cylinder head passages for restrictions.
2. Scrape gasket material, oil, carbon, and rust from head. Use a powered wire brush to clean sealing surfaces.

IMPORTANT: Be sure to remove all plugs before cleaning head, as parts can be damaged or destroyed by hot tank solutions.

3. Clean cylinder head in a chemical hot tank, or with solvent and a brush.
4. Dry with compressed air and blow out all passages.

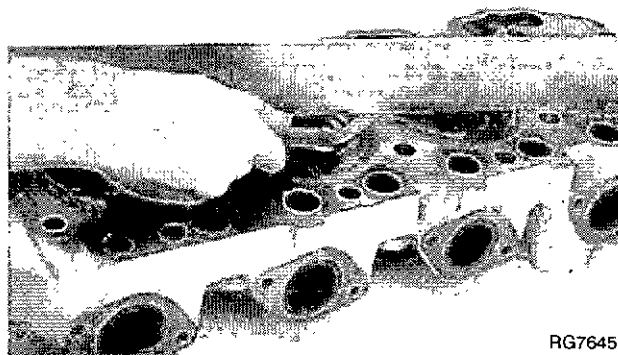
CHECK CYLINDER HEAD FLATNESS

Check cylinder head flatness using D05012ST Precision Straightedge and feeler gauge. Check lengthwise, crosswise, and diagonally in several places.

CYLINDER HEAD FLATNESS SPECIFICATIONS

Maximum Acceptable Out-of-Flat:
For Entire Length or Width 0.08 mm (0.003 in.)
For Every 150 mm (5.90 in.) 0.03 mm (0.001 in.)

If out-of-flat exceeds specifications, the cylinder head must be reconditioned or replaced. (See MEASURE CYLINDER HEAD THICKNESS later in this group.)

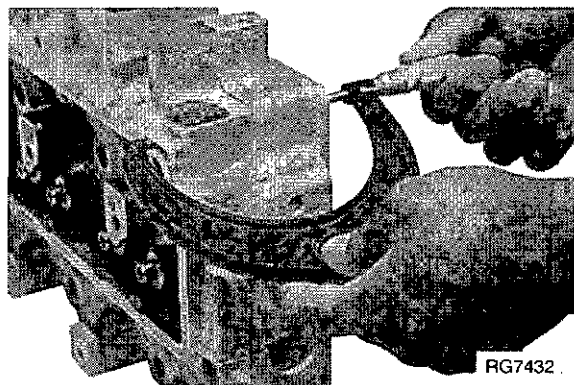


MEASURE CYLINDER HEAD THICKNESS

1. Measure head thickness from valve cover gasket rail-to-combustion face.

If cylinder head thickness is less than minimum allowable thickness, **DO NOT** attempt to resurface. Install a new cylinder head.

When resurfacing cylinder head, remove **ONLY** what is necessary to restore flatness.



CYLINDER HEAD SPECIFICATIONS

New Cylinder Head Thickness 104.87—105.13 mm
(4.129—4.139 in.)

Minimum Acceptable Thickness 104.24 mm (4.104 in.)

Combustion Face Surface Finish
(Surface Grind Only) (AA) 0.7—3.2 micrometers
(31—125 micro-in.)

Maximum Wave Depth 0.012 mm (0.0005 in.)

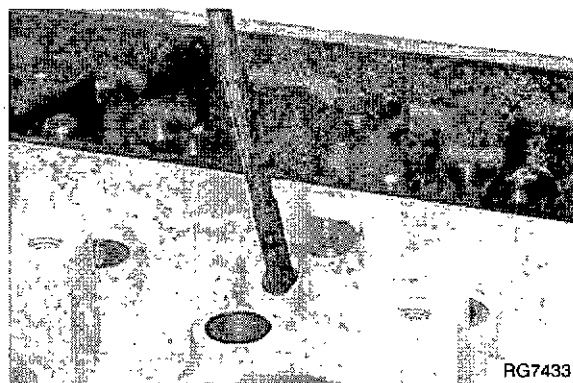
IMPORTANT: After resurfacing cylinder head, check for flatness as described earlier. Also check surface finish on combustion face of head.

Measure and record valve recess in cylinder head. (See **CHECK VALVE RECESS IN CYLINDER HEAD** earlier in this group.)

05
30

CLEAN INJECTION NOZZLE BORES

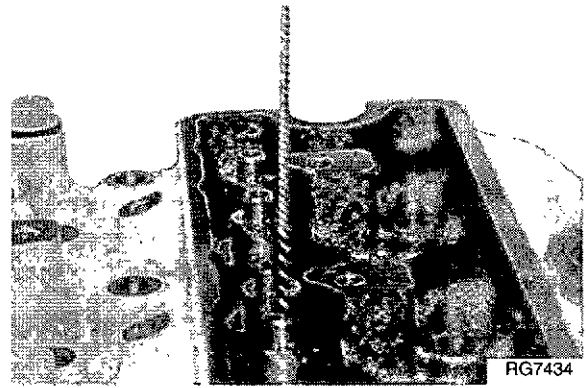
1. Clean carbon deposits from nozzle bores with JDE39 Nozzle Bore Cleaning Tool. Blow debris from bore with compressed air.



CLEAN VALVE GUIDES

1. Clean valve guides before inspection or repair, with a plastic brush.

NOTE: A few drops of light oil or kerosene will help clean the guides.



MEASURE VALVE GUIDES

- Using a telescopic gauge, measure valve guide wear.

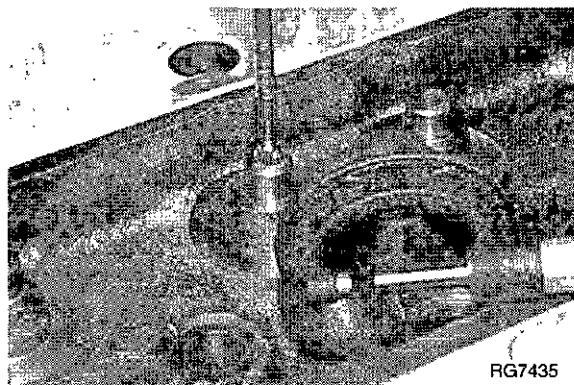
VALVE GUIDE SPECIFICATIONS

Valve Guide Bore I.D. (new)	7.912—7.938 mm (0.312—0.313 in.)
Valve Guide-to-Valve Stem Clearance (new)	0.05—0.10 mm (0.002—0.004 in.)
Wear Limit	0.15 mm (0.006 in.)

NOTE: Valves are available with 0.38 mm (0.015 in.) and 0.76 mm (0.030 in.) oversize stems.

- If valve guide-to-stem oil clearance exceeds the wear limit, oversize valve stems are available. Have a qualified machine shop ream valve guides to assure guide-to-stem clearance is within specification.
- If valve guide-to-stem oil clearance exceeds the wear limit, but is less than 0.20 mm (0.008 in.), it is acceptable to knurl guides and ream to size. However, installing oversize valve stems is preferred. (See **KNURL VALVE GUIDES**, later in this group.)

IMPORTANT: Production valve guides have a 5/6-24NF modified internal thread the entire length of guide with major diameter of 8.052—8.128 mm (0.3170—0.3199 in.) Have qualified machine shop thread valve guides accordingly after reaming for oversize valve stems.



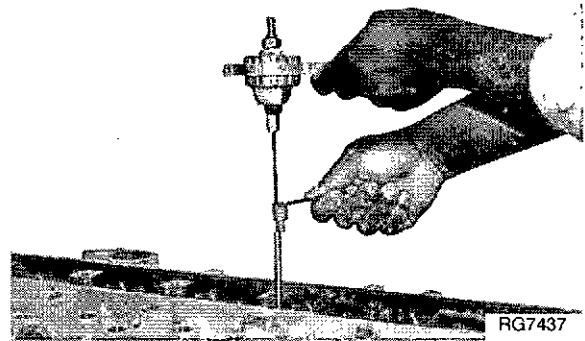
RG7435

KNURL VALVE GUIDES

IMPORTANT: Valve guide knurling should only be done by experienced personnel familiar with equipment and capable of maintaining required specification.

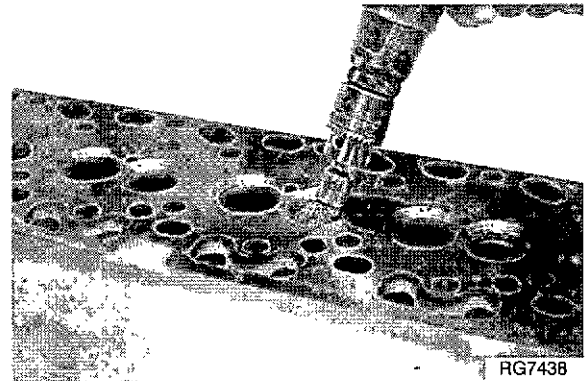
ALWAYS knurl valve guides before reaming to assure proper valve guide-to-stem clearance.

1. Use JT05949 Valve Guide Knurler Kit to knurl valve guides. Use kit exactly as directed by the manufacturer.
2. After knurling, ream valve guide to finished size to provide specified stem-to-guide clearance.



CLEAN AND INSPECT VALVE SEATS

1. Use an electric hand drill with D17024BR End Brush to remove all carbon on valve seats.
2. Inspect seats for excessive wear, cracks, or damage.
3. Check entire combustion face for rust, scoring, pitting, or cracks.



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33

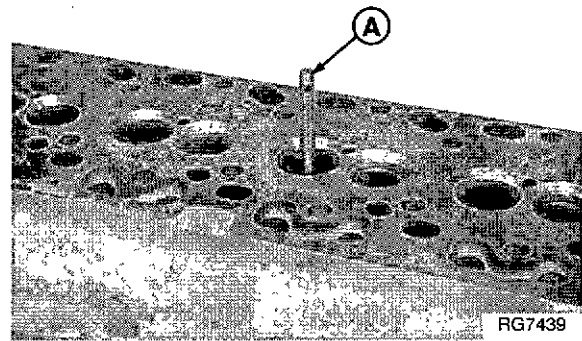
GRIND VALVE SEATS

IMPORTANT: Valve seat grinding should only be done by experienced personnel familiar with equipment and capable of maintaining required specifications. **ALWAYS** keep valve guides and work area clean when grinding valve seats to maintain valve guide bore-to-seat runout.

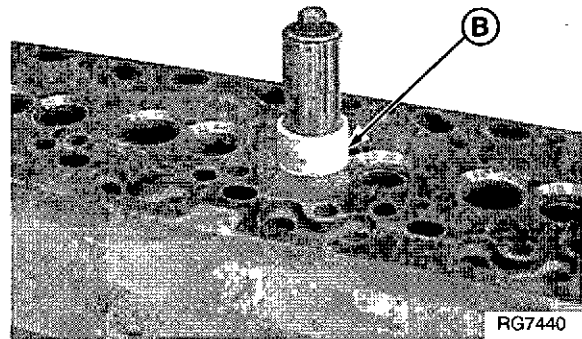
Grinding valve seats increases seat width and valve recess in cylinder head. **DO NOT** grind excessively. Only a few seconds are required to recondition the average valve seat. Dress grinding stone as necessary to maintain specified seat angle.

Support the weight of grinder to avoid excessive pressure on the stone.

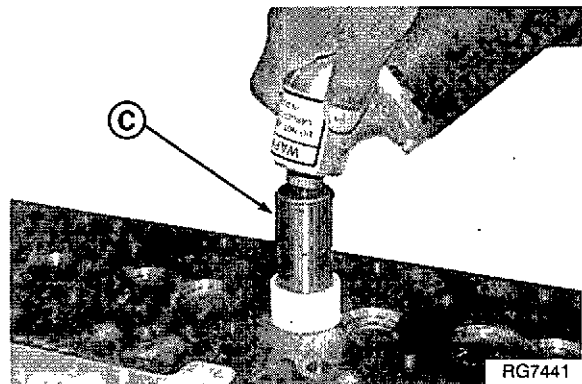
Blend or radius all sharp edges after grinding valve seats for a more effective valve face-to-seat seal.



RG7439



RG7440

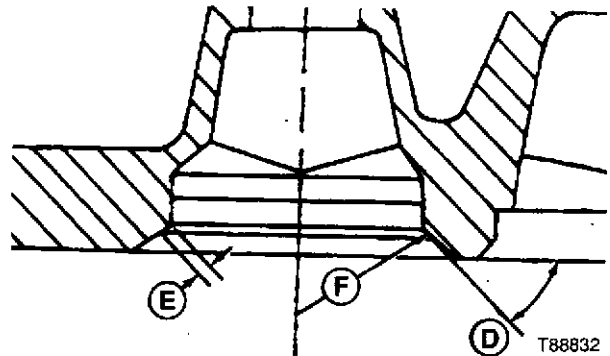


RG7441

1. Install appropriate pilot (A) in valve guide bore.
2. Install appropriate grinding stone (B) on arbor (C) and position onto valve seat.
3. Using drill from JT05893 Heavy Duty Seat Grinder Set, grind valve seats to the following specifications:

VALVE SEAT GRINDING SPECIFICATIONS

Valve Seat Angle (D)	30°
Valve Seat Width (E)	1.50—2.00 mm (0.059—0.079 in.)
Maximum Valve Seat Runout (F)	0.8 mm (0.003 in.)



T88832

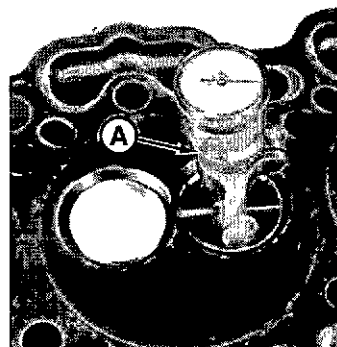
- A—Pilot
- B—Grinding Stone
- C—Arbor
- D—Valve Seat Angle
- E—Valve Seat Width
- F—Valve Seat Runout

05
34

4. Use a vernier caliper or scale to measure seat width. If valve seat is too wide, reduce the width with a narrowing stone.

NOTE: A narrowing stone will change the top angle of the seat and reduce the outer diameter of the valve seating area. Varying the width changes the fine contact between valve face and seat. If seat width is too narrow, valve may burn or erode.

5. If valve does not seat properly, use an eccentricimeter (A) to check valve seat runout. Use a new or refaced valve and blueing to check contact between valve seat and face. If necessary, lap the valve onto its seat using a lapping tool and lapping compound. Replace valves and inserts as necessary.
6. Install new or refaced valve and check valve recess in cylinder head after grinding. (See CHECK VALVE RECESS IN CYLINDER HEAD earlier in this group.)



RG6318

REMOVE VALVE SEAT INSERTS

IMPORTANT: Be careful not to damage cylinder head when removing valve seats.

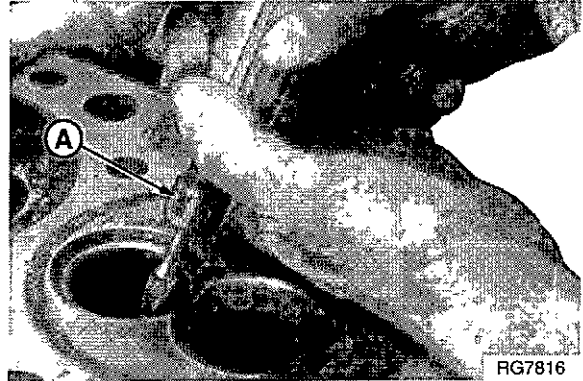
Valve seat removal should only be done by experienced personnel familiar with procedures.

Valve seat inserts are made of sintered (powdered) metal. Remove inserts by one of the following methods:

IMPORTANT: DO NOT use an oxy-acetylene torch to remove valve seat inserts, as it alters the hardness of the cylinder head.

- Raising burr on valve seat insert

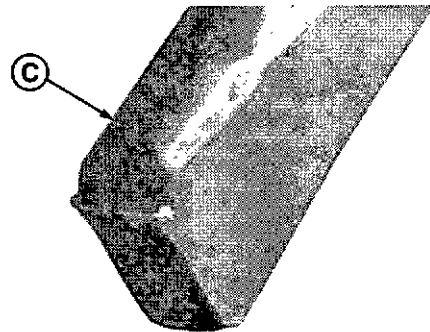
1. Using a carbide deburring tool, (A) raise a burr (B) on bottom of valve seat insert.
2. Protect surface of cylinder head with cardboard or cloth. Using a chisel with special ground end (C), tap handle of chisel with hammer until valve seat insert (D) comes loose.



RG7816

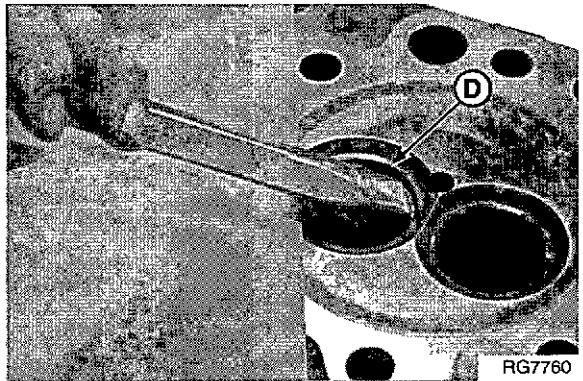


RG7817



RG7818

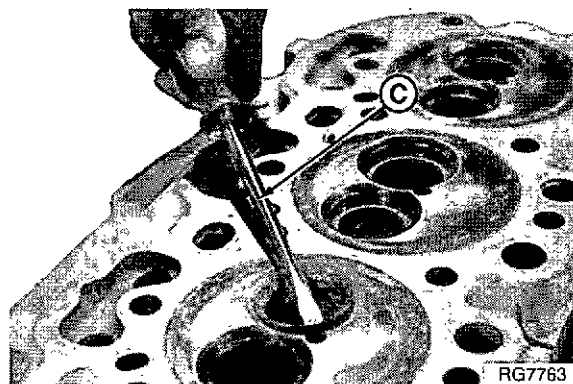
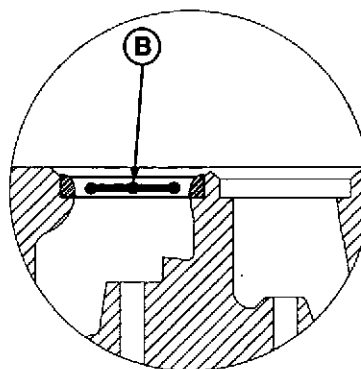
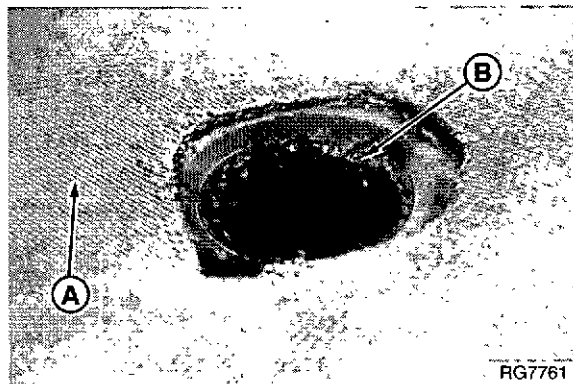
- A—Deburring Tool
- B—Burr
- C—Special Ground Chisel
- D—Valve Seat Insert



RG7760

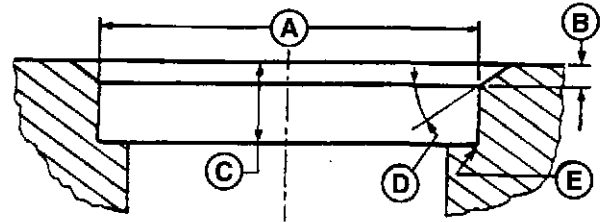
• **Using an arc welder**

1. Protect the valve guide by installing a cap screw or dowel in guide to protect from weld spatter.
2. Protect the cylinder head surface with a non-flammable welder's cloth (A). Apply a thin bead of weld (B) around ID of valve seat insert. Allow insert to cool and use a screwdriver (C) or similar tool and carefully pry insert from bore.
3. After removal of inserts, thoroughly clean area around valve seat bore and inspect for damage or cracks. Replace cylinder head as necessary.



MEASURE VALVE SEAT BORE IN CYLINDER HEAD

1. If bore dimensions are not within specification, machine head to the following specifications:



RG5606

Exhaust Valve Seat Insert Bore Specifications:

A	.....	42.987—43.013 mm (1.6924—1.6934 in.)
B	.....	3.82 mm (0.150 in.) Reference
C	.....	9.936—10.064 mm (0.3912—0.3962 in.)
D	.....	38—42°
E	.....	Maximum Radius 0.5 mm (0.019 in.)
Maximum surface finish of bore "A"		0.00158 mm (0.000062 in.)

Intake Valve Seat Insert Bore Specifications:

A	.....	47.104—47.130 mm (1.8545—1.8555 in.)
B	.....	3.45 mm (0.136 in.) Reference
C	.....	9.936—10.064 mm (0.3912—0.3962 in.)
D	.....	38—42°
E	.....	Maximum Radius 0.5 mm (0.019 in.)
Maximum surface finish of bore "A"		0.00158 mm (0.000062 in.)

Replacement Valve Seat Insert OD:

Intake	.....	47.155—47.181 mm (1.8565—1.8575 in.)
Exhaust	.....	43.038—43.064 mm (1.6944—1.6954 in.)

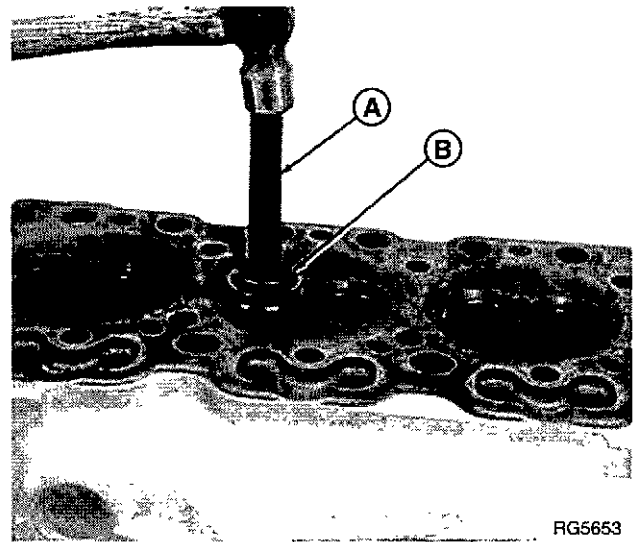
05
38

INSTALL VALVE SEAT INSERTS

1. Use JDG676 Pilot Driver (A) and JDG675 Valve Seat Insert Installing Adapter (B) to install valve seat inserts in cylinder head.

Use one end of JDG675 Adapter to install intake valve seat inserts and the other end to install exhaust valve seat inserts.

2. Install valves and measure valve recess. (See MEASURE VALVE RECESS IN CYLINDER HEAD, earlier in this group.)
3. Grind valve seats as required to maintain correct valve recess and valve face-to-seat seal. (See GRIND VALVE SEATS earlier in this group.)



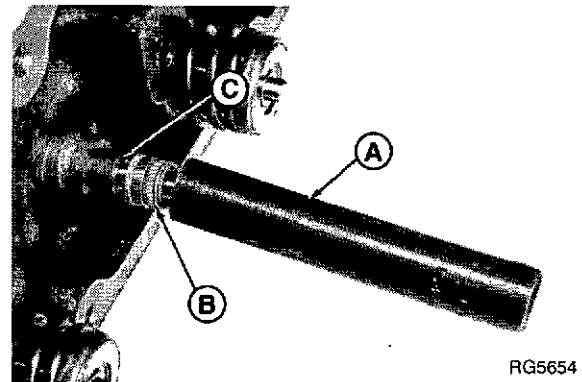
INSTALL VALVES

1. Lubricate valve stems and guides with AR44402 Valve Stem Lubricant or clean engine oil.

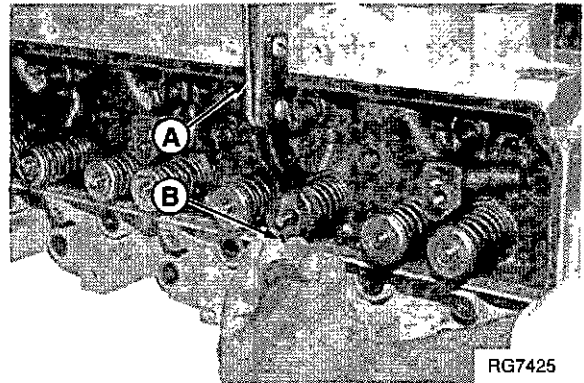
NOTE: Valves must move freely in guide and seat properly in head to form an effective seal.

2. Insert valves in head (if valves are reused, install in same location from which removed).
3. Use JDG678 Valve Stem Seal Installer (A) to slide valve stem seals (B) over valve stems and onto valve guide tower (C).

NOTE: JDG678 Installer may also be used to install oversize valve stem seals on oversize valve stems.

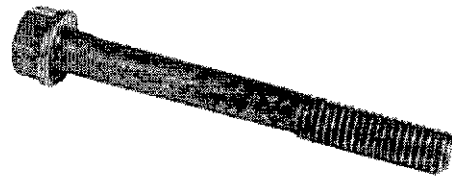


4. Install valve springs and rotators.
5. Compress valve springs using JDE138 Valve Spring Compressor (A) and install retainer locks (B) on valve stems.
6. Strike end of each valve three or four times with a soft mallet (non-metallic) to insure proper positioning of the retainer locks.
7. Recheck valve recess. (See MEASURE VALVE RECESS IN CYLINDER HEAD, earlier in this group.)



CLEAN AND INSPECT CYLINDER HEAD CAP SCREWS

1. Clean entire length of cap screws. Use a wire brush and solvent to remove rust and scale. Dry cap screws with compressed air.
2. Inspect cap screws for corrosion damage and overall condition of threads. CAP SCREWS WITH CORROSION OR OTHER IMPERFECTIONS MUST BE REPLACED.



RG6319

INSPECT AND CLEAN EXHAUST MANIFOLD

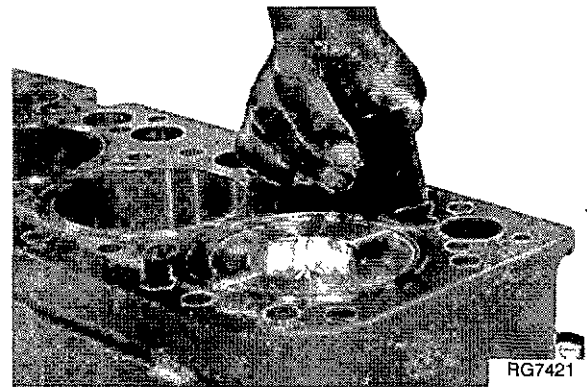
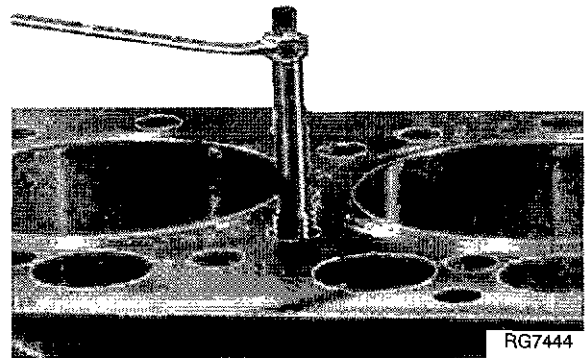
1. Thoroughly clean all passages and gasket surfaces in exhaust manifold and exhaust elbow.
2. Inspect entire exhaust manifold for cracks or damage. Replace parts as necessary.

CLEAN AND INSPECT TOP DECK OF CYLINDER BLOCK

1. Remove gasket material, rust, carbon, and other foreign material from top deck. Gasket surface must be clean.
2. Clean threaded holes in cylinder block using JDG680 Tap or any 1/2-13 UNC-2A tap about 76 mm (3.0 in.) long. Use compressed air to remove debris and fluids from the cap screw holes. Replace block if there is evidence of damage.
3. Use compressed air to remove all loose foreign material from cylinders and top deck.

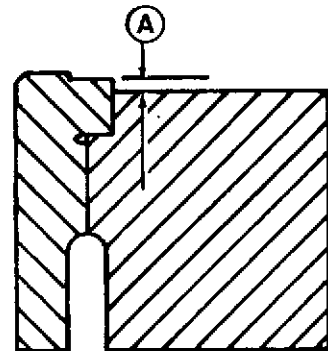
IMPORTANT: All debris must be cleaned from the camshaft followers before assembling the engine.

4. If not previously done, remove camshaft followers from block and wash in solvent. Lubricate with clean engine oil and install in the same bore.
5. Inspect top deck for flatness and serviceability. (See Group 10.)



**MEASURE CYLINDER LINER STANDOUT
(HEIGHT ABOVE BLOCK)**

1. Secure liners using cap screws and flat washers. Flat washers should be at least 3.18 mm (1/8 in.) thick. Tighten cap screws to 68 N·m (50 lb-ft).
2. Using JDG451 or KJD10123 Height Gauge (B) and D17526CI or D17527CI Dial Indicator (C), measure liner height (A) at approximately 1, 5, 7, and 11 o'clock positions as viewed from flywheel end of engine. Record all measurements by cylinder number.



RG6439

LINER STANDOUT SPECIFICATIONS

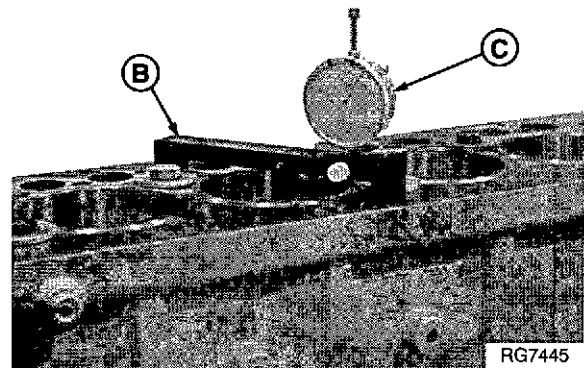
Liner Height Above Block. 0.030—0.100 mm
(0.0010—0.0040 in.)

Maximum Permissible Height Difference
at Nearest Point of Two Adjacent Liners,
or Within One Liner 0.051 mm
(0.0020 in.)

**IMPORTANT: ONE LINER SHIM ONLY may be
installed under each liner flange.**

3. Remove and shim, or replace, any liner that does not meet height specifications.

*NOTE: Two sizes of shims are available: 0.05 mm
(0.002 in.) and 0.10 mm (0.004 in.).*



RG7445

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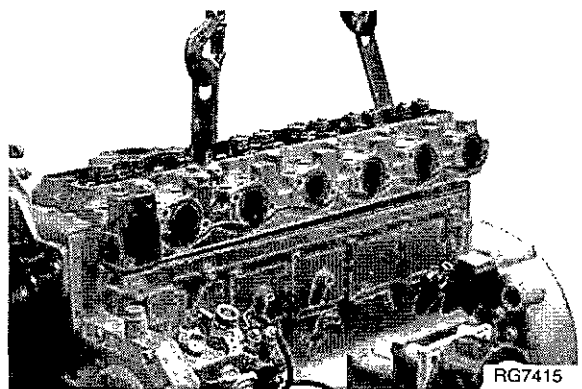
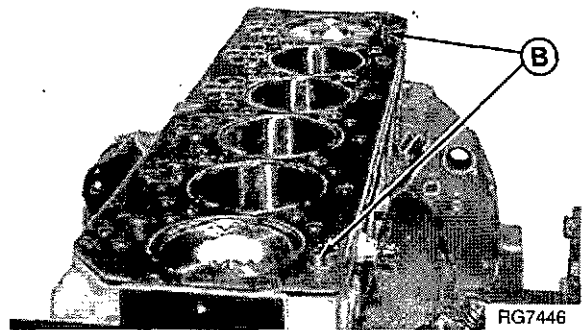
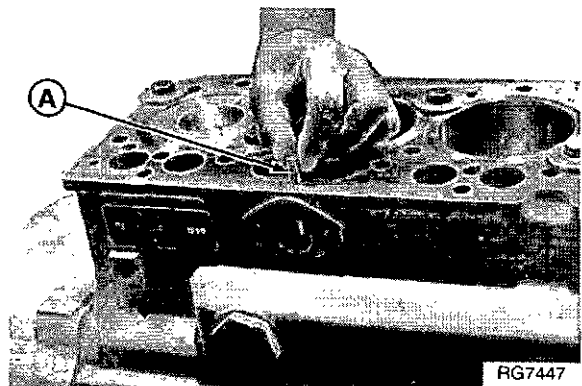
INSTALL CYLINDER HEAD

IMPORTANT: ALWAYS thoroughly inspect cylinder head gasket for possible manufacturing imperfections. Return any gasket that does not pass inspection.

1. Dip fuel supply pump push rod (A) (if equipped) in clean engine oil and carefully install in cylinder block before installing cylinder head.
2. Install two guide studs (B) in cylinder block at locating holes.
3. Place new head gasket on cylinder block. Do not use sealant; install dry.

IMPORTANT: The O-ring seals in head gasket can be damaged if head is repositioned while resting on engine block. Use guide studs to position cylinder head on block.

4. Position cylinder head over guide studs and lower onto cylinder block.



5. Dip entire cap screw in clean engine oil. Remove excess oil from screw.
6. Remove guide studs. Install flanged-head cylinder head cap screws.
7. Tighten all cap screws to specified torque (in sequence, beginning with No. 1) before proceeding to next step:

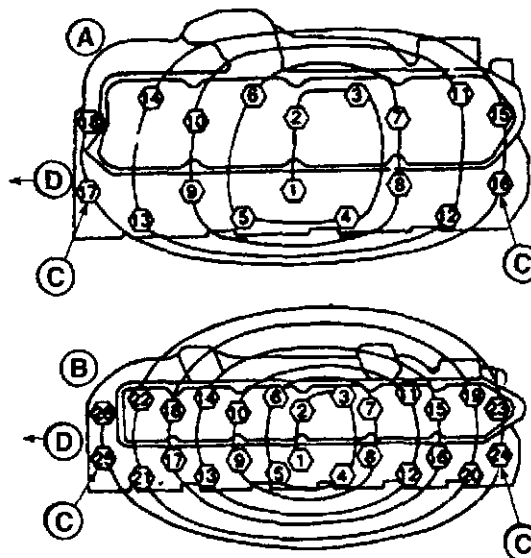
— Step 1 - Tighten all cap screws to 100 N·m (75 lb-ft).

— Step 2 - Tighten all cap screws to 150 N·m (110 lb-ft).

— Step 3 - Wait 5 minutes. Verify 150 N·m (110 lb-ft).

— Step 4 - Tighten each screw an additional $60^{\circ} \pm 10^{\circ}$. (See TORQUE-TURN METHOD FOR PROPER TORQUE next in this group.)

Retorque of cylinder head cap screws after engine break-in is not required when using the recommended torque procedure along with flanged-head cap screw.



RG7646

- A—4-Cylinder Engine
- B—6-Cylinder Engine
- C—Locating Holes (Guide Stud Locations)
- D—Arrow Toward Front of Engine

TORQUE-TURN METHOD FOR PROPER TORQUE

1. After tightening cap screws to 150 N·m (110 lb-ft), use JT05993 Torque Angle Gauge or the line scribe method below to tighten each cap screw an additional 60°.

Line scribe method:

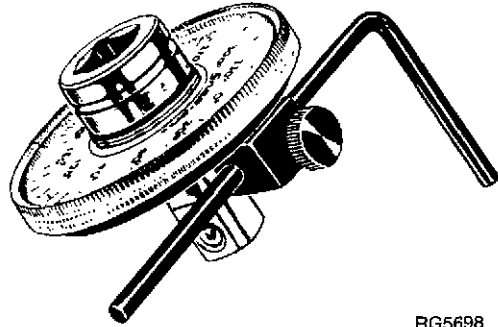
Step A—Make two marks on socket 1/6 turn (60°±10°) apart.

Step B—Make a mark on cylinder head next to each cap screw.

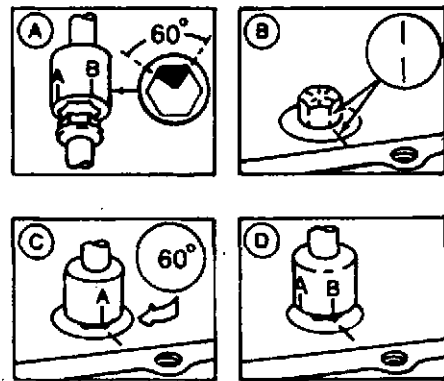
Step C—Place socket on cap screw so first mark aligns with mark on cylinder head.

Step D—Tighten (in sequence) all cap screws until second mark on socket aligns with mark on cylinder head.

Retorque of cylinder head cap screws after engine break-in is not required when using the recommended torque procedure along with flanged-head cap screws.



RG5698



INSTALL ROCKER ARM ASSEMBLY

1. Install push rods in same location from which removed.

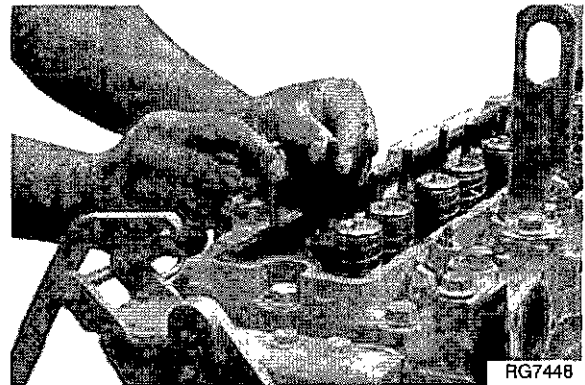
NOTE: Valve stem tips are specially hardened, wear caps are not required

IMPORTANT: Relieve tension on rocker arm adjusting screw to avoid damaging rocker arm shaft during installation.

2. Position rocker arm assembly on engine.

IMPORTANT: Oil supply hole in rocker arm shaft must be positioned at the flywheel end of engine and facing downward when rocker shaft is installed.

3. Lubricate all rocker arms with engine oil and make sure they move freely. Tighten rocker arm support studs to 80 N·m (59 lb-ft).
4. Adjust valve clearance. (See CHECK AND ADJUST VALVE CLEARANCE earlier in this group.)



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INSPECT AND CLEAN VENTILATOR OUTLET HOSE

1. Check ventilator outlet hose (A) on rocker arm cover for bent or damaged condition. Replace if necessary.
2. Clean ventilator hose and tube if they are restricted.

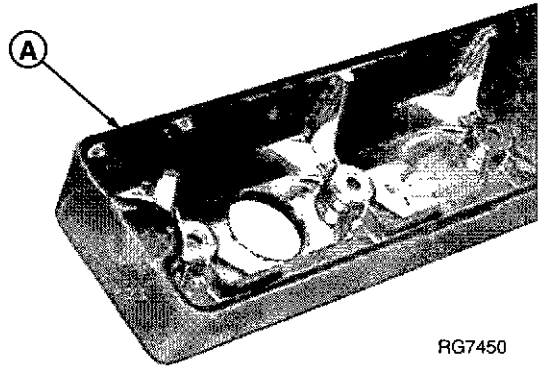


INSTALL ROCKER ARM COVER

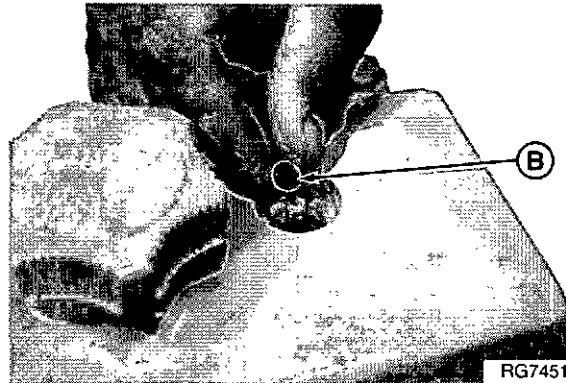
IMPORTANT: Dispose of sealing ring (A) if there is evidence of damage. Otherwise, do NOT remove seal from groove.

If the sealing ring is defective, the following procedure should be used to install a new sealing ring:

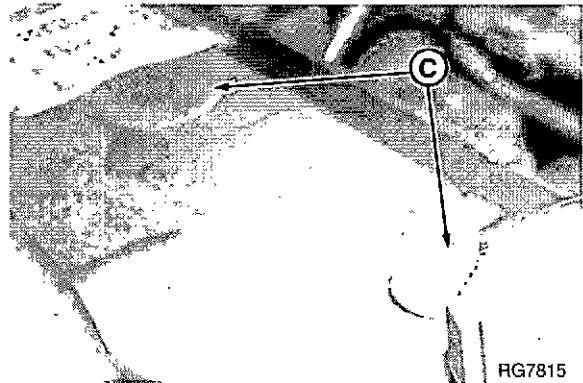
- Carefully remove the old sealing ring from rocker arm cover. Do not use any cutting tool that could damage the cover.
 - Clean the groove with acetone. Dry with compressed air.
 - When installing new ring in groove, start at ends and work toward the center of the cover. Do not use sealant on seal ring.
1. Install rocker arm cover with seal ring.
 2. Install O-rings (B) and nuts.
 3. Tighten all nuts to 35 N·m (26 lb-ft), starting at the center and alternate sides until reaching the ends. **DO NOT OVERTIGHTEN.**
 4. Install rocker arm cover button plugs (C).



RG7450



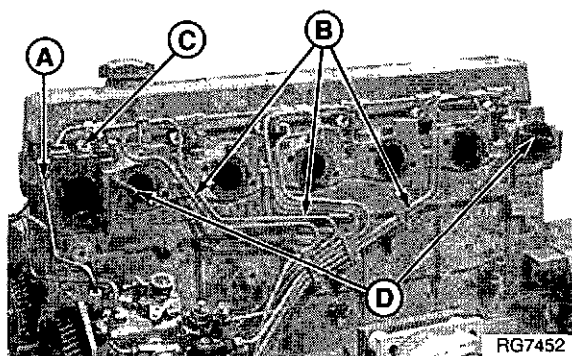
RG7451



RG7815

COMPLETE FINAL ASSEMBLY

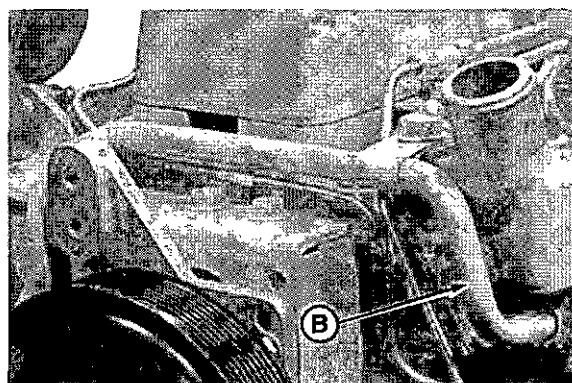
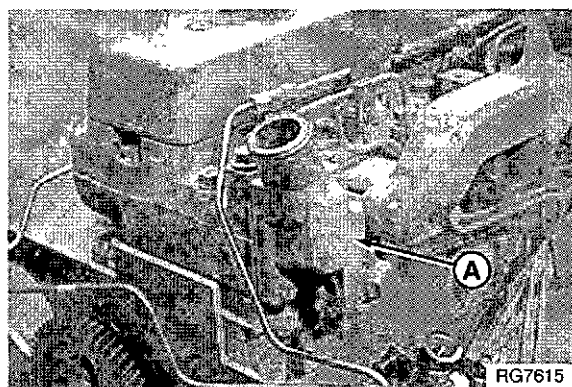
1. Install injection nozzles (C). Install injection lines (B) as an assembly. (See Group 35.)
2. Install fuel leak-off line (A). (See Group 35.)
3. Install guide pins (D) in cylinder head to aid in installation of exhaust manifold.



A—Fuel Leak-off Line
B—Injection Lines
C—Injection Nozzles
D—Guide Pins

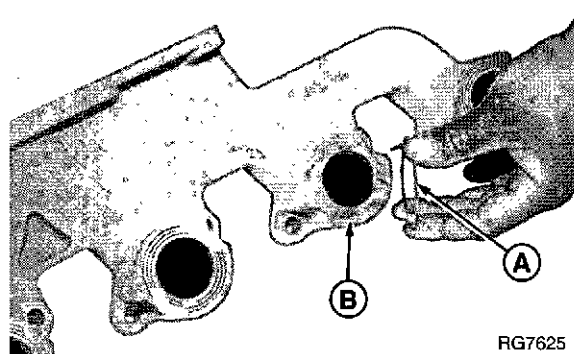
NOTE: On some engines, the thermostat housing/water manifold is part of the cylinder head.

4. Install thermostat housing/water manifold (A). (See Group 25.)
5. Install thermostat housing-to-water pump tube (B).

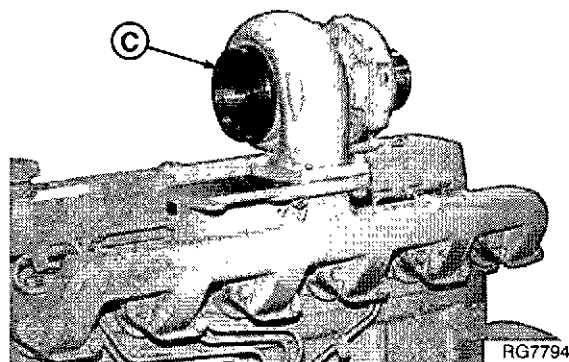


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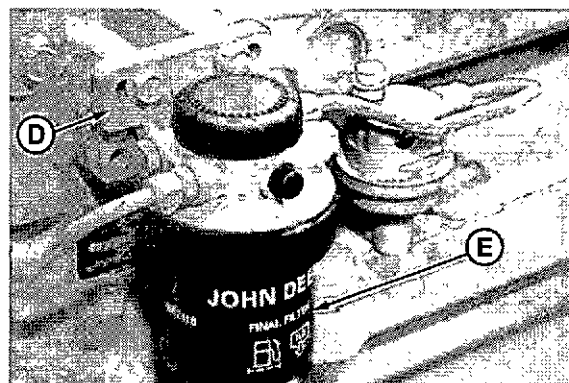
6. Using guide studs, install exhaust manifold (B) with stainless steel gaskets (A). (See Group 30.)
7. Install turbocharger (C, if equipped) and exhaust elbow (shown removed). (See Group 30.)
8. Install fuel filter base (D) and fuel filter (E). (See Group 35.)
9. Install fuel supply pump. (See Group 35.)
10. Install air intake elbow. (See Group 30.)
11. On turbocharged engines, connect turbocharger oil inlet line (F).
12. Install alternator if removed. Tighten alternator pulley nut to 80 N-m (59 lb-ft). Tighten alternator-to-timing gear cover cap screw to 70 N-m (52 lb-ft).
13. If engine oil was drained from crankcase, install new oil filter and fill engine with clean oil of correct grade and viscosity. (See Group 02.)
14. Fill cooling system with clean coolant. (See Group 02.)



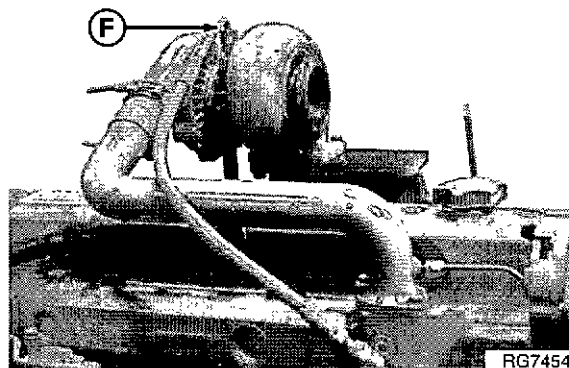
RG7625



RG7794



- A—Stainless Steel Gasket
- B—Exhaust Manifold
- C—Turbocharger
- D—Fuel Filter Base
- E—Fuel Filter
- F—Turbocharger Oil Inlet Line



RG7454

PERFORM ENGINE BREAK-IN

1. Run engine at slow idle no load for 1 minute. Check for fuel, coolant, and oil leaks.
2. Increase RPM to fast idle, then load down to 50 rpm above rated speed for 10 minutes.

NOTE: Dynamometer is the preferred load control, but engine can be loaded by matching drag loads to gear selection.

3. Recheck valve clearances and adjust as necessary after engine cools. (See CHECK AND ADJUST VALVE CLEARANCE, earlier in this group.)
4. Install rocker arm cover. Tighten rocker arm cover nuts to 35 N·m (26 lb-ft). (See INSTALL ROCKER ARM COVER earlier in this group.)

Retorque of cylinder head cap screws after engine break-in is not required.

IMPORTANT: After engine break-in, follow ALL recommended hourly service intervals outlined in your operator's manual.

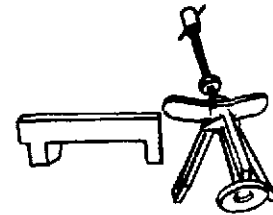
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SPECIAL OR ESSENTIAL TOOLS

NOTE: Order tools according to information given in the U.S. SERVICEGARD™ Catalog or in the European Microfiche Tool Catalog (MTC).

Cylinder Liner Puller D01062AA,
D01073AA, or KCD10001

Used to remove and install cylinder liners.



RG5019

Flexible Cylinder Hone D17004BR

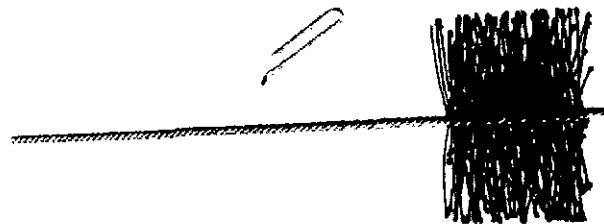
Hone cylinder liners.



RG5074

O-Ring Groove Cleaning Brush D17015BR

Clean cylinder liner O-ring groove in block.



RG5075

Ring Groove Wear Gauge JDE62 or JDG957

Check wear of keystone ring groove on pistons.

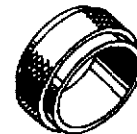
NOTE: Depending on engine application and the piston used, one or the other gauge will be used.



RG5076

Piston Ring Compressor JDE84

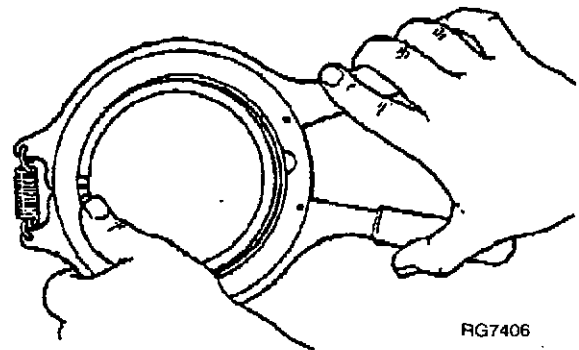
Compress rings while installing pistons.



RG5031

Piston Ring Expander JDE85, JDE135,
or KJD10140

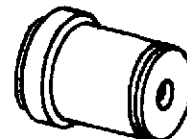
Remove and install piston rings.



RG7406

Piston Pin Bushing Remover
and Installer JDE88 (Small Pin)
JD286 (Large Pin)

Replace piston pin bushing in connecting rods with
straight pin-end.



RG5107

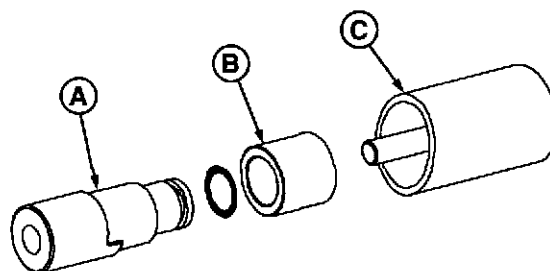
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Connecting Rod Bushing Service Set JDG953

Replace pin bushing in connecting rods with tapered pin-end.

Set consists of:

- A—Remover/Replacer Driver JDG953-1
- B—Installer Pilot JDG738-2
- C—Receiver Cup JDG953-2



RG7633

Dial Indicator (English, in.) D17526CI
or (Metric, mm) D17527CI

Use with JDG451 to measure valve recess and cylinder liner height-to-cylinder block top deck.

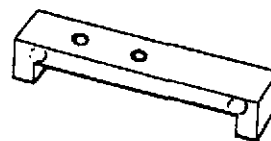


RG6246

Piston and Liner Height Gauge JDG451

Measure piston and liner heights.

NOTE: A dial indicator is not supplied with JDG451. Use D17526CI (English, in.) or D17527CI (Metric, mm) Dial Indicator with JDG451.

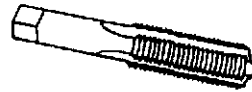


RG7029

Cylinder Block, Liners, Pistons, and Rods

Tap JDG680

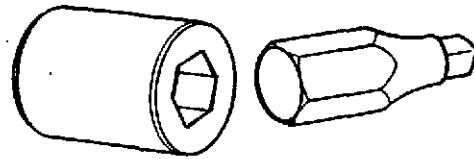
Used to restore threaded holes in cylinder block for cylinder head cap screws.



RG5100

Oil Galley Plug Tool JDG782

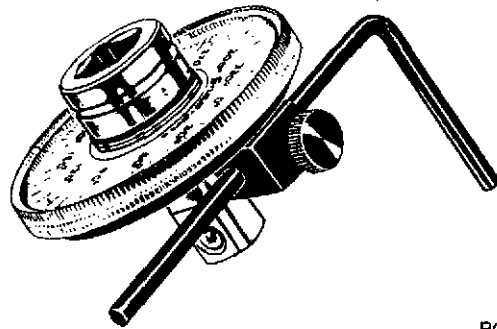
Used to remove and install oil galley plug.



RG6612

Torque Angle Gauge JT05993

Used to TORQUE-TURN flanged-head cylinder head and connecting rod cap screws.



RG5698

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SERVICE EQUIPMENT AND TOOLS

NOTE: Order tools from the U.S. SERVICEGARD™ Catalog or from the European Microfiche Tool Catalog (MTC). Some tools may be available from a local supplier.

Name	Use
D05012ST Precision "Bevelled Edge" Straightedge	Check cylinder head flatness.
Piston Ring Groove Cleaner	Clean piston ring grooves.
Cylinder Bore Ridge Reamer	Remove carbon from liner bore.

OTHER MATERIAL

Number	Name	Use
AR54749	Soap Lubricant	Coat O-rings on cylinder liners.
_____	PLASTIGAGE	Determine connecting rod bearing-to-journal oil clearance.
LOCTITE 242	Thread Lock and Sealer	Coat threads of oil gallery plugs.

CYLINDER BLOCK, LINERS, PISTONS, AND RODS SPECIFICATIONS

ITEM	SPECIFICATION	WEAR LIMIT
Balancer Shaft Bore ID in Cylinder Block: (Bushing Removed)	43.262—43.288 mm (1.7032—1.7042 in.)	_____
Balancer Shaft Bushing ID: (Bushing Installed)	40.177—40.237 mm (1.5818—1.5841 in.)	_____
Balancer Shaft Journal-to-Bushing Clearance	0.016—0.102 mm (0.006—0.0040 in.)	_____
Main Bearing Bore in Cylinder Block	84.455—84.481 mm (3.3250—3.3260 in.)	_____
Centerline of Main Bearing Bore-to-Top Deck of Block	337.896—337.972 mm (13.3029—13.3059 in.)	_____
Maximum Acceptable Top Deck Out-of-Flat: For Entire Length or Width	0.08 mm (0.003 in.)	_____
For Every 150 mm (5.90 in.) Length or Width	0.025 mm (0.001 in.)	_____
Top Deck Surface Finish (Surface Grind Only) (AA)	0.8—3.2 micrometers (32—125 micro-in.)	_____
Maximum Wave Depth	0.012 mm (0.0005 in.)	_____
Liner Flange Counterbore Depth in Block	5.952—5.988 mm (0.2343—0.2357 in.)	_____
Camshaft Follower Bore ID in Block	31.70—31.75 mm (1.248—1.250 in.)	_____
Camshaft Follower OD	31.61—31.64 mm (1.245—1.246 in.)	_____
Camshaft Follower-to-Bore Clearance	0.06—0.13 mm (0.002—0.005 in.)	_____

* 4045 (4-cylinder) Engine only

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CYLINDER BLOCK, LINERS, PISTONS, AND RODS SPECIFICATIONS—CONTINUED

ITEM	SPECIFICATION	WEAR LIMIT
Camshaft Bore ID:		
*Front (No. 1) in Block (without bushing)	59.961—59.987 mm (2.3607—2.3617 in.)	_____
Front (No. 1) in Block (with bushing)	55.961—55.987 mm (2.2031—2.2042 in.)	_____
All Except No. 1	55.986—56.012 mm (2.2042—2.2052 in.)	_____
Camshaft Journal-to-Bushing Oil Clearance:		
No. 1 Bore with Bushing	0.063—0.115 mm (0.0025—0.0045 in.)	_____
All Except No. 1 Bore	0.088—0.140 mm (0.0035—0.0055 in.)	_____
Fuel Supply Pump Push Rod Bore in Block	10.00—10.05 mm (0.3937—0.3957 in.)	_____
Fuel Supply Pump Push Rod OD	9.891—9.917 mm (0.3894—0.3904 in.)	_____
Lower Block Bore for Seating Liner	115.75—115.80 mm (4.557—4.559 in.)	_____
Upper Block Bore for Seating Liner	120.70—120.75 mm (4.752—4.754 in.)	_____
Liner Flange ID in Block	126.33—126.35 mm (4.973—4.974 in.)	_____
OD of Liner at Upper Bore	120.61—120.69 mm (4.7484—4.7516 in.)	_____
Clearance Between Liner and Cylinder Block:		
At Lower Bore	0.035—0.100 mm (0.001—0.004 in.)	_____
At Upper Bore	0.10—0.14 mm (0.004—0.005 in.)	_____
Liner Flange Thickness	6.022—6.058 mm (0.2371—0.2385 in.)	_____
Liner Height Above Block	0.030—0.100 mm (0.001—0.004 in.)	_____
Maximum Permissible Height Difference at Nearest Point of Two Adjacent Liners or Within a Single Liner		0.05 mm (0.002 in.)

* Front cam bore in block has a replaceable bushing; remaining machined bores do not have bushings.

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CYLINDER BLOCK, LINERS, PISTONS, AND RODS SPECIFICATIONS—CONTINUED

ITEM	SPECIFICATION	WEAR LIMIT
Thickness of Liner Shim CD15466	0.05 mm (0.002 in.)	_____
Thickness of Liner Shim R65833	0.10 mm (0.004 in.)	_____
Cylinder Liner ID	106.48—106.52 mm (4.192—4.194 in.)	_____
Maximum Permissible Cylinder Wear .....		.10 mm (0.004 in.)
Maximum Permissible Cylinder Taper .....		.05 mm (0.002 in.)
Maximum Permissible Cylinder Out-of-Round .....		.05 mm (0.002 in.)
Piston-to-Liner Clearance (Measured at Bottom of Piston Skirt):		
All Naturally Aspirated Engines	0.08—0.14 mm (0.003—0.005 in.)	_____
All Turbocharged Engines	0.08—0.15 mm (0.003—0.006 in.)	_____
Piston OD at 28 mm (1.1 in.) from Bottom of Skirt and Measured 90° to Piston Pin		
	106.38—106.40 mm (4.188—4.189 in.)	_____
Piston Protrusion Above Block Deck	0.08—0.30 mm (0.003—0.012 in.)	_____
Piston Height (Measured from Center of Piston Pin Bore-to-Top of Piston)	71.64—71.70 mm (2.820—2.823 in.)	_____
Maximum Allowable Clearance Between Second and Third Piston Ring and Ring Groove .....		.20 mm (0.008 in.)
Piston Ring End Gap*:		
4045DF, TF150 and 6068DF, TF150 Engines		
No. 1 Compression Ring	0.33—0.58 mm (0.013—0.023 in.)	_____
No. 2 Compression Ring	1.24—1.49 mm (0.049—0.059 in.)	_____
No. 3 Oil Control Ring	0.30—0.56 mm (0.011—0.022 in.)	_____
4045TF250 and 6068TF250 Engines		
No. 1 Compression Ring	0.33—0.64 mm (0.013—0.025 in.)	_____
No. 2 Compression Ring	0.75—1.00 mm (0.030—0.039 in.)	_____
No. 3 Oil Control Ring	0.33—0.64 mm (0.013—0.025 in.)	_____

* When measuring piston ring end gap, the No. 2 compression ring gap should be greater than the No. 1 compression ring.

CYLINDER BLOCK, LINERS, PISTONS, AND RODS SPECIFICATIONS—CONTINUED

ITEM	SPECIFICATION	WEAR LIMIT
Piston Pin Bore ID:		
Small Pin	34.935—34.945 mm (1.3754—1.3758 in.)	_____
Large Pin	41.285—41.295 mm (1.6254—1.6258 in.)	_____
Piston Pin OD:		
Small Pin	34.920—34.930 mm (1.3748—1.3752 in.)	34.907 mm (1.3743 in.)
Large Pin	41.270—41.280 mm (1.6248—1.6252 in.)	41.257 mm (1.6243 in.)
Piston Pin Length	71.51—72.11 mm (2.815—2.839 in.)	_____
Connecting Rod Pin Bushing ID (Assembled):		
Small Pin	34.950—34.976 mm (1.3760—1.3770 in.)	35.026 mm (1.3790 in.)
Large Pin	41.300—41.326 mm (1.6260—1.6270 in.)	41.376 mm (1.6290 in.)
Connecting Rod Pin Bore ID (Without Bushing):		
Small Pin	38.087—38.113 mm (1.4995—1.5005 in.)	_____
Large Pin	46.025—46.051 mm (1.1820—1.8130 in.)	_____
Piston Pin-to-Bushing Oil Clearance	0.020—0.056 mm (0.0007—0.0022 in.)	0.102 mm (0.0040 in.)
Connecting Rod Bore ID (Without Bearings) :		
Maximum Permissible Bore Out-of-Round	82.677—82.703 mm (3.2550—3.2560 in.)	_____
	0.038 mm (0.0015 in.)	_____

CYLINDER BLOCK, LINERS, PISTONS, AND RODS SPECIFICATIONS—CONTINUED

ITEM	SPECIFICATION	WEAR LIMIT
Connecting Rod Bearing Bore-to-Pin Bushing Bore (Center-to-Center) Distance	202.95—203.05 mm (7.990—7.994 in.)	_____
Connecting Rod Bearing-to-Journal Oil Clearance	0.050—0.127 mm (0.0020—0.0050 in.)	0.152 mm (0.0060 in.)
Maximum Rod Journal Taper	0.010 mm (0.0004 in.)	_____
Crankshaft Rod Journal OD	77.800—77.826 mm (3.0629—3.0640 in.)	_____
Assembled Rod Bearing ID	77.876—77.927 mm (3.0659—3.0679 in.)	_____
Maximum Crankshaft Rod Journal Out-of-Roundness	0.005 mm (0.0002 in.)	_____
Undersize Connecting Rod Bearings Available*	0.25 mm (0.010 in.)	_____

*See CRANKSHAFT GRINDING GUIDELINES later in this group.

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CYLINDER BLOCK, LINERS, PISTONS, AND RODS SPECIFICATIONS—CONTINUED

TORQUES

Piston Cooling Orifices Into Cylinder Block	11 N·m (8 lb-ft)
Connecting Rod Cap Screws:	
Initial	58 N·m (43 lb-ft)
Final	Plus 90—100°
Cylinder Liner Cap Screws (for checking liner standout)	68 N·m (50 lb-ft)

REMOVE PISTONS AND CONNECTING RODS

If engine is to be removed from the machine, see your machine technical manual.



CAUTION: Do not drain engine coolant until it cools below operating temperature. Then slowly loosen block drain valve to relieve any pressure.

1. Drain coolant and engine oil.

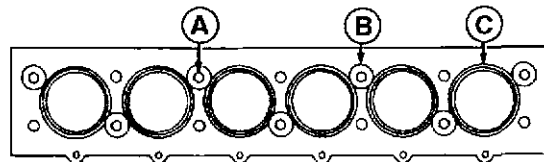
NOTE: If engine is to be completely disassembled, see **ENGINE DISASSEMBLY SEQUENCE** in Group 04.

2. Remove cylinder head. (See REMOVE CYLINDER HEAD in Group 05.)
3. Remove camshaft followers and keep in order for reassembly in same position.
4. Clean all foreign material from cylinder block top deck.

IMPORTANT: Cap screws and washers must be tightened to the correct specification to achieve an accurate reading when checking liner standout (height above block), as detailed later in this group.

5. Use short cap screws (A) and 3 mm (1/8 in.) thick washers (B) to bolt down cylinder liners (C). Fasten each liner in two locations. Tighten cap screws to 68 N·m (50 lb-ft).

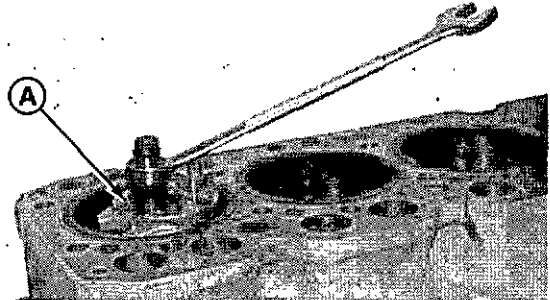
NOTE: Do not rotate crankshaft with cylinder head removed unless liners are fastened down.



RG3819

NOTE: Always follow manufacturer's directions provided with ridge reamer.

6. Remove carbon from liner bore with a scraper or ridge reamer (A). Use compressed air to remove loose material from cylinders.



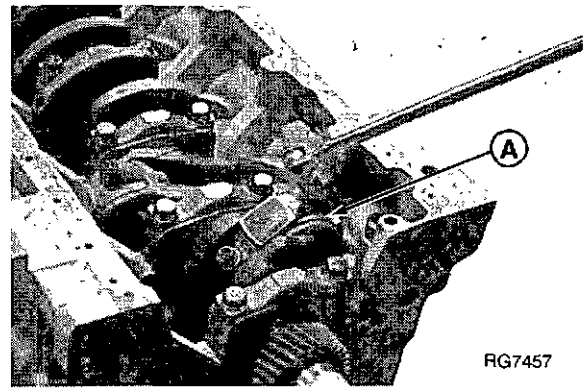
RG7455

7. Remove oil pan, oil pump, and outlet tube. (See Group 20.)
8. Mark rods, pistons, and caps to insure correct assembly in same location.

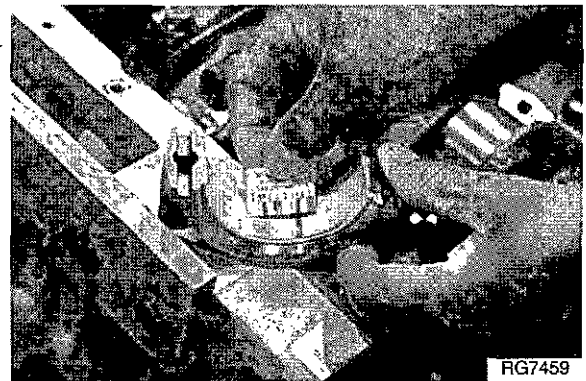
IMPORTANT: Keep inserts with their respective caps for rod and main bearings.

9. Remove all rod caps (A) with bearings.
10. Measure rod bearing-to-journal oil clearance with PLASTIGAGE before removing piston and rod assembly. Record measurements. (See INSPECT AND MEASURE CONNECTING ROD BEARINGS, later in this group.)

NOTE: Use PLASTIGAGE as directed by the manufacturer. PLASTIGAGE will determine bearing-to-journal oil clearance, but will not indicate the condition of either surface.



RG7457



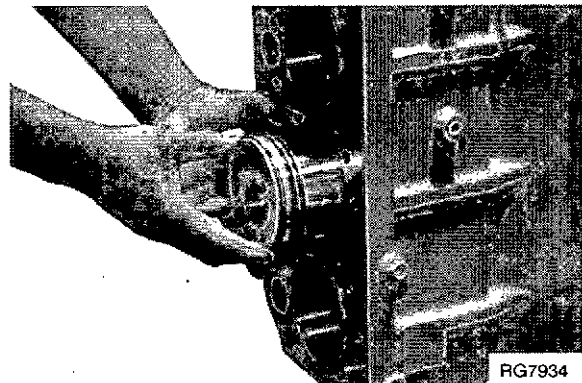
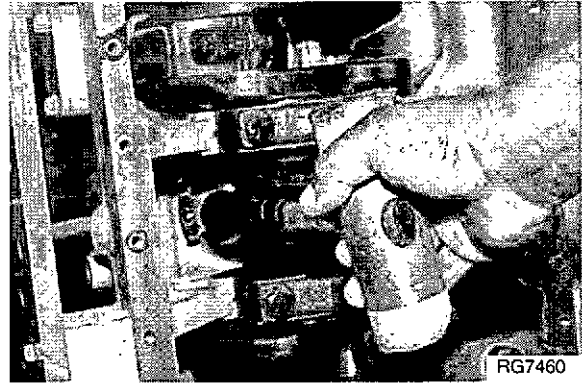
RG7459

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IMPORTANT: Hold on to piston to prevent piston from dropping. Piston will drop once piston rings have cleared cylinder liner.

If liners are to be reused, be extremely careful not to let connecting rod hit liner bore when removing piston and rod assembly.

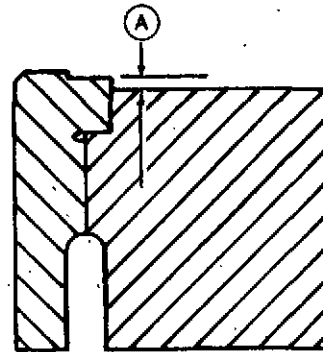
11. Gently tap piston through top of cylinder block from the bottom.
12. Remove pistons and rods from engine.
13. Remove all main bearing caps with bearings. Remove crankshaft from engine.



REMOVE CYLINDER LINERS

IMPORTANT: Cap screws and washers must be tight to achieve an accurate liner height reading.

1. Using D17526CI (or D17527CI) Dial Indicator and JDG451 Gauge (or KJD10123 Gauge), measure height (A) of each liner at 1, 5, 7, and 11 o'clock positions as viewed from rear of engine. Record all measurements.



RG6439

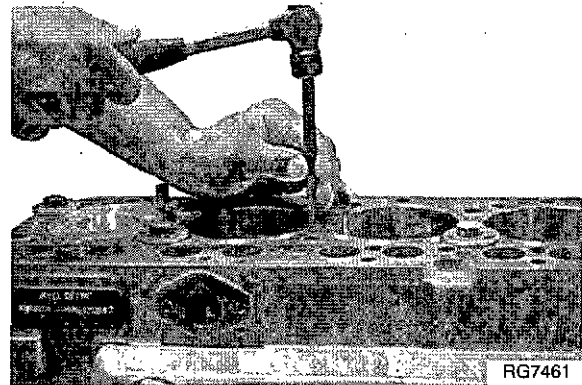
CYLINDER LINER HEIGHT SPECIFICATIONS

Liner height above block	0.030—0.100 mm (0.001—0.004 in.)
Maximum permissible difference between readings within one cylinder or between adjacent cylinders	0.05 mm (0.002 in.)

2. Remove cap screws and washers securing liners to cylinder block.

IMPORTANT: DO NOT stamp top of piston. Piston may be damaged.

3. Number cylinder liners and pistons. Stamp front of liner to assure correct assembly. Do not stamp liner flange; stamp on fire dam only.



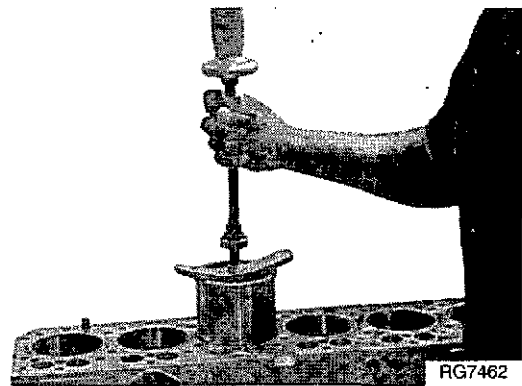
RG7461

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14

IMPORTANT: Keep matched pistons and liners together. Liners must be reinstalled in same cylinder bore.

4. Pull liners out of cylinder block with D01062AA or KCD10001 Puller.

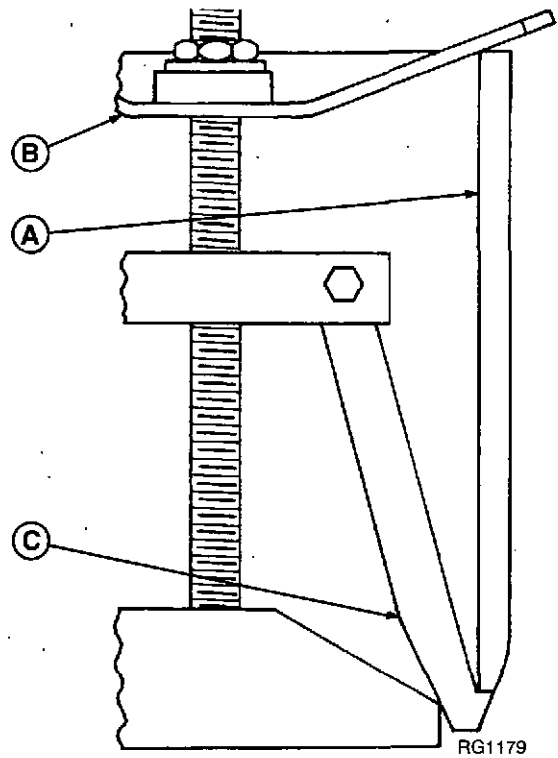
NOTE: If the KCD10001 Puller is used, secure puller with two cylinder head cap screws. If the D01062AA or D01073AA Puller is used, see next module.



RG7462

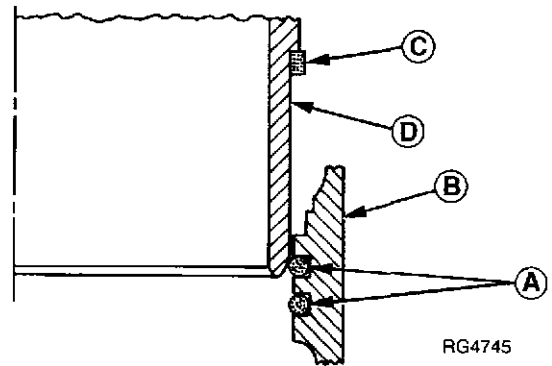
IMPORTANT: When using D01062AA (or D01073AA) Cylinder Liner Puller (B) to remove liners (A), be sure jaw (C) of puller is correctly positioned before attempting to remove liner.

DO NOT over-tighten liner puller to remove liners. Doing so could easily break liners.



5. Remove cylinder liner O-rings (A) from grooves in cylinder block (B). Also remove packing (C) from cylinder liner (D).

A—O-Rings
B—Cylinder Block
C—Packing
D—Cylinder Liner



COMPLETE DISASSEMBLY OF CYLINDER BLOCK (IF REQUIRED)

If not previously removed, also remove:

1. Crankshaft pulley. (Group 15)
2. Oil pressure regulating plug, valve, and spring in timing gear cover. (Group 16)
3. Timing gear cover, timing gears, and camshaft. (Group 16)
4. Camshaft bushing. (Group 16)
5. Balancer shafts and balancer shaft bushings (if equipped). (Group 16)
6. Front plate and oil-bypass valve. (Group 16)
7. Crankshaft and main bearings. (Group 15)
8. Piston cooling orifices.
9. Remove water gallery plugs.
10. If necessary to "Hot Tank" the block, also remove screw-in type oil gallery plugs and the engine serial number plate.

PRELIMINARY LINER, PISTON AND ROD CHECKS

- **Scuffed or Scored Pistons:**

Insufficient lubrication.
Insufficient cooling.
Improper piston-to-liner clearance.
Coolant leakage in crankcase.
Misaligned or bent connecting rod.
Improperly installed piston.
Low oil level.
Improper operation.
Incorrect connecting rod bearing clearance.
Carbon build-up in ring groove.
Improper break-in.
Worn piston.
Contaminated oil.
Distorted cylinder liner.

- **Worn or Broken Compression Rings:**

Insufficient lubrication.
Insufficient cooling.
Improper ring installation.
Improper combustion.
Improper timing.
Abrasives in combustion chamber.

- **Clogged Oil Control Ring:**

Improper oil.
Excessive blow-by.
Contaminated oil.
Improper periodic service.
Low operating temperature.

- **Dull Satin Finish and Fine Vertical Scratches on Rings:**

Dirt and abrasive in air intake system.

- **Stuck Rings:**

Improper oil classification.
Improper periodic service.
Poor operating conditions.
Coolant leakage in crankcase.
Excessive cylinder liner taper.

- **Cylinder Liner Wear and Distortion:**

Incorrectly installed compression rings.
Insufficient lubrication.
Uneven cooling around liner.
Improper piston-to-liner clearance.
Liner bore damage.

- **Warped Cylinder Block:**

Insufficient cooling.

- **Broken Connecting Rod:**

Inadequate piston-to-liner clearance.
Worn connecting rod bearing.
Distorted cylinder liner.
Piston pin failure.

- **Piston Pin and Snap Ring Failure:**

Misaligned connecting rod.
Excessive crankshaft end play.
Incorrect snap rings.

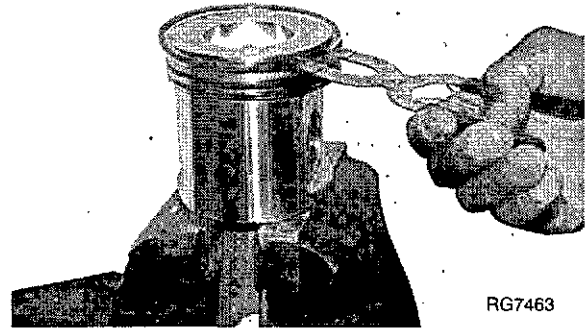
- **Mottled, Grayish or Pitted Compression Rings:**

Internal coolant leaks.

DISASSEMBLE PISTON AND ROD ASSEMBLY

IMPORTANT: DO NOT reuse piston rings.

1. Remove piston rings using the JDE135 (shown), JDE85, or KJD10140 Piston Ring Expander.



2. Remove and discard piston pin snap rings.
3. Separate piston and rod. Keep these parts in place with their respective cylinder liner.



CLEAN PISTONS



CAUTION: Always follow manufacturer's instructions, and safety steps exactly.

1. Clean piston ring grooves using a piston ring groove cleaning tool.

IMPORTANT: When washing pistons, always use a stiff bristle brush—**NOT A WIRE BRUSH**—to loosen carbon residue.

DO NOT bead blast ring groove areas.

2. Clean pistons by any of the following methods:
 - Immersion-Solvent "D-Part".
 - Hydra-Jet Rinse Gun.
 - Hot water with liquid detergent soap.

If cleaning with hot water and liquid detergent, soak pistons in a 50 percent solution of liquid household detergent and hot water for 30 to 60 minutes. Use a stiff bristle brush—**NOT A WIRE BRUSH**—to loosen carbon residue. Dry with compressed air.



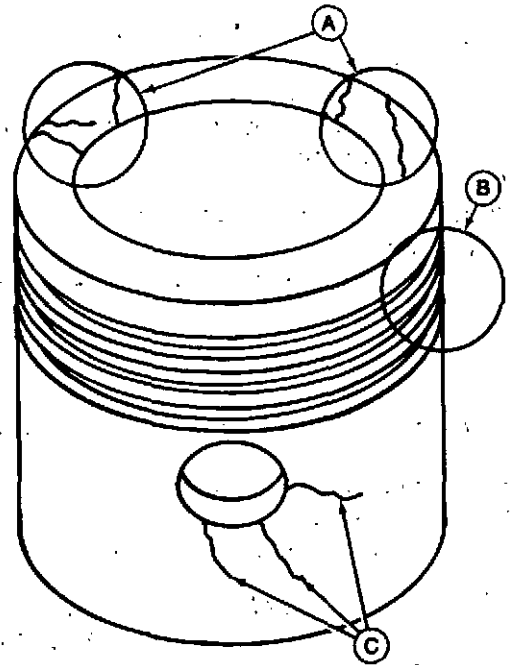
RG7465

VISUALLY INSPECT PISTONS

1. Carefully inspect pistons under magnification.
Check for:

- signs of fatigue
- fine cracks in the piston head (A)
- bent or broken ring lands (B)
- cracks in the skirt (C) at inner and outer ends of piston pin bore
- excessive piston skirt wear. (Original machining marks must be visible.)

If any imperfections are found, replace the piston and liner as a set.



RG3326

(Defects Exaggerated)

CLEAN CYLINDER LINERS

1. Use a stiff bristle brush to remove all debris, rust, and scale from O.D. of liners, under liner flange, and in O-ring packing areas. Make certain there are no nicks or burrs in areas where packings will seat.

IMPORTANT: Do not use gasoline, kerosene or commercial solvents to clean liners. Solvents will not remove all abrasives from liner walls.

2. Thoroughly clean liner I.D. with a 50 percent solution of hot water and liquid detergent.
3. Rinse thoroughly and wipe dry with a clean rag.
4. Swab out liner as often as necessary with clean SAE 10W oil. Clean liner until a clean, white rag shows no discoloration.

VISUALLY INSPECT CYLINDER LINERS

IMPORTANT: If liner pitting has occurred, check condition of coolant.

1. Inspect exterior length of liner for pitting (A). Check packing step for erosion (B). If pitting or erosion is observed, measure depth of pits with a fine wire or needle. Replace piston and liner if:

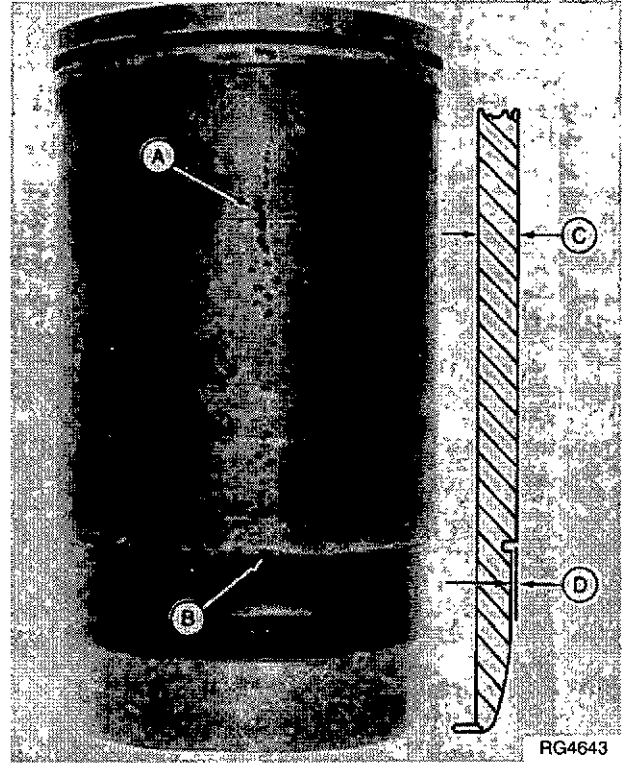
- Depth of any pit is one-half or more of liner thickness (C).
- Depth of erosion is one-half or more of the packing step (D).

NOTE: When installing reusable liners, rotate 90° from original position. The liners should be deglazed and ring sets installed in pistons.

CYLINDER LINER SPECIFICATIONS

Cylinder Liner Thickness 5.875—6.375 mm
(0.2313—0.2510 in.)

Packing Step Dimension 2.0185—2.2865 mm
(0.07947—0.09002 in.)



RG4643

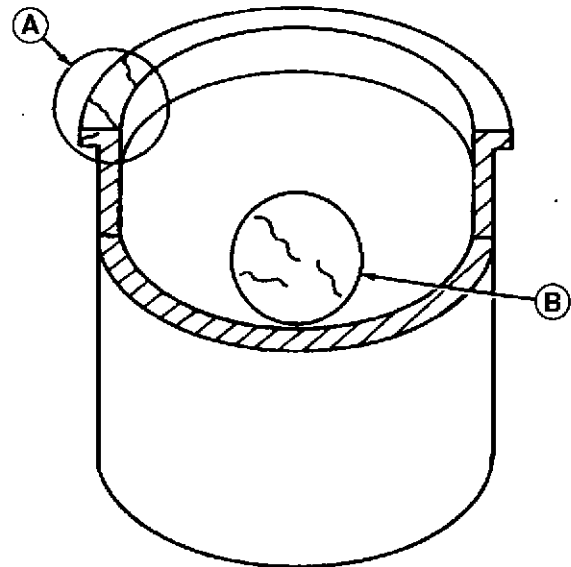
- A—Liner Pitting
- B—Liner Erosion
- C—Liner Thickness
- D—Packing Step

2. Visually inspect liner ID. Replace piston and liner if:

- The crosshatch honing pattern is not visible immediately below the top ring turn-around area for turbocharged engines.
- The hone pattern is not visible all the way around the liner in over 75 percent of the ring travel area for naturally aspirated engines.
- Liners are pitted or contain deep vertical scratches that can be detected by the fingernail.

3. Carefully examine liner for signs of fatigue, such as fine cracks in the flange area (A) and cracks in the ring travel area (B).

NOTE: Inspect block for cracks or erosion in the O-ring packing areas. (See *INSPECT AND CLEAN CYLINDER BLOCK* later in this group.)



(Exaggerated defects)

RG1188

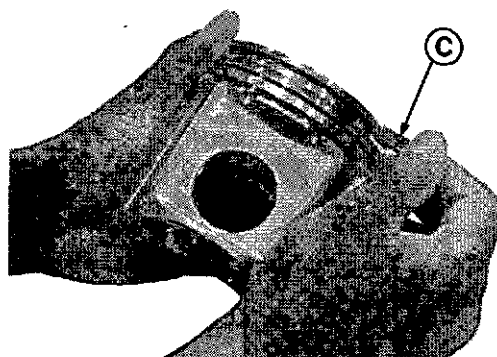
CHECK PISTON RING GROOVE WEAR

Pistons with tapered rods will use JDE62 Ring Groove Wear Gauge and pistons with straight rods will use JDG957 Ring Groove Wear Gauge.

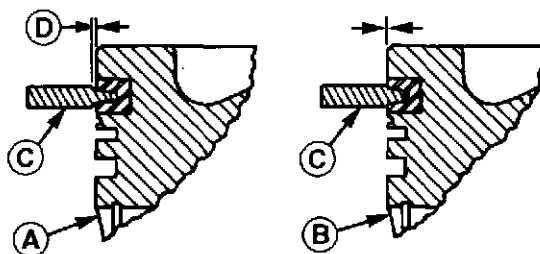
1. Use the appropriate ring groove wear gauge (C) to check wear of keystone ring groove (top groove). Check grooves at several locations around the circumference of piston.

Gauge shoulders should not contact ring land. Clearance (D) between shoulders of tool and ring land indicate ring groove is good.

If ring groove is worn, replace piston and liner as a matched set. If ring groove is good, proceed to next step.



RG7467



RG4746

- A—Piston with Good Keystone Ring Groove
- B—Piston with Worn Keystone Ring Groove
- C—Ring Groove Wear Gauge
- D—Clearance

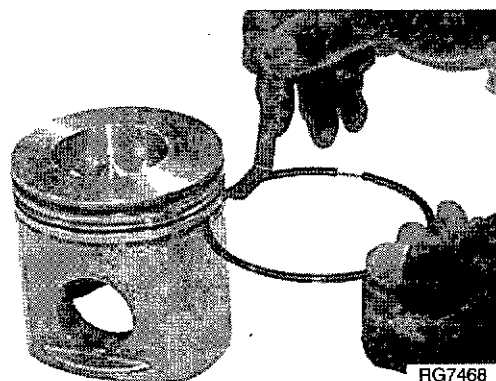
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2. Check second and third ring grooves using a new piston ring and a feeler gauge. Measure clearance at several points. Compare measurements with specifications given below.

Replace piston and liner (as a set) if clearance exceeds specification.

PISTON RING-TO-GROOVE SPECIFICATIONS

Maximum piston ring-to-groove clearance with new piston ring (second and third ring grooves) 0.20 mm (0.008 in.)



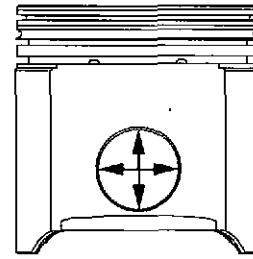
RG7468

MEASURE PISTON PIN BORE

1. Measure piston pin bore. If bore is not within specification, replace piston and liner set.

PISTON PIN BORE SPECIFICATIONS

Piston Pin Bore ID:	
Small Pin	34.935—34.945 mm (1.3754—1.3758 in.)
Large Pin	41.285—41.295 mm (1.6254—1.6258 in.)



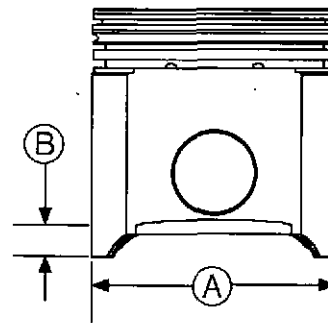
RG7402

MEASURE PISTON SKIRT

1. Measure piston skirt (A) 90° to piston pin bore and 28 mm (1.1 in.) from bottom of piston (B). Record measurement.
2. Measure cylinder liner as directed later in this group and compare with piston measurement.

PISTON SKIRT DIAMETER SPECIFICATION

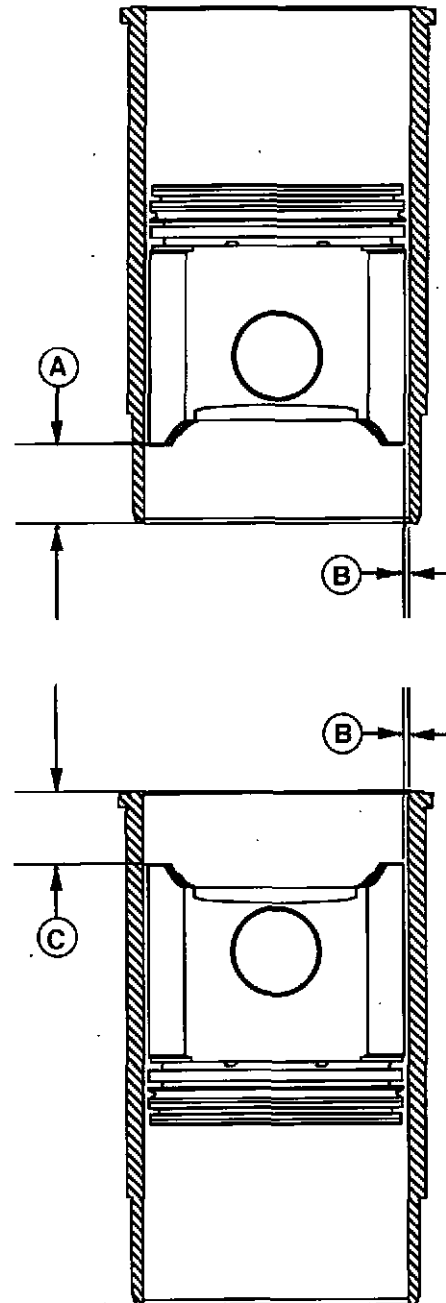
Bottom of skirt 28 mm (1.1 in.) from bottom of piston	
	106.38—106.40 mm (4.188—4.189 in.)



RG7403

DETERMINE PISTON-TO-LINER CLEARANCE

1. Put piston (without rings) in matched liner with piston "front" and liner "front"* aligned. Move piston down until bottom edge of piston skirt is 25.4 mm (1.00 in.) (A) from bottom of liner. Use a feeler gauge to measure clearance (B) between piston skirt and liner 90° to pin bore. Record the measured clearance.
2. Turn piston 90° in liner. Measure clearance between piston skirt and liner 90° to pin bore. Record the clearance.
3. Put piston upside down in liner with piston "front" and liner "front" aligned. Move piston so bottom edge of piston skirt is 25.4 mm (1.00 in.) (C) below top of liner. Measure clearance (B) between piston skirt and liner at 90° to pin bore. Record the clearance.
4. Turn piston 90° in liner. Measure clearance between piston skirt and liner 90° to pin bore. Record the clearance.
5. The difference between clearances in Steps 1 and 2 is the amount liner is out-of-round at bottom of the liner.
6. The difference between clearances in Steps 3 and 4 is the amount liner is out-of-round at top of the liner.
7. The difference between clearances in Steps 1 and 3 is the amount liner is tapered.



RG7404

PISTON AND CYLINDER LINER SPECIFICATIONS

Piston-to-Liner Clearance:

(Measured at bottom of piston skirt)

Naturally Aspirated Engines	0.08—0.14 mm (0.003—0.005 in.)
Turbocharged Engines	0.08—0.15 mm (0.003—0.006 in.)

Maximum Cylinder Out-Of-Round (top or bottom) 0.05 mm
(0.002 in.)

Maximum Cylinder Taper 0.05 mm (0.002 in.)

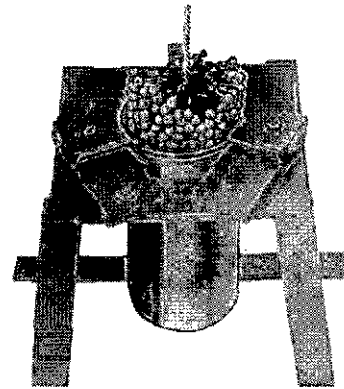
8. If cylinder liner geometry is not within specifications, replace piston and liner set.

* As marked during liner removal from engine.

DEGLAZE CYLINDER LINERS

1. Secure cylinder liner in a holding fixture. (See Dealer Fabricated Tools, Group 199 for assembly of holding fixture.)
2. Use D17004BR Flexible Cylinder Hone to deglaze cylinder liner.

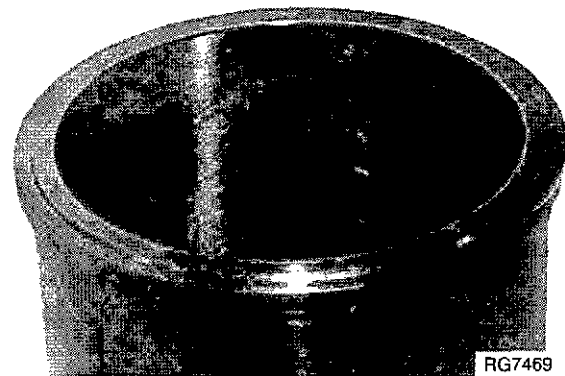
NOTE: Use honing oil along with flex hone when deglazing liners.



R26164

3. Use D17004BR Hone according to instructions supplied with tool to obtain a 45° cross-hatch pattern.

Thoroughly clean liners after deglazing. See **CLEAN CYLINDER LINERS** earlier in this group for proper cleaning procedures.



RG7469

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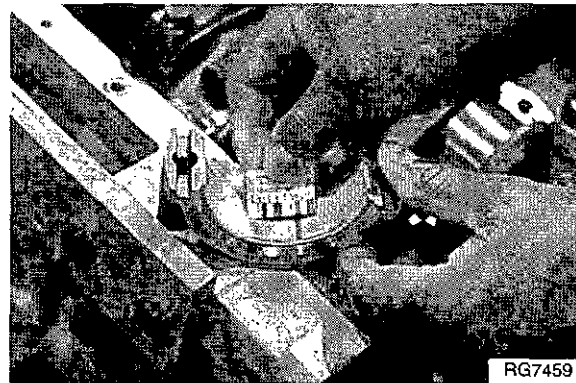
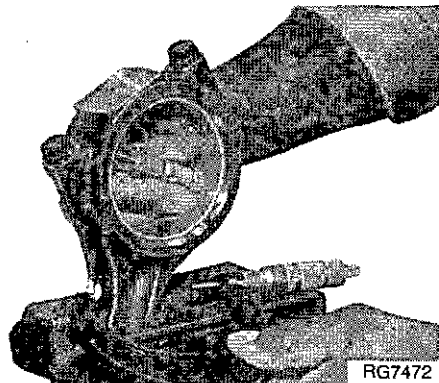
REPLACE PISTON AND LINER SETS

IMPORTANT: ALWAYS install a new (matched set) liner when replacing a piston.

DO NOT stamp top of piston. Piston may be damaged.

Mark matched piston and liner for placement in the same cylinder location.

INSPECT AND MEASURE CONNECTING ROD BEARINGS



Inspect rod bearings for damage or wear.

Measure bearing-to-journal clearance with PLASTIGAGE if rod and crankshaft are assembled in engine. If rod is out of engine, measure rod bearing ID and crankshaft journal OD to determine oil clearance.

- **Rod removed from engine:**

1. Measure crankshaft rod journal OD at several points.
2. Assemble connecting rod, cap, and bearings with OLD cap screws. Tighten cap screws to 68 N·m (50 lb-ft). Tighten cap screw an additional 90—100°. (See TORQUE-TURN CONNECTING ROD CAP SCREWS later in this group.)
3. Measure assembled rod bearing ID.
4. Subtract crankshaft journal OD from rod bearing ID to determine oil clearance. Replace bearings if oil clearance is out of specification.

CONNECTING ROD JOURNAL AND BEARING SPECIFICATIONS

Crankshaft Journal OD	77.800—77.826 mm (3.0629—3.0640 in.)
Assembled Rod Bearing ID	77.876—77.927 mm (3.0659—3.0879 in.)
Rod Bearing-to-Journal Oil Clearance (new parts)	0.050—0.127 mm (0.0020—0.0050 in.)
Wear Limit	0.152 mm (0.0600 in.)

- **Rod and crankshaft assembled in engine:**

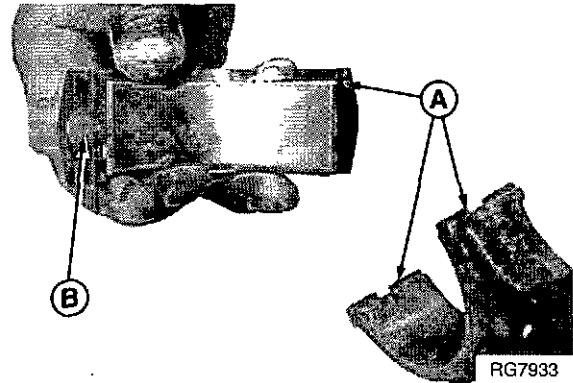
NOTE: Use PLASTIGAGE as directed by manufacturer. PLASTIGAGE will determine oil clearance, but will not indicate condition of either surface.

IMPORTANT: Use hand wrenches, pneumatic wrenches may cause thread damage.

1. Remove rod cap. Place a piece of PLASTIGAGE in center of bearing. Install rod cap using OLD cap screws. Tighten cap screws to 58 N·m (43 lb-ft). Tighten cap screw an additional 90—100°. (See TORQUE-TURN CONNECTING ROD CAP SCREWS later in this group.)
2. Remove rod cap. Compare width of PLASTIGAGE with scale provided on package to determine clearance. Replace bearings if oil clearance is out of specification.

INSPECT ROD AND CAP

1. Inspect rod and cap for wear or damage, such as chips or cracks in the joint area (A).
2. Inspect in and around cap screw holes in cap (B). If any imperfections are found, replace rod and cap.
3. Carefully clamp rod in a soft-jawed vise (cap end upward).



IMPORTANT: Never use new connecting rod cap screws when checking rod bore ID. Use new cap screws only for final assembly of connecting rods.

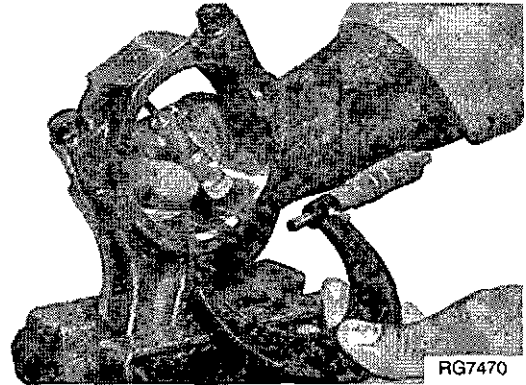
4. Install cap WITHOUT bearing inserts. Use old cap screws.
5. Tighten cap screws to 58 N·m (43 lb-ft). Turn cap screw an additional 90—100°.

See TORQUE-TURN CONNECTING ROD CAP SCREWS later in this group.

6. Using an inside micrometer, measure rod bore at center of bore and record measurements as follows:

- A. At right angle to rod-to-cap joint.
- B. At 45 degrees left of measurement step "A".
- C. At 45 degrees right of measurement step "A".

7. Subtract OD of crankshaft rod journals from ID of rod bearings to obtain oil clearance.

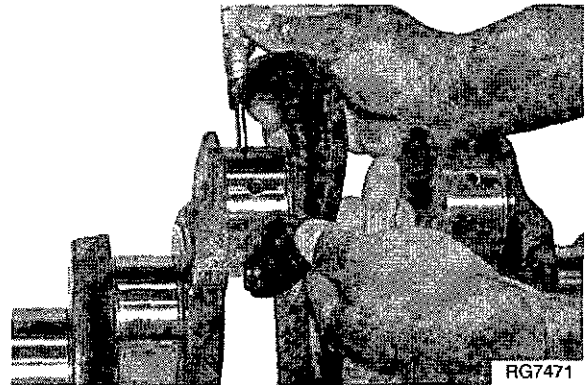


**ROD BORE (WITHOUT BEARING INSERTS) AND CRANKSHAFT
ROD JOURNAL SPECIFICATIONS**

Rod Bore ID..... 82.677—82.703 mm
(3.2550—3.2560 in.)

Maximum Permissible Bore Out-of-Round..... 0.038 mm
(0.0015 in.)

8. If difference between the greatest and least measurement exceeds out-of-round specification, replace connecting rod.

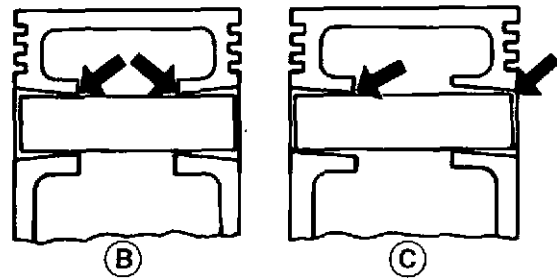
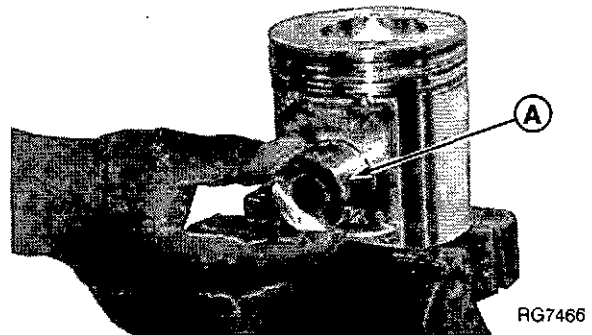


INSPECT PISTON PINS AND BUSHINGS

1. Visually inspect piston pin. Pin must be in good condition with no visible wear.

IMPORTANT: Do not attempt to polish or refinish piston pin. Pin has a highly polished surface.

2. Dip piston pin in clean engine oil.
3. Install pin (A) through piston. Pin should pass through piston using only light thumb pressure.
4. Insert pin from both sides. If pin enters freely, but binds in the center, the bore could be tapered (B).
5. Insert pin to check for bore alignment (C). Pin should not "click" or need to be forced into bore on opposite side.
6. Measure piston pin OD. Replace if not within specification.



PISTON PIN SPECIFICATIONS

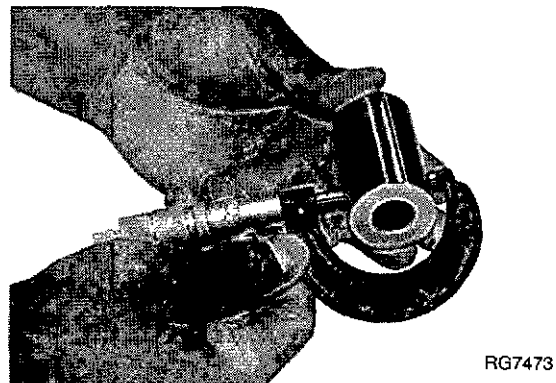
Piston Pin OD:

Small Pin 34.920—34.930 mm
(1.3748—1.3752 in.)

Wear Limit 34.907 mm (1.3743 in.)

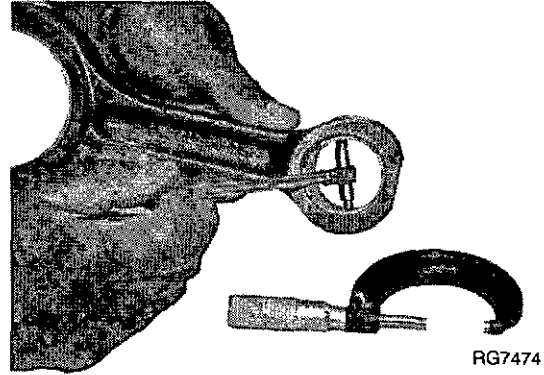
Large Pin 41.270—41.280 mm
(1.6248—1.6252 in.)

Wear Limit 41.257 mm (1.6243 in.)



NOTE: Straight-end rods have an oil hole; tapered-end rods do not.

7. Lubrication hole must be open.
8. Measure pin bushing ID and compare to pin OD to determine oil clearance.
9. Insert pin from either side of rod bushing. If pin is free on one end, but tight on the other, the bore could be tapered (A). If pin enters freely from both sides, but is tight in the center, bore is bell mouthed (B).



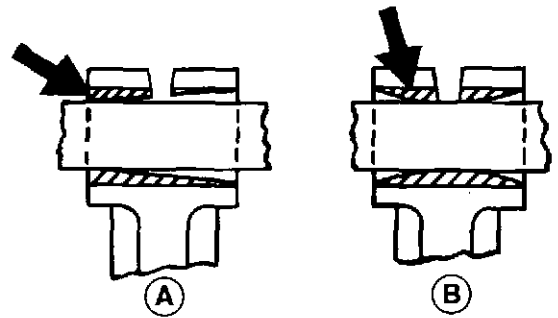
PISTON PIN BUSHING SPECIFICATIONS

Piston Pin Bushing ID (Installed):

Small Pin	34.950—34.976 mm (1.3760—1.3770 in.)
Wear Limit	35.026 mm (1.3790 in.)

Large Pin	41.300—41.326 mm (1.6260—1.6270 in.)
Wear Limit	41.376 mm (1.6290 in.)

Piston Pin-to-Bushing Oil Clearance	0.020—0.056 mm (0.0007—0.0022 in.)
Wear Limit	0.102 mm (0.0040 in.)



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REMOVE PISTON PIN BUSHING

- **Removing piston pin bushing on straight pin-end rod:**

1. Use JD286 Driver for 41 mm (1.6 in.) pin, or JDE88 Driver for 35 mm (1.3 in.) pin to remove bushing.

- **Removing piston pin bushing on tapered pin-end rod:**

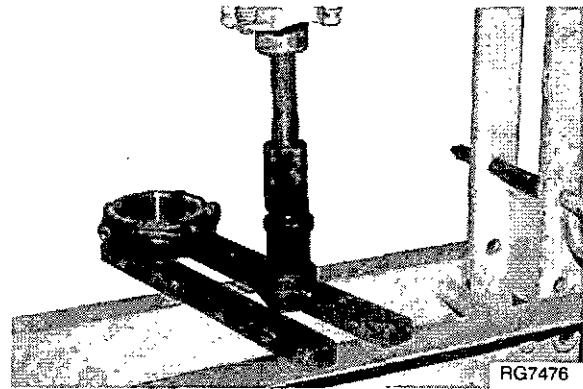
1. Select Driver JDG953-1 (A) and Receiver Cup JDG953-2 (B) to remove bushing (C) from tapered rod.
2. Slide driver into one side of rod bushing. Turn driver until taper on driver flange matches up with taper on the bushing.
3. Install receiver cup onto opposite side of rod bushing.

NOTE: Stud in cup keeps rod properly located on the cup.

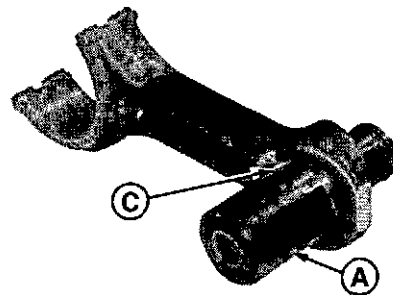
4. Using hydraulic press, press bushing out of the rod until driver and bushing fall into receiver cup.

IMPORTANT: If bushing is heavily worn, the driver may contact the I.D. of the rod bore. Be careful not to damage the rod bore.

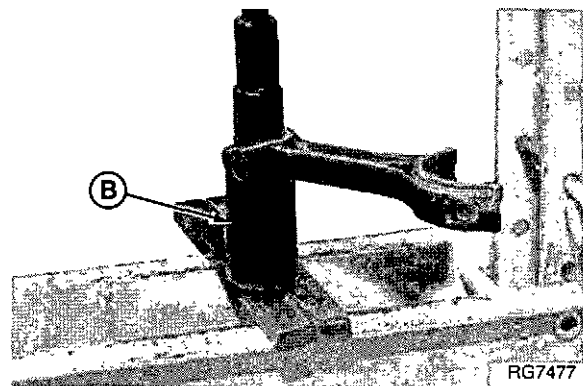
Clean, inspect, and measure I.D. of rod pin bore, as described later in this group.



Straight Pin-End Rod



Tapered Pin-End Rod

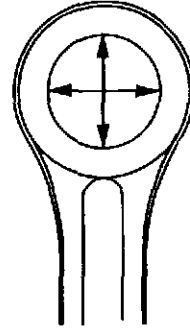


Tapered Pin-End Rod

CLEAN AND INSPECT CONNECTING ROD PIN BORE

1. Clean bore of rod with medium grit emery cloth.
2. Inspect for cracks or other damage. Make sure that lube oil hole in top of straight pin-end rod is open.
3. Measure bore diameter in two places, 90° apart. Replace rod if not within specification.

IMPORTANT: If bushing has spun in rod, replace connecting rod.



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CONNECTING ROD PIN BORE ID SPECIFICATIONS (Bushing Removed)

Small pin	38.087—38.113 mm (1.4995—1.5005 in.)
Large pin	46.025—46.051 mm (1.8120—1.8130 in.)

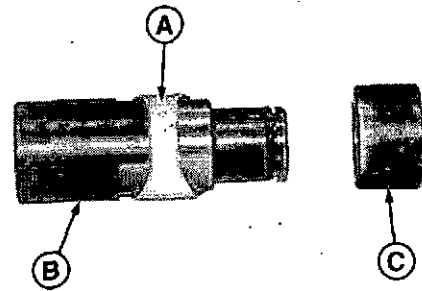
INSTALL PISTON PIN BUSHING IN CONNECTING ROD

Carefully file a slight chamfer on edge of rod pin bore. Remove any burrs or sharp edges from edge of bushing bore.

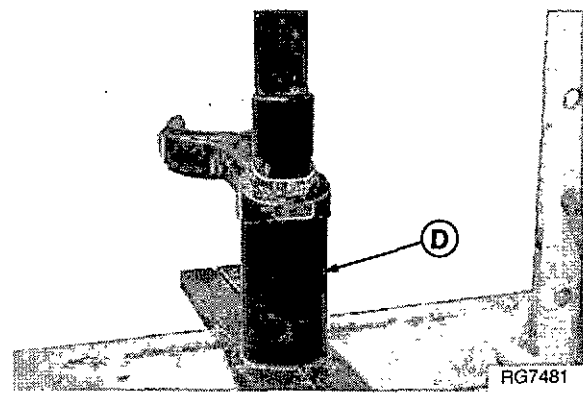
NOTE: Tapered pin-end rods do not have a lubrication hole in the rod or bushing.

- **Installing piston pin bushing in tapered pin-end rod:**

1. Slide bushing (A) onto JDG953-1 Driver (B) and install JDG738-2 Installer Pilot (C) onto O-ring end of driver. Apply clean engine oil or grease to O.D. of new bushing, O.D. of pilot ring, and I.D. of rod pin bore.
2. Insert driver into rod pin bore so pilot ring pilots in rod bore, and bushing taper aligns with taper on driver flange.
3. Install JDG953-2 Receiver Cup (D) onto the opposite side of rod.
4. Press bushing into rod bore until edge of bushing is flush or just slightly below rod face.
5. If necessary, precision bore bushing to obtain an oil clearance of 0.020—0.056 mm (0.0007—0.0022 in.) with piston pin.



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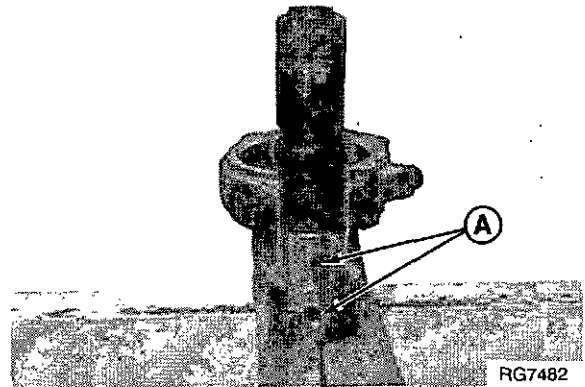


A—Piston Pin Bushing
 B—JDG953-1 Driver
 C—JDG738-2 Installer Pilot
 D—JDG953-3 Receiver Cup

- **Installing piston pin bushing in straight pin-end rod:**

IMPORTANT: Oil holes (A) **MUST** be aligned. If holes are not aligned, remove and **discard bushing**. Install a new bushing. **DO NOT** attempt to reuse the bushing. Install bushing in rod.

1. Use JD286 Driver for 41 mm (1.6 in.) pin or JDE88 Driver for 35 mm (1.3 in.) pin to install bushing.
2. Press bushing into rod bore until edge of bushing is flush or just slightly below machined surface on face of rod.
3. Remove rod from press.
4. I.D. of bushing must be precision bored to proper size as specified below.



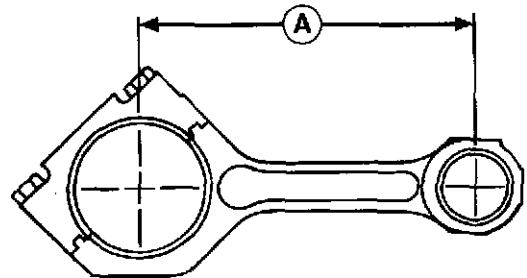
CONNECTING ROD AND PIN BUSHING SPECIFICATIONS

Pin-to-Bushing Oil Clearance 0.020—0.056 mm (0.0007—0.0022 in.)
Wear Limit 0.102 mm (0.0040 in.)

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MEASURE ROD CENTER-TO-CENTER BORES

1. Measure rod center-to-center bores (with bushings removed). Compare to specifications given below. Replace rod if necessary.



BEARING BORE-TO-PIN BUSHING BORE SPECIFICATION

Bearing Bore-to-Pin Bushing Bore (Center-to-Center) Length (A) 202.95—203.05 mm (7.990—7.994 in.)
-------------------------------------------------------------------	---------------------------------------------

INSPECT AND CLEAN CYLINDER BLOCK

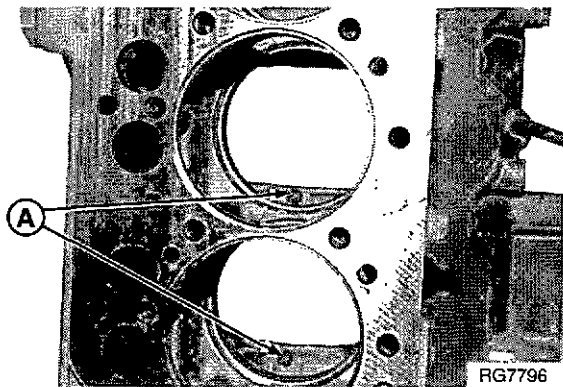
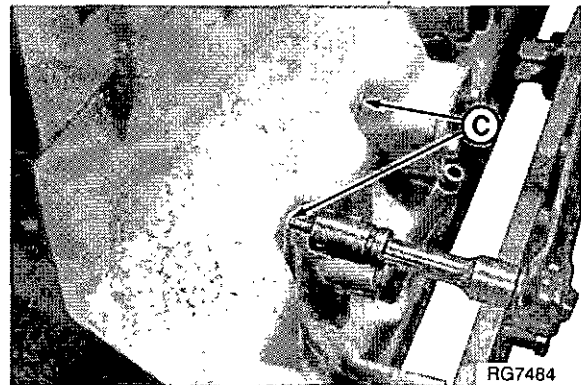
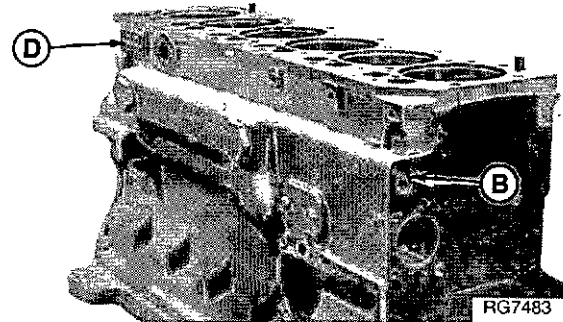
Before inspecting and cleaning cylinder block, remove all of the following:

- piston cooling orifices (A)
- soft plugs (B)
- oil galley plugs (C) [using JDG782 Oil Galley Plug Tool]
- all external and internal mounted components [refer to the proper group for removal procedures]

1. Clean block thoroughly using cleaning solvent, pressure steam, or a hot tank.

IMPORTANT: If block is cleaned in a hot tank, be sure to remove any aluminum parts [such as nameplates (D)]. Aluminum parts can be damaged or destroyed by hot tank solutions.

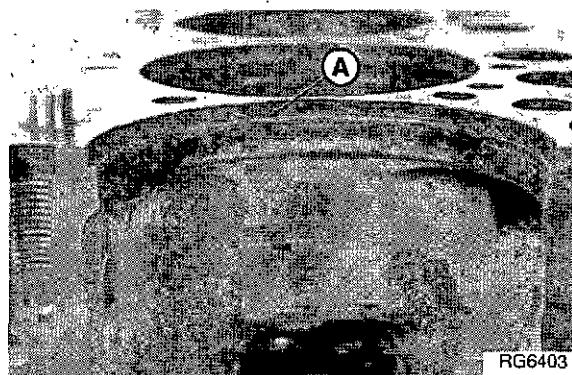
2. All passages and crevices must be clear of sludge, and grease.
3. All coolant passages must be clear of lime deposits and scale.



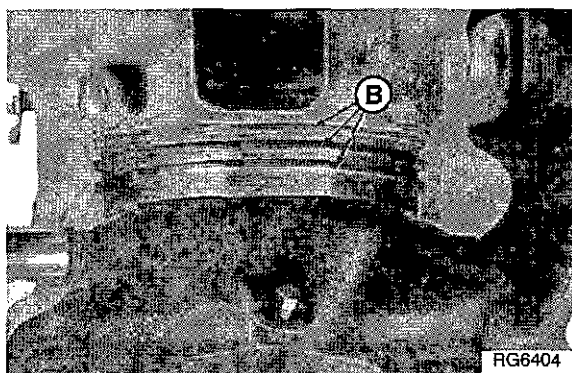
- A—Piston Cooling Orifice
- B—Soft Plug
- C—Oil Galley Plug
- D—Nameplate

4. Inspect liner support flange (A) for burrs. If burrs are present, use a small half-moon file and LIGHTLY file (in a circular motion) burr off at a 60° angle. DO NOT let file hit top of cylinder block while filing.

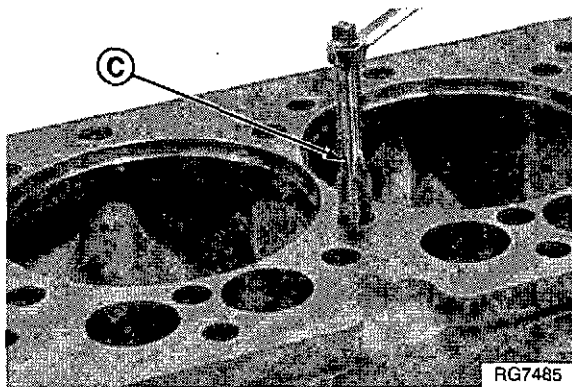
IMPORTANT: DO NOT file liner support flange excessively. Excess filing can damage liner support flange and allow an improper liner fit. Thoroughly clean all filings from cylinder block.



5. Carefully inspect block for cracks or damage. If a cracked block is suspected, pressure-test the block. A procedure for pressure testing is outlined in FOS (Fundamentals of Service) Manual-ENGINES. Check for erosion or cracks in the liner O-ring/packing area (B). Replace cracked or damaged blocks.



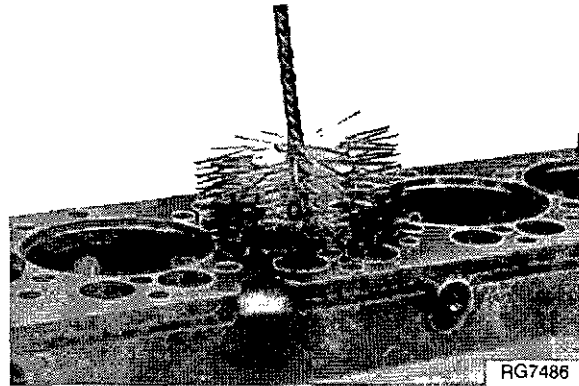
6. If cylinder block is serviceable, clean out all threaded holes for cylinder head mounting cap screws in top deck of cylinder block, using JDG680 Tap (C) or an equivalent 1/2-13 UNC-2A x 76 mm (3.0 in.) long tap. Remove debris or fluid from tapped holes with compressed air.



CLEAN CYLINDER LINER O-RING BORE

1. Use D17015BR O-Ring Bore Cleaning Brush to thoroughly clean lower liner O-ring bore.

NOTE: Use brush exactly as directed by the manufacturer.



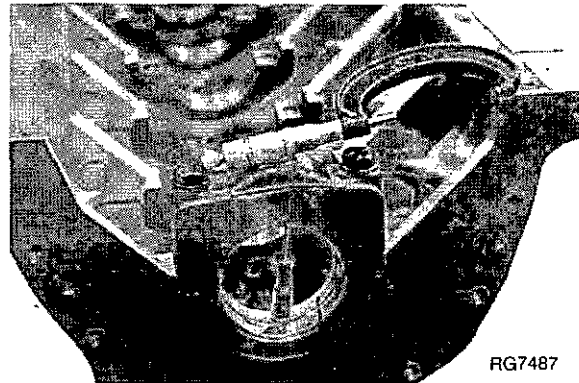
MEASURE CYLINDER BLOCK MAIN BEARING BORE

Measure main bearing bore diameter.

CYLINDER BLOCK MAIN BEARING SPECIFICATIONS

Main Bearing Bore Diameter 84.455–84.481 mm
(3.3250–3.3260 in.)

If bearing caps are damaged, or bore is not within specification, replace caps and line bore to specifications. (See MEASURE ASSEMBLED ID OF MAIN BEARING CAPS in Group 15.)



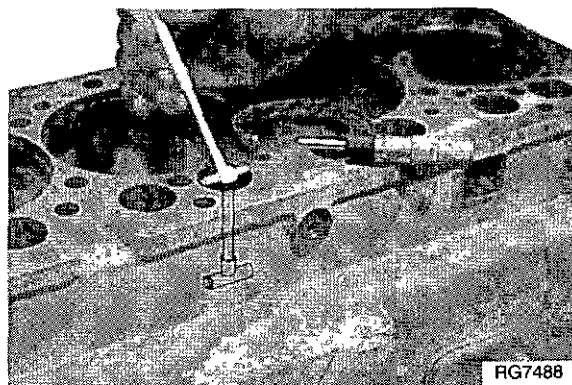
MEASURE CAMSHAFT FOLLOWER MACHINED BORE IN BLOCK

Measure camshaft follower bore diameter at all bore locations.

CAMSHAFT FOLLOWER BORE SPECIFICATIONS

Camshaft Follower Bore ID in Block	31.70—31.75 mm (1.248—1.250 in.)
Camshaft Follower OD (New)	31.61—31.64 mm (1.245—1.246 in.)
Camshaft Follower-to-Bore Clearance	0.06—0.13 mm (0.002—0.005 in.)

If any one camshaft follower bore ID and follower-to-bore clearance exceed specified maximum, install a new cylinder block.



MEASURE CAMSHAFT BUSHING BORES IN BLOCK

Replaceable bushings (A) are installed in front camshaft bore only. Remaining bores in cylinder block act as camshaft bushings.

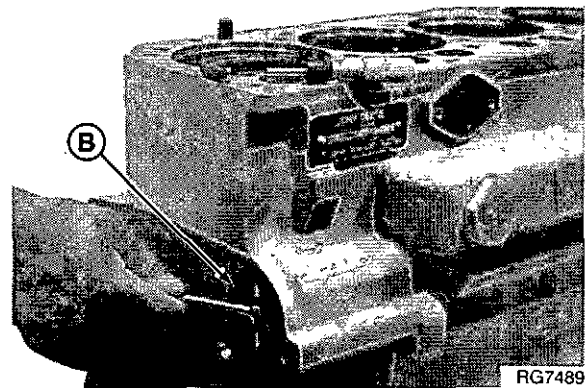
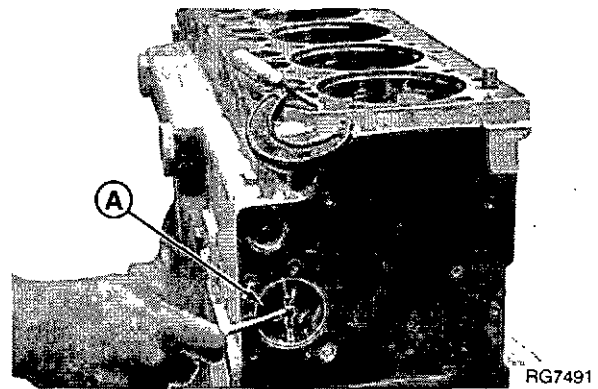
1. Visually inspect and measure front camshaft bushing ID.

If bushing is worn or not within specification, install new bushings. (See REMOVE AND INSTALL CAMSHAFT BUSHING in Group 16.)

2. If necessary to replace bushing, remove bushing and measure bore diameter in block.

If bushing bore (B) in block is not within specification, repair or replace cylinder block as required.

3. Measure remaining camshaft bores in block and compare with specification given. Repair or replace cylinder block as required.



CAMSHAFT BUSHING AND BORE SPECIFICATIONS

Camshaft Bore ID:

Front (No. 1) in Block (without bushing) 59.961—59.987 mm
(2.3607—2.3617 in.)

All Except No. 1 55.986—56.012 mm
(2.2042—2.2052 in.)

Front (No. 1) in Block (with bushing) 55.961—55.987 mm
(2.2031—2.2042 in.)

Camshaft Journal-to-Bushing Oil Clearance:

No 1. Bore with Bushing 0.063—0.115 mm
(0.0025—0.0045 in.)

All Except No. 1 Bore 0.088—0.140 mm
(0.0035—0.0055 in.)

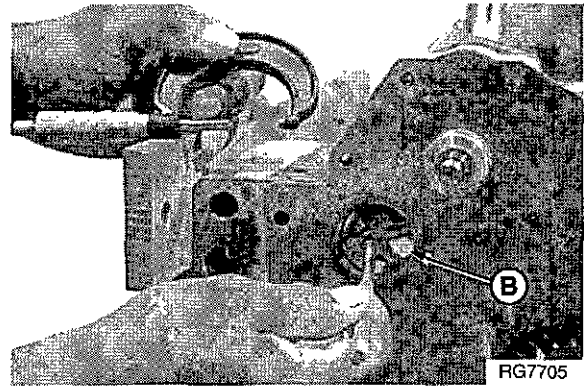
MEASURE BALANCER SHAFT BUSHING ID IN BLOCK—4-CYLINDER ENGINES

1. Visually inspect and measure balancer shaft bushing ID.

If bushing is worn or not within specification, install new bushings. (See REPLACE BALANCER SHAFT BUSHINGS in Group 16.)

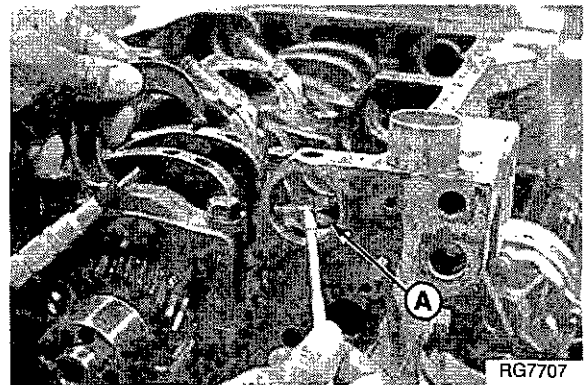
2. If necessary to replace bushing, remove bushing and measure bore diameter in block.

If bore diameter in block is not within specification, install a new cylinder block.



BALANCER SHAFT BUSHING AND BORE SPECIFICATIONS

Balancer Shaft Bore ID in Block (Bushing Removed) (B)	43.262—43.288 mm (1.7032—1.7042 in.)
Balancer Shaft Bushing ID (Bushing Installed) (A)	40.177—40.237 mm (1.5818—1.5841 in.)
Balancer Shaft Journal-to-Bushing Clearance	0.016—0.102 mm (0.0006—0.0040 in.)

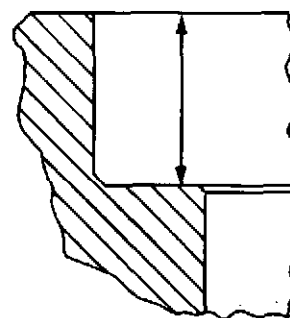
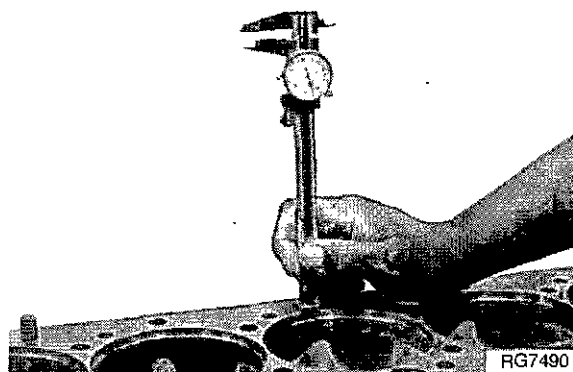


MEASURE LINER FLANGE COUNTERBORE DEPTH IN BLOCK

1. Measure liner flange counterbore depth in block and compare to specification given below. If depth is not within specification, liner shims are available.

LINER FLANGE COUNTERBORE DEPTH IN BLOCK SPECIFICATION

Liner Flange Counterbore Depth in Block 5.952—5.988 mm
(0.2343—0.2357 in.)

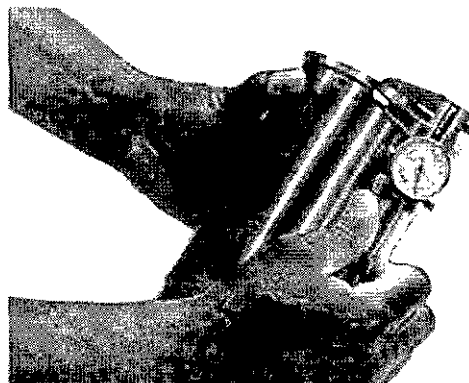


MEASURE LINER FLANGE THICKNESS

Measure cylinder liner flange thickness at several locations. If liner flange is not within specifications, liner shims are available or replace piston and liner set.

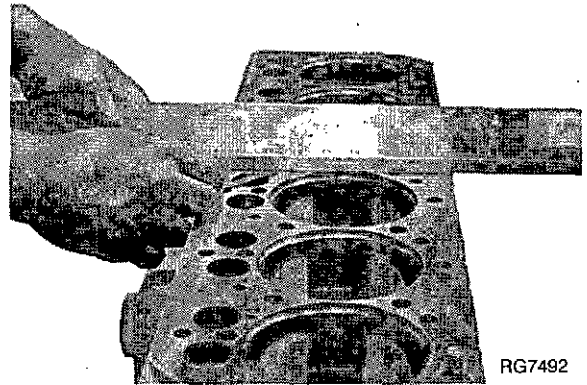
LINER FLANGE SPECIFICATIONS

Flange Thickness 6.022—6.058 mm
(0.2371—0.2385 in.)



MEASURE CYLINDER BLOCK TOP DECK FLATNESS

Measure cylinder block top deck flatness using D05012ST Precision Straightedge and feeler gauge. If flatness is not as specified, clean up top deck of cylinder block.



CYLINDER BLOCK TOP DECK SPECIFICATIONS

Maximum Acceptable Out-of-Flat:

Entire Length or Width (Used) 0.08 mm (0.003 in.)
Any 150 mm (5.90 in.) Length 0.025 mm (0.001 in.)

Top Deck Surface Finish

(Surface Grind Only) (AA) 0.8—3.2 micrometers
(32—125 micro-in.)
Maximum Wave Depth 0.012 mm (0.0005 in.)

Main Bearing Bore Centerline-to-Cylinder

Block Top Deck Distance 337.896—337.972 mm
(13.3029—13.3059 in.)

IMPORTANT: When cylinder block top deck or main bearing bores are machined, the dimension from crankshaft centerline to top deck will be changed. Make sure this dimension is within specifications, otherwise, piston may contact cylinder head.

REMOVE, INSPECT, AND INSTALL PISTON COOLING ORIFICES

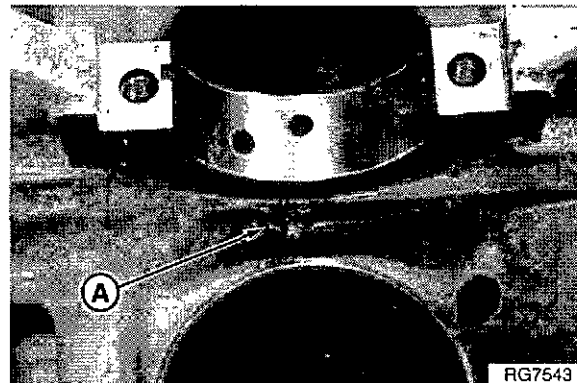
1. Remove and clean each piston cooling orifice (A) to make sure it is not plugged or damaged. Replace if questionable.

IMPORTANT: A piston cooling orifice failure could cause damage to pistons, piston pins, rod pin bushings, and liners. If a piston cooling orifice is left out, low or no oil pressure will result.



RG7493

2. Install and tighten orifices to 11 N·m (8 lb-ft).
3. Install new oil and water galley plugs as required, if removed.



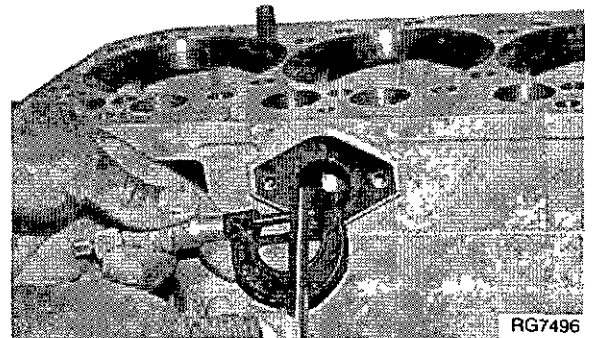
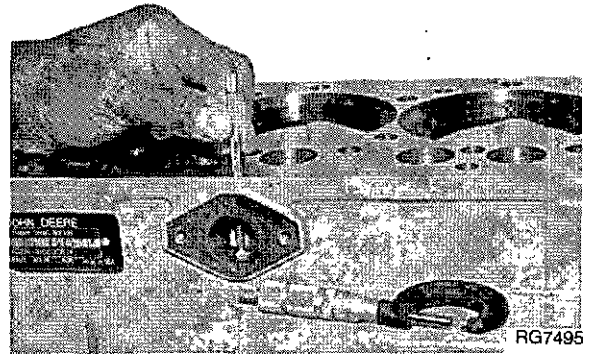
MEASURE FUEL SUPPLY PUMP PUSH ROD BORE AND PUSH ROD OD

1. Visually inspect and measure fuel supply pump push rod OD.

If rod is worn or not within specification, install a new rod.

FUEL SUPPLY PUMP PUSH ROD AND BORE SPECIFICATIONS

Push Rod OD.....	9.891—9.917 mm (0.3894—0.3904 in.)
Push Rod Bore in Block.....	10.00—10.05 mm (0.3937—0.3957 in.)



MEASURE CYLINDER LINER STANDOUT (HEIGHT ABOVE BLOCK)

NOTE: If a new liner assembly is being installed in a new or used cylinder block, liner height must be checked.

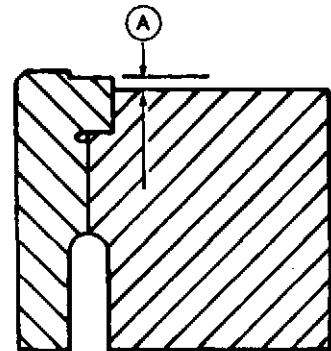
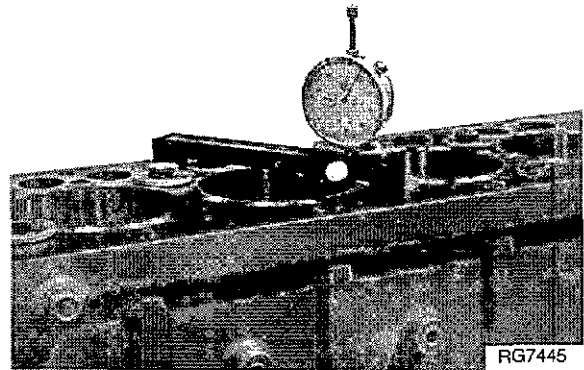
1. Be sure liner bore in cylinder block and top deck of block are clean.

IMPORTANT: Liner should rotate smoothly by hand when installed without O-rings or packing. If not, remove liner and clean block.

2. Install liner without O-rings and packing. If liner does not rotate smoothly by hand, remove liner and polish lower pilot bore in block with emery cloth or D17015BR Brush. Use a shop towel or other suitable means to collect debris when polishing bore.

Locate liner mark toward the front of the engine. Secure with cap screws and washers (approximately 3 mm [1/8 in.] thick). Tighten screws to 68 N·m (50 lb-ft).

3. Using JDG451 or KJD10123 Gauge and D17526CI or D17527CI Dial Indicator, measure height (A) of liner at 1, 5, 7, and 11 o'clock positions as viewed from flywheel end of engine.



LINER HEIGHT SPECIFICATIONS

Liner Height Above Block 0.030—0.100 mm
(0.001—0.004 in.)

Maximum Permissible Height Difference
At Nearest Point of Two Adjacent Liners,
or Within a Single Liner 0.05 mm (0.002 in.)

If liner height is above specification, check cylinder block for burrs on liner support flange or incorrect counterbore depth.

IMPORTANT: ONE LINER SHIM ONLY may be installed under each liner flange. If liner requires more than one shim, install a new liner or cylinder block.

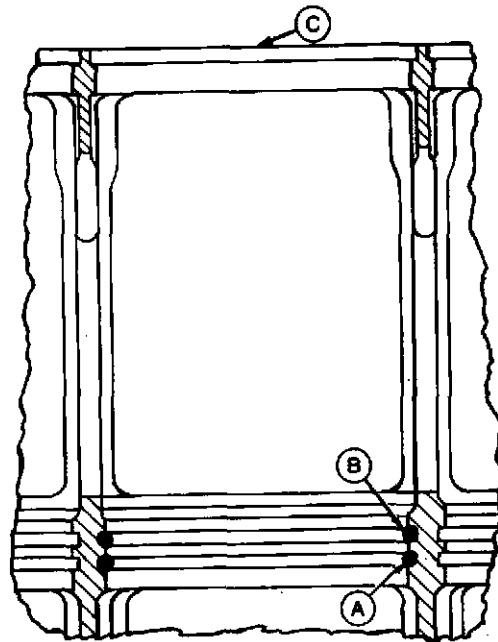
If liner height is no more than 0.08 mm (0.003 in.) below top deck of block, install one liner shim under liner flange.

NOTE: Two shim sizes are available; 0.05 mm (0.002 in.) and 0.10 mm (0.004 in.).

INSTALL PACKING ON CYLINDER LINER AND O-RINGS IN BLOCK

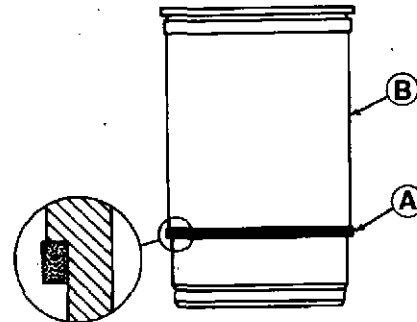
IMPORTANT: DO NOT use oil or hand cleaner soap on cylinder liner packing or O-rings. Petroleum products will cause the red (or white) O-ring to swell, which may result in O-ring damage during liner installation.

1. Pour AR54749 Soap Lubricant into a suitable container.
2. Dip O-rings in AR54749 Soap Lubricant.
3. Install the black O-ring (A) in the lower O-ring groove in the cylinder block (C).
4. Install the red (or white) O-ring (B) in the upper O-ring groove in the cylinder block.



RG3826

5. Turn cylinder liner (B) upside-down. Dip square packing (A) in soap and install over outside of liner.
6. Slide packing down firmly against shoulder on liner. Make sure packing is not twisted.
7. Coat the liner packing sealing area of the cylinder liner and block O-rings with liquid soap.



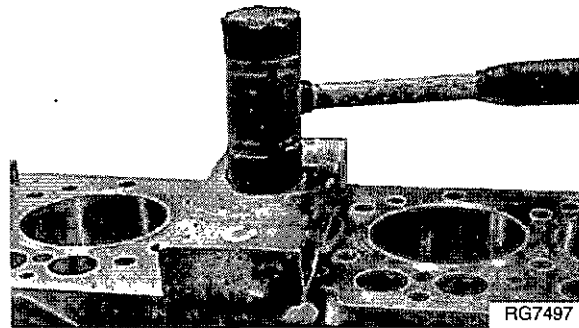
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INSTALL CYLINDER LINER IN BLOCK

IMPORTANT: Install cylinder liners into same cylinder block bore as removed. **DO NOT** scuff the liner packing across the upper counterbore.

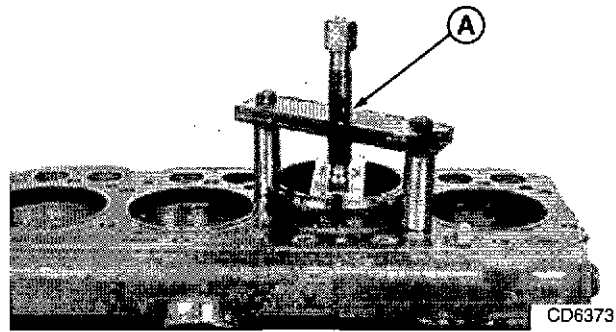
Pitted or eroded liners that meet reuse guidelines should be rotated 90° from their removed position. (See **VISUALLY INSPECT CYLINDER LINERS** earlier in this group for reuse guidelines.)



1. Install liner in block bore with mark toward front of engine, unless liner OD is pitted or eroded.

If liner OD is pitted or eroded, but still within acceptable service limits, rotate liner 90° from its removed position. Pitted sections of the liner should be facing the front or rear of engine.

2. A resistance will be felt when cylinder liner is aligned in pilot bore. Finish seating liners using clean, hardwood block and mallet. Gently tap hardwood block over top of cylinder liner with mallet. KCD10001 Puller (A) may also be used to seat liners.



NOTE: Cylinder liner will protrude over top of cylinder block more than normal due to uncompressed packings and O-rings.

IMPORTANT: If you suspect a packing may have sheared or displaced during liner installation, remove and examine the liner and packing assembly. If no damage is found, check packings for proper position. Resoap packings, and reinstall liner assembly.

3. Hold liners in place with large flat washers and cap screws. Turn cap screws snug but do not tighten.
4. Clean cylinder liner bores with waterless hand cleaner after installation. Wipe dry with clean towels.
5. Apply clean engine oil to liner bores immediately to prevent corrosion.

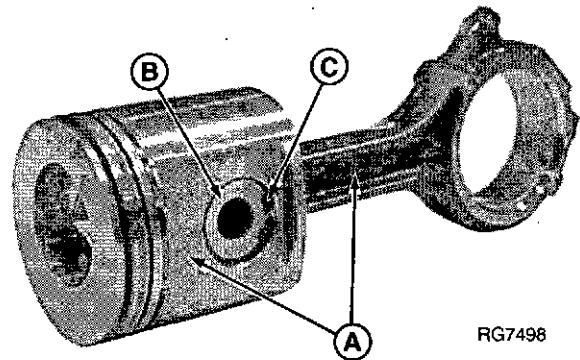
ASSEMBLE PISTON AND CONNECTING ROD

IMPORTANT: If a new piston and liner assembly is to be installed, **DO NOT** remove piston from liner. Push piston out of liner bottom only far enough to install piston pin.

1. Lubricate piston pin and bushing with clean engine oil.

IMPORTANT: Pistons must be installed on connecting rods from which they were removed and new piston pin snap rings must be used.

Piston and connecting rod must be assembled so combustion bowl in piston is offset toward fuel injection pump side of engine when long side of connecting rod is toward the camshaft side of engine.



2. Assemble pistons and connecting rods, making sure the word "FRONT" (A) on side of piston and side of connecting rod are facing same direction.
3. Insert piston pin (B) into piston pin bore. Install NEW piston pin snap rings (C) with sharp edge of ring facing away from piston pin. Make sure snap rings are seated in grooves of piston pin bore.

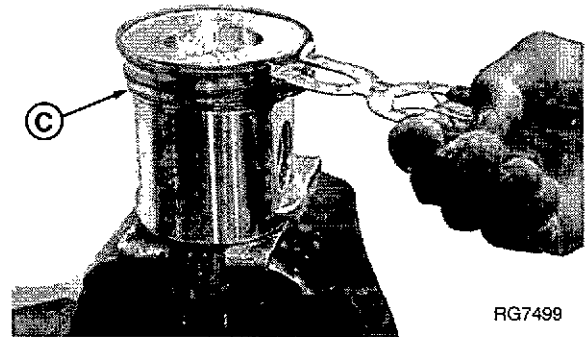
INSTALL PISTON RINGS

IMPORTANT: Piston rings can be damaged if expanded too far. Expand piston rings only as far as necessary to install rings on piston.

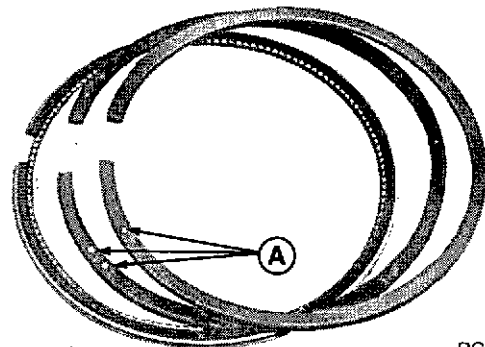
1. When installing new piston rings, use JDE85, JDE135, or KJD10140 Piston Ring Expander. Install oil ring expander in bottom ring groove. Position end gap toward either side of piston pin.
2. Install oil control ring (C) in bottom ring groove over ring expander. Install with end gap on opposite side of piston from ring expander gap.
3. Identify top side of compression rings. Top side of rectangular and keystone compression rings will be identified by depression marks (A) on the top side of two rings.

NOTE: Rectangular compression ring with two depression marks goes in the second groove.

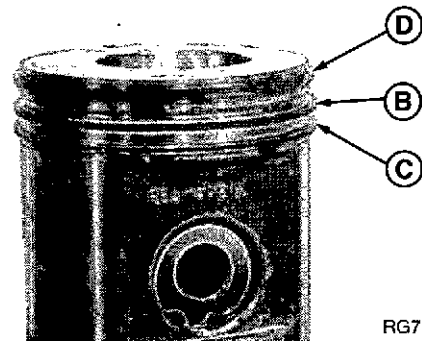
4. Install rectangular compression ring (B) in center ring groove with top of ring toward top of piston.
5. Position gap in rectangular compression ring on opposite side of piston from oil control ring (C) gap.
6. Install keystone compression ring (D) in top ring groove with top of ring toward top of piston.
7. Position gap in Keystone compression ring on opposite side of piston from rectangular compression ring gap.



RG7499



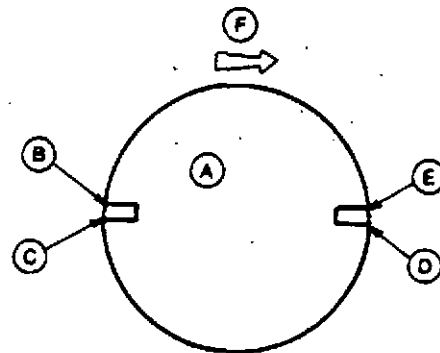
RG7797



RG7500

- A—Depression Marks
- B—Rectangular Compression Ring
- C—Oil Control Ring
- D—Keystone Compression Ring

8. Stagger ring gaps on pistons as shown.
9. Coat pistons, liners and inside of JDE84 Ring Compressor with clean engine oil.



- A—Piston Head
- B—Top Compression Ring
- C—Oil Control Ring Gap
- D—Expander Ring Gap
- E—Bottom Compression Ring Gap
- F—Front of Engine

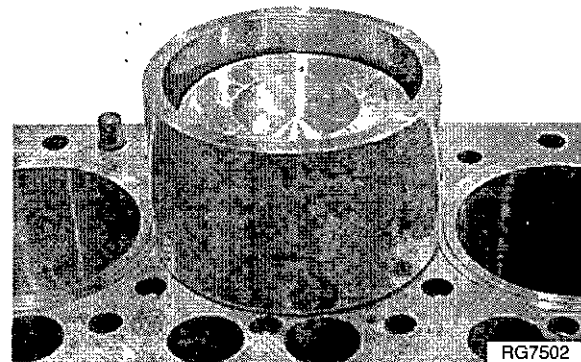
INSTALL PISTON AND CONNECTING ROD ASSEMBLY

IMPORTANT: Be careful so crankshaft journals and liner walls are not damaged by connecting rod when installing piston and rod in liner.

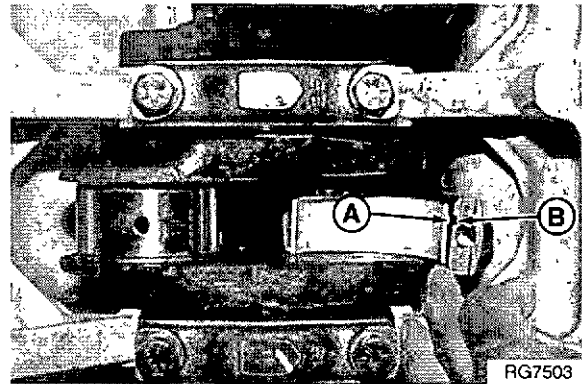
1. Carefully place JDE84 Piston Ring Compressor with piston and rod over liner so the word "FRONT" on side of rod and on the side of piston faces toward the front of the engine.

NOTE: If arrow indicating "FRONT" is not visible on top of pistons, install piston and rod so combustion bowl in piston is offset toward fuel injection pump side of engine, and the long side of the connecting rod is toward camshaft side of engine.

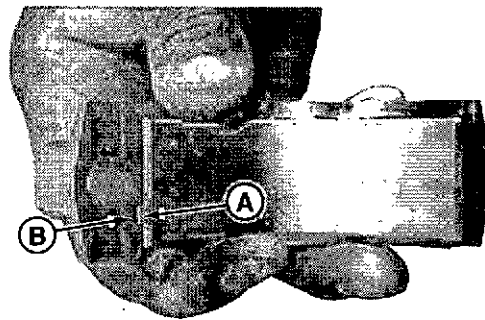
2. With piston centered in ring compressor and rings staggered correctly, push piston into liner.



3. Install bearing insert in connecting rod with tang (A) in groove (B).
4. Apply clean engine oil on insert and crankshaft journal. Carefully pull connecting rod and insert against crankshaft journal.

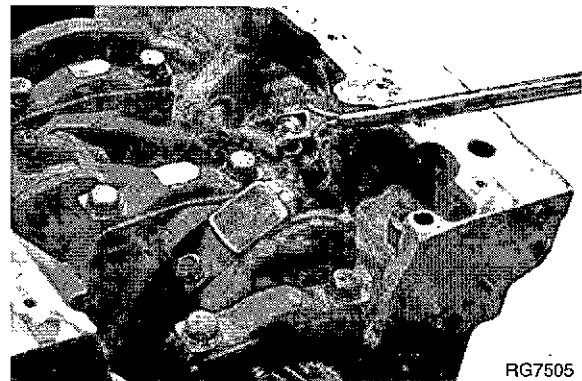


5. Install bearing insert in connecting rod cap with tang (A) in groove (B).
6. Apply clean engine oil to bearing insert. Install cap on connecting rod with tangs to same side.



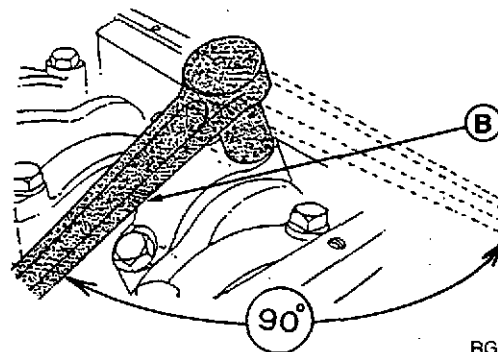
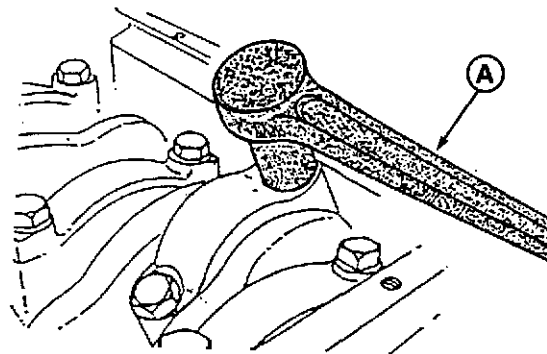
IMPORTANT: NEVER use connecting rod cap screws more than once for final engine assembly. Once rod cap screws have been tightened, they cannot be reused for final assembly.

7. Dip NEW connecting rod cap screws in clean oil and install.
8. Tighten cap screws alternately to 58 N·m (43 lb-ft).
9. Secondly, TORQUE-TURN all cap screws to 90—100 degrees. (See TORQUE-TURN CONNECTING ROD CAP SCREWS next in this group.)



TORQUE-TURN CONNECTING ROD CAP SCREWS

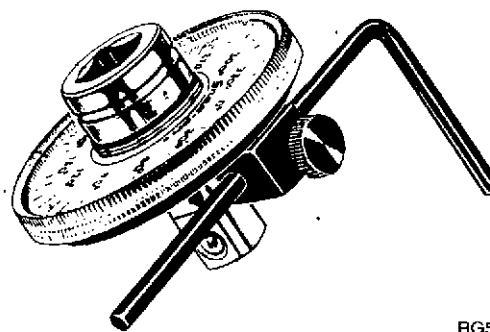
- Using engine axis method to TORQUE-TURN connecting rod cap screws:
 1. After tightening cap screws to initial torque values, mark connecting rod cap and socket.
 2. Position handle of wrench parallel to centerline of engine crankshaft axis (A).
 3. Tighten 1/4 turn (90—100°) clockwise until handle of wrench is perpendicular to centerline of engine crankshaft axis (B) as shown.



RG7047

- Using JT05993 Torque Angle Gauge to TORQUE-TURN connecting rod cap screws:

1. After tightening cap screws to initial torque values provided earlier, follow directions provided with gauge and TORQUE-TURN each cap screw 90°—100°.



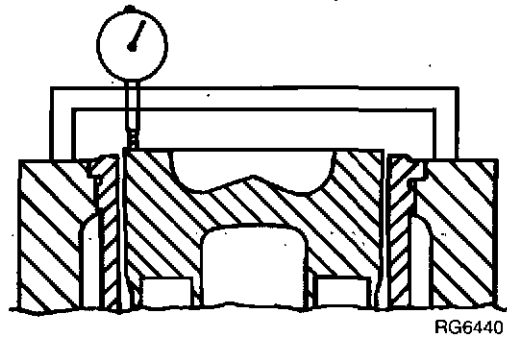
RG5698

CHECK ENGINE ROTATION FOR EXCESSIVE TIGHTNESS

1. Rotate crankshaft several revolutions to be sure engine rotates without excessive tightness.
2. Check liners for deep scratches caused by an improperly installed or broken piston ring.
3. Check side clearance of rods. Must have slight side-to-side movement.

MEASURE PISTON PROTRUSION

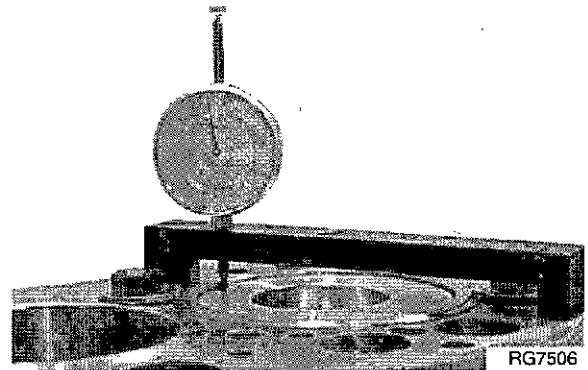
1. Press down on top of piston to remove oil clearances before measuring piston protrusion.
2. Use JDG451 or KJD10123 Gauge (or use a magnetic base dial indicator) to measure piston protrusion. Place gauge on top of cylinder block so dial indicator can be set to "zero" with top of block.
3. Position gauge across piston. While pressing gauge downward, rotate crankshaft until piston is at TDC position. Measure piston height at several positions around the piston. If using JDG451 Gauge, piston height must be checked at outer most diameter of piston.
4. Piston protrusion must be within the following specifications to prevent piston-to-exhaust valve contact.



PISTON PROTRUSION SPECIFICATIONS

Piston protrusion (above block deck) 0.08—0.30 mm
(0.003—0.012 in.)

If protrusion does not meet specifications, check dimensions of piston, connecting rod, cylinder block, crankshaft, and bearings to determine the cause.



COMPLETE FINAL ASSEMBLY

1. Install oil pump outlet tube O-ring in cylinder block. Install oil pump and outlet tube. (See Group 20.)
2. Install balancer shaft bushings (4-cylinder engines) and camshaft bushings. (See Group 16.)
3. Install oil bypass valve (in front of block) and front plate. (See Group 16.)
4. Install balancer shafts (if equipped). (See Group 16.)
5. Install camshaft, timing gears, and timing gear cover. (See Group 16.)
6. Install oil pressure regulator valve, spring, and plug in timing gear cover. (See Group 16.)
7. Install oil pan. (See Group 20.)
8. Install crankshaft pulley. (See Group 15.)
9. Install camshaft followers. (See Group 16.)
10. Install cylinder head with new gasket. (See Group 05.)
11. Fill engine with clean oil and proper coolant.
12. Perform engine break-in. (See Group 05.)

SPECIAL OR ESSENTIAL TOOLS

NOTE: Order tools according to information given in the U.S. SERVICEGARD™ Catalog or in the European Microfiche Tool Catalog (MTC).

Dial Indicator (English, in.) D17526Cl
or (Metric, mm) D17527Cl
or FKM10103*

Use with JDG451 to measure valve recess and cylinder liner height-to-cylinder block top deck.

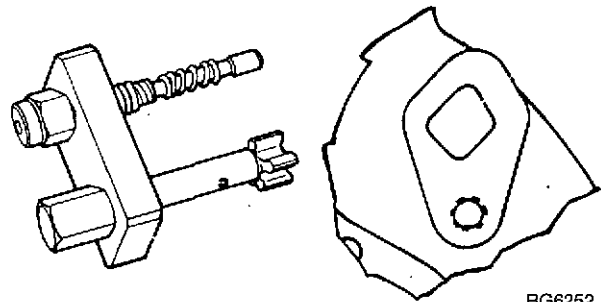


RG6246

* Part of KJD10123 Piston/Liner Height Gauge

Flywheel Turning Tool (A) JD281A

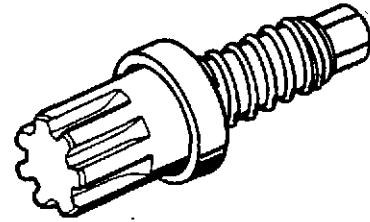
Used on engines with 142-tooth flywheel ring gear and a diamond-shaped tool guide bore (B) in flywheel housing. Tool has its own spring-loaded timing pin which threads into flywheel housing.



RG6252

Flywheel Turning Tool JDG820

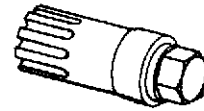
Used to rotate flywheel on engine, with 129-tooth flywheel ring gear and a 29.9 mm (1.18 in.) ID flywheel housing guide bore diameter, to check damper radial runout and time engine. JDE81-1 may be used also if JDG820 is not available.



RG7056

Flywheel Turning Tool JDE83

Used to rotate flywheel on engines with 142-tooth flywheel ring gear and a 26.5 mm (1.04 in.) ID flywheel housing guide bore diameter. Use with JDE81-4 Timing Pin.



RG6251

Seal Remover JDG22

Remove crankshaft rear oil seal without removing flywheel housing.

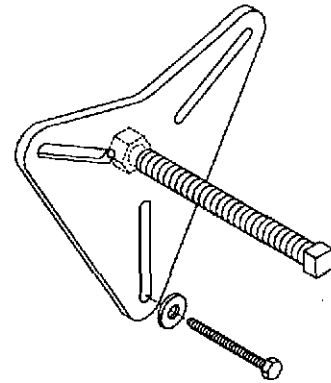


RG5109

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2

Seal and Wear Sleeve Remover JDG698A

Remove unitized (non-separable) crankshaft rear oil seal and wear sleeve.



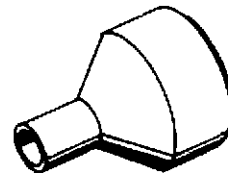
RG5631

Seal Puller Adapter JDG719

Used with a standard metal screw, JDE38-2 Shank, and JDE38-3 Slide Handle to remove front crankshaft oil I seal with timing gear cover installed. Also used to remove rear crankshaft oil seal with seal housing installed.

Set consists of:

- Adapter JDG719-1
- Screw (not shown) 11200



RG6214

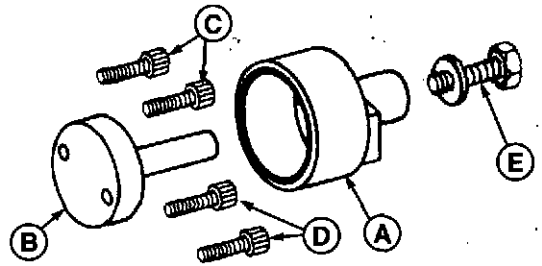
Rear Seal and Wear Sleeve

Installer Set JT30040B
or KCD10002

Install crankshaft rear oil seal and wear sleeve assembly.

JT30040B Set consists of:

- A—Driver JT30042
- B—Pilot JT30041A
- C—English Socket-Head Cap Screws 10903
- D—Metric Socket Head Cap Screws 221663
- E—Screw with Washer 10870



RG7719

Crankshaft Gear and Front Oil Seal

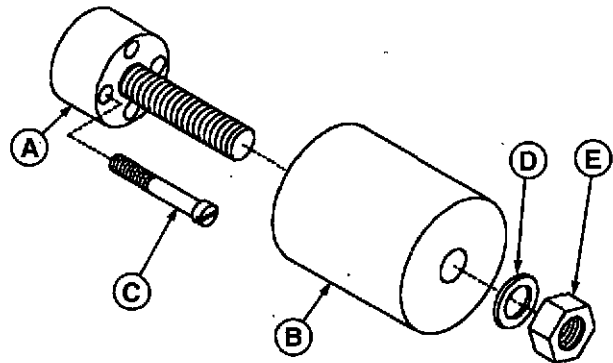
Installer JDG954

Used to install crankshaft gear either prior to, or after, installing crankshaft into engine. Also used to install front oil seal with timing gear cover installed on engine.

NOTE: JDG954-1 Installer may be used to install the crankshaft gear when the crankshaft is REMOVED from the engine.

Set consists of:

- A—Adapter JDG954-2
- B—Installer JDG954-1
- C—Special Cap Screws JDG954-3
- D—Thrust Washer 206747
- E—Hex Nut 22301



RG7442

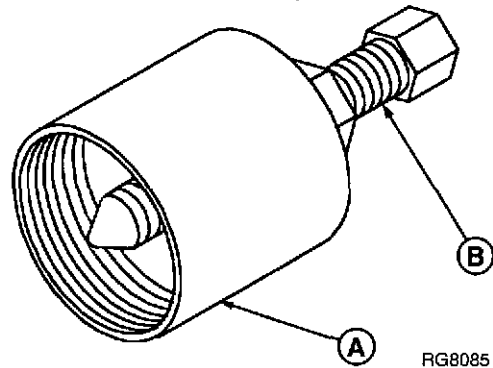
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Front Wear Sleeve Puller JDG992

Used to remove front wear sleeve with timing gear cover installed.

Set consists of:

- A—Threaded Collet JDG992-1
- B—Forcing Screw 311099



RG8085

SERVICE EQUIPMENT AND TOOLS

NOTE: Order tools from the U.S. SERVICEGARD™ Catalog or from the European Microfiche Tool Catalog (MTC). Some tools may be available from a local supplier.

Name	Use
D01047AA 17-1/2 and 30-Ton Puller Set	Remove crankshaft gear from crankshaft.
D01045AA Bushing, Bearing, and Seal Driver Set	Install pilot bearing in flywheel.
Cylinder Bore Ridge Reamer	Remove carbon from liner bore.
JDG966 Crankshaft Front/Rear Rotation Adapter	Rotate crankshaft from front and rear with flywheel removed.

OTHER MATERIAL

Number	Name	Use
LOCTITE 242 (TY9370)	Thread Lock and Sealer	Coat threads of flywheel mounting cap screws.
LOCTITE 515 (TY6304)	Flexible Sealant	Serves as flywheel housing-to-cylinder block gasket.
LOCTITE 680 (TY15969)	Retaining Compound	Coat OD of crankshaft flange for installation of rear oil seal/wear sleeve. Coat ID of front wear sleeve prior to installation.
_____	PLASTIGAGE	Check main bearing-to-crankshaft journal oil clearance during engine disassembly.
_____	Brake Kleen or Ignition Cleaner	Remove sealant from crankshaft flange.

CRANKSHAFT, MAIN BEARINGS, AND FLYWHEEL SPECIFICATIONS

ITEM	SPECIFICATION	WEAR LIMIT
Maximum Vibration Damper Radial Runout*	1.50 mm (0.060 in.)	_____
Maximum Vibration Damper Wobble*:		
(Outer Ring)	1.50 mm (0.060 in.)	_____
(Inner Ring)	0.50 mm (0.020 in.)	_____
Crankshaft End Play (Thrust Bearing Clearance):		
Engine with Two-Piece Thrust Bearing	0.05—0.25 mm (0.002—0.010 in.)	_____
Main Bearing Journal OD	79.324—79.350 mm (3.1229—3.1240 in.)	_____
Main Bearing Assembled ID	79.391—79.433 mm (3.1256—3.1273 in.)	_____
Main Bearing-to-Journal Clearance	0.041—0.109 mm (0.0016—0.0043 in.)	_____
Thrust Bearing Journal Width	38.952—39.028 mm (1.5335—1.5365 in.)	_____
Thrust Bearing Overall Width	38.79—38.87 mm (1.527—1.530 in.)	_____
Maximum Main or Rod Journal Taper	0.010 mm (0.0004 in.)	_____
Maximum Main or Rod Journal Out-of-Roundness	0.005 mm (0.0002 in.)	_____
Undersize Main and Rod Bearing Available	0.25 mm (0.010 in.)	_____
Main Bearing Bore Specifications:		
ID Without Bearing Inserts	84.455—84.481 mm (3.3250—3.3260 in.)	_____
Bore Centerline-to-Top Deck of Block	337.896—337.972 mm (13.3029—13.3059 in.)	_____

* 6-cylinder engines only

CRANKSHAFT, MAIN BEARINGS, AND FLYWHEEL SPECIFICATIONS—CONTINUED

ITEM	SPECIFICATION	WEAR LIMIT
Engine Stroke	127 mm (5.00 in.)	_____
Rod Bearing Journal OD	77.800—77.826 mm (3.0629—3.0640 in.)	_____ _____
Crankshaft Grinding Surface Finish:*		
Main and Connecting Rod Journals	Lap 0.20 μ m (8 AA)	_____
Thrust Faces	Lap 0.40 μ m (16 AA)	_____
Flywheel Housing Face Run-Out:		
12 O'clock position	0.30 mm (0.012 in.)	_____
3 and 9 O'clock positions	0.25 mm (0.010 in.)	_____
Flywheel Face Flatness:		
Maximum Variation	0.23 mm (0.009 in.)	_____
Maximum Variation per 25 mm (1.0 in.) of Travel	0.013 mm (0.0005 in.)	_____
Flywheel Pilot Bushing Bore ID:		
Flywheel Option Code 1508	34.978—35.004 mm (1.3770—1.3781 in.)	_____ _____
Flywheel Option Code 1502 and 1515	44.978—45.004 mm (1.7708—1.7719 in.)	_____ _____
Flywheel Housing Seal Bore Run-Out (Maximum)	0.152 mm (0.006 in.)	_____

* Grind clockwise (crankshaft rotation viewed from flywheel end); lap counterclockwise.

CRANKSHAFT, MAIN BEARINGS, AND FLYWHEEL SPECIFICATIONS—CONTINUED

TORQUES

Pulley or Damper with Pulley-to-Crankshaft*:	
Step 1.....	60 N·m (44 lb-ft)
Step 2.....	80 N·m (59 lb-ft)
Main Bearing Cap Screw	135 N·m (100 lb-ft)
Flywheel-to-Crankshaft.....	138 N·m (102 lb-ft)
Flywheel Housing-to-Cylinder Block	125 N·m (92 lb-ft)
Piston Cooling Orifices	11 N·m (8 lb-ft)

* Tighten cap screws in a cross sequence.

CRANKSHAFT AND MAIN BEARING FAILURE ANALYSIS

- **Scored Main Bearing:** (Diagnosis also applies to connecting rod bearing.)

Oil starvation.
Contaminated oil.
Engine parts failure.
Excessive heat.
Poor periodic service.

- **Galled or "Wiped" Bearings:**

Fuel in lubricating oil (incomplete combustion).
Coolant in lubrication system (cracked block, liner seal failure, or leaking water pump seal with plugged hole).
Insufficient bearing oil clearance.
Parts not lubricated prior to engine operation.
Wrong bearing size.

- **Inconsistent Wear Pattern:**

Misaligned or bent connecting rod.
Warped or bowed crankshaft.
Distorted cylinder block.

- **Broken Main Bearing Caps:**

Improper installation.
Dirt between bearing and crankshaft journal.
Low oil pressure.
Oil pump failure.

- **Cracked, Chipped or Broken Bearings:**

Overspeeding.
Excessive idling.
Lugging.
Excessive oil clearance.
Improper installation.

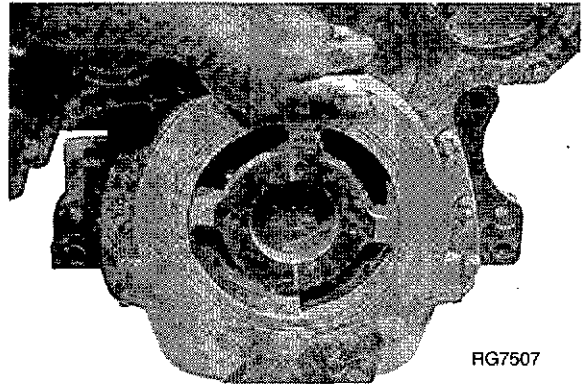
INSPECT VIBRATION DAMPER (6-CYLINDER ENGINE)

IMPORTANT: Do not immerse the vibration damper in cleaning solvent or any petroleum product. Rubber portion of damper may be damaged.

Never apply thrust on outer ring. Damper is sensitive to impact damage, such as being dropped or struck with a hammer.

The damper assembly is not repairable. Replace damper every 5 years or 4500 hours, whichever occurs first. Also, replace damper whenever crankshaft is replaced or after major engine overhaul.

1. Grasp outer ring of damper and attempt to turn it in both directions. If rotation is felt, damper is defective and should be replaced. Also, if rubber is separated, partially missing, or displaced, replace damper.

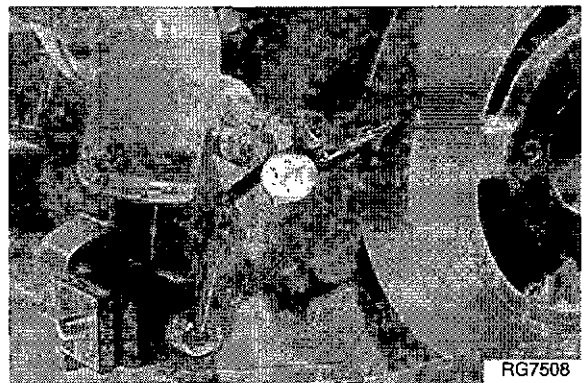


RG7507

2. Check vibration damper radial runout by positioning a dial indicator so probe contacts damper OD.
3. With engine at operating temperature, rotate crankshaft using engine rotation tool.
4. Note dial indicator reading. If runout exceeds specifications given below, replace vibration damper.

DAMPER RADIAL RUNOUT SPECIFICATION

Maximum Damper Radial Runout 1.50 mm (0.060 in.)



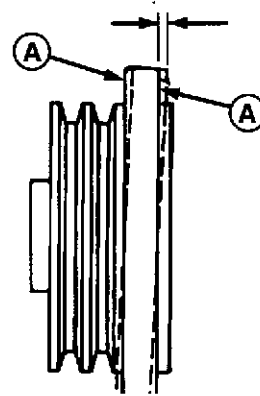
RG7508

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5. Check vibration damper wobble using a dial indicator.

Measure wobble at the outer edges of damper face (A).

6. Rotate crankshaft one complete revolution using engine rotation tool, and note total dial indicator movement. Compare readings with specifications below.



RG5679

DAMPER PULLEY WOBBLE SPECIFICATION

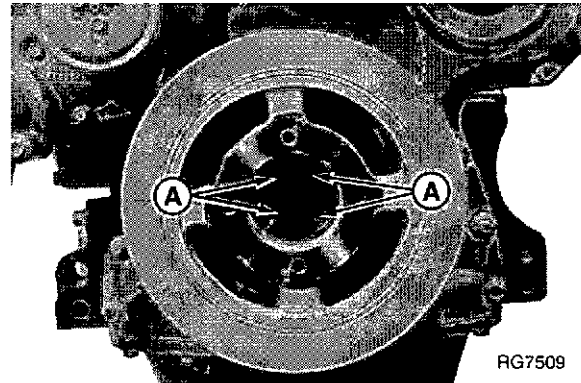
Outer Ring (Maximum) 1.50 mm (0.060 in.)

Inner Ring (Maximum) 0.5 mm (0.020 in.)

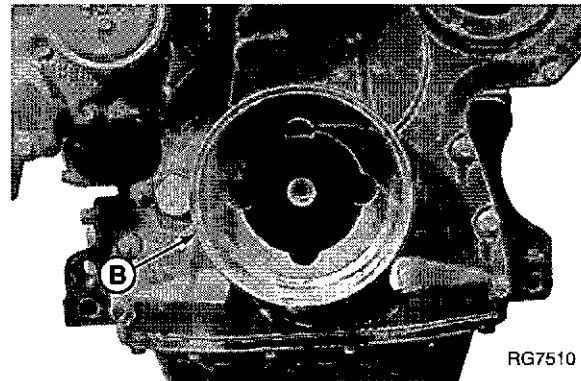
REMOVE PULLEY OR VIBRATION DAMPER AND PULLEY

IMPORTANT: Never apply thrust on outer ring of damper. Do not drop or hammer on damper.

1. Remove four cap screws (A) from vibration damper.
2. Grasp damper and remove from crankshaft.
3. Remove belt pulley (B).



RG7509



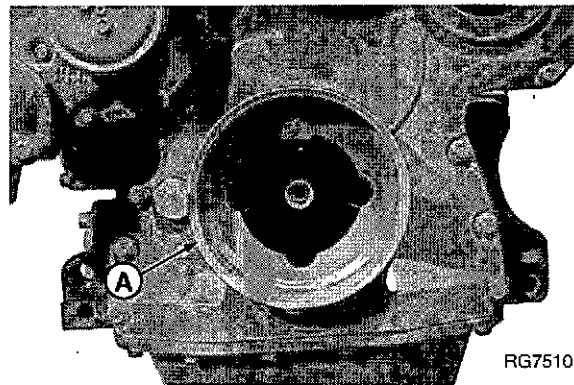
RG7510

INSTALL PULLEY OR VIBRATION DAMPER PULLEY

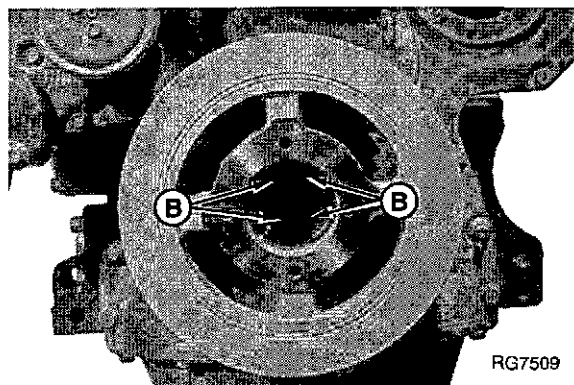
1. Install belt pulley (A).
2. Position damper on crankshaft. Handle vibration damper with care to avoid impact damage.

IMPORTANT: Damper or pulley-to-crankshaft cap screw must be SAE Grade 8 or higher.

3. Dip cap screws (B) in clean SAE30 engine oil.
4. Install cap screws and tighten in a cross sequence to 60 N·m (44 lb-ft). Final tighten cap screws to 80 N·m (59 lb-ft).



RG7510



RG7509

CHECKING VIBRATION DAMPER OR PULLEY

NOTE: When cleaning damper, never soak in a cleaning solvent. Use a steam cleaner, soap solution or water only.

1. Prior to disassembly, check the following specifications:

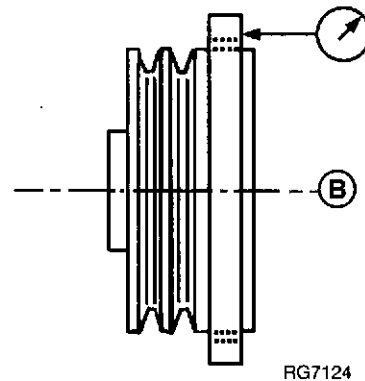
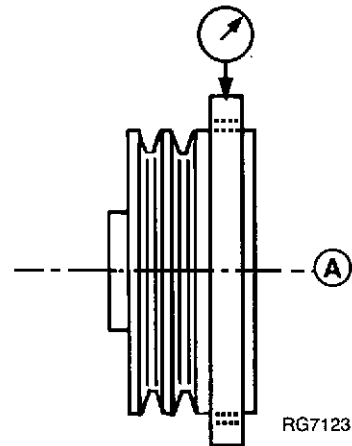
SPECIFICATIONS

Vibration damper only:

Maximum radial run-out (A) 1.50 mm (0.060 in.)
 Maximum wobble (B) 1.50 mm (0.060 in.)

2. Replace damper if total run-out (A) or wobble (B) exceeds specifications, or if outer ring has slipped relative to rubber member or drive hub.
3. Grasp damper and attempt to turn in both directions (clockwise and counterclockwise). If rotation is felt, replace damper.

IMPORTANT: Replace damper after 4500 hours or every five years, whichever occurs first.



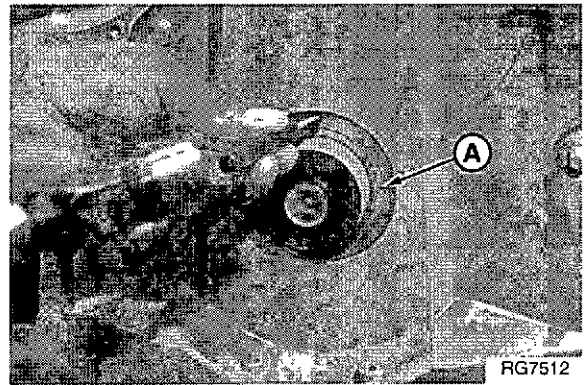
REPLACE FRONT CRANKSHAFT OIL SEAL AND WEAR SLEEVE (WITHOUT REMOVING TIMING GEAR COVER)

- Remove front crankshaft oil seal:

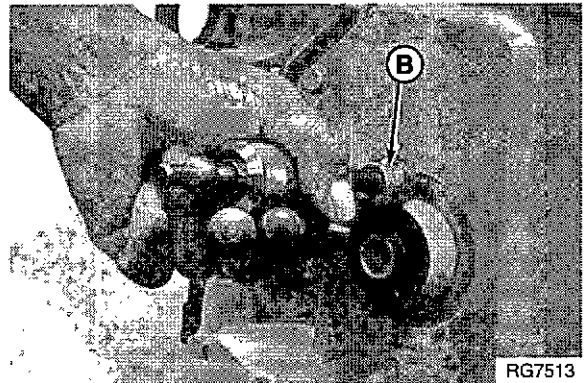
1. Remove poly-vee belts.
2. Remove vibration damper/pulley or pulley from crankshaft as previously instructed in this group.

IMPORTANT: Whenever front oil seal is replaced, the wear sleeve must also be replaced.

3. Check oil seal (A) for wear, damage, or leakage.
4. Center punch seal casing at 12 o'clock position and drill 1/8 in. hole in casing.
5. Remove seal from timing gear cover using JDG22 Seal Remover or JDG719 Seal Puller along with JDE38-2 Shank and JDE38-3 Slide Hammer (B). Be careful not to damage seal bore in timing gear cover.



RG7512

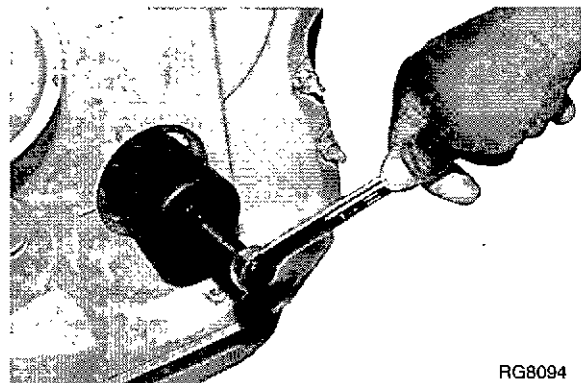
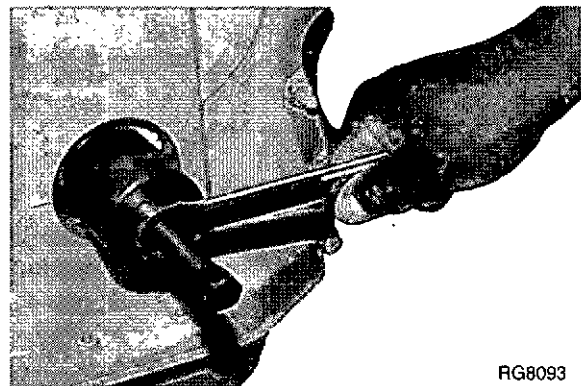
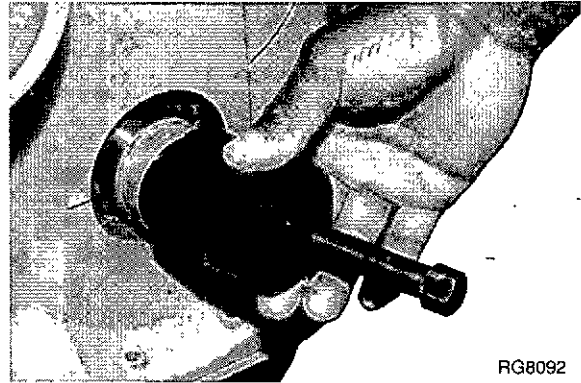


RG7513

• **Remove crankshaft wear sleeve:**

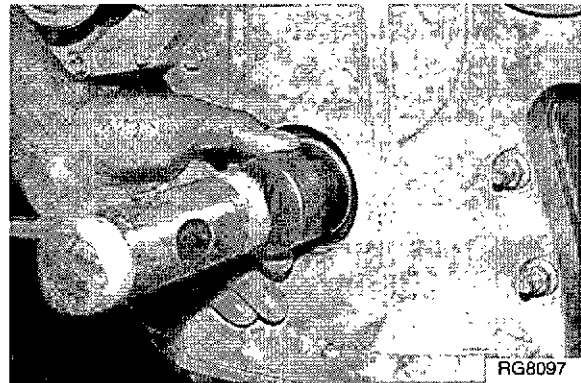
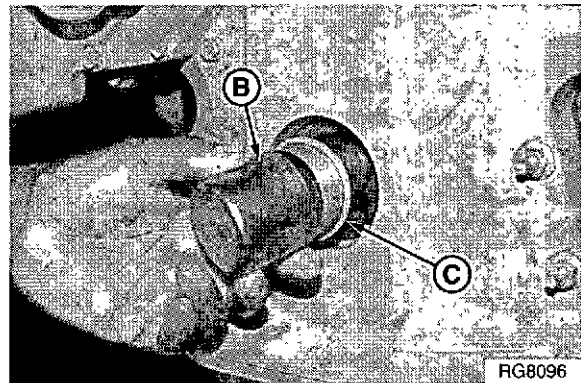
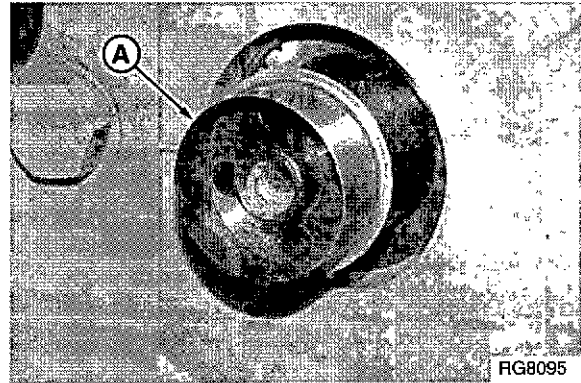
NOTE: You may want to apply inward pressure on collet as it is threaded onto wear sleeve.

1. Lock flywheel with JDE81-4 Timing Pin.
2. Back out forcing screw and position JDG992-1 Collet onto crankshaft flange until threaded ID contacts wear sleeve.
3. Thread collet onto wear sleeve and securely tighten until wear sleeve can be removed from crankshaft flange.
4. Lubricate threads of forcing screw. Tighten forcing screw until wear sleeve is removed from front crankshaft flange.
5. Clean crankshaft flange using Brake Kleen, Ignition Cleaner, or equivalent.



• **Install crankshaft wear sleeve:**

1. Coat ID of new wear sleeve with LOCTITE 680 (TY15969) Retaining Compound.
2. Install wear sleeve (A) on nose of crankshaft with flange of sleeve toward crankshaft.
3. Position installation tool (B) provided in kit over wear sleeve. Install wear sleeve until tool bottoms on nose of crankshaft, using a dead blow hammer. Flange on wear sleeve should contact crankshaft gear.
4. Clean any sealant from OD of crankshaft flange (C) and wear sleeve.



• **Install front crankshaft oil seal:**

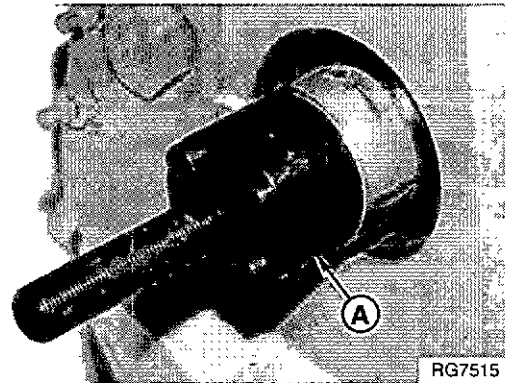
1. Inspect and clean seal bore in timing gear cover. Check for nicks or burrs. Use a medium-grit emery cloth to smooth rough areas.

IMPORTANT: To assure proper sealing, the OD of the crankshaft and wear sleeve **MUST BE** cleaned with **Brake Kleen, Ignition Cleaner, or equivalent** and dry prior to installing seal (C).

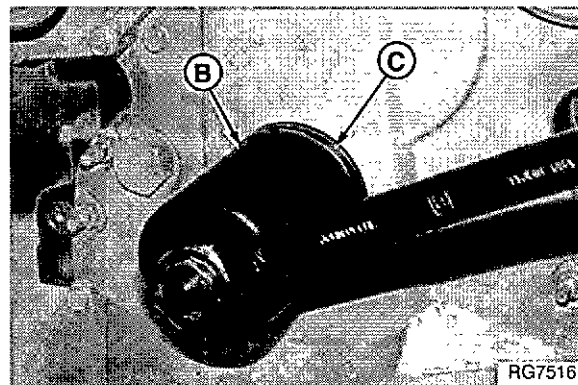
2. Slide JDG954-2 Adapter (A) on nose of crankshaft and tighten cap screws.
3. Apply a light coating of clean engine oil to lips of seal and position seal on crankshaft flange. (The spring-loaded side of seal goes into timing gear cover first.)

IMPORTANT: **DO NOT** allow oil to contact coating on OD of seal.

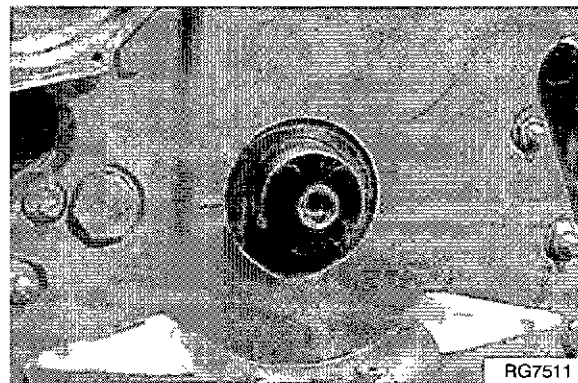
4. Place JDG954-1 Installer (B) over adapter. Tighten screw until driver bottoms on nose of crankshaft.
5. Install belt pulley
6. Place damper on crankshaft. Handle vibration damper with care to avoid impact damage.
7. Dip cap screws in clean SAE30 engine oil.
8. Install cap screws and tighten in a cross sequence to 60 N·m (45 lb-ft). Final tighten cap screws to 80 N·m (60 lb-ft).
9. Install poly-vee belts.



RG7515



RG7516



RG7511

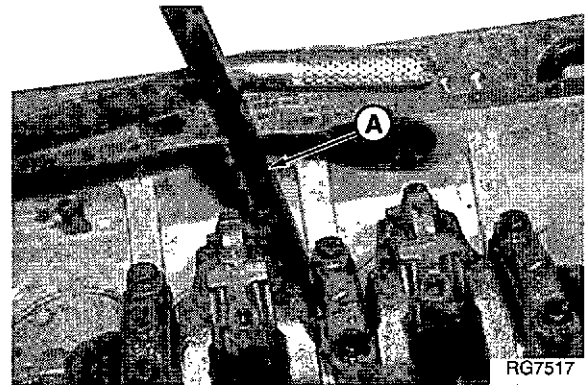
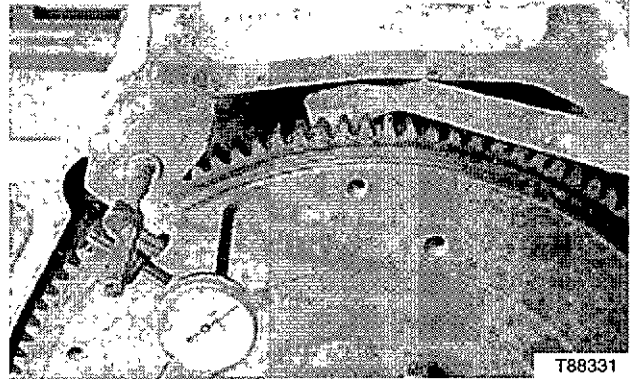
CHECK CRANKSHAFT END PLAY

Measure end play prior to removing crankshaft to determine condition of thrust bearings.

1. Position dial indicator on contact face of flywheel, on front crankshaft nose, on damper, or front pulley assembly if installed.

IMPORTANT: Do not apply too much pressure with pry bar (A), as this could damage bearings.

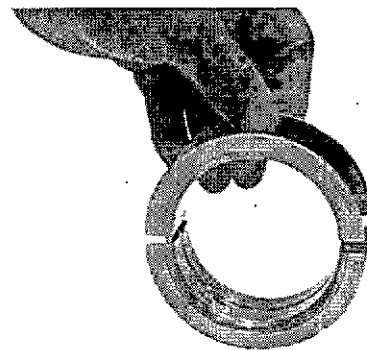
2. Using a pry bar, gently push crankshaft as far to rear of engine as possible.
3. Zero the dial indicator.
4. Gently pry the crankshaft as far forward as possible. Note indicator reading. If end play is not within specifications, install new thrust bearing.



CRANKSHAFT END PLAY SPECIFICATIONS

New Parts:	
Two-Piece Thrust Bearing	0.05—0.25 mm (0.002—0.010 in.)

If new thrust bearing does not restore proper end play, install a two-piece thrust bearing with oversize thrust washers.



INSPECT FLYWHEEL

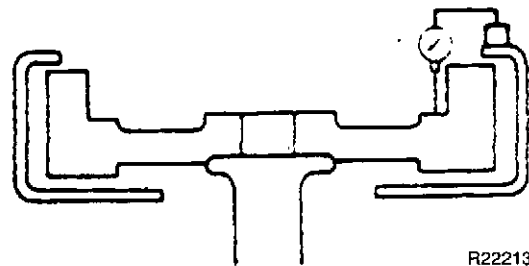
1. Inspect the clutch contact face for scoring, overheating, or cracks. Replace or resurface flywheel if defective.
2. Examine flywheel ring gear for worn or broken teeth. Replace ring gear if defective, as described later in this group.

CHECK FLYWHEEL FACE FLATNESS

1. Mount dial indicator base on flywheel housing. Position pointer to contact driving ring mounting surface. Do not allow pointer to contact driving ring mounting holes.

IMPORTANT: Maintain constant end pressure on crankshaft to hold shaft against thrust bearing when measuring flywheel face runout.

2. Rotate flywheel by turning crankshaft. Read total indicator movement. Resurface flywheel face or replace as required.



R22213

FLYWHEEL FACE FLATNESS SPECIFICATION

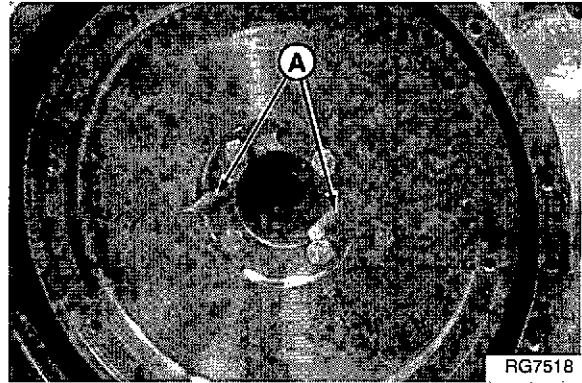
Maximum variation.....	0.23 mm (0.009 in.)
Maximum variation per 25 mm (1.0 in.) of travel.....	0.013 mm (0.0005 in.)

REMOVE FLYWHEEL



CAUTION: Flywheel is heavy. Plan a proper lifting procedure to avoid personal injury.

1. Remove two cap screws and install guide studs (A) in their place (shown installed). Remove the other cap screws and install them into the threaded holes, to push flywheel off crankshaft.
2. Remove flywheel. Remove guide studs from crankshaft.



REPLACE FLYWHEEL RING GEAR

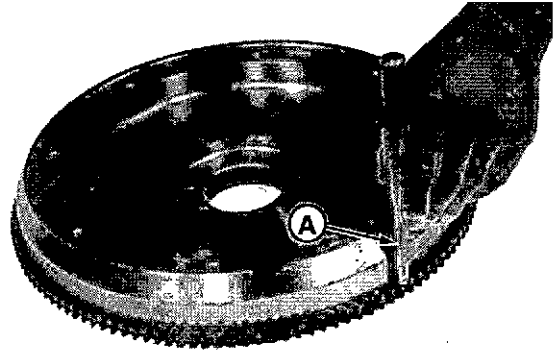


CAUTION: Oil fumes or oil can ignite above 193°C (380°F). Use a thermometer and do not exceed 182°C (360°F). Do not allow a flame or heating element to be in direct contact with the oil. Heat the oil in a well ventilated area. Plan a safe handling procedure to avoid burns.

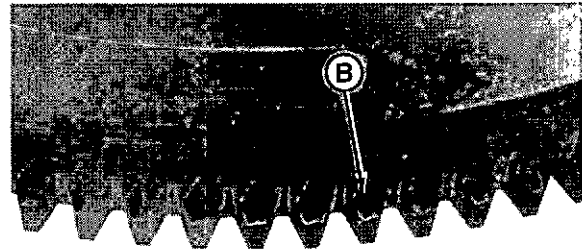
1. Place the flywheel on a solid flat surface.
2. Drive ring gear off with a brass drift (A) and hammer.
3. Heat new ring gear to 148°C (300°F) using either heated oil, oven heat, or flame heat.

IMPORTANT: If flame heat is used, be sure gear is heated uniformly around circumference. **DO NOT OVERHEAT. SEE CAUTION.** Overheating may also destroy original heat treatment of gear.

4. Turn gear so side with chamfer (B) is toward engine with flywheel installed.
5. Install ring gear against shoulder of flywheel.



RG7519

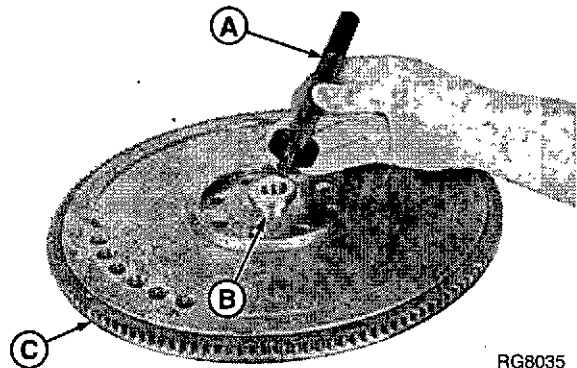


RG7520

REPLACE PILOT BUSHING IN FLYWHEEL—IF EQUIPPED

NOTE: Some engines are equipped with a pilot bushing (B) in flywheel (C). Flywheel must be removed from the engine to replace this bushing.

1. With flywheel removed from engine, drive bushing out of flywheel using appropriate disks and handle (A) from D01045AA Bushing, Bearing and Seal Driver Set. Discard bushing.
2. Measure flywheel bore diameter. If bore is larger than specifications, replace flywheel.



RG8035

FLYWHEEL PILOT BUSHING BORE ID SPECIFICATIONS

Flywheel Option Code 1508	34.978—35.004 mm (1.3770—1.3781 in.)
Flywheel Option Code 1502 and 1515	44.978—45.004 mm (1.7708—1.7719 in.)

3. Drive new pilot bushing into rear face of flywheel using appropriate disks and handle from same driver set, until bushing shoulder bottoms on flywheel face. Check bushing for smooth operation.

INSTALL FLYWHEEL



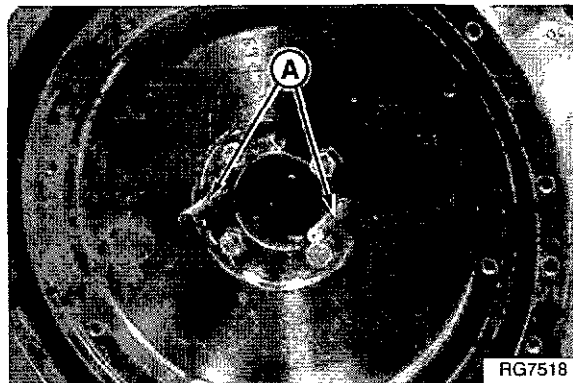
CAUTION: Flywheel is heavy. Plan a proper handling procedure to avoid injuries.

IMPORTANT: Flywheel **MUST BE** clean and free of any oil, grease or debris.

1. Install two guide studs (A) in crankshaft cap screw threaded holes. Place flywheel on studs and slide into position against crankshaft.

IMPORTANT: **ALWAYS** install new flywheel cap screws when flywheel has been removed.

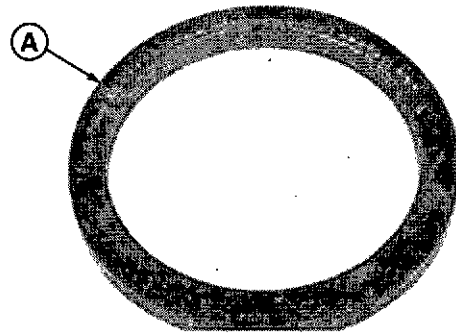
2. Apply LOCTITE 242 (TY9370) to threads of all flywheel mounting cap screws. Start cap screws in crankshaft. Do not tighten until guide studs are removed and all cap screws are started. Tighten cap screws to 138 N·m (102 lb-ft).



CRANKSHAFT REAR OIL SEAL AND WEAR SLEEVE HANDLING PRECAUTIONS

Use the following precautions for handling seal and wear sleeve assembly (A):

- Seal and wear sleeve are assembled. **DO NOT SEPARATE**. If parts become separated, discard and replace with a new assembly. Attempts to reassemble will cause the wear sleeve to damage the seal allowing engine oil to leak past seal.
- Always install seal and wear sleeve assembly immediately after removal from plastic bag to avoid possible dirt contamination.
- No lubrication of any kind is to contact seal when installing. Use of a lubricant may result in premature seal failure.
- Install oil seal/wear sleeve assembly with the open side of seal and wear sleeve ID chamfer toward the engine. If seal is reversed, engine oil may be lost because grooves in oil seal lip would be incorrect with respect to direction of crankshaft rotation.



RG5640

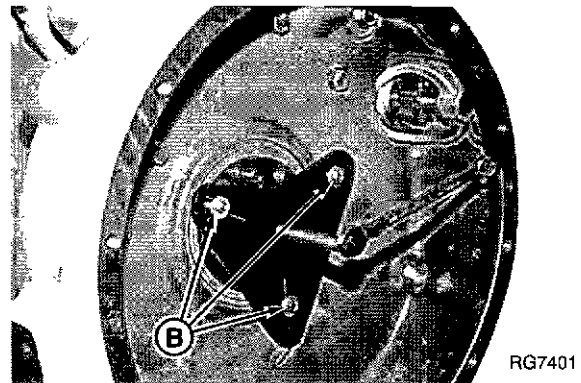
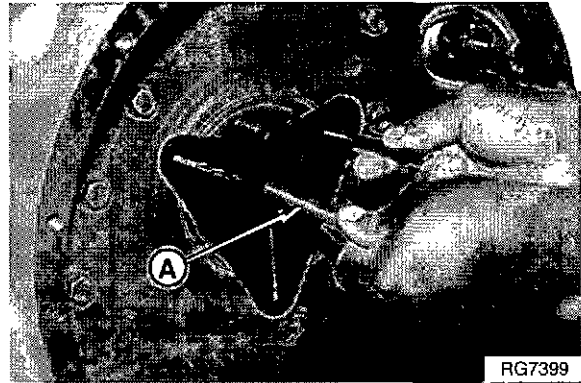
REMOVE UNITIZED (NON-SEPARABLE) CRANKSHAFT REAR OIL SEAL AND WEAR SLEEVE

The unitized (non-separable) oil seal and wear sleeve **MUST BE** removed before removing flywheel housing.

1. Remove flywheel.
2. Adjust forcing screw (A) on JDG698A Seal and Wear Sleeve Remover and position screw so it centers tool on crankshaft flange.
3. Use the slots in JDG698A Remover as a template, mark three locations on seal casing where screws should be installed for removal purposes. Remove tool from crankshaft flange.

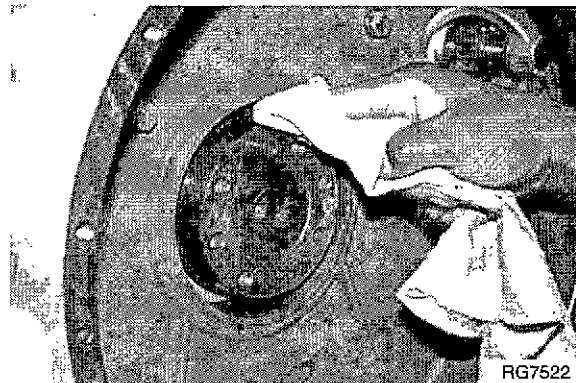
IMPORTANT: Holes must be drilled at outer edge of seal case. Screws will pull seal against wear ring, thereby removing both pieces.

4. Drill a 5/32 in. hole through wear sleeve lip and seal casing at the three marked locations.
5. Position JDG698A Remover on end of crankshaft.
6. Install three 2-1/2 in. (approximate) sheet metal screws with washers (B) into slots of removal tool and thread screws into holes in seal casing. Evenly tighten screws until plate is flush with rear face of crankshaft.
7. Tighten forcing screw (plate should pull evenly against the three screws) until seal and wear sleeve assembly is removed from engine



8. Clean OD of crankshaft flange and ID of flywheel housing with cleaning solvent, trichloroethylene, acetone, or any other suitable cleaner that will remove sealant.
9. Look for nicks or burrs on wear ring surface and bore in flywheel housing. If necessary, use polishing cloth to remove nicks or burrs.

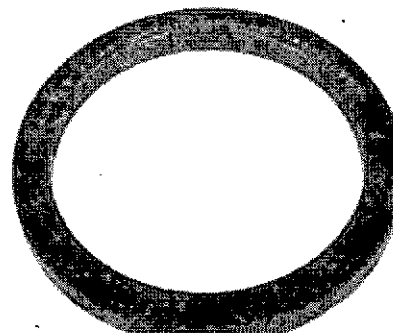
Finish cleaning by wiping flange with a clean rag.



INSTALL CRANKSHAFT REAR OIL SEAL AND WEAR SLEEVE

IMPORTANT: No lubrication of any kind is to contact seal when installing. Use of a lubricant may result in premature seal failure.

Install seal and wear sleeve assembly immediately after removal from plastic bag to avoid possible dirt contamination.



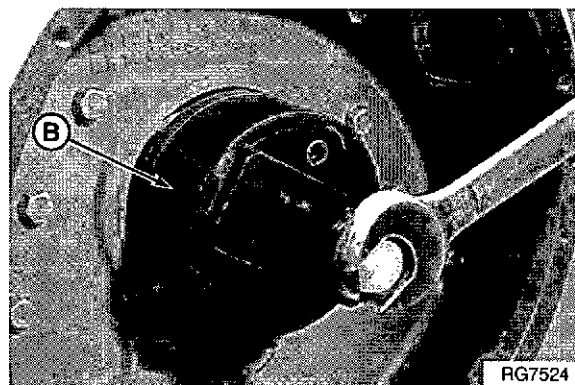
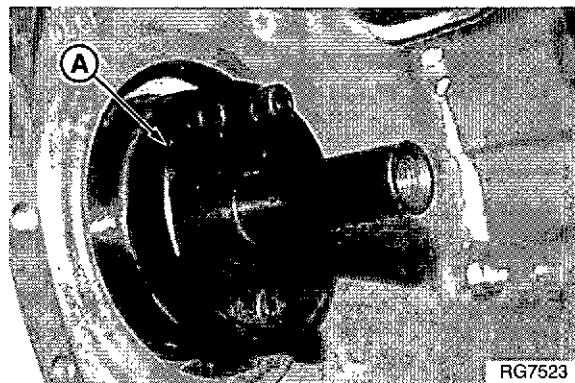
1. If not previously done, clean OD of crankshaft flange and ID of wear sleeve with trichloroethylene or equivalent just prior to application of sealant. Make sure that OD of crankshaft flange and ID of seal housing bore are free from nicks or burrs.
2. Apply a light coating of LOCTITE 680 (TY15969) Retaining Compound completely around the leading edge of crankshaft flange. Wipe away sealant that may have gotten on flywheel housing seal bore.

15
26

3. Install JT30041A Pilot (A) from the JT30040B Seal and Wear Sleeve Installer Set on end of crankshaft using two socket-head cap screws. Tighten both cap screws until they touch base of pilot then back them off approximately 1/2 turn.
4. Install JT30042 Driver (B) over JT30041A Pilot as shown until driver cross-plate bottoms on pilot. This will properly center pilot with crankshaft flange.

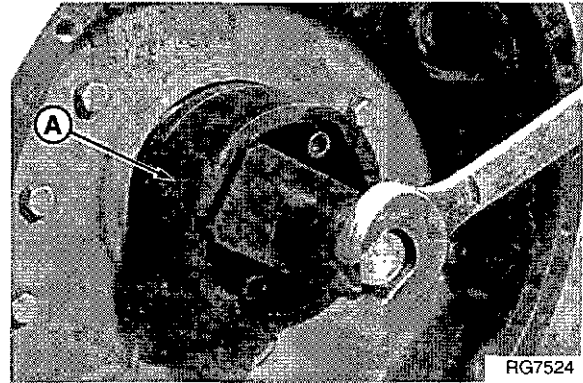
NOTE: It may be necessary to lift up on pilot to install driver to full depth over pilot and crankshaft flange.

5. Tighten two pilot socket head cap screws securely. Remove driver from pilot.



IMPORTANT: Handle the rear oil seal and sleeve assembly carefully. If wear sleeve surface is scratched, gouged or any sealant (liquid) is present, order a new seal assembly.

6. Carefully start oil seal and wear sleeve over pilot and crankshaft flange with open side of seal toward engine.
7. Attach JT30042 Driver (A) and thrust washer to the guide plate with cap screw. Tighten the cap screw until driver bottoms on pilot.
8. Remove seal driver and pilot plate. Check that seal and wear sleeve assembly is properly positioned on crankshaft flange and installed square in flywheel housing bore.

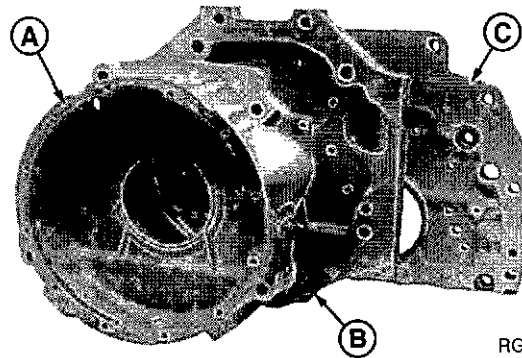


REMOVE FLYWHEEL HOUSING

1. Remove flywheel. (See REMOVE FLYWHEEL earlier in this group.)
2. Remove starter if desired. Starter and flywheel housing may be removed as an assembly.
3. Remove crankshaft rear oil seal as described earlier in this group.



CAUTION: The flywheel housing is heavy. Plan a proper handling procedure to avoid injuries.



RG4919

4. Remove flywheel housing-to-cylinder block cap screws and flywheel housing-to-oil pan cap screws. Remove flywheel housing from block.

NOTE: Illustration shows three different types of flywheel housings used:

- SAE 2, 3, and 4 housings (A).
- Standard flat housings (B).
- Special flat housings (C).

REMOVE CRANKSHAFT MAIN BEARINGS

1. Drain oil from engine crankcase and remove oil pan. (See Group 20.)
2. Remove timing gear cover and front plate. (See Group 16.)
3. Remove flywheel housing. (See Group 15.)
4. Remove connecting rods from crankshaft. (See Group 10.)

IMPORTANT: Before removing main bearing caps, check for proper torque on all main bearings.

NOTE: When crankshaft is to be removed, leave front and rear main bearing caps installed until all connecting rod caps have been removed.

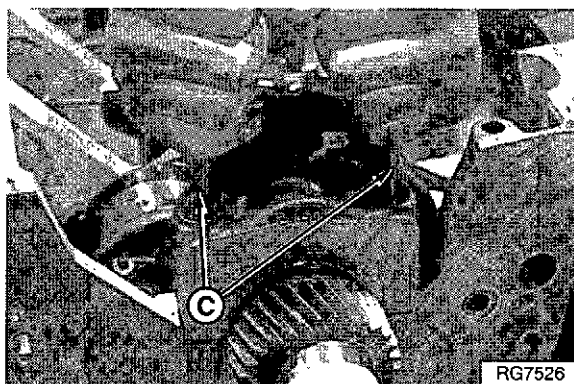
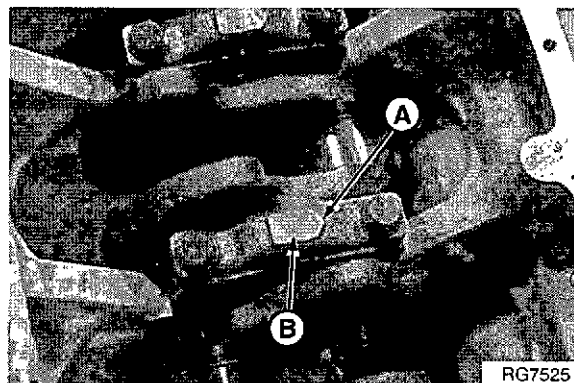
5. Check main bearing caps for arrows (A, cast in main bearing cap) and numbers (B) stamped on cap and oil pan rail. Arrow points toward camshaft side of engine.

If there are no numbers, stamp corresponding numbers on cap and oil pan rail to assure correct placement of bearing caps during reassembly.

6. Remove main bearing caps by extending cap screws (C) and forcing heads of screws together. Wiggle bearing cap back and forth while applying an upward force with cap screws until free from main bearing cap support.

IMPORTANT: Keep matched bearings with their respective main bearing cap for comparison with crankshaft journal (surface wear) from which removed.

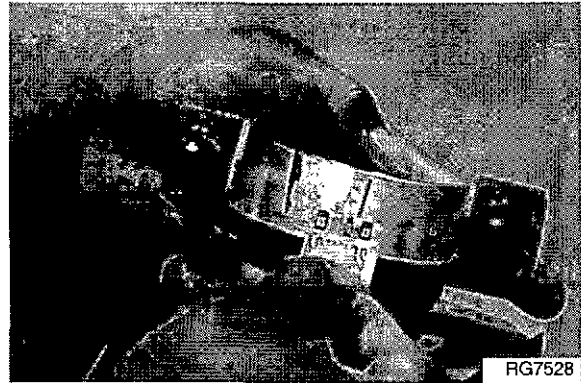
7. Visually inspect condition of bearing inserts and crankshaft main journals as bearing caps are removed.



CHECK MAIN BEARING OIL CLEARANCE

NOTE: The use of PLASTIGAGE will determine wear (crankshaft-to-bearing oil clearance) but will not determine condition of either bearing or journal surface.

1. Place a strip of PLASTIGAGE in the center of the main bearing cap (with insert) about three-fourths of the width of the bearing or on crankshaft journal to measure oil clearance.
2. Use clean (SAE30) oil on PLASTIGAGE to prevent smearing.
3. Install cap and tighten cap screws to 135 N·m (100 lb-ft).
4. Remove cap and compare width of PLASTIGAGE with scale provided on wrapper to determine clearance.



MAIN BEARING OIL CLEARANCE SPECIFICATIONS

Main Bearing-to-Journal Oil Clearance 0.041—0.109 mm
(0.0016—0.0043 in.)

REMOVE AND INSTALL CRANKSHAFT GEAR (CRANKSHAFT INSTALLED IN ENGINE)

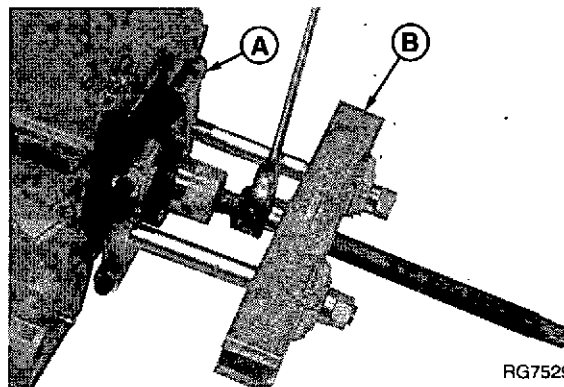
NOTE: Remove crankshaft gear for replacement only; it is not necessary to remove gear for crankshaft removal.

- **To Remove Crankshaft Gear:**

1. Lock engine at No. 1 "TDC" compression.
2. Remove timing gear cover. (See Group 16.)
3. Remove oil pump. (See Group 20.)
4. Remove upper idler gear and lower idler gear and shaft. (See Group 16.)
5. Remove front plate. (See Group 16.)

NOTE: On 4-cylinder engines it is not necessary to remove balancer shafts, if equipped.

6. Install No.1123 (D01218AA) Pulling Attachment (A) or larger onto crankshaft gear.
7. Install D01200AA Push Puller (B). Remove crankshaft gear.



RG7529

• To Install Crankshaft Gear:



CAUTION: Oil fumes or oil can ignite above 193°C (380°F). Use a thermometer and do not exceed 182°C (360°F). Do not allow a heating element to be in direct contact with the oil. Heat the oil in a well-ventilated area. Plan a safe handling procedure to avoid burns.

NOTE: Chamfered side of gear should be installed toward engine.

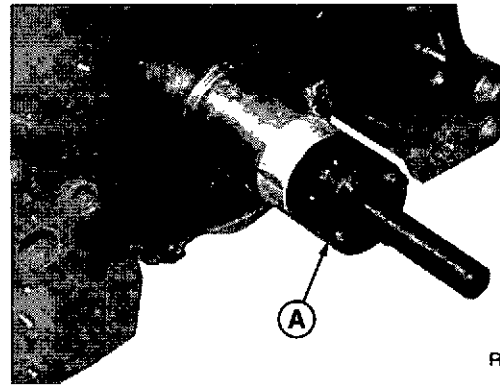
1. Heat crankshaft gear to 148°C (300°F) using either heated oil or oven heat.

IMPORTANT: If flame heat is used, be sure gear is heated uniformly around circumference. **DO NOT OVERHEAT. SEE CAUTION.** Overheating may also destroy original heat treatment of gear.

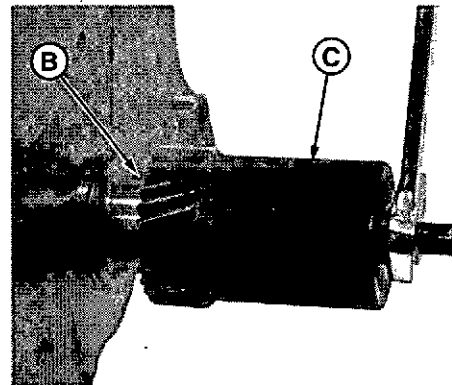
2. Install JDG954-2 Adapter (A) on nose of crankshaft. Tighten cap screws securely.

IMPORTANT: When installing gear, do not gouge or nick crankshaft flange or wear sleeve.

3. Place gear on crankshaft flange. Be sure Woodruff key (B) on crankshaft is properly aligned with keyway in gear.
4. Install JDG954-1 Installer (C) over adapter.
5. Tighten nut clockwise until gear firmly seats against crankshaft flange. Allow gear to cool before removing installer.
6. Refer to appropriate group to complete final assembly of parts removed to access crankshaft gear.



RG7533



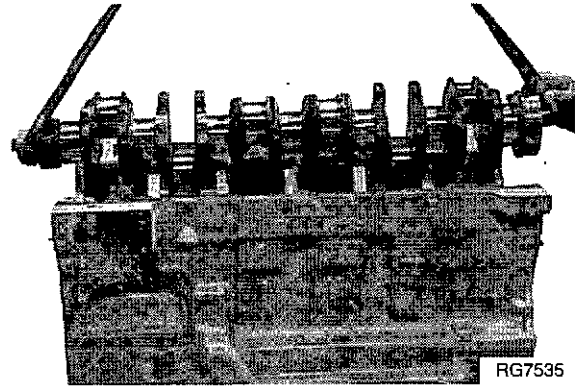
RG7534

REMOVE CRANKSHAFT

1. Remove engine front plate. (See Group 16.)
2. Remove flywheel housing and flywheel. (See REMOVE FLYWHEEL HOUSING earlier in this group.)
3. Remove main bearing caps and connecting rod caps, as described earlier in this group.



CAUTION: Crankshaft is very heavy. Plan a proper handling procedure to avoid injury.



RG7535

4. Attach a lifting sling to crankshaft. Using proper lifting equipment, carefully raise crankshaft out of cylinder block.
5. Clean crankshaft, especially oil passages, using solvent and compressed air.
6. Place crankshaft on clean V-blocks.
7. If main bearing inserts are to be replaced, remove inserts from cylinder block. Otherwise, leave bearing inserts in block until assembled ID has been measured.

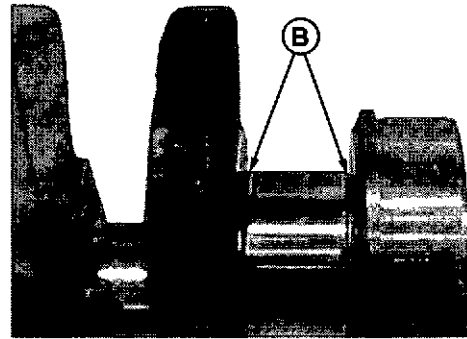
INSPECT CRANKSHAFT

NOTE: If vibration damper damage was discovered during teardown, it is recommended that the crankshaft be magna-fluxed. This will verify whether or not it has microscopic cracks or fissures. See **INSPECT VIBRATION DAMPER** earlier in this group.

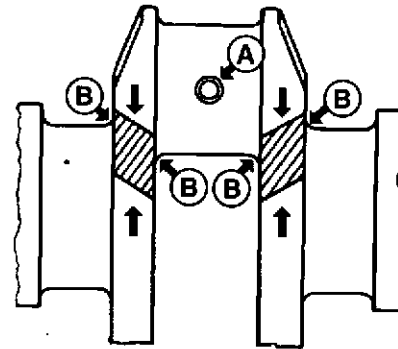
1. Thoroughly clean crankshaft. Clear restrictions from all oil passages.

IMPORTANT: Small cracks may not be visible to the eye. Use a method such as the **Fluorescent Magnetic Particle Method**. This method magnetizes the crank, employs magnetic particles which are fluorescent and glow under 'black light'. The crankshaft must be de-magnetized after inspection.

2. Inspect crankshaft for signs of load stress, cracks, scoring, or journal scratches. Replace crankshaft if cracks are found.
3. Check each journal for evidence of excessive overheating or discoloration. If either condition exists, replace crankshaft since heat treatment has probably been destroyed.
4. Inspect front crankshaft gear for cracks, chipped teeth, or excess wear. Replace gear as required.
5. Inspect the keyway for evidence of cracks or wear. Replace crankshaft as necessary.
6. Carefully inspect the rear hub of the crankshaft in the area of the wear sleeve contact surface for evidence of a rough or grooved condition. Any imperfections in this area will result in oil leakage. Slight ridges may be cleaned up with emery cloth or crocus cloth.
7. Carefully check the crankshaft for cracks in the area of rod journal holes (A) and at journal fillets (B). Replace crankshaft if any cracks are found.



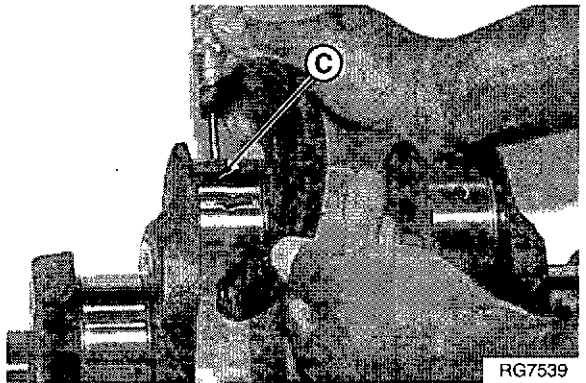
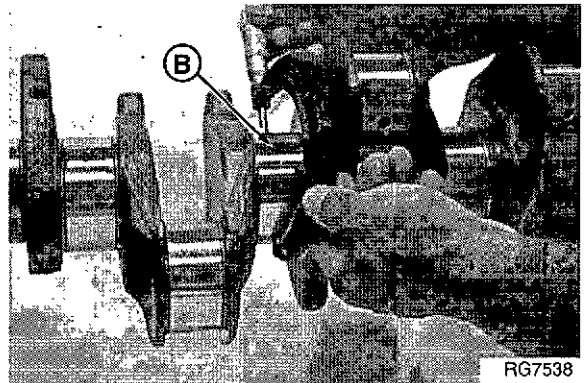
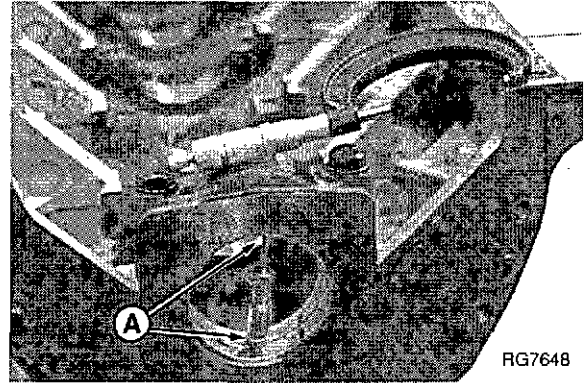
RG7536



CD7147

MEASURE ASSEMBLED MAIN BEARING ID AND OD OF CRANKSHAFT MAIN JOURNAL AND ROD JOURNAL

1. With crankshaft removed from engine, assemble main bearing caps with bearing inserts. Be sure inserts are installed correctly.
2. Tighten main bearing cap screws to 135 N·m (100 lb-ft).
3. Measure and record main bearing assembled ID (A) at several points with an inside micrometer.
4. Measure and record crankshaft main journal OD (B) and rod journal OD (C) at several points around each journal.
5. Compare measurements with specifications given below.



MAIN BEARING AND CRANKSHAFT JOURNAL SPECIFICATIONS

Main Bearing ID	79.391—79.433 mm (3.1256—3.1273 in.)
Crankshaft Journal OD	79.324—79.350 mm (3.1229—3.1240 in.)
Main Bearing-to-Journal Oil Clearance	0.041—0.109 mm (0.0016—0.0043 in.)
Maximum Main or Rod Journal Taper	0.010 mm (0.0004 in.)
Maximum Main or Rod Journal Out-of-Roundness ..	0.005 mm (0.0002 in.)

Replace or recondition crankshaft if it does not fall within above specifications.

NOTE: If an undersized crankshaft has been installed, measured dimensions will not meet above specifications. However, bearing-to-journal oil clearance must be within specification. See **CRANKSHAFT GRINDING GUIDELINES** later in this group.

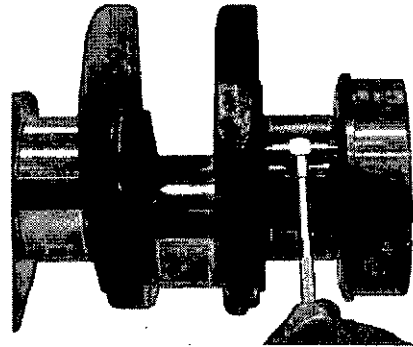
MEASURE MAIN THRUST JOURNAL WIDTH AND THRUST BEARING WIDTH

1. Measure and record crankshaft main thrust journal width.

NOTE: If crankshaft has been previously reconditioned, thrust journal width may not be within above specifications. However, oil (side) clearance must be within specification.

If crankshaft thrust journal width is not within specifications, recondition crankshaft and use an. oversize thrust washer set or install a new crankshaft.

2. Measure and record width of main thrust bearing. Oil (side) clearance between thrust bearing and thrust journal must be within specifications.

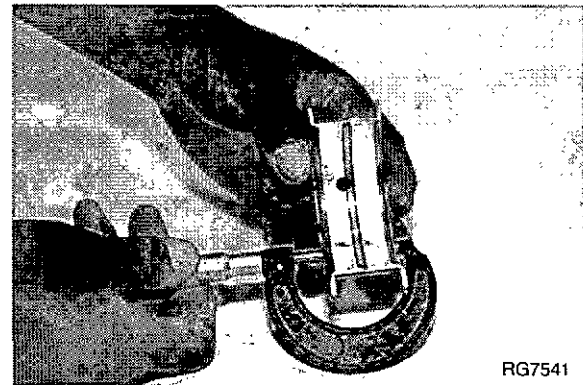


RG7540

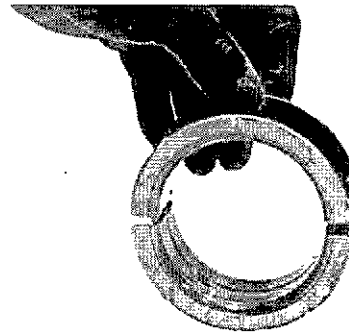
MAIN THRUST JOURNAL AND THRUST BEARING SPECIFICATIONS

Thrust Bearing Journal Width (new) 38.952—39.028 mm
(1.5335—1.5365 in.)

Thrust Bearing Overall Width 38.79—38.87 mm
(1.527—1.530 in.)



RG7541

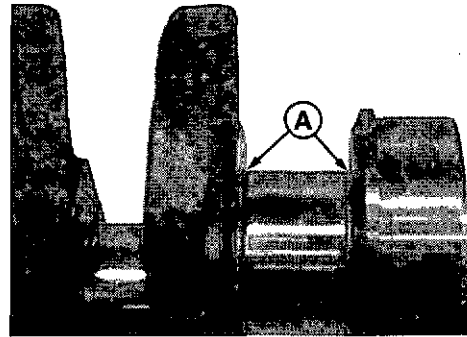


RG7542

CRANKSHAFT GRINDING GUIDELINES

IMPORTANT: Crankshaft grinding should be done **ONLY** by experienced personnel on equipment capable of maintaining crankshaft size and finish specifications.

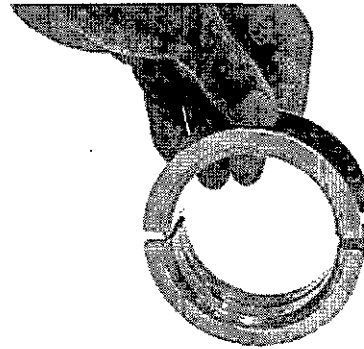
Undercut and rolled fillets (A) have taken the place of ground (tangential) fillets. **DO NOT** grind within this undercut area when undersize bearings are used.



RG7536

Crankshafts have micro-finished journal surfaces.

IMPORTANT: If undersize bearings are installed, recheck bearing-to-journal clearance. If oil clearance is not within specifications, premature wear of bearings and journals will result.



RG7542

CRANKSHAFT GRINDING GUIDELINES—CONTINUED

If the crankshaft is to be reground, use the following recommended guidelines:

1. Compare the crankshaft journal measurements taken during inspection and determine the size which the journals are to be reground.
2. Grind all main journals or all connecting rod journals to the same required size.

IMPORTANT: Care must be taken to avoid localized heating which often produces grinding cracks. Use coolant generously to cool the crankshaft while grinding. DO NOT crowd the grinding wheel into the work.

Grind crankshaft with journals turning counterclockwise, as viewed from the front end of the crankshaft. Lap or polish journals in opposite direction of grinding.

3. Polish or lap the ground surfaces to the specified finish to prevent excessive wear of the journals.

IMPORTANT: When thrust surfaces are reground and an oversize washer is used, crankshaft end play specification must be maintained.

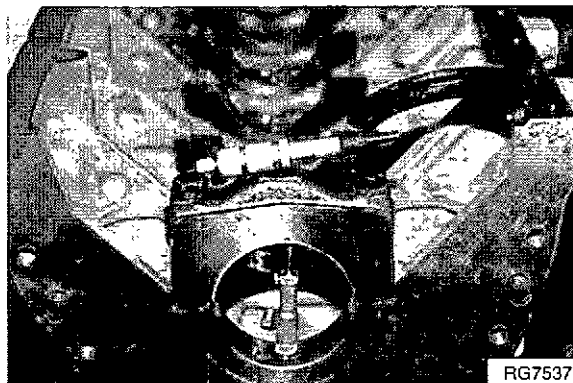
4. If the thrust surfaces of the crankshaft are worn or grooved excessively, they must be reground and polished. Care must be taken to maintain the specified radius between each thrust surface and the bearing journal. An oversize thrust washer set is available.
5. Stone the edge of all oil holes in the journal surfaces smooth to provide a radius of approximately 1.50 mm (0.060 in.).
6. When finished grinding, inspect the crankshaft by the fluorescent magnetic particle method, or other similar method to determine if cracks have originated due to the grinding operation.
7. De-magnetize the crankshaft after inspection.
8. Thoroughly clean the crankshaft and oil passages with solvent. Dry with compressed air.

CRANKSHAFT GRINDING SPECIFICATIONS

Bearing Size	Crankshaft Main Journal OD	Crankshaft Rod Journal OD
Standard	79.324—79.350 mm (3.1229—3.1240 in.)	77.800—77.826 mm (3.0629—3.0640 in.)
0.25 mm (0.010 in.) Undersize	79.074—79.100 mm (3.1131—3.1141 in.)	77.550—77.576 mm (3.0531—3.0541 in.)
Main and Connecting Rod Journal Surface Finish (AA) Lap 0.20 um (8 AA)		
Thrust Surface Finish (AA) Lap 0.40 um (16 AA)		
Thrust Bearing Journal Width 38.952—39.028 mm (1.5335—1.5365 in.)		
Direction of Crankshaft Rotation (viewed from flywheel end):		
Grinding	clockwise	
Lapping	counterclockwise	
Engine Stroke	127 mm (5.00 in.)	

MEASURE ASSEMBLED ID OF MAIN BEARING CAPS

1. Remove bearing inserts from caps and cylinder block. Keep inserts in correct order if they are to be reused.
2. Clean and inspect caps for damage. Small burrs or nicks on flat surfaces may be removed with a file. Use a medium-grit polishing cloth to dress curved bearing surfaces.
3. Install bearing caps (without bearings) in cylinder block. Tighten cap screws to 135 N·m (100 lb-ft).
4. Measure ID of bearing cap bores.

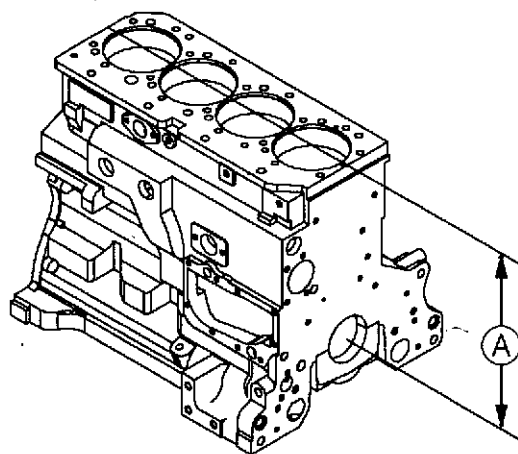


MAIN BEARING BORE SPECIFICATIONS

Main Bearing Bore Without Bearings 84.455—84.481 mm
(3.3250—3.3260 in.)

Main Bearing Bore Centerline-to-Top Deck
Distance 337.896—337.972 mm
(13.3029—13.3059 in.)

IMPORTANT: When cylinder block is line bored, dimension (A) from centerline of main bearing bore to cylinder block top deck will be changed. Piston may contact cylinder head if this dimension is less than specified above. Main bearing line boring should be done **ONLY** by experienced personnel on equipment capable of maintaining bore specifications.



5. If bearing caps are damaged or bore is not within specification, install a new cap and line bore to specified size. (See MEASURE MAIN BEARING ID AND CRANKSHAFT JOURNAL OD, earlier in this group.)

NOTE: Replacement bearing caps are supplied with unfinished bearing bore.

REMOVE, INSPECT, AND INSTALL PISTON COOLING ORIFICES

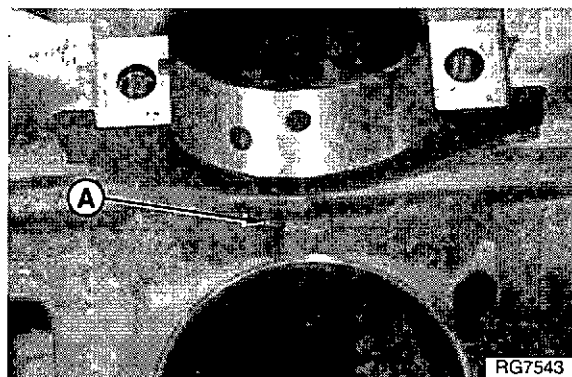
1. Remove and inspect each cooling orifice to make sure it is not plugged or damaged.
2. Use a soft wire and compressed air to clean orifice. Replace if condition is questionable.

IMPORTANT: A piston cooling orifice failure could cause damage to pistons, piston pins, rod pin bushings, and liners. If a piston cooling orifice is left out, low or no oil pressure will result.

3. Install orifices (A) in block and tighten to 11 N·m (8 lb-ft).



RG7493

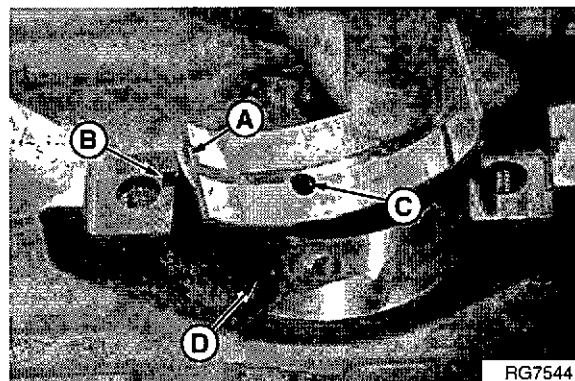


RG7543

INSTALL MAIN AND THRUST BEARING INSERTS IN BLOCK

NOTE: Lower half of bearing insert with oil hole goes in block.

1. Install main bearing inserts. Make sure that tang (A) in insert is engaged with slot (B) in the cylinder block and main bearing caps. Also make sure oil holes in insert (C) line up with oil passages in block (D).



RG7544

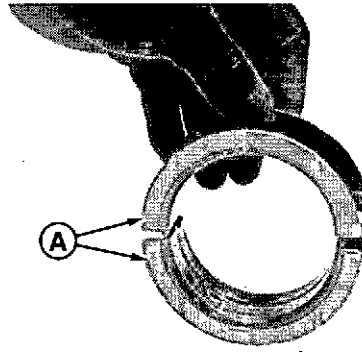
- A—Tang in Insert
- B—Slot in Block
- C—Oil Holes in Insert
- D—Oil Passages in Block

NOTE: Only two-piece bearings (A) are provided for service.

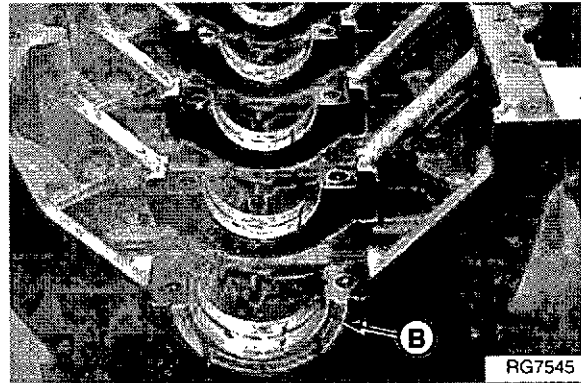
During assembly, apply a liberal coating of clean engine oil to:

- All main bearing webs in block
- Both sides of main bearing inserts and thrust bearing inserts
- Entire OD of crankshaft main bearing journal

2. Install main thrust bearing (B) in thrust web of cylinder block.



RG7542



RG7545

INSTALL CRANKSHAFT

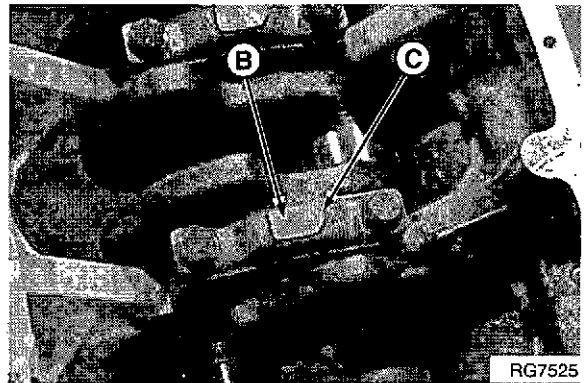
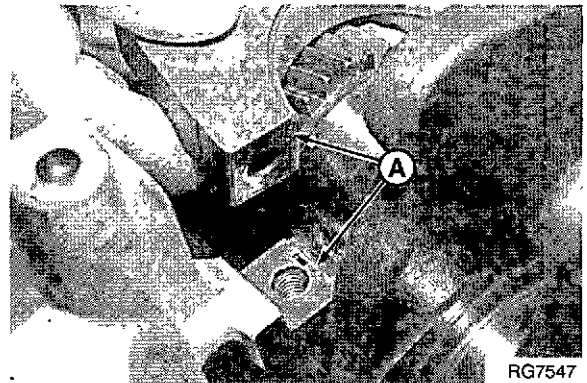
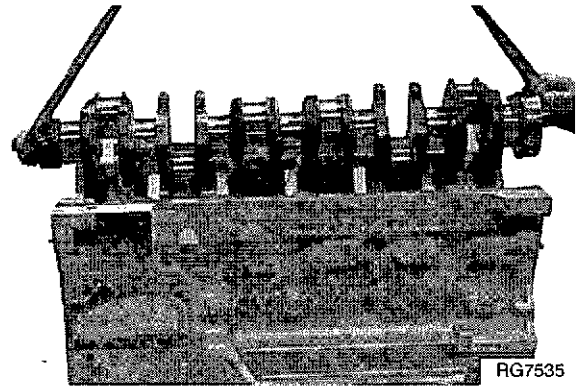


CAUTION: Crankshaft is heavy. Plan a proper lifting procedure to avoid injuries.

1. Carefully position crankshaft onto main bearing inserts using a hoist and lift sling.
2. Apply a liberal amount of clean oil to bearing insert. Dip entire main bearing cap screws in clean engine oil and position them in main bearing caps.

IMPORTANT: Make sure main bearing caps are installed in locations from which they were removed. Numbers (B) stamped on the caps should match number stamped on pan rail of block. Arrow (C) on cap must point toward camshaft side of block.

3. Install main bearing caps so bearing tang (A) in cap and cylinder block are together on same side of cylinder block.

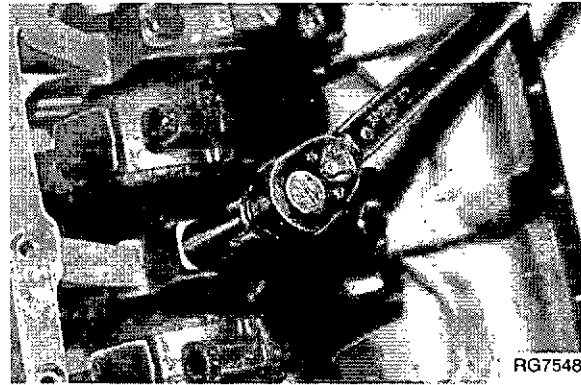


IMPORTANT: Do not use pneumatic wrench to install main bearing cap screws, as damage may occur to threads.

4. Tighten all main bearing cap screws to 135 N·m (100 lb-ft) except rear main (thrust) bearing cap screws. Tighten rear main (thrust) bearing cap screw fingertight.

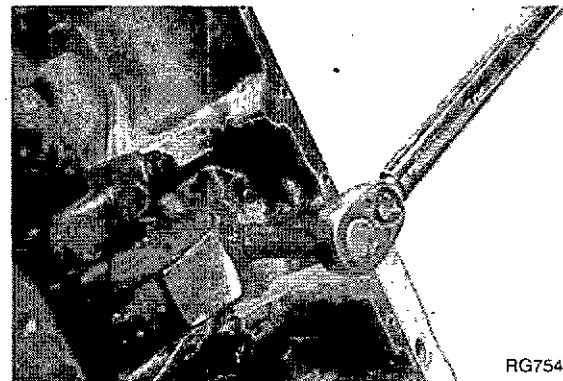
IMPORTANT: DO NOT pry on thrust washer when forcing crankshaft back and forth to align thrust bearings.

5. Before tightening rear main (thrust) bearing cap screws, align upper and lower thrust bearings. Carefully force crankshaft and main thrust bearing cap to rear using a prybar between crank throw and block web. Then, force crankshaft to front to line up thrust bearing surfaces.
6. Tighten rear main (thrust) bearing cap screws to specified torque.
7. Turn crankshaft by hand. If crankshaft does not turn easily, disassemble parts and determine the cause.



IMPORTANT: Using pneumatic wrenches to install cap screws may cause damage to the threads. Never reuse connecting rod cap screws.

8. Install connecting rod caps and bearings. Install new cap screws and tighten to specification. (See Group 10.)
9. Check crankshaft for 0.05—0.25 mm (0.002—0.010 in.) end play.

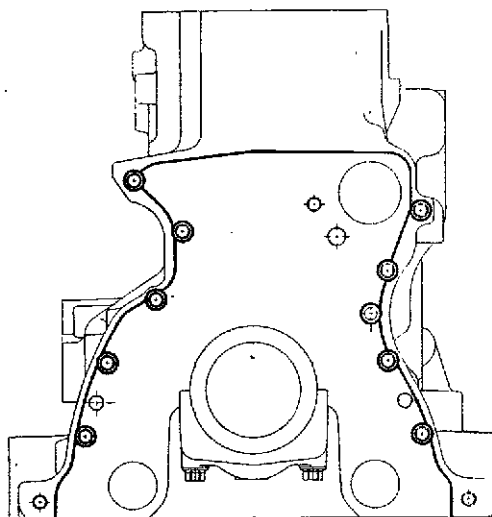


INSTALL FLYWHEEL HOUSING

1. Inspect and clean cylinder block and flywheel housing gasket surfaces using a brass scraper and/or steam cleaner. Remove any previously applied sealant.
2. Rinse well with plain water to remove all soap residue from gasket surfaces.

IMPORTANT: Surfaces to be bonded MUST BE free of oil, dirt, or cleaning agents.

3. Apply LOCTITE 515 (TY6304) General Purpose Flexible Sealant in a continuous 1.5—2 mm bead to cylinder block as shown:
4. Locate bead in the center of mating surfaces and completely encircle cap screw and dowels holes.
5. Install flywheel housing on cylinder block.



RG8055

IMPORTANT: Tighten cap screws to 125 N·m (92 lb-ft) using a cross pattern, within 10 minutes after parts are assembled.

6. Check flywheel housing seal bore run-out. If run-out exceeds specification replace housing.

FLYWHEEL HOUSING RUN-OUT SPECIFICATIONS

Maximum Permissible Run-Out of Flywheel	
Housing Seal Bore	0.152 mm (0.006 in.)

7. Install crankshaft rear oil seal assembly. (See **INSTALL CRANKSHAFT REAR OIL SEAL AND WEAR SLEEVE** earlier in this group.)

COMPLETE FINAL ASSEMBLY

Use new gaskets and O-rings during final engine assembly. Clean all engine components as necessary prior to assembly.

1. Install oil by-pass valve assembly in front face of block. (Group 20)
2. Install front plate, balancer shafts (if equipped), timing gear train, and camshaft. (Group 16)
3. Install oil pump assembly. (Group 20)
4. Install timing gear cover gasket, timing gear cover, oil pressure regulating valve assembly, and front oil seal. (Groups 15 and 16)
5. Install oil pan. (Group 20)
6. Install crankshaft pulley, or vibration damper. (Group 15)
7. Install push rods, and rocker arm assembly. (Groups 05)
8. Install fuel supply pump and injection pump. (Group 35)
9. Install starting motor.
10. Adjust valve clearance. (Group 05)
11. Install and adjust poly-vee belts. (Group 25)
12. Fill engine with clean oil and proper coolant. (Group 02)
13. Perform engine break-in. (Group 05)

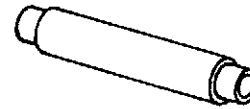
15
48

SPECIAL OR ESSENTIAL TOOLS

NOTE: Order tools according to information given in the U.S. SERVICEGARD™ Catalog or in the European Microfiche Tool Catalog (MTC).

Balancer Shaft Bushing Driver JD249

Use with JDG963 Balancer Shaft Bushing Adapter to replace balancer shaft bushings.



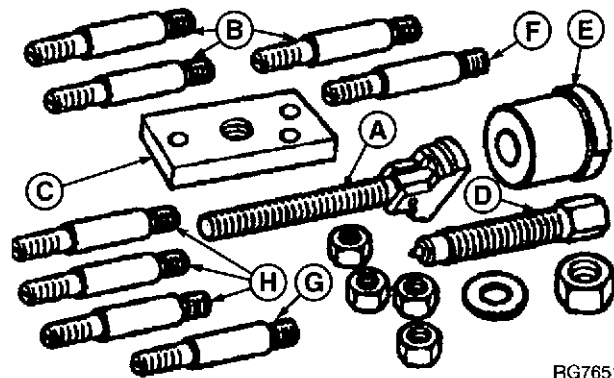
RG5120

Camshaft Bushing Service Set JDG739B

Used to remove and install front camshaft bushing.

Set consists of:

- A—Bushings Remover JDG739-1
- B—Flat Bottom Legs (3/8-16) (3) JDG739-2
- C—Removing/Installing Plate JDG739-3
- D—Bushings Installer Screw JDG739-4
- E—Bushings Installer JDG739-5B
- F—Tapered Bottom Leg (3/8-16) JDG739-6
- G—Tapered Bottom Leg (M8 x 1.25) JDG739-7*
- H—Flat Bottom Leg (M8 x 1.25) (3) JDG739-8*



RG7651

**If you already have JDG739A Camshaft Bushing Service Set, you may order JDG739-7 and JDG739-8 metric hardware individually.*

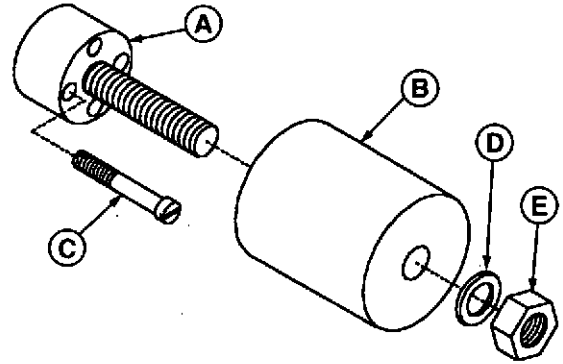
Crankshaft Gear and Front Oil Seal
 Installer JDG954

Used to install crankshaft gear either prior to, or after, installing crankshaft into engine. Also used to install front oil seal with timing gear cover installed on engine.

NOTE: JDH7 Driver may be used to install the crankshaft gear when the crankshaft is REMOVED from the engine.

Set consists of:

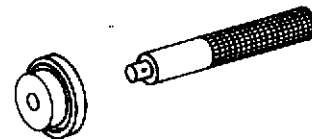
- A—Adapter JDG954-2
- B—Installer JDG954-1
- C—Special Cap Screws JDG954-3
- D—Thrust Washer 206747
- E—Hex Nut 22301



RG7442

Idler Gear Bushing Driver JD252
 Handle JDG537(OTC815)

Install idler gear bushings in idler gear, on engines with helical gears.

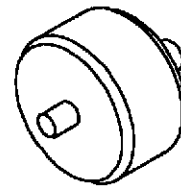


RG5111

16
2

Idler Gear Installer Pilot JDG791A

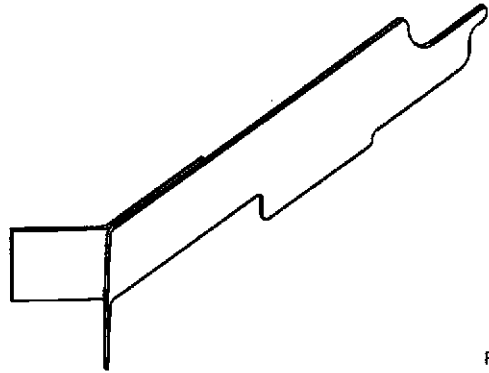
Guide upper idler gear onto idler shaft.



RG7939

Gear Timing Tool JD254A

Time camshaft gear, injection pump gear, and balancer shafts.



RG7443

Seal Remover JDG22

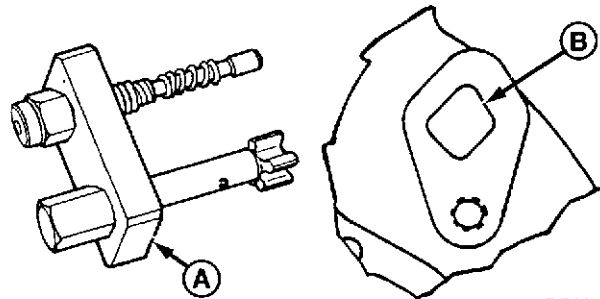
Remove crankshaft rear oil seal without removing flywheel housing.



RG5109

Flywheel Turning Tool (A) JD281A

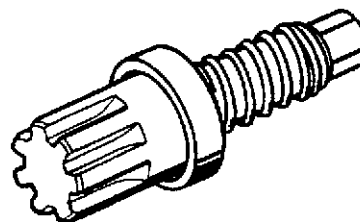
Used on engines with 142-tooth flywheel ring gear and a diamond-shaped tool guide bore (B) in flywheel housing. Tool has its own spring-loaded timing pin which threads into flywheel housing.



RG6252

Flywheel Turning Tool JDG820

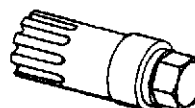
Used to rotate flywheel on engine, with 129-tooth flywheel ring gear and a 29.9 mm (1.18 in.) ID flywheel housing guide bore diameter, to check damper radial runout and time engine. JDE81-1 may be used also if JDG820 is not available.



RG7056

Flywheel Turning Tool JDE83

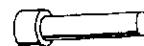
Used to rotate flywheel on engines with 142-tooth flywheel ring gear and a 26.5 mm (1.04 in.) ID flywheel housing guide bore diameter. Use with JDE81-4 Timing Pin.



RG6251

Timing Pin JDE81-4

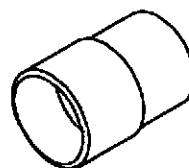
Lock engine at TDC when installing injection pump or timing valve train. Use with JDG820, JDE81-1, or JDE83 Flywheel Turning Tool.



RG5068

Balancer Shaft Bushing Adapter JDG963

Use with JD249 Balancer Shaft Bushing Driver to remove and install balancer shaft bushings.



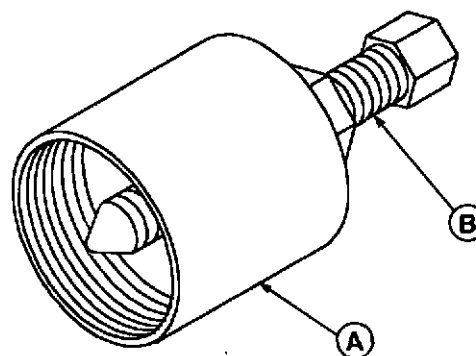
RG7940

Front Wear Sleeve Puller JDG992

Used to remove front wear sleeve with timing gear cover installed.

Set consists of:

- A—Threaded Collet JDG992-1
- B—Forcing Screw 311099



RG8085

SERVICE EQUIPMENT AND TOOLS

NOTE: Order tools from the U.S. SERVICEGARD™ Catalog or from the European Microfiche Tool Catalog (MTC). Some tools may be available from a local supplier.

Name	Use
D15001NU Magnetic Follower Holder Kit	Hold cam followers when removing and installing cam.
JD247 Balancer Shaft Holding Tool	Hold balancer shaft while pressing gear on shaft.
TORX® Drive Set	Remove and install front plate mounting hardware.
JDG966 Crankshaft Front/Rear Rotation Adapter	Rotate crankshaft from front and rear with flywheel removed.

TORX is a registered trademark of Camcar/Textron

OTHER MATERIAL

Number	Name	Use
LOCTITE 680 (TY15969)	Retaining Compound	Front crankshaft wear sleeve (ID).
LOCTITE 515 (TY6304)	Flexible Sealant	Apply to front face of cylinder block before installing front plate.
TY6333 or TY6347	High Temperature Grease	Coat cam followers, camshaft lobes, journals, and bushings during installation. Coat idler gear, bushing, and shaft during installation.

CAMSHAFT, BALANCER SHAFTS, AND TIMING GEAR TRAIN SPECIFICATIONS

ITEM	SPECIFICATION	WEAR LIMIT
Camshaft Journal OD	55.872—55.898 mm (2.1997—2.2007 in.)	55.85 mm (2.199 in.)
Camshaft Bore ID:		
*Front (No. 1) in Block (without bushing)	59.961—59.987 mm (2.3607—2.3617 in.)	_____
Front (No. 1) in Block (with bushing)	55.961—55.987 mm (2.2031—2.2042 in.)	_____
All Except No. 1	55.986—56.012 mm (2.2042—2.2052 in.)	_____
Camshaft Journal-to-Bushing Oil Clearance:		
No. 1 Bore with Bushing	0.063—0.115 mm (0.0025—0.0045 in.)	_____
All Except No. 1 Bore	0.088—0.140 mm (0.0035—0.0055 in.)	_____
Camshaft End Play	0.08—0.23 mm (0.003—0.009 in.)	0.38 mm (0.015 in.)
Camshaft Thrust Plate Thickness	3.96—4.01 mm (0.156—0.158 in.)	3.83 mm (0.151 in.)
Camshaft Thrust Plate Clearance	0.08—0.23 mm (0.03—0.009 in.)	_____
Camshaft Follower OD	31.61—31.64 mm (1.245—1.246 in.)	_____
Camshaft Follower Bore Diameter in Cylinder Block	31.70—31.75 mm (1.248—1.250 in.)	_____
Camshaft Follower-to-Bore Clearance	0.06—0.13 mm (0.002—0.005 in.)	_____
Valve Lift at 0.00 mm (in.) Clearance:		
Intake Valve	11.56—12.37 mm (0.455—0.487 in.)	11.13 mm (0.438 in.)
Exhaust Valve	11.28—12.12 mm (0.444—0.477 in.)	10.85 mm (0.427 in.)
Camshaft Lobe Height:		
Intake Lobe	6.93—7.42 mm (0.273—0.292 in.)	6.68 mm (0.263 in.)
Exhaust Lobe	6.76—7.26 mm (0.266—0.286 in.)	6.50 mm (0.256 in.)

**CAMSHAFT, BALANCER SHAFTS, AND TIMING GEAR TRAIN SPECIFICATIONS—
CONTINUED**

ITEM	SPECIFICATION	WEAR LIMIT
Balancer Shaft Bearing Journal Diameter	40.135—40.161 mm (1.5801—1.5811 in.)	_____
Balancer Shaft Bushing ID	40.177—40.237 mm (1.5818—1.5841 in.)	_____
Bushings-to-Journal Clearance	0.016—0.102 mm (0.0006—0.0040 in.)	_____
Cylinder Block Bore Diameter for Balancer Shaft Bushings (Standard)	43.262—43.288 mm (1.7032—1.7042 in.)	_____
Balancer Shaft Thrust Plate Thickness	2.97—3.02 mm (0.117—0.119 in.)	_____
Balancer Shaft End Play	0.05—0.26 mm (0.002—0.010 in.)	_____
Upper Idler Gear Shaft OD	69.757—69.777 mm (2.7463—2.7471 in.)	_____
Upper Idler Gear Bushing ID	69.802—69.832 mm (2.7481—2.7493 in.)	_____
Lower Idler Gear Shaft OD	44.437—44.463 mm (1.7495—1.7505 in.)	_____
Lower Idler Gear Bushing ID	44.489—44.539 mm (1.7515—1.7535 in.)	_____
Upper and Lower Idler Gear End Play	0.095—0.145 mm (0.0037—0.0057 in.)	_____
Spring Pin Protrusion from Shaft: On Lower and Upper Idler Gear	2.79—4.83 mm (0.11—0.19 in.)	_____
Oil Clearance: Upper Idler Gear Bushing-to-Shaft	0.075—0.125 mm (0.0030—0.0049 in.)	_____
Lower Idler Gear Bushing-to-Shaft	0.026—0.102 mm (0.0010—0.0040 in.)	_____

**CAMSHAFT, BALANCER SHAFTS, AND TIMING GEAR TRAIN SPECIFICATIONS—
CONTINUED**

ITEM	SPECIFICATION	WEAR LIMIT
Timing Gear Backlash:		
Upper Idler Gear-to-Camshaft Gear	0.077—0.412 mm (0.0030—0.0162 in.)	_____
Camshaft Gear-to-Auxiliary Drive Gear	0.053—0.368 mm (0.0021—0.0145 in.)	_____
Upper Idler Gear-to-Injection Pump Gear	0.077—0.412 mm (0.0030—0.0162 in.)	_____
Upper Idler Gear-to-Crankshaft Gear	0.065—0.322 mm (0.0025—0.0127 in.)	_____
Lower Idler Gear-to-Crankshaft Gear	0.067—0.336 mm (0.0026—0.0132 in.)	_____
Oil Pump-to-Balancer Shaft Gear*	0.065—0.358 mm (0.0025—0.0141 in.)	_____
Lower Idler Gear-to-Oil Pump Gear	0.081—0.342 mm (0.0032—0.0135 in.)	_____
Lower Idler Gear-to-Balancer Shaft Gear*	0.071—0.359 mm (0.0028—0.0141 in.)	_____
Fuel Supply Pump Camshaft Lobe Diameter	42.67—42.93 mm (1.680—1.690 in.)	_____
Fuel Supply Pump Push Rod OD	9.891—9.917 mm (0.3894—0.3904 in.)	_____
Fuel Supply Pump Push Rod Bore ID in Block	10.00—10.05 mm (0.3937—0.3957 in.)	_____

* 4-cylinder engines only

**CAMSHAFT, BALANCER SHAFTS, AND TIMING GEAR TRAIN SPECIFICATIONS—
CONTINUED**

	TORQUES
Camshaft Thrust Plate-to-Cylinder Block	35 N·m (26 lb-ft)
Balancer Shaft Thrust Plate-to-Cylinder Block	35 N·m (26 lb-ft)
Front Plate-to-Cylinder Block:	
Flat Head (TORX) Screws (no washers)	25 N·m (18 lb-ft)
Studs	35 N·m (26 lb-ft)
Oil Pump Drive Gear-to-Shaft, Retaining Nut (Staked)	50 N·m (37 lb-ft)
Upper Idler Gear Cap Screw	80 N·m (59 lb-ft)
Lower Idler Gear Cap Screw	80 N·m (59 lb-ft)
Oil Pressure Regulating Valve in Timing Gear Cover	95 N·m (70 lb-ft)
Timing Gear Cover-to-Front Plate and Cylinder Block	35 N·m (26 lb-ft)
Auxiliary Gear Cover-to-Timing Gear Cover	95 N·m (70 lb-ft)
Oil Pan-to-Timing Gear Cover	35 N·m (26 lb-ft)
Oil Pan-to-Cylinder Block	35 N·m (26 lb-ft)
Oil Pan-to-Flywheel Housing	35 N·m (26 lb-ft)
Rotary Fuel Injection Pump Drive Gear-to-Shaft, Retaining Nut:	
—Stanadyne	
Model DB2	122 N·m (90 lb-ft)
Model DB4	203 N·m (150 lb-ft)
—Lucas	
Model DP201	122 N·m (90 lb-ft)
Model DP203	81 N·m (60 lb-ft)
Rotary Fuel Injection Pump-to-Front Plate	27 N·m (20 lb-ft)
In-Line Injection Pump Drive Gear-to-Pump Hub	48 N·m (35 lb-ft)
In-Line Injection Pump-to-Front Plate	70 N·m (52 lb-ft)
In-Line Injection Pump Drive Gear Cover, cap screws	2 N·m (18 lb-in.)
Oil Fill Tube-to-Cylinder Block	35 N·m (26 lb-ft)
Tachometer (Magnetic Pick-up) Sensor	20 N·m (15 lb-ft)
Pulley or Damper with Pulley-to-Crankshaft*:	
1st Step	60 N·m (44 lb-ft)
Final Step	80 N·m (59 lb-ft)
Rocker Arm Cover	35 N·m (26 lb-ft)
Water Pump-to-Timing Gear Cover	16 N·m (12 lb-ft)

* Tighten cap screws in a cross sequence.

MEASURE VALVE LIFT

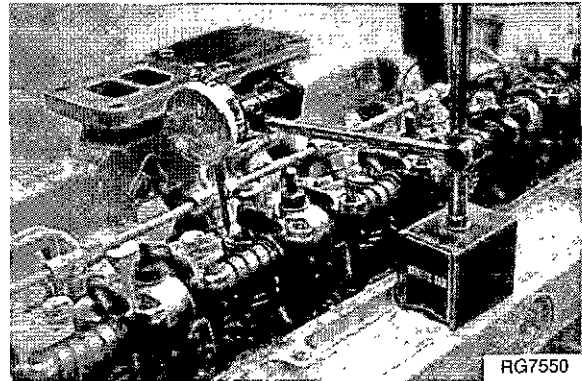
IMPORTANT: For a more accurate measurement, measure valve lift at 0.00 mm (in.) rocker arm-to-valve tip clearance.

NOTE: Measuring valve lift provides an indication of wear on camshaft lobes and cam followers or push rods.

1. Remove rocker arm cover.
2. Lock No. 1 piston at TDC compression stroke and install JDE81-4 Timing Pin in flywheel.

See CHECK AND ADJUST VALVE CLEARANCE in Group 05 for engine valve locations:

3. Set rocker arm-to-valve tip clearance to 0.00 mm (in.) for:
 - No. 1 and 3 exhaust and No. 1 and 2 intake valves on 4-cylinder engines.
 - No. 1, 3, and 5 exhaust and No. 1, 2, and 4 intake valves on 6-cylinder engines.
4. Place dial indicator tip on top of valve rotator. Preload indicator tip and set dial at 0.0 mm (in.).
5. Remove timing pin from flywheel and manually rotate engine one full revolution (360°) in running direction.



6. Observe dial indicator reading as valve is moved to full open. Record maximum reading and compare with specifications given below.

VALVE LIFT SPECIFICATION
[At 0.00 mm (in.) Valve Clearance]

Intake Valves	11.56—12.37 mm (0.455—0.487 in.)
Wear Limit	11.13 mm (0.438 in.)
Exhaust Valves	11.28—12.12 mm (0.444—0.477 in.)
Wear Limit	10.85 mm (0.427 in.)

7. If valve lift on all valves is within specifications, adjust valve lash to specified clearance. (See CHECK AND ADJUST VALVE CLEARANCE in Group 05.)

If valve lift on one or more valves is not within specification, remove and inspect entire valve train and camshaft.

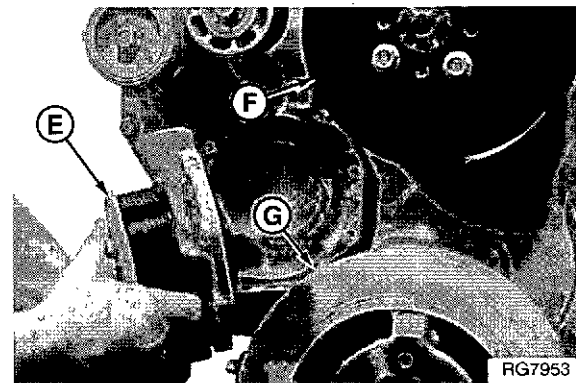
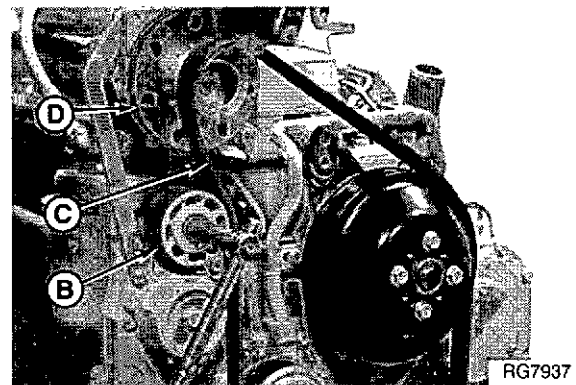
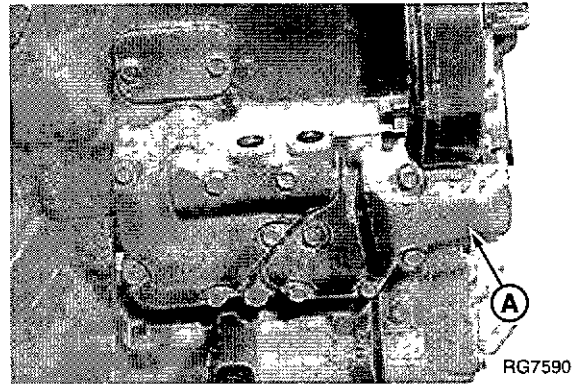
8. Rotate engine one full revolution (360°). Lock engine at:
 - TDC No. 4 compression stroke for 4-cylinder engines.
 - TDC No. 6 compression stroke for 6-cylinder engines.
9. Set rocker arm-to-valve tip clearance to 0.0 mm (in.) for:
 - No. 2 and 4 exhaust and No. 3 and 4 intake valves on 4-cylinder engines.
 - No. 2, 4, and 6 exhaust and No. 3, 5, and 6 intake valves on 6-cylinder engines.
10. Repeat steps 4—7.

16
12

REMOVE TIMING GEAR COVER

NOTE: It is not necessary to remove water pump pulley, water pump, or belt tightener when removing timing gear cover.

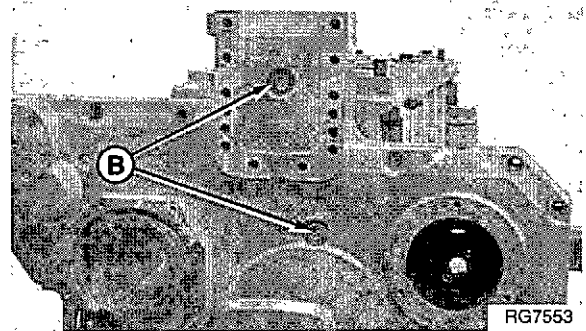
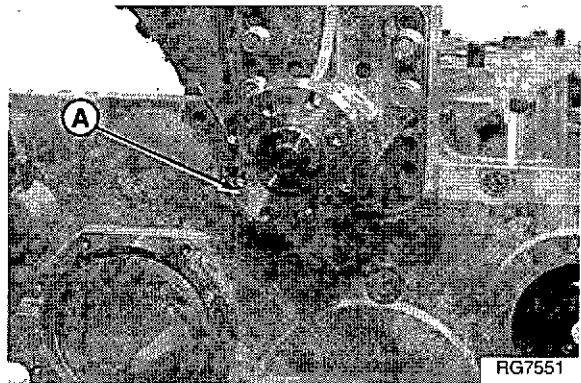
1. Drain oil from engine crankcase.
2. Remove fan.
3. Remove oil pan.
4. Remove oil cooler-to-water manifold elbow (A) at front plate.
5. Release fan belt tensioner (B) and remove fan belt (C).
6. Remove alternator (D) and alternator mounting bracket.
7. Remove water pump (E), if desired.
8. Remove fan pulley (F).
9. Remove crankshaft pulley or damper (G). (See Group 15.)



- A—Oil Cooler-to-Water Manifold Elbow
- B—Fan Belt Tensioner
- C—Fan Belt
- D—Alternator
- E—Water Pump
- F—Fan Pulley
- G—Crankshaft Pulley or Damper

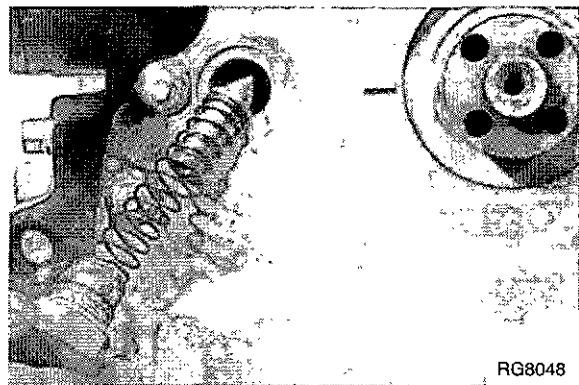
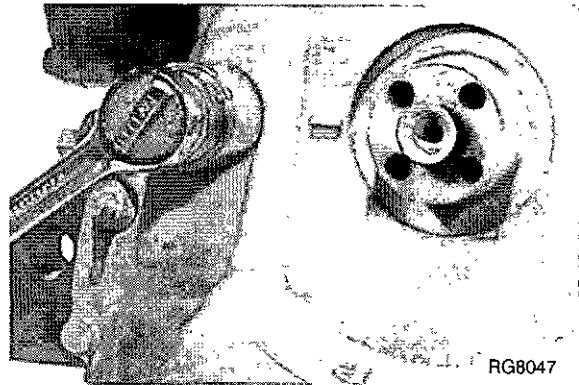
10. Remove adjustable fan drive assembly (A).

11. Remove cap screws (B).

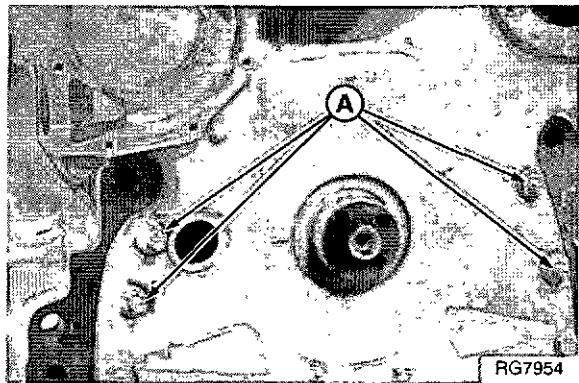


16
14

12. Unscrew oil pressure regulating valve plug.
Remove spring and valve.



13. Remove auxiliary drive cover and gears, if equipped, as described later in this group.
14. Remove wear sleeve. (See Group 15.)
15. Remove timing gear cover-to-cylinder block stud nuts and washers (A). Remove cover.
16. Remove oil seal from timing gear cover.

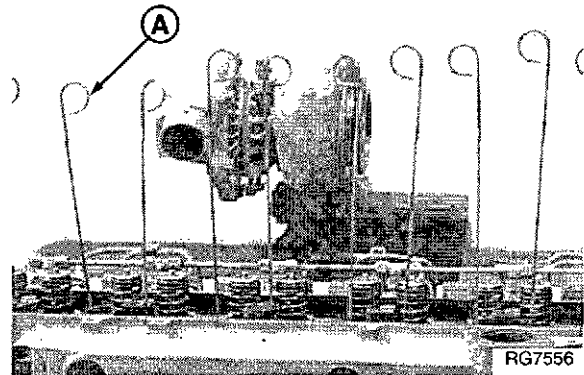


REMOVE AND INSTALL CAMSHAFT BUSHING WITH FRONT PLATE INSTALLED

NOTE: A camshaft bushing is installed in front (No. 1) camshaft bore only. The front plate has a chamfered edge allowing camshaft bushing removal and installation with the front plate installed.

- **Remove camshaft bushing:**

1. Set engine at No. 1 "TDC" compression.
2. On turbocharged engines, disconnect the turbocharger oil inlet line. (See DISCONNECT TURBOCHARGER OIL INLET LINE in Group 03.)
3. Remove timing gear cover, as described earlier in this group.
4. Remove rocker arm cover and rocker arm assembly. (See procedure in Group 05.)
5. Remove push rods. (See procedure in Group 05.)
6. On engines with rotary fuel injection pumps, remove fuel supply pump. (See Group 35.)
7. Revolve engine to an angle where camshaft followers fall away from camshaft or use D15001NU Magnetic Holding Set (A) to hold followers.



8. Remove camshaft. (See procedure later in this group.)

IMPORTANT: Engine **MUST** remain in a position where camshaft followers rest against cylinder head or are held in up position by magnetic holders so that followers do not fall into engine crankcase. If camshaft followers fall into crankcase, cylinder head removal will be required.

9. Remove countersunk TORX® cap screw (A). Install JDG739-7 (M8 x 1.25) tapered bottom leg (B) from JDG739B Camshaft Bushing Service Kit into hole that has chamfered screw and star washer.

IMPORTANT: Block must be replaced if camshaft bore is damaged. Be careful when removing or installing bushing.

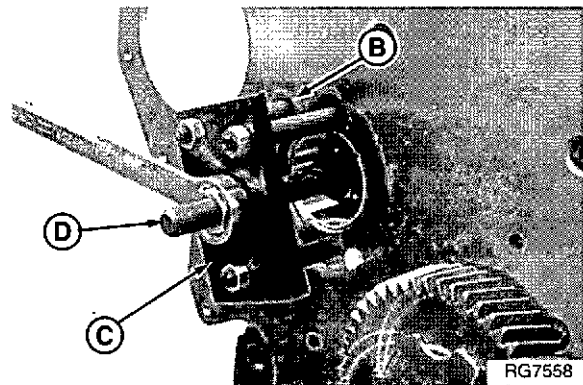
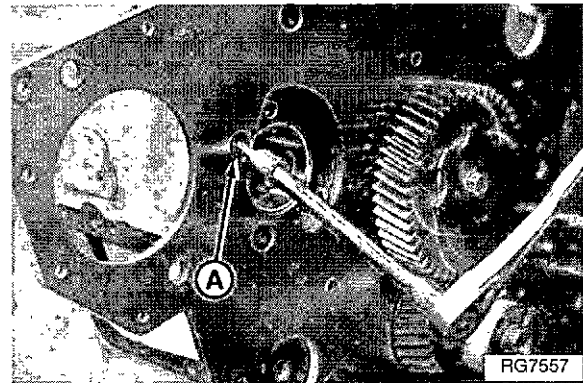
10. Install JDG739-8 (M8 x 1.25) flat bottom legs and JDG739-3 Removing/Installing Plate (C) to cylinder block so plate is parallel with front plate and centered over camshaft bore. Tighten legs and hex nuts securely.

11. Insert JDG739-1 Bushing Remover into camshaft bore so puller pilots in bushing ID and JDG739-4 Bushing Installer Screw (D) extends through plate.

IMPORTANT: Cylinder block bore may be damaged if puller is not properly piloted in bushing. Be sure puller is properly piloted before pulling bushing.

12. Install thrust washer and hex nut. Tighten hex nut until bushing is free of block bore. Remove puller and discard bushing.

13. Clean and inspect bore in cylinder block. If bore is damaged, replace cylinder block.

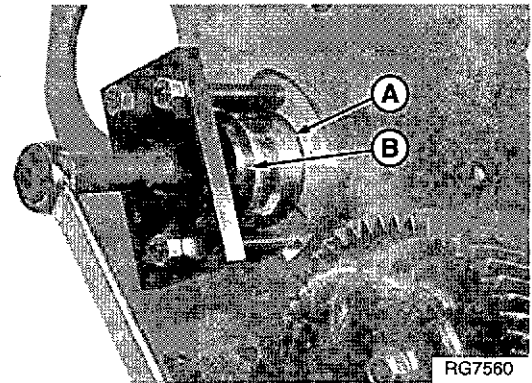
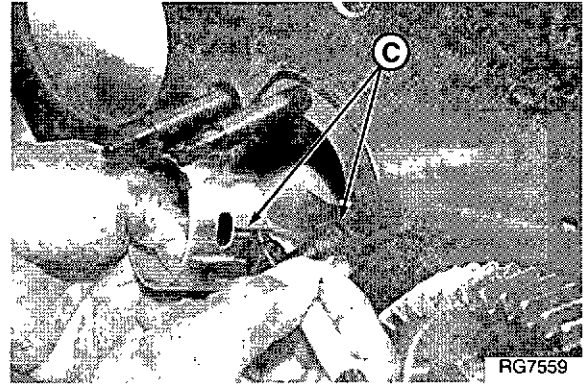


A—TORX® Cap Screw
 B—JDG739-7 Tapered Bottom Leg (8 mm)
 C—JDG739-3 Removing/Installing Plate
 D—JDG739-4 Bushing Installer Screw

- **Install camshaft bushing:**

IMPORTANT: Bushings must be installed so oil supply hole in bushing aligns with oil drilling in block bore.

1. Mark orientation of oil supply hole (C) on front face of block and on bushing to help with bushing alignment during installation.
2. Apply TY6333 High-Temperature Grease to ID and OD of new bushing (A), and to ID of bushing bore. Slide bushing onto JDG739-5B Bushing Installer (B) so notched end of bushing will be toward front end of engine when installed.
3. Thread JDG739-4 Bushing Installer Screw into JDG739-3 Removing/Installing Plate. With bushing started, square in bore and oil hole aligned, tighten forcing screw until flange of bushing driver bottoms against face of block.
4. Remove bushing tool from cylinder block and check oil supply hole for correct alignment. If holes are not aligned, remove and discard bushing. Install a new bushing.



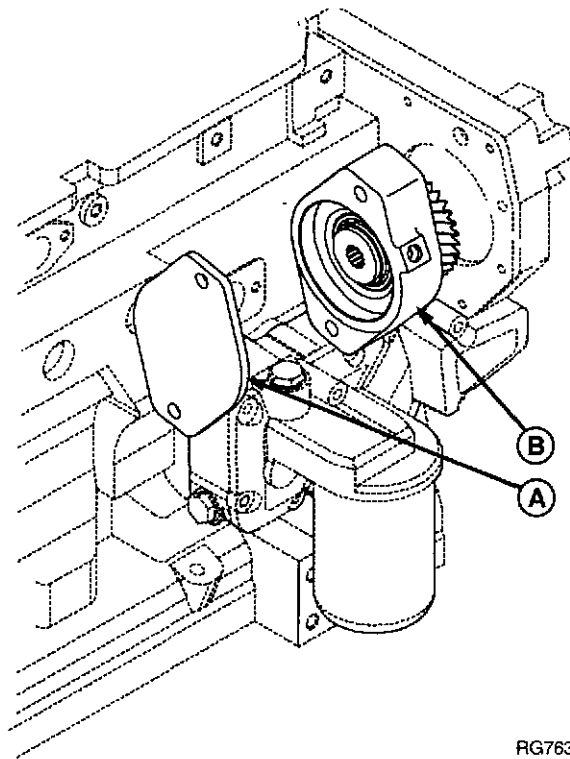
REMOVE, INSPECT, AND INSTALL CAMSHAFT GEAR-DRIVEN AUXILIARY DRIVE—IF EQUIPPED

NOTE: Various auxiliary drive options are available; removal and installation of all options are similar. The auxiliary drive is integrated into the engine front timing gear cover.

1. Remove auxiliary drive gear cover (A).
2. Clean and inspect cover for cracks or damage.
3. Remove auxiliary drive assembly (B).

NOTE: Auxiliary drive assembly is not repairable; install a new assembly if damage is detected. Refer to CTM67 - OEM Accessories for additional service information.

4. Inspect for cracked housing, worn or damaged bearings, damaged gear or spline.
5. Replace auxiliary drive assembly as needed.
6. Install cover and tighten cap screws or nuts to 95 N·m (70 lb·ft).



RG7634

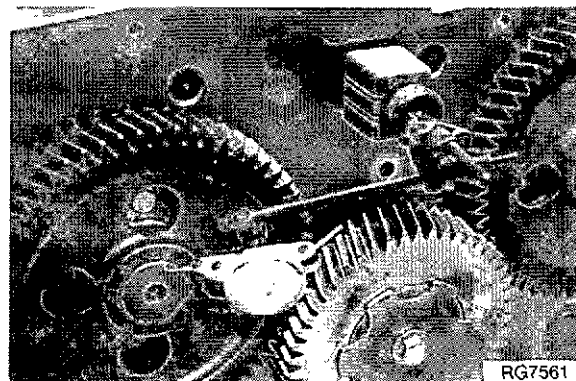
MEASURE CAMSHAFT END PLAY

Measure camshaft end play.

CAMSHAFT END PLAY SPECIFICATIONS

Camshaft end play 0.08—0.23 mm
(0.003—0.009 in.)

If end play is excessive, check thrust plate thickness with camshaft removed. (See MEASURE CAMSHAFT THRUST PLATE CLEARANCE, later in this group.)



RG7561

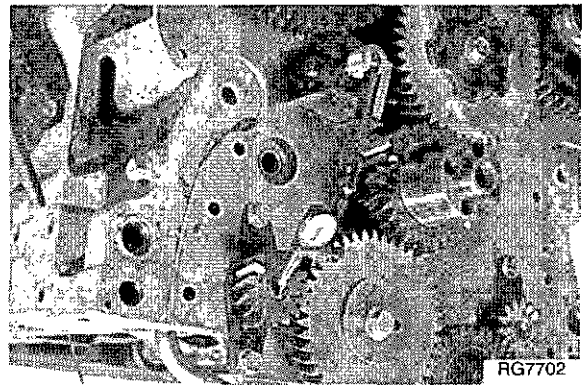
MEASURE BALANCER SHAFT END PLAY (4-CYLINDER ENGINES)

Measure balancer shaft end play.

BALANCER SHAFT END PLAY SPECIFICATIONS

Balancer Shaft End Play 0.05—0.26 mm
(0.002—0.010 in.)

If balancer shaft end play exceeds specifications, check thrust plate thickness. (See INSPECT BALANCER SHAFT GEARS AND THRUST PLATES, later in this group.)



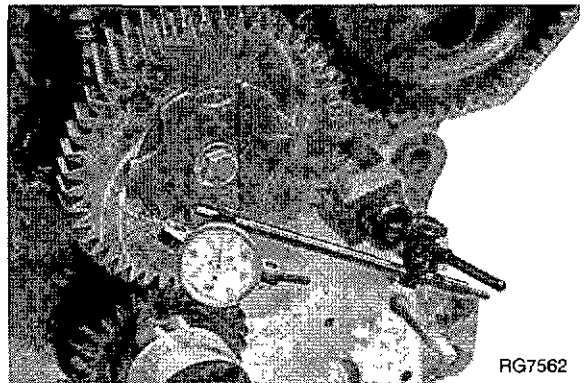
MEASURE IDLER GEAR END PLAY

Check end play of upper and lower idler gears.

IDLER GEAR END PLAY SPECIFICATIONS

Upper and Lower Idler Gear End Play 0.095—0.145 mm
(0.0037—0.057 in.)

If idler gear end play does not meet specifications, check idler gear, idler shaft, and thrust washer for wear. (See MEASURE IDLER GEAR, BUSHING AND SHAFT later in this group.)



16
20

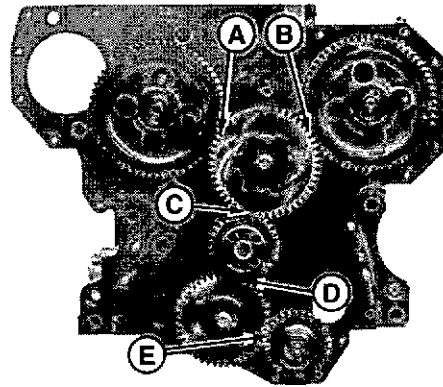
MEASURE TIMING GEAR BACKLASH

NOTE: All gears have helical cut teeth.

1. Measure timing gear backlash. Compare against the following specifications.

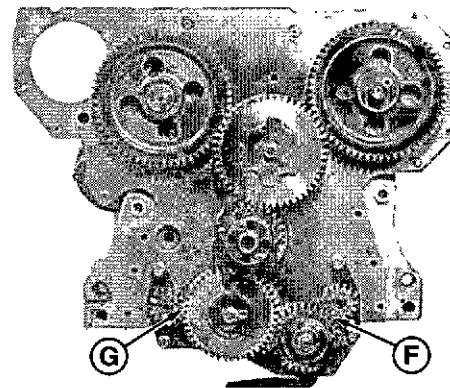
TIMING GEAR BACKLASH SPECIFICATIONS

Camshaft-to-Upper Idler (A)	0.077—0.412 mm (0.0030—0.0162 in.)
Injection Pump-to-Upper Idler (B)	0.077—0.412 mm (0.0030—0.0162 in.)
Upper Idler-to-Crankshaft (C)	0.065—0.322 mm (0.0025—0.0127 in.)
Crankshaft-to-Lower Idler (D)	0.067—0.336 mm (0.0026—0.0132 in.)
*Balancer Shaft-to-Oil Pump (F)	0.065—0.358 mm (0.0025—0.0141 in.)
Oil Pump-to-Lower Idler (E)	0.081—0.342 mm (0.0032—0.0135 in.)
*Lower Idler-to-Balancer Shaft (G)	0.071—0.359 mm (0.0028—0.0141 in.)
Camshaft-to-Auxiliary Drive (not shown)	0.053—0.368 mm (0.0021—0.0145 in.)



RG7530

6-Cylinder Engine



RG7703

4-Cylinder Engine

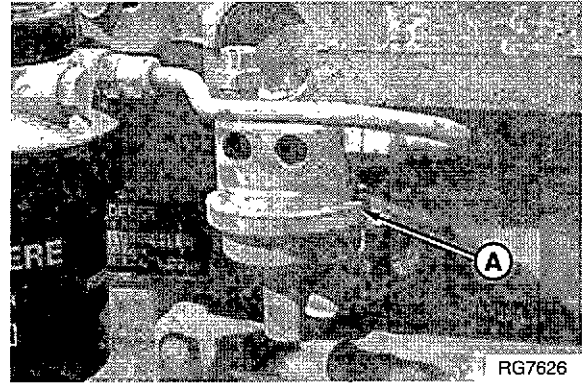
- A—Camshaft Gear-to-Upper Idler Gear
- B—Injection Pump Gear-to-Upper Idler Gear
- C—Upper Idler Gear-to-Crankshaft Gear
- D—Crankshaft Gear-to-Lower Idler Gear
- E—Oil Pump Gear-to-Lower Idler Gear
- F—Balancer Shaft Gear-to-Oil Pump Gear*
- G—Lower Idler Gear-to-Balancer Shaft Gear*

* 4-cylinder engine only

REMOVE CAMSHAFT

NOTE: It is not necessary to remove cylinder head from engine for camshaft removal. If push rods are bent or show excessive scuffing, it may be necessary to remove cylinder head for inspection of block, head, cam followers. (See REMOVE CYLINDER HEAD in Group 05.)

1. Drain engine oil and coolant, if not previously done.
2. Measure valve lift. (See MEASURE VALVE LIFT, earlier in this group.)
3. Remove rocker arm assembly and push rods. (See Group 05.)
4. Remove timing gear cover. (See REMOVE TIMING GEAR COVER, earlier in this group.)
5. Remove camshaft activated fuel supply pump (A). (See REMOVE FUEL SUPPLY PUMP in Group 35.)

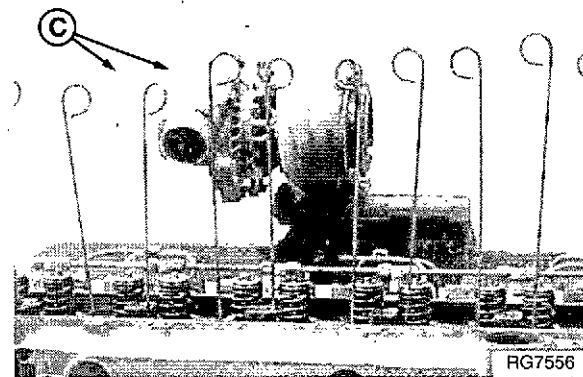
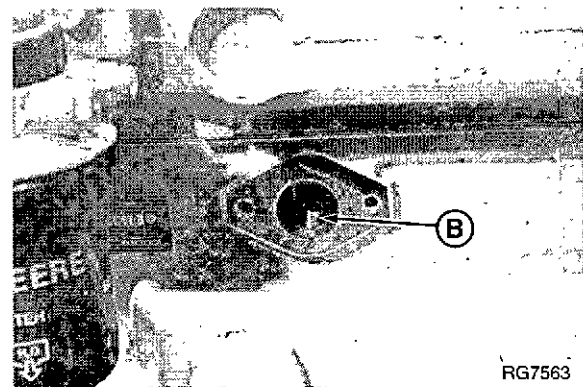
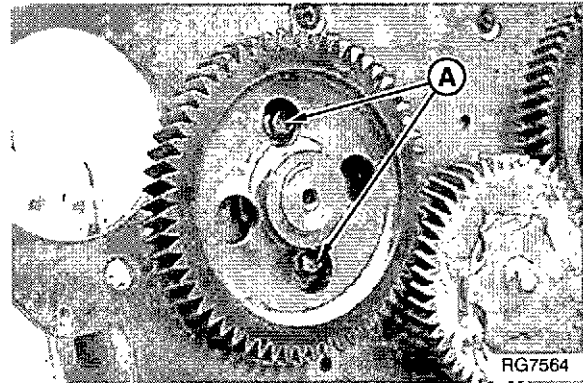


6. Rotate engine gear train until cap screws (A) can be removed.

IMPORTANT: Engine **MUST** remain in a position where camshaft followers rest against cylinder head or are held in up position with magnetic holders so that followers do not fall into engine crankcase. If camshaft followers fall into crankcase, cylinder head removal is required.

7. Revolve engine on repair stand to an angle where camshaft followers and fuel supply pump activator pin (B) falls away from camshaft lobes.

NOTE: D15001NU Magnetic Follower Holder Kit (C) may also be used to hold camshaft followers away from lobes.

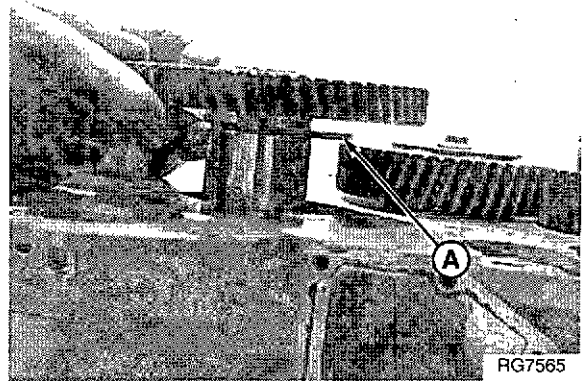


IMPORTANT: DO NOT allow camshaft lobes to drag in bushing or honed bores.

8. Carefully pull camshaft straight up, out of cylinder block.

NOTE: Rotate camshaft carefully to aid in removing.

9. Remove thrust plate (A) from slot behind camshaft gear.

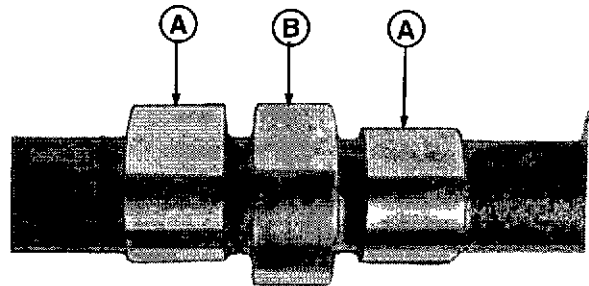


VISUALLY INSPECT CAMSHAFT

1. Clean camshaft in solvent. Dry with compressed air.
2. Inspect all camshaft lobes (A) and journals (B) for wear or damage. Replace camshaft as necessary.

IMPORTANT: New camshaft followers can be used with old camshaft. DO NOT reuse old camshaft followers with a new camshaft. (See Group 05 for camshaft follower replacement.)

NOTE: Very light score marks are acceptable if valve lift is within specification. If pitting or galling exists, replace camshaft. (See MEASURE VALVE LIFT earlier in this group.)



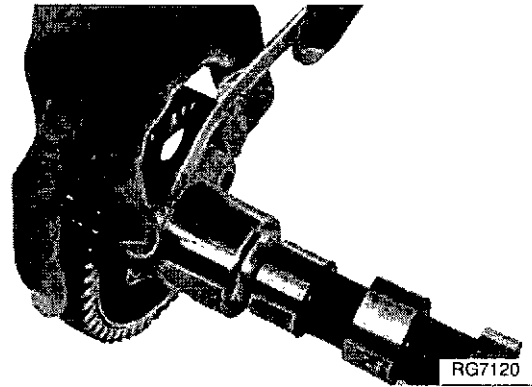
MEASURE CAMSHAFT THRUST PLATE CLEARANCE

1. Clean camshaft thrust plate and check clearance using a feeler gauge. Replace parts as necessary.

CAMSHAFT THRUST PLATE CLEARANCE

Camshaft Thrust Plate Clearance 0.08—0.23 mm
(0.003—0.009 in.)

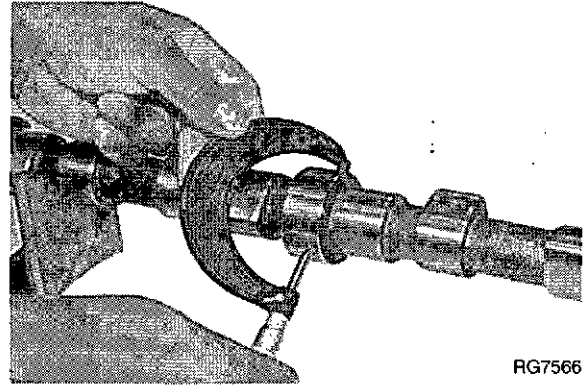
NOTE: *Thrust plate clearance determines camshaft end play.*



INSPECT AND MEASURE CAMSHAFT BUSHING ID AND JOURNAL OD

All engine camshafts have a (replaceable) bushing installed in No. 1 (front) camshaft bore.

1. Measure camshaft journals. If a camshaft journal is damaged or does not meet specification, install a new camshaft.



RG7566

CAMSHAFT BEARING BORE AND JOURNAL SPECIFICATIONS

Camshaft Journal OD 55.872—55.898 mm
(2.1997—2.2007 in.)

Camshaft Bore ID:
Front (No.1) in Block (without bushing) 59.961—59.987 mm
(2.3607—2.3617 in.)

Front (No. 1) in Block (with bushing) 55.961—55.987 mm
(2.2031—2.2042 in.)

All Except No. 1 55.986—56.012 mm
(2.2042—2.2052 in.)

Camshaft Journal-to-Bushing Oil Clearance:
No. 1 Bore with Bushing 0.063—0.115 mm
(0.0025—0.0045 in.)

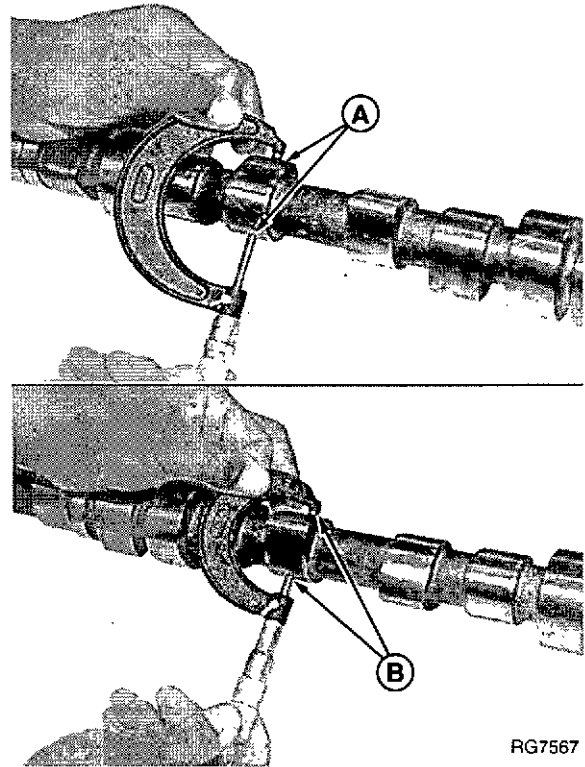
All Except No. 1 Bore 0.088—0.140 mm
(0.0035—0.0055 in.)

2. Measure camshaft bushing ID and remaining bores in cylinder block. If camshaft bore is damaged or is not within specification, have a qualified machine shop install new bushings.

If No. 1 camshaft bushing ID does not meet specifications, replace camshaft bushing. (See REMOVE AND INSTALL CAMSHAFT BUSHING earlier in this group.)

MEASURE CAMSHAFT LOBE HEIGHT

1. Measure each camshaft lobe at highest point (A) and at narrowest point (B). The difference between these dimensions is camshaft lobe height. If height is not within specification on any lobe, install a new camshaft.



CAMSHAFT LOBE HEIGHT SPECIFICATIONS

Intake Lobe Height 6.93—7.42 mm
(0.273—0.292 in.)

Exhaust Lobe Height 6.76—7.26 mm
(0.266—0.286 in.)

2. Measure fuel supply pump camshaft lobe diameter. If diameter is not within specification or lobe surface is grooved, install a new camshaft.

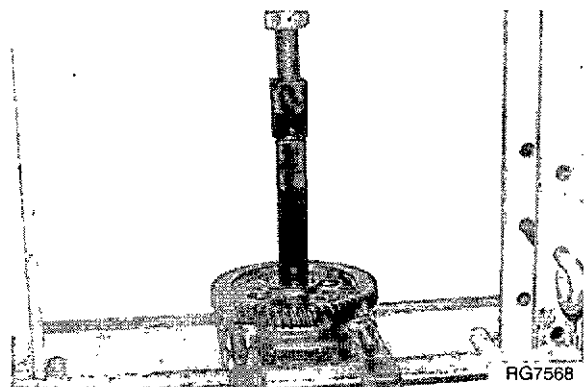
FUEL SUPPLY PUMP CAMSHAFT LOBE SPECIFICATIONS

Lobe Diameter 42.67—42.93 mm
(1.680—1.690 in.)

REMOVE AND INSTALL CAMSHAFT GEAR

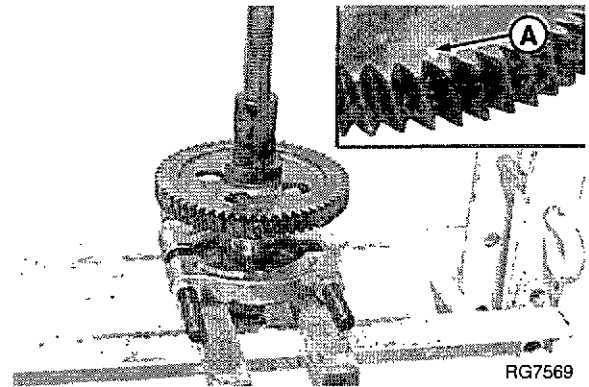
IMPORTANT: Camshaft must be replaced if dropped or damaged, do not allow camshaft to strike floor when removing gear.

1. Press camshaft out of gear.
2. Clean camshaft and gears in solvent. Dry with compressed air.
3. Inspect cam journals for nicks and scratches. Replace camshaft if damage is found.



RG7568

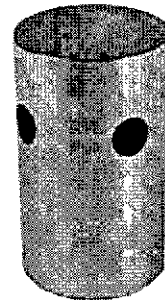
4. Support camshaft under first bearing journal in a hydraulic press.
5. Apply TY6333 High-Temperature Grease to camshaft nose and gear ID to ease installation.
6. Install Woodruff key in camshaft nose.
7. Install gear with timing mark (A) away from camshaft (towards front timing gear cover). Press gear onto camshaft with a tubular driver until gear bottoms against camshaft shoulder.



INSPECT CAMSHAFT FOLLOWERS

NOTE: Cylinder head must be removed before camshaft followers can be removed from engine. (See Group 05.)

1. Inspect followers for uneven wear or damage. Also inspect corresponding camshaft lobe for wear or damage. Replace as necessary.
2. Measure follower OD and follower bore ID in cylinder block.



CAMSHAFT FOLLOWER AND BORE SPECIFICATIONS

Camshaft Follower OD.	31.61—31.64 mm (1.245—1.246 in.)
Camshaft Follower Bore ID in Block	31.70—31.75 mm (1.248—1.250 in.)

Replace cam followers that are not within specification.

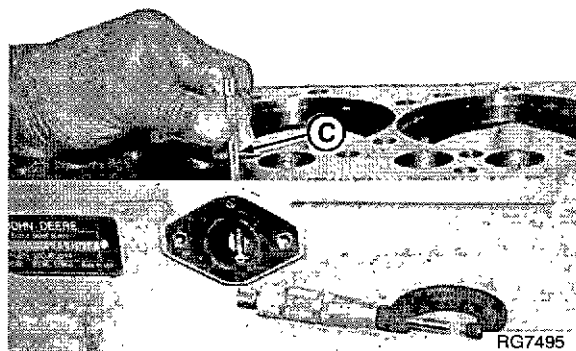
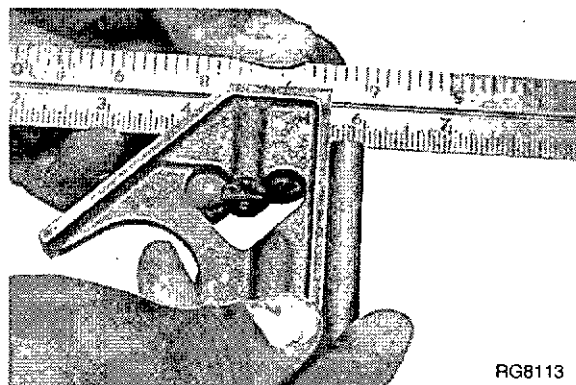
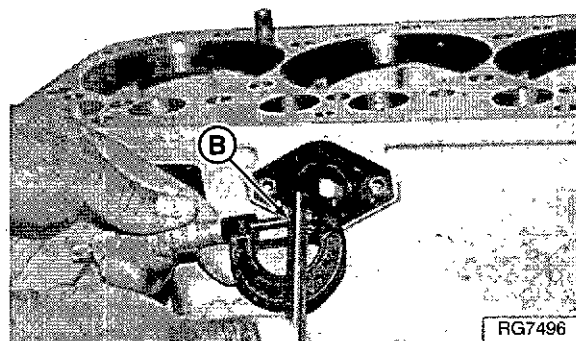
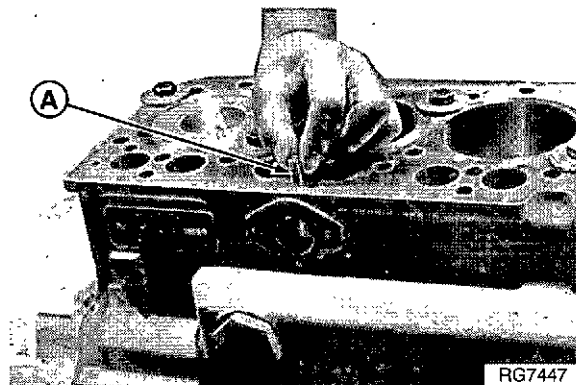
Replace cylinder block if any one cam follower bore is not within specification.

INSPECT, MEASURE, AND INSTALL FUEL SUPPLY PUMP PUSH ROD—IF APPLICABLE

1. Remove and clean push rod (A). Label end(s) for reassembly in same orientation.
2. Measure push rod OD (B). If OD is less than 9.891—9.917 mm (0.3894—0.3904 in.), install a new push rod.
3. Check crown on push rod ends. If flat or concave, replace push rod and check camshaft lobe for wear. (See Group16).
4. Measure push rod bore ID (C) in block. Bore specification is 10.00—10.05 mm (0.3937—0.3957 in.)

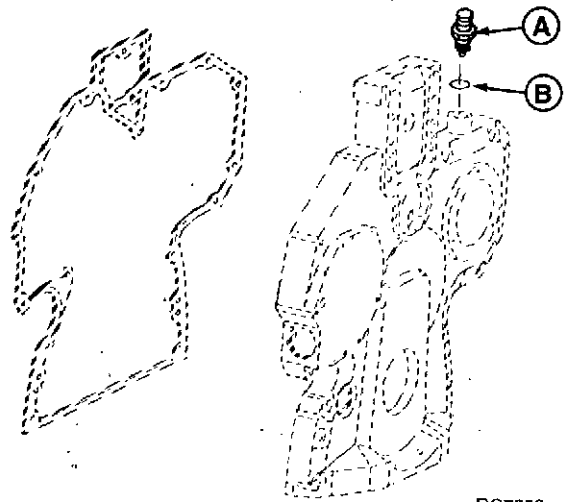
Repair or replace block as necessary.

5. Lubricate push rod with clean engine oil and install in bore with same end orientation as removed.



REPLACE ELECTRONIC TACHOMETER (MAGNETIC PICK-UP) SENSOR

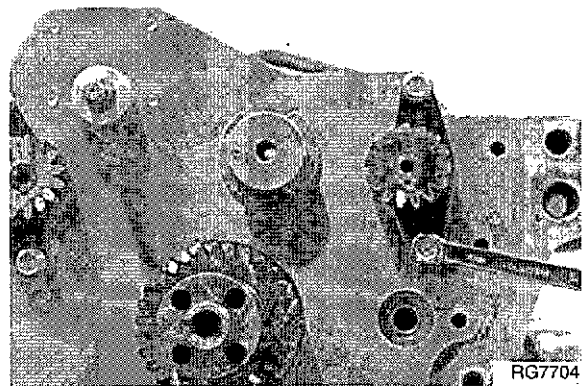
1. Replace sensor (A) and O-ring (B), in timing gear cover, as needed. Tighten to 20 N·m (15 lb-ft).



RG7958

REMOVE BALANCER SHAFTS—IF EQUIPPED (4-CYLINDER ENGINES)

1. Remove lower idler gear and oil pump gear (shown removed).
2. Remove cap screws from balancer shaft thrust plate.

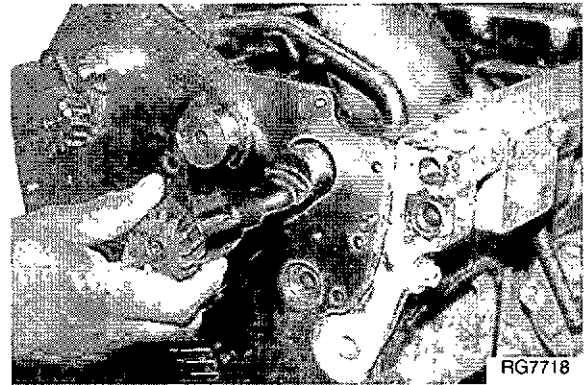


RG7704

IMPORTANT: Identify left and right balancer shafts for correct assembly. Permanently mark a letter "R" or letter "L" on the rear of the shaft for identification.

Journals are lapped for one direction of rotation. Interchanging shaft locations could cause premature wear of shafts and bushings.

NOTE: When removing balancer shafts, use care that neither shaft journals nor bushings are damaged in cylinder block.



3. Remove balancer shafts.

INSPECT AND MEASURE BALANCER SHAFT BUSHINGS AND JOURNALS

1. Inspect, measure and record bushing ID (A) at all locations.

BALANCER SHAFT BUSHING AND JOURNAL SPECIFICATIONS

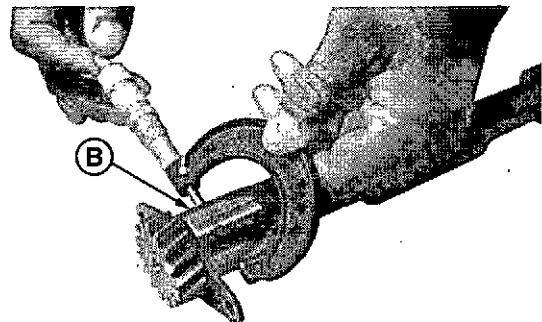
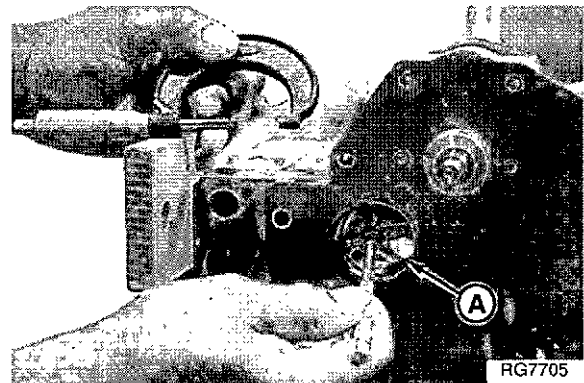
New Balancer Shaft Bushing ID 40.177—40.237 mm
(1.5818—1.5841 in.)

Balancer Shaft Journal OD 40.135—40.161 mm
(1.5801—1.5811 in.)

Journal-to-Bushing Oil Clearance 0.016—0.102 mm
(0.0006—0.0040 in.)

2. Measure balancer shaft journal OD (B). Difference between journal OD and bushing ID is oil clearance.

If oil clearance is not within specification, install new bushings and, if necessary, new balancer shaft.



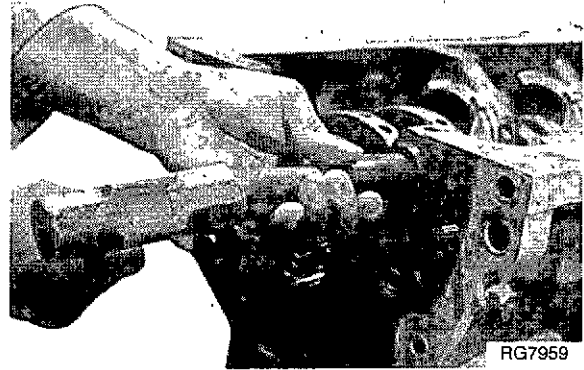
REMOVE AND INSTALL BALANCER SHAFT BUSHINGS (4-CYLINDER ENGINES)

IMPORTANT: Cylinder block front plate must be removed in order to replace balancer shaft bushings.

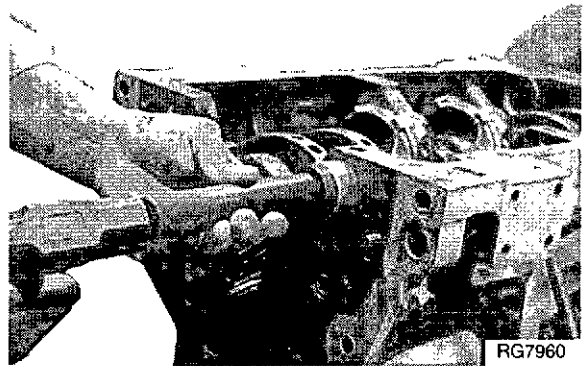
1. Remove all fuel lines from injection or rotary pump.
2. Remove front plate. See REMOVE CYLINDER BLOCK FRONT PLATE, later in this group.
3. Remove bushings from block with JD249 Balancer Shaft Bushing Driver and JDG963 Adapter. To remove the rear (third) bushing, the flywheel housing must be removed.
4. Install new bushings in block with same tools as used during removal.

IMPORTANT: Make sure oil holes in bushing and block are aligned for proper bushing and journal lubrication.

5. Insert balancer shaft to check for bushing-to-shaft clearance. If shaft can be rotated by hand with a slight-to-moderate drag, adequate bushing-to-balancer shaft clearance exists. It is not necessary to hone bushings to obtain specified oil clearance. Excessive clearance can result in shaft seizure.



Removing bushing



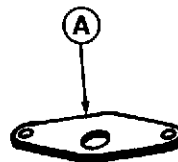
Installing Bushing

INSPECT BALANCER SHAFT GEARS AND THRUST PLATES

1. Inspect for broken, cracked or excessively worn gears.

NOTE: Gear removal is required for thrust plate removal.

2. Inspect thrust plate (A) for scoring or excessive wear.



RG7708

BALANCER SHAFT THRUST PLATE SPECIFICATIONS

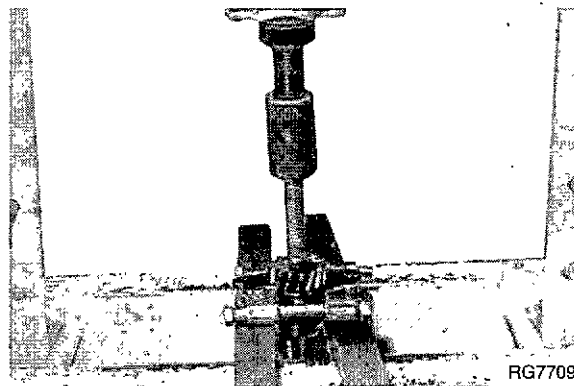
Thrust Plate Thickness (new) 2.97—3.02 mm
(0.117—0.119 in.)

REMOVE AND INSTALL BALANCER SHAFT GEARS

IMPORTANT: DO NOT intermix gears and shafts. Shafts are finish lapped in different locations, therefore, balancer shafts MUST BE installed in the location from which removed. Reversing shaft locations could result in excessive bushing and shaft wear. If in doubt about proper shaft locations, replace the balancer shaft and bushings.

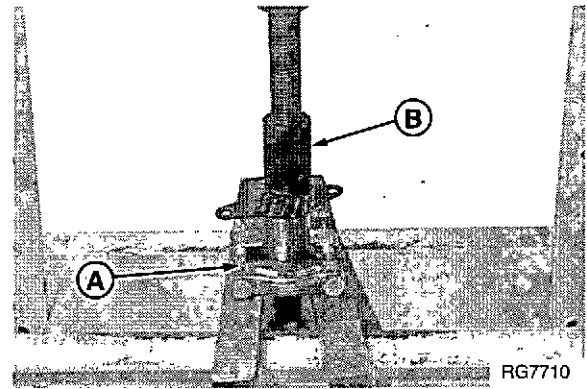
NOTE: Balancer shaft kits provided for service are delivered without gear.

1. Support back side of gear in a press and push on balancer shaft to remove gear.
2. Inspect Woodruff key, gear, and thrust plate for cracks and wear. Replace if necessary.



RG7709

3. Position balancer shaft in JD247 Balancer Shaft Holding Tool or bearing pulling attachment (A).
4. Install thrust plate and gear on balancer shaft. Be sure timing mark is on front face of gear.
5. Press gear onto shaft with a tube-type driver (B) until gear is flush with shaft.



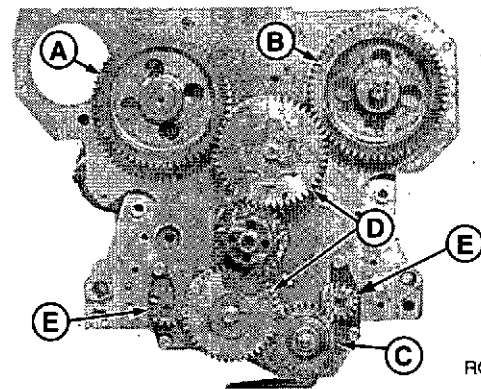
BALANCER SHAFT ASSEMBLY SPECIFICATIONS

Thrust Plate-to-Gear Clearance. 0.05—0.26 mm
(0.002—0.010 in.)

REMOVE CYLINDER BLOCK FRONT PLATE

Before the front plate can be removed, the following components must first be removed:

- Timing gear cover.
- Camshaft and gear (A)
- Injection pump drive gear (B)
- Injection pump (See Group 35.)
- Oil pump drive gear (C)
- Oil pump (See Group 20.)
- Idler gears (D)
- Balancer shafts (E)*



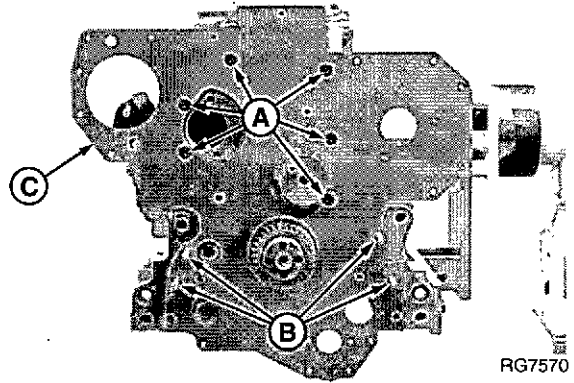
4-Cylinder Engine

- A—Camshaft and Gear
- B—Injection Pump Drive Gear
- C—Oil Pump Drive Gear
- D—Idler Gears (Upper and Lower)
- E—Balancer Shafts*

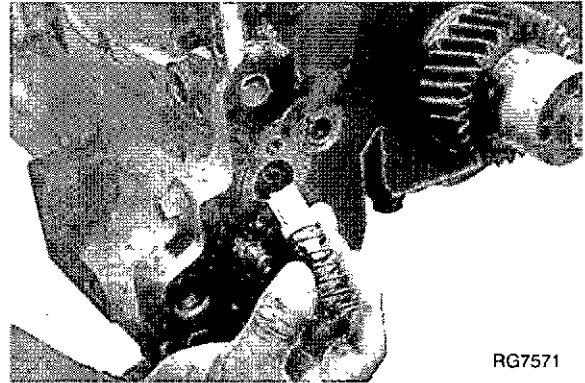
* On 4-cylinder engines only

16
34

1. Remove six countersunk, TORX® screws (A) from front plate.
2. Remove four threaded studs (B).
3. Remove front plate (C).

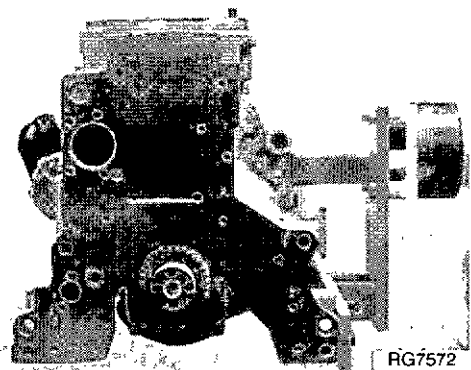


4. Remove oil by-pass valve and spring.



IMPORTANT: All surfaces must be free of oil and dirt.

5. Thoroughly clean front face of cylinder block.



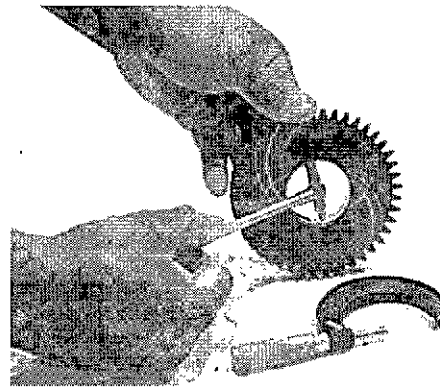
MEASURE IDLER GEAR BUSHING AND SHAFT

1. Measure idler gear bushing ID and shaft OD to determine oil clearance. If oil clearance exceeds specification, replace worn parts.

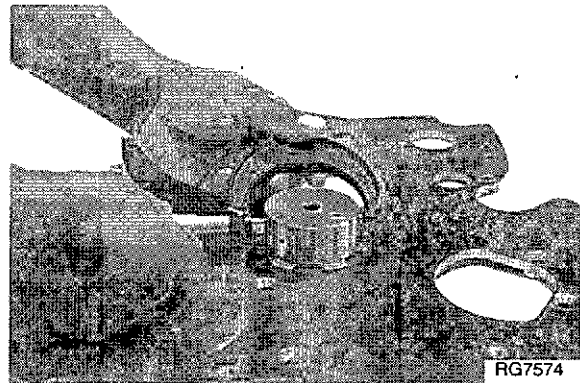
IDLER GEAR, BUSHING, AND SHAFT SPECIFICATIONS

Upper Idler Gear Bushing ID	69.802—69.832 mm (2.7481—2.7493 in.)
Lower Idler Gear Bushing ID	44.489—44.539 mm (1.7515—1.7535 in.)
Upper Idler Gear Shaft OD	69.757—69.777 mm (2.7463—2.7471 in.)
Lower Idler Gear Shaft OD	44.437—44.463 mm (1.7495—1.7505 in.)
Bushing-to-Shaft Oil Clearance:	
Upper Idler	0.075—0.125 mm (0.0030—0.0049 in.)
Lower Idler	0.026—0.102 mm (0.0010—0.0040 in.)
Upper and Lower Idler Gear End Play	0.095—0.145 mm (0.0037—0.057 in.)

2. If idler gear end play, measured earlier in this group, was out of specification, remove idler shaft and thrust washer from front plate. (See REMOVE LOWER AND UPPER IDLER SHAFTS, later in this group.)
3. Check thrust washer for wear.
4. Measure idler gear hub width and shaft width. Replace worn parts that are out of specification.



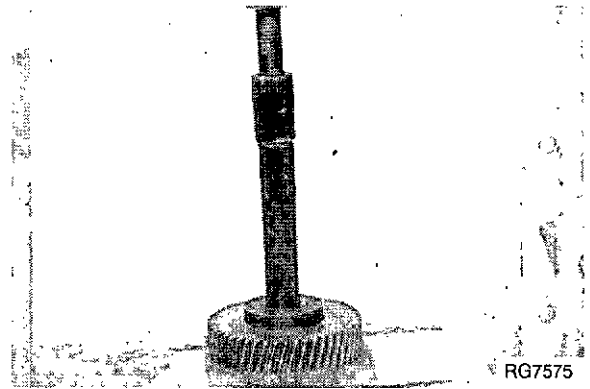
RG7573



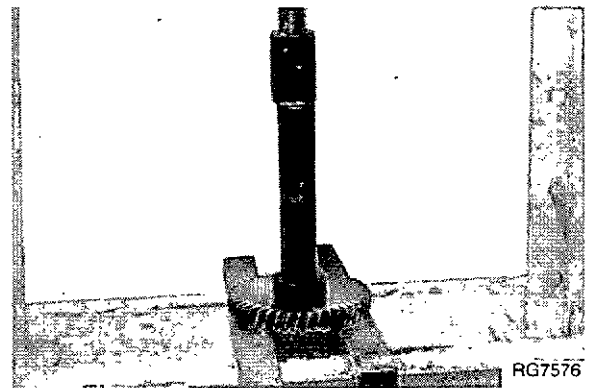
RG7574

REMOVE AND INSTALL IDLER GEAR BUSHINGS

1. Press worn idler gear bushing out of gear using JD252 Driver and JDG537 (OTC815) Handle.



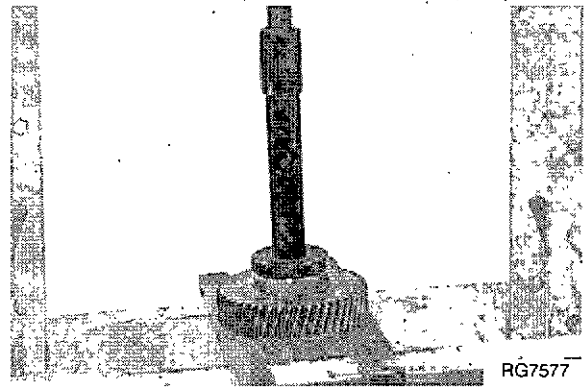
Upper Idler Gear



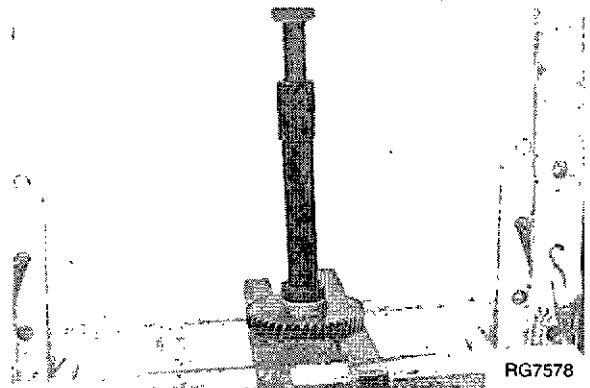
Lower Idler Gear

IMPORTANT: Bushing failure will result if upper and lower bushings are interchanged. Lower idler gear bushings are splash lubricated and have a spiral oil groove; upper idler gear bushings are pressure lubricated and DO NOT have oil grooves.

- 2.. Coat ID and OD of idler gear bushing and ID of gear with TY6333 High-Temperature Grease. Install bushing into idler gear using JD252 Driver and JDG537 (OTC815) Handle.



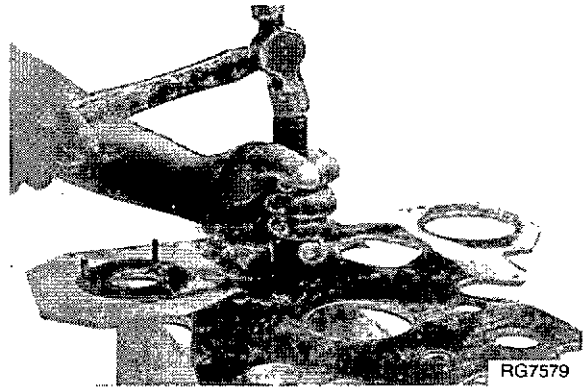
Upper Idler Gear



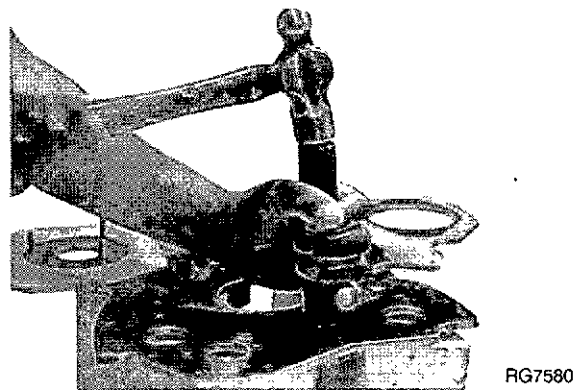
Lower Idler Gear

REMOVE LOWER AND UPPER IDLER SHAFTS

1. Remove lower idler shaft and thrust washer by driving or pressing on shaft from block side of front plate.
2. Remove upper idler shaft and thrust washer by driving or pressing on shaft from block side of front plate.



Upper Idler Shaft



Lower Idler Shaft

CLEAN AND INSPECT FRONT PLATE

IMPORTANT: All surfaces must be free of oil and dirt.

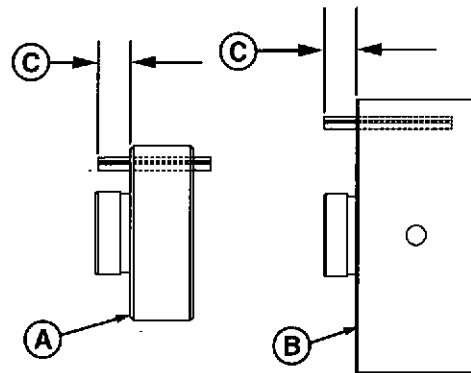
1. Clean front plate with hot soapy water.
2. Rinse well with plain water to remove all soap residue from gasket surface.
3. Inspect front plate for damage.

ESTABLISHING ROTARY FUEL INJECTION PUMP TIMING MARK ONTO REPLACEMENT FRONT PLATE

IMPORTANT: Replacement front plates do not have a rotary injection pump timing mark. It is extremely important that timing be accurately established after dynamically timing the engine. Refer to Group 115.

INSTALL IDLER SHAFT SPRING PINS

1. Install spring pins in lower (A) and upper (B) idler gear shaft which locks thrust washer to shaft to allow 4.32 mm (0.170 in.) (C) projection above front face of each shaft. The pin on idler shafts extends through both rear and front thrust washer.



RG7942

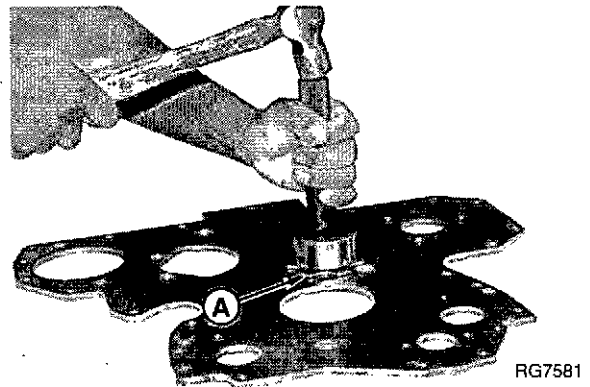
IDLER SHAFT SPRING PIN PROTRUSION SPECIFICATIONS

Lower and Upper Idler Shaft	2.79—4.83 mm (0.11—0.19 in.)
---------------------------------------	---------------------------------

INSTALL UPPER IDLER SHAFT IN FRONT PLATE

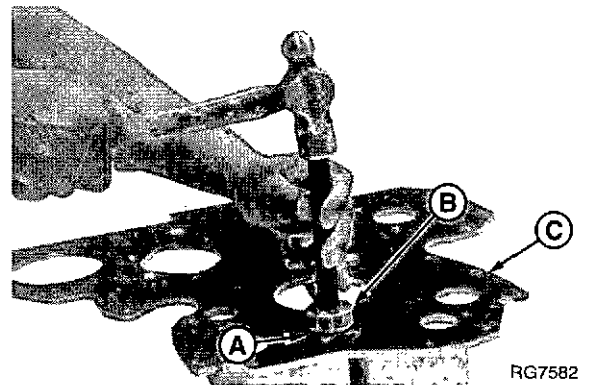
IMPORTANT: Oil holes in idler shaft must be properly indexed to provide adequate lubrication to idler gear bushing.

1. Install thrust washer (A) and upper idler shaft into front plate. Spring pin must extend through hole in thrust washer and front plate.
2. Drive or press shaft into front plate until thrust washer is fully seated.



INSTALL LOWER IDLER SHAFT IN FRONT PLATE

1. Install thrust washer (A) and lower idler shaft with spring pin (B). Spring pin must extend through hole in thrust washer and front plate.
2. Drive shaft into plate (C) until thrust washer is fully seated.



INSTALL ENGINE FRONT PLATE

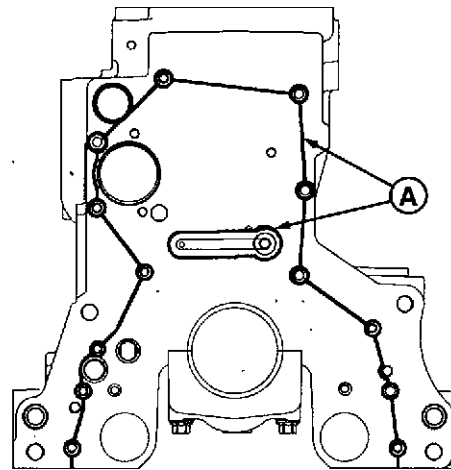
1. Install oil by-pass valve and spring into block.



- If not previously done, use a brass scraper and remove any previously applied sealant.

IMPORTANT: Be sure cylinder block and front plate surfaces are free of oil, dirt, previously applied sealant, and cleaning agents.

- Wash gasket surfaces with a steam cleaner using hot soapy water. Rinse well with plain water to remove all soap residue from gasket surface.
- Apply LOCTITE 515 Flexible Form-In-Place Gasket (TY6304) in a continuous 1.5—2.0 mm bead (A) to cylinder block.
- Locate bead in the center of the mating surfaces and completely encircle cap screw and dowel holes.



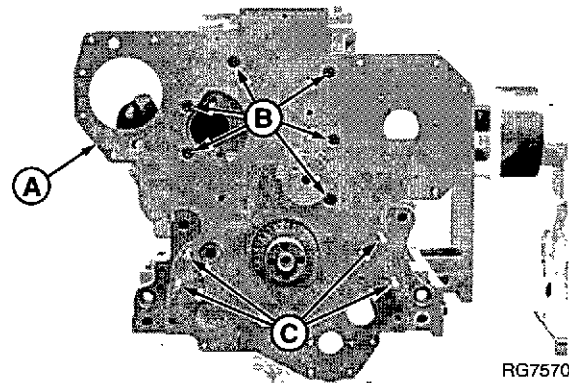
RG8030

- Install front plate (A).

IMPORTANT: Tighten screws to specified torque using a cross pattern, within 10 minutes after parts are assembled.

TORQUE SPECIFICATIONS

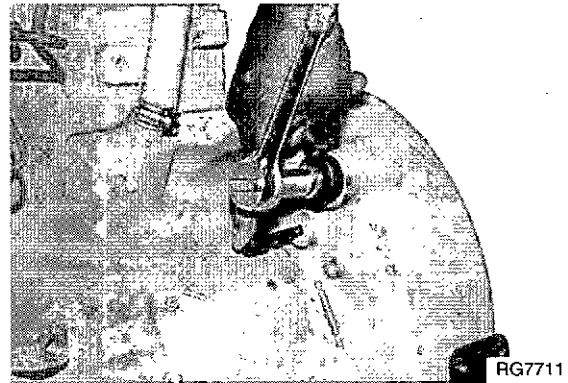
Countersunk (TORX) Screws (B)	25 N-m (18 lb-ft)
Threaded Studs (C)	35 N-m (26 lb-ft)



RG7570

INSTALL AND TIME BALANCER SHAFTS— IF EQUIPPED (4-CYLINDER ENGINES)

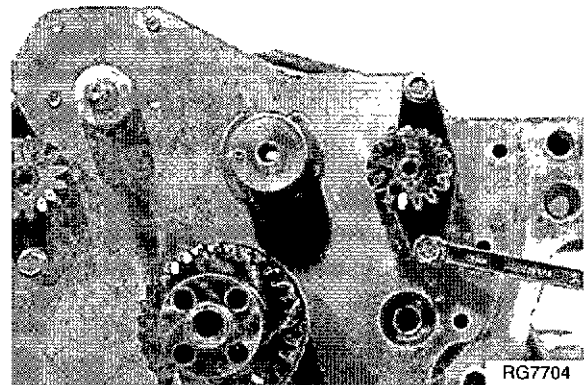
1. Using engine rotation tool and timing pin, lock No. 1 piston at TDC compression stroke.



2. Lubricate balancer shaft bushings and journals with clean engine oil.

IMPORTANT: Balancer shafts are finish lapped in different locations, therefore, shafts **MUST BE** installed in the location from which removed. Reversing shaft locations could result in excessive bushing and shaft wear. If in doubt about proper shaft locations, replace the balancer shaft and bushings.

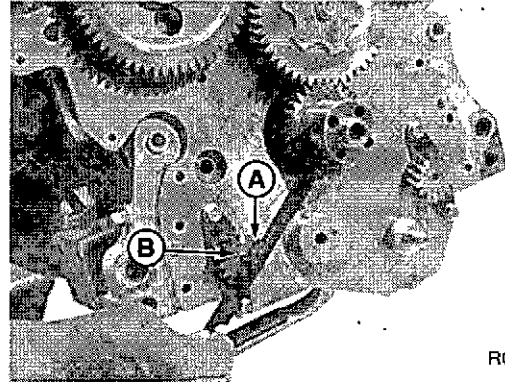
3. Install balancer shafts and thrust plates. Tighten thrust plate cap screws to 35 N·m (26 lb-ft).



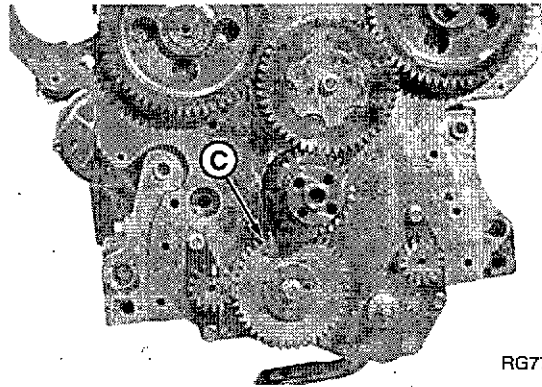
- Turn right (camshaft side) balancer shaft so timing mark (A) is aligned with JD254A Timing Tool. Timing mark on balancer shaft gear must point to centerline of crankshaft when correctly timed.

NOTE: Keyway (B) in balancer shaft gear will be at 12 O'clock position, when engine is locked at No. 1 TDC compression.

- Apply TY6333 High-Temperature Grease to idler gear bushing ID and shaft OD. Install lower idler gear without turning balancer shaft.
- Install thrust washer over lower idler gear (C) and shaft.
- Install cap screw through idler shaft into threaded leg of oil pump housing and finger tighten only.

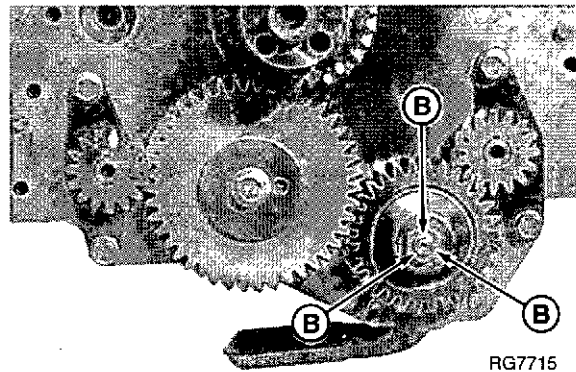
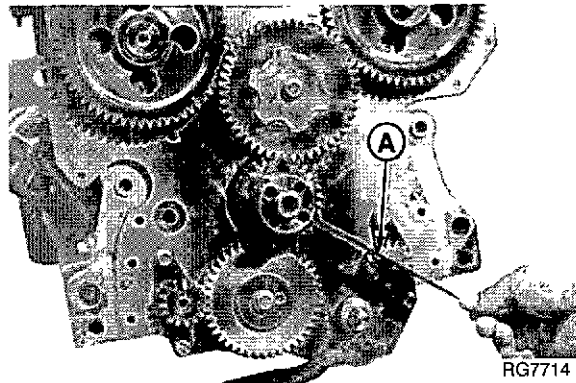


RG7712



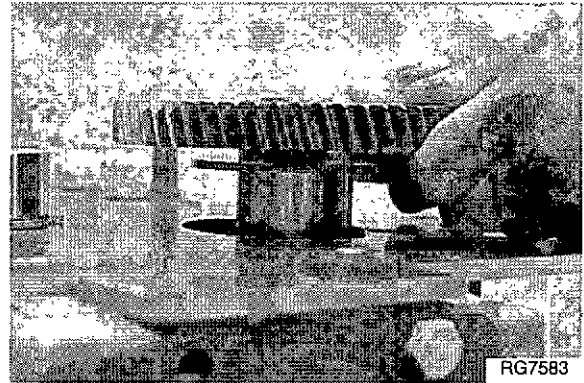
RG7713

8. Turn left (injection pump side) balancer shaft so timing mark (A) is aligned with JD254A Timing Tool.
9. Install oil pump gear. Finger tighten gear retaining nut.
10. Recheck gear timing for both balancer shafts
11. Tighten oil pump drive gear retaining nut to 50 N·m (37 lb-ft). Stake nut to shaft in three places (B). (See Group 20 for oil pump installation.)
12. Tighten lower idler gear cap screw to 80 N·m (59 lb-ft).



INSTALL AND TIME CAMSHAFT AND ROTARY FUEL INJECTION PUMP

1. Lock engine with No. 1 piston at TDC compression stroke.
2. Install fuel injection pump on front plate.
3. Install fuel injection pump drive gear and new retaining nut. Time injection pump to engine. (See Group 35 for injection pump timing.)
4. Tighten injection pump-to-front plate hex nuts to 27 N·m (20 lb-ft). Tighten drive gear retaining nut to:



DRIVE GEAR RETAINING NUT TORQUE SPECIFICATIONS

Stanadyne:

Model DB2	122 N·m (90 lb-ft)
Model DB4	203 N·m (150 lb-ft)

Lucas:

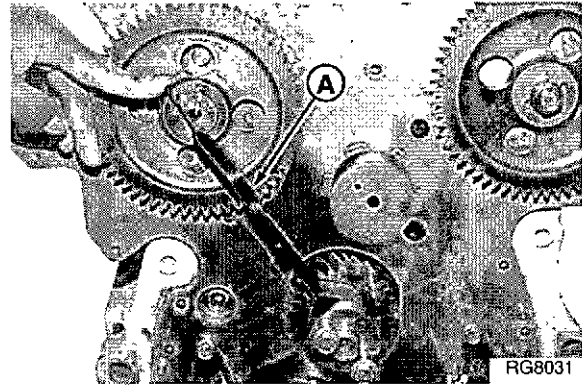
Model DP201	122 N·m (90 lb-ft)
Model DP203	81 N·m (60 lb-ft)

5. Lubricate camshaft bearing journals, lobes, and followers with TY6333 High-Temperature Grease.

IMPORTANT: DO NOT allow camshaft lobes to drag on camshaft bore or bushing surfaces while installing camshaft. Bearing surfaces may become scratched or scored. Rotate camshaft during installation to avoid obstruction in any bore.

6. Install camshaft and thrust plate in cylinder block. Be careful not to damage bushing ID.
7. Install thrust plate cap screws and tighten to 35 N·m (26 lb-ft).

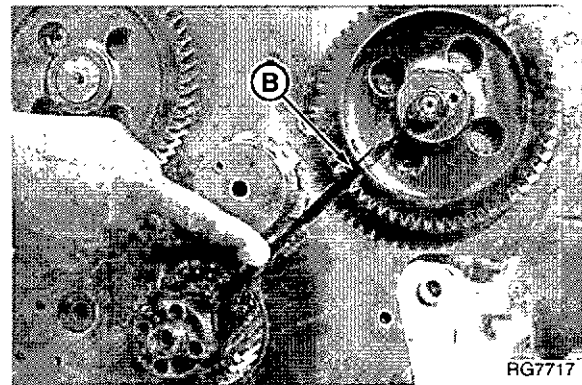
8. With JD254A Timing Tool resting on nose of crankshaft and center of camshaft (as shown), turn camshaft until timing mark (A) on camshaft gear aligns with timing tool.
9. Check injection pump gear timing with JD254A Timing Tool resting on nose of crankshaft and center of injection pump shaft. Timing mark (B) on injection pump drive gear, as described in table below, must align with timing tool (as shown).



IMPORTANT: Use the timing mark corresponding to the number of cylinders the engine has that is being timed.

INJECTION PUMP GEAR TIMING MARKS

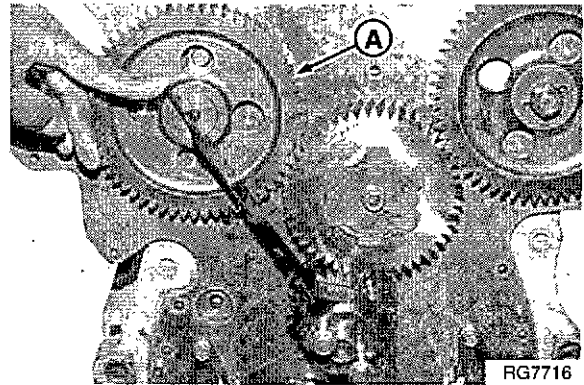
Injection Pump Model	Timing Mark
4-Cylinder Engine:	
Stanadyne DB2	SD2 4
Stanadyne DB4	SD4 4
Lucas DP201 and DP203	L4
6-Cylinder Engine:	
Stanadyne DB4	S6
Lucas DP201 and DP203	L6



10. Lubricate upper idler gear bushing ID and shaft OD with TY6333 High-Temperature Grease. Using JDG791A Idler Gear Installer Pilot, install idler gear without turning camshaft gear or injection pump gear.

IMPORTANT: To ensure proper lubrication of new upper idler gear bushing and camshaft bushing, install new upper idler gear with the reference number facing away from engine.

11. Install upper idler gear thrust washer and cap screw. Tighten cap screw to 80 N·m (59 lb-ft).
12. Recheck camshaft gear (A) and injection pump drive gear timing to make sure they are correct.



CLEAN AND INSPECT TIMING GEAR COVER

1. Drive crankshaft front oil seal out of cover.
2. Remove material and sealant from cylinder block and timing gear cover gasket surfaces. If necessary, remove oil filler neck and gasket and injection pump drive gear nut cover plate and gasket.
3. If engine is equipped with the auxiliary drive, remove auxiliary drive as described earlier in this group.
4. If engine is equipped with electronic tachometer (magnetic pick-up) sensor, remove sensor and O-ring. See REPLACE ELECTRONIC TACHOMETER (MAGNETIC PICK-UP) SENSOR, as described earlier in this group.
5. Clean timing gear cover in solvent. Dry with compressed air.
6. Inspect cover for cracks or damage. Make sure seal bore is clean and free of nicks.

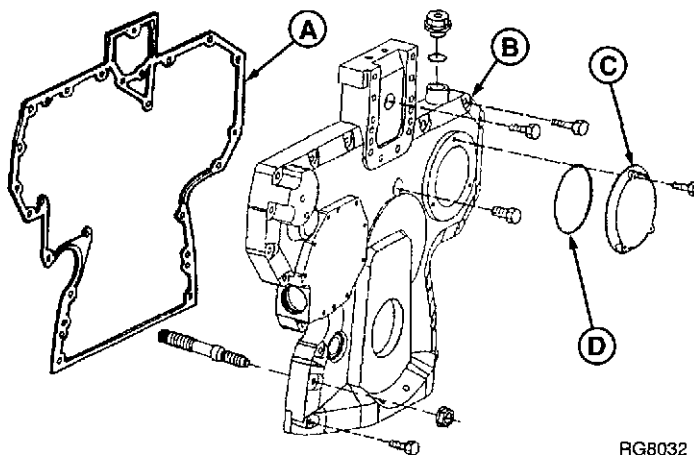


CAUTION: Do not spin bearings when drying with compressed air.

16

48

INSTALL TIMING GEAR COVER



- A—Gasket
- B—Timing Gear Cover
- C—Injection Pump Drive Gear Cover Plate
- D—Seal Ring

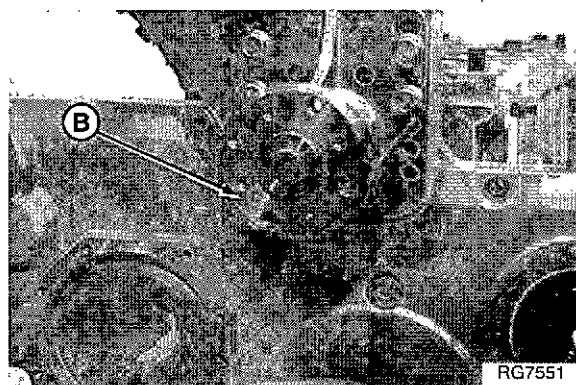
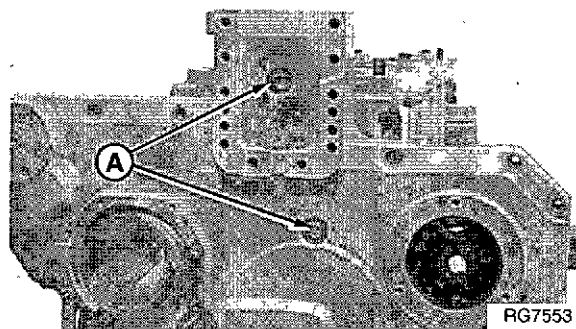
1. Make sure gasket surfaces on cover and front plate are clean. See **CLEAN AND INSPECT ENGINE FRONT PLATE**, earlier in this group.
2. Install injection pump drive gear cover plate (C) using a new seal ring (D), if necessary. Tighten screws to 2 N·m (17 lb-in.).
3. Install timing gear cover (B) on engine and apply the following torques:

TORQUE SPECIFICATIONS

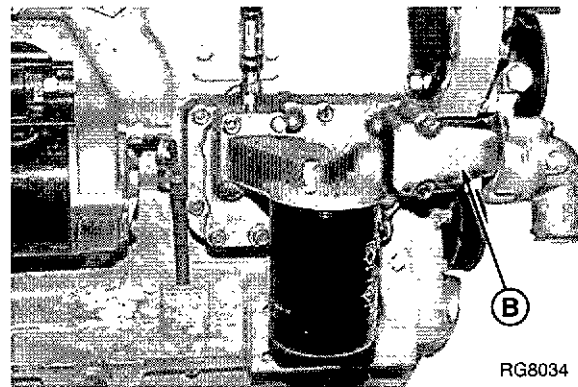
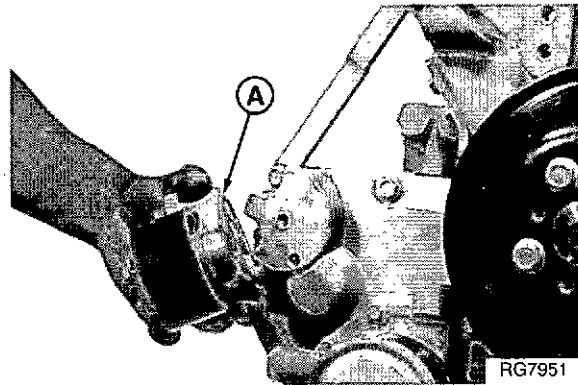
Timing Gear Cover-to-Front Plate and Cylinder Block	35 N·m (26 lb-ft)
Oil Pan-to-Timing Gear Cover	35 N·m (26 lb-ft)
Electronic Tachometer (Magnetic Pick-up) Sensor	20 N·m (15 lb-ft)

4. Install oil pressure regulating valve assembly. (See Group 20.)

5. Install cap screws (A) and tighten to 35 N·m (26 lb-ft).
6. Install adjustable fan drive and fan pulley (B). (See Group 25.)



7. Install water pump, if removed. (See Group 25.)
8. Install belt tensioner (A), if removed. (See Group 25.)
9. Install oil cooler-to-water manifold elbow (B) at front plate. (See Group 20.)
10. Install oil pan. (See Group 20.)

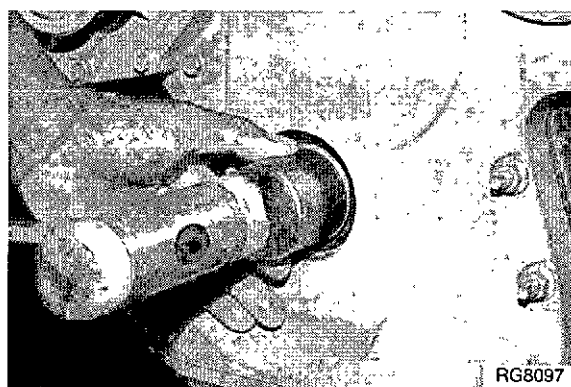
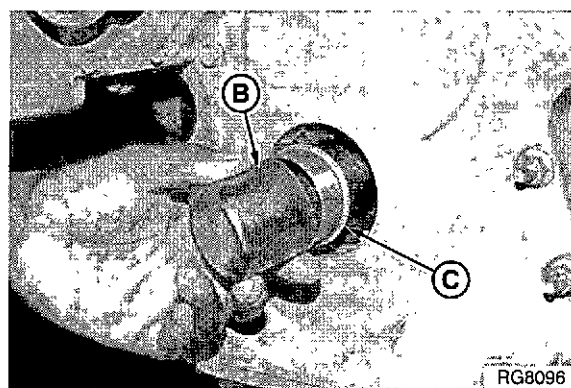
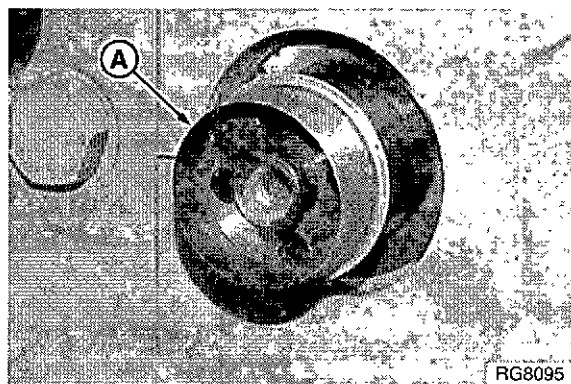


INSTALL CRANKSHAFT FRONT WEAR SLEEVE AND OIL SEAL

1. Coat ID of new wear sleeve with LOCTITE 680 Retaining Compound.
2. Install wear sleeve (A) on nose of crankshaft with lip of sleeve toward crankshaft.

NOTE: Flange on wear sleeve should be seated against crankshaft drive gear when properly installed.

3. Position installation tool (B) provided in kit over wear sleeve. Install wear sleeve until tool bottoms on nose of crankshaft, using a dead blow hammer.
4. Clean any sealant from OD of crankshaft flange (C) and wear sleeve.



• **Install front crankshaft oil seal:**

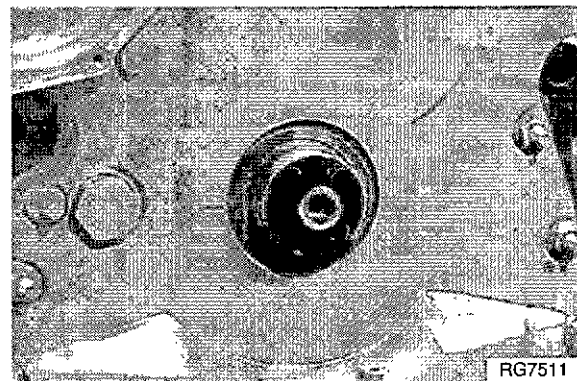
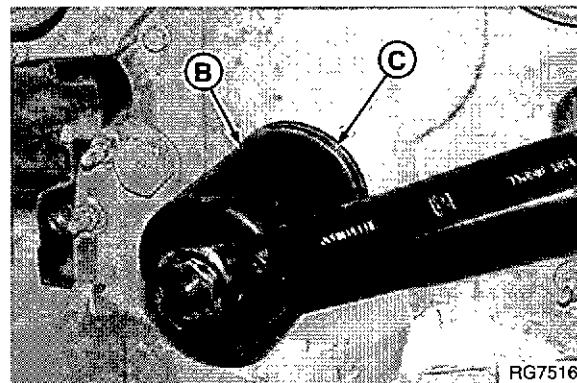
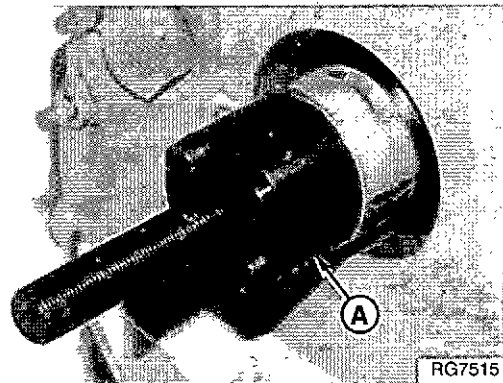
1. Inspect and clean seal bore in timing gear cover. Check for nicks or burrs. Use a medium-grit emery cloth to smooth rough areas.

IMPORTANT: To assure proper sealing, the OD of the crankshaft and wear sleeve **MUST BE cleaned with Brake Kleen, Ignition Cleaner, or equivalent and dry prior to installing seal (C).**

2. Slide JDG954-2 Adapter (A) on nose of crankshaft and tighten cap screws.
3. Apply a light coating of clean engine oil to lips of seal and position seal on crankshaft flange. (The spring-loaded side of seal goes into timing gear cover first.)

IMPORTANT: **DO NOT** allow oil to contact coating on OD of seal.

4. Place JDG954-1 Installer (B) over adapter. Tighten screw until driver bottoms on nose of crankshaft.
5. Install belt pulley.
6. Place damper on crankshaft. Handle vibration damper with care to avoid impact damage.
7. Dip cap screws in clean SAE30 engine oil.
8. Install cap screws and tighten in a cross sequence to 60 N·m (44 lb-ft). Final tighten cap screws to 80 N·m (59 lb-ft).
9. Install poly-vee belts.



COMPLETE FINAL ASSEMBLY

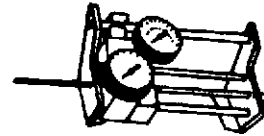
1. Install fuel supply pump. (Group 35)
2. Remove cam follower holding tools (if used for camshaft removal).
3. Install push rods and rocker arm assembly. (Group 05)
4. Adjust valve clearance and install rocker arm cover and sealing ring. (Group 05)
5. Install alternator and fan. (Group 25)
6. Fill engine crankcase with clean oil having correct viscosity and grade specifications. (Group 02)
7. Perform engine break-in as outlined in Group 05.

SPECIAL OR ESSENTIAL TOOLS

NOTE: Order tools according to information given in the U.S. SERVICEGARD™ Catalog or in the European Microfiche Tool Catalog (MTC).

Spring Compression Tester D01168AA

Test oil bypass valve spring and oil pressure regulating valve spring compression.



RG5061

Bushing Driver (A) JD248A

Handle (B) JDG536 (OTC813)

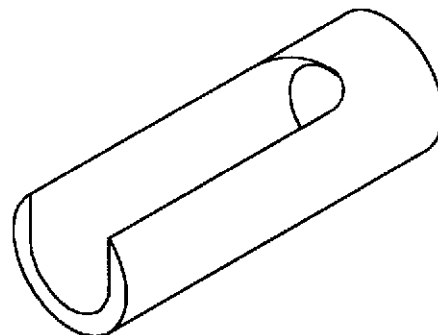
Install oil pressure relief valve bushing.



RG5183

Dipstick Tube Driver JDG965

Used to install dipstick tube.



RG7982

SERVICE EQUIPMENT AND TOOLS

NOTE: Order tools from the U.S. SERVICEGARD™ Catalog or from the European Microfiche Tool Catalog (MTC). Some tools may be available from a local supplier.

Name	Use
D01061AA Blind Hole Puller Set	Remove oil pressure regulating valve seat and dipstick tube from block.
D01299AA Slide Hammer, No. 28250 Actuator Pin, and No. 33856 5/16 in. Collet	Remove dipstick tube from cylinder block.

OTHER MATERIAL

Number	Name	Use
LOCTITE 515 (TY6304)	Flexible Form-In-Place Gasket (General Purpose)	To seal oil pan gasket surfaces.
LOCTITE 592 (TY9374)	Pipe Sealant with TEFLON	To seal oil pan elbow drain fitting.
LOCTITE 680 (TY15969)	Retaining Compound	To seal dipstick tube.

LUBRICATION SYSTEM SPECIFICATIONS

ITEM	SPECIFICATION	WEAR LIMIT
Oil Pump:		
Drive shaft bore in pump housing	16.052—16.102 mm (0.6320—0.6339 in.)	_____ _____
Diameter of idler shaft journal	12.316—12.332 mm (0.4849—0.4855 in.)	_____ _____
Diameter of drive shaft journal	16.017—16.037 mm (0.6306—0.6314 in.)	_____ _____
Thickness of gears	35.975—36.025 mm (1.4163—1.4183 in.)	_____ _____
Gears-to-pump housing radial clearance	0.131—0.211 mm (0.005—0.008 in.)	_____ _____
Gears-to-pump cover axial clearance	0.045—0.165 mm (0.0018—0.0065 in.)	_____ _____

LUBRICATION SYSTEM SPECIFICATIONS—CONTINUED

ITEM	SPECIFICATION	WEAR LIMIT
Spring for Oil Pressure Regulating Valve		
4-Cylinder Engines:		
Free length of spring (approx.)	115.5 mm (4.55 in.)	_____
Spring tension at length of 42.5 mm (1.68 in.)	45 N (9.1—11.1 lb-force)	_____
6-Cylinder Engines:		
Free length of spring (approx.)	119 mm (4.68 in.)	_____
Spring tension at length of 42.5 mm (1.68 in.)	66 N (13.5—16.5 lb-force)	_____
Bypass Valve Spring:		
Free length of spring.	51 mm (2.00 in.)	_____
Spring tension at length of 29 mm (1.14 in.)	87.8 N (20 lb-force)	_____
Minimum oil pressure at 850 rpm and engine oil temperature		
at 93°C (200°F)	100 kPa (1 bar) (14 psi)	_____

LUBRICATION SYSTEM SPECIFICATIONS—CONTINUED

	TORQUES
Oil Pump-to-Front Plate*	35 N·m (26 lb-ft)
Oil Pump Drive Gear-to-Shaft, Retaining Nut (Staked)	50 N·m (37 lb-ft)
Oil Suction Tube-to-Oil Pump	35 N·m (26 lb-ft)
Oil Pan-to-Cylinder Block	35 N·m (26 lb-ft)
Oil Pan-to-Timing Gear Cover	35 N·m (26 lb-ft)
Oil Fill Tube-to-Cylinder Block	35 N·m (26 lb-ft)
Oil Pan-to-Flywheel Housing	35 N·m (26 lb-ft)
Oil Pan Drain Plug	47 N·m (35 lb-ft)
Oil Pressure Regulating Valve Plug in Timing Gear Cover	95 N·m (70 lb-ft)
Oil Cooler Housing-to-Cylinder Block	35 N·m (26 lb-ft)
Oil Cooler Covers-to-Cylinder Block	35 N·m (26 lb-ft)
Oil Filter Housing-to-Cylinder Block	35 N·m (26 lb-ft)
Oil Cooler-to-Oil Cooler Housing	12 N·m (9 lb-ft)
Oil Pump Drive Gear Retaining Nut (Staked)	50 N·m (37 lb-ft)
Lower Idler Gear-to-Oil Pump Housing	80 N·m (59 lb-ft)

* See *INSTALL ENGINE OIL PUMP*, later in this group, for proper cap screw tightening sequence.

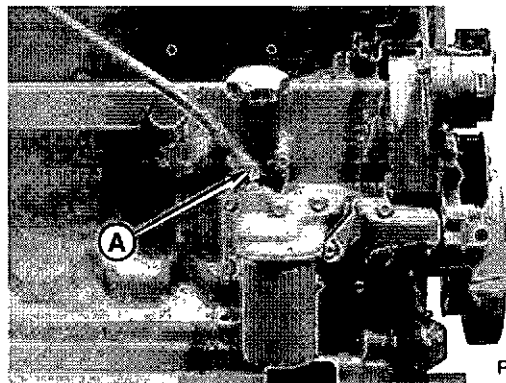
GENERAL LUBRICATION SYSTEM INFORMATION

- The oil filter can be located on right side of the engine or remotely located on left side.
- Dipsticks and oil fill locations can be located on either side of the engine. The oil fill can also be specified in the rocker arm cover.
- The pressure regulating valve and the bypass valve are located in the front face of the block. Two regulating valve springs are available: one for 4-cylinder engines and one for 6-cylinder engines.
- Oil coolers are full-flow, plate-type coolers. They may be equipped with 3-, 5-, 7-, or 9-plates.
- One oil pump is available and is used on both 4- and 6-cylinder engines.

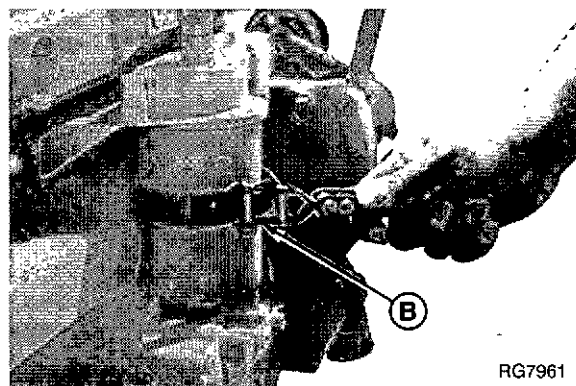
REMOVE, INSPECT, AND INSTALL OIL FILTER BASE

Several oil filter locations are available. Three versions are being shown in this procedure.

1. Disconnect turbocharger oil inlet line (A) from oil filter header.
2. Remove oil filter (B) using a suitable filter wrench.

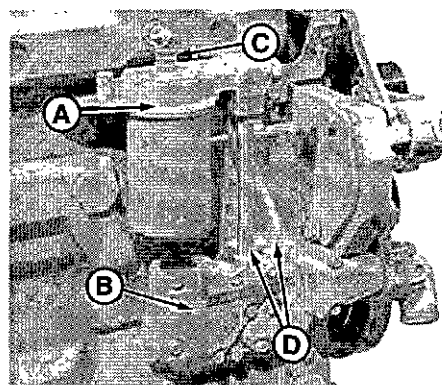
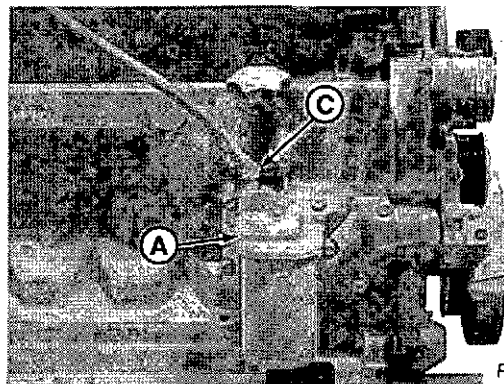


RG7962



RG7961

3. Remove oil filter header/rear adapter (A). Remove oil tube adapter (B), if equipped.
4. Disconnect tubes (D), if equipped.
5. Clean all gasket material from mating surfaces. Inspect all parts and replace if needed.
6. Using a new gasket, install oil filter header. Tighten cap screws to 35 N·m (26 lb-ft).
7. Using a new gasket, install adapter, if equipped. Tighten cap screws to 35 N·m (26 lb-ft).
8. Connect turbocharger oil inlet line (C).
9. Spread a layer of clean engine oil on new filter packing. Install filter and tighten until packing contacts filter base. Tighten an additional 1/2—3/4 turn after packing contacts base. DO NOT overtighten oil filter.

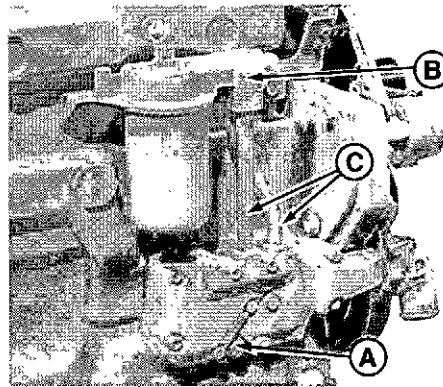


A—Oil Filter Header/Rear Adapter
 B—Oil Tube Adapter/Oil Cooler Cover
 C—Turbocharger Oil Inlet Line
 D—Tubes

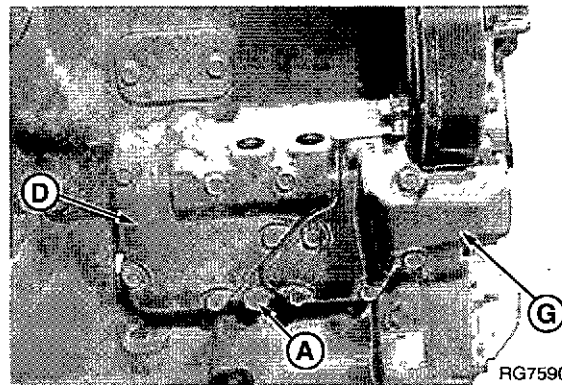
REMOVE, INSPECT, AND INSTALL OIL COOLER

• Remove Oil Cooler Assembly:

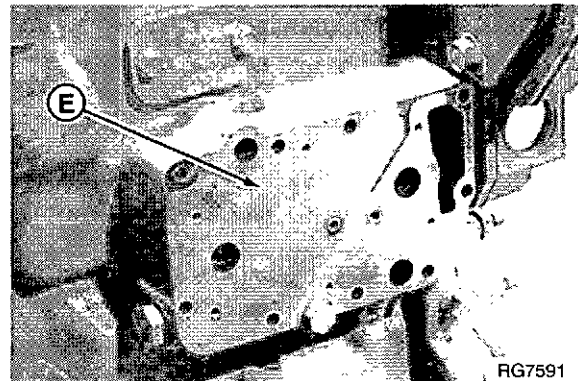
1. Remove oil cooler drain plug (A) and drain coolant.
2. Remove oil filter header (B) with tubes (C), adapter (D) (if equipped), and elbow adapter (G), if equipped. See REMOVE, INSPECT, AND INSTALL OIL FILTER BASE, earlier in this group.
3. Remove housing (E) and oil cooler (F).



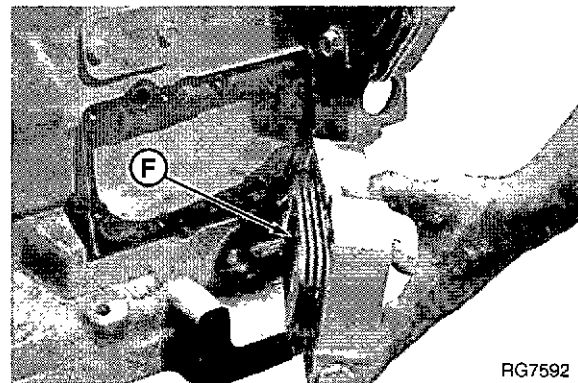
RG7588



RG7590



RG7591



RG7592

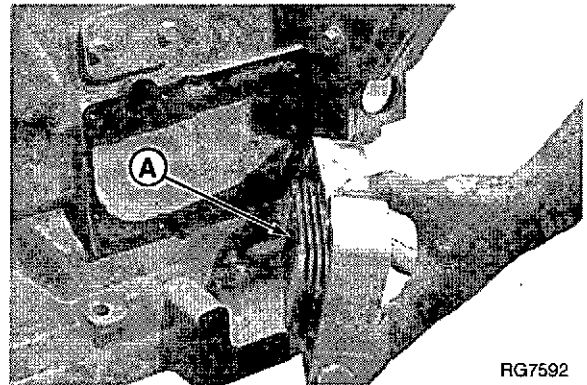
- A—Oil Cooler Drain Plug
- B—Oil Filter Header
- C—Oil Tubes
- D—Oil Tube Adapter/Oil Cooler Cover
- E—Oil Cooler Housing
- F—Oil Cooler
- G—Elbow Adapter

• **Inspect Oil Cooler Assembly:**

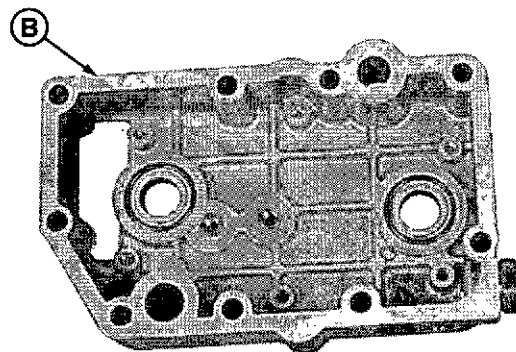
1. Inspect oil cooler (A) for physical damage, plugging, or leakage which may allow mixing of oil and coolant.
2. Back flush oil cooler to clean all debris from core.
3. Pressure test oil cooler in liquid and compressed air if mixing of oil and coolant is suspected.

Oil cooler should show no leakage when 140—170 kPa (1.4—1.7 bar) (20—25 psi) air pressure is applied for a minimum of 30 seconds.

4. Inspect oil cooler housing (B).
5. Replace parts as needed. **DO NOT** attempt to repair oil cooler.



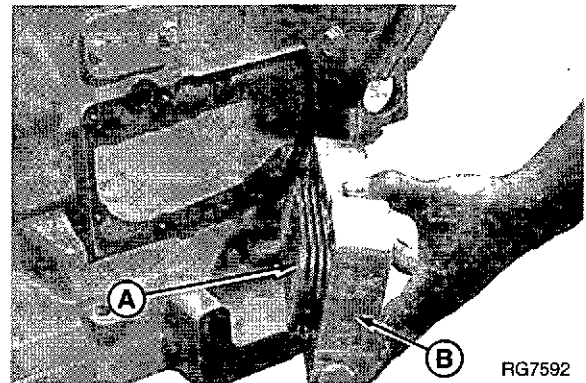
RG7592



RG7969

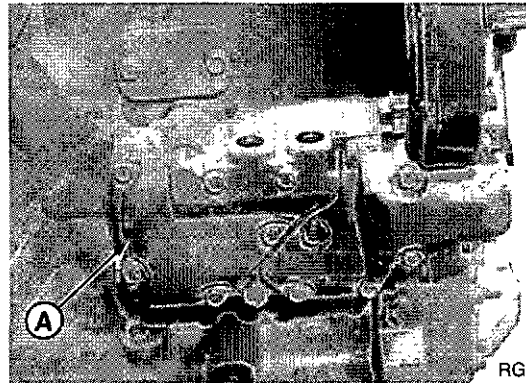
• **Install Oil Cooler Assembly**

1. Lubricate new O-rings with clean engine oil.
2. Install oil cooler (A) in oil cooler housing (B).
3. Apply **LOCTITE 242 Thread Lock and Sealer** to oil cooler-to-oil cooler housing cap screws. Tighten to 12 N·m (9 lb-ft).
4. Using a new gasket, install oil cooler assembly. Be sure gasket is properly aligned with cap screw holes.



RG7592

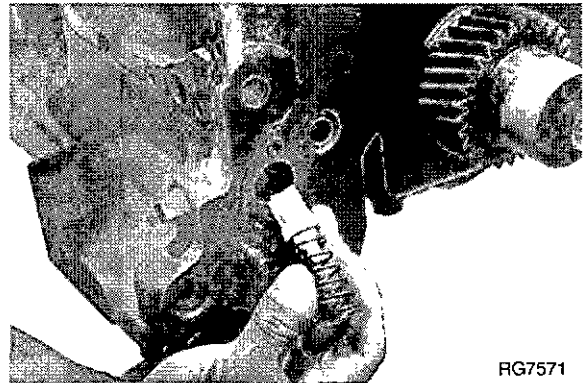
5. Install oil tube adapter/oil cooler cover (A), if equipped. Tighten cap screws to 35 N-m (26 lb-ft).
6. Install oil filter header (B) and tubes (C), if equipped. See REMOVE, INSPECT, AND INSTALL OIL FILTER BASE, earlier in this group.



RG7590

REMOVE, INSPECT, AND INSTALL OIL BYPASS VALVE

1. Remove timing gear cover and front plate as described in Group 16.
2. Remove oil bypass valve and spring.
3. Inspect valve and spring for damage. Replace parts if necessary.
4. Check bypass valve spring free length and compression strength using D01168AA Spring Compression Tester. Replace parts if not within specification.



RG7571

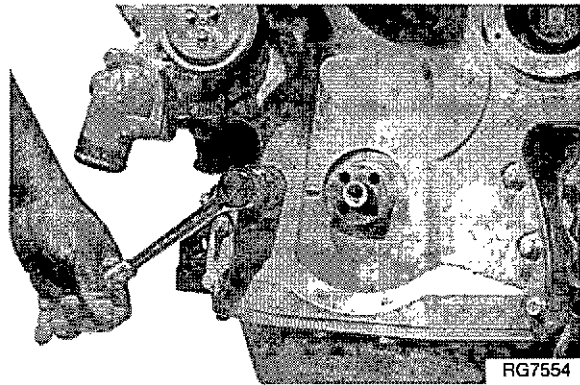
BYPASS VALVE SPRING SPECIFICATIONS

Free Length	51 mm (2.00 in.)
Spring Load at 29 mm (1.14 in.) Compressed Length	87.8 N (20 lb-force)

5. Install oil bypass valve and spring in cylinder block.
6. Install front plate and timing gear cover as described earlier in Group 16.

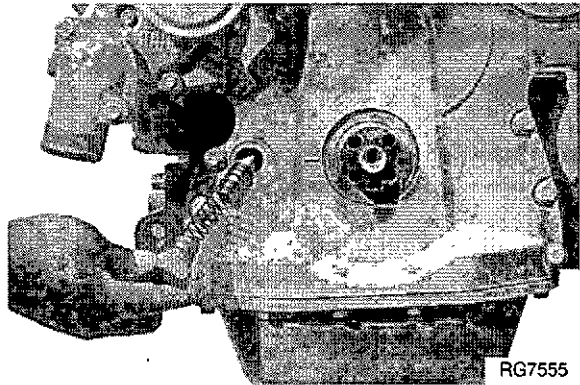
REMOVE AND INSTALL OIL PRESSURE REGULATING VALVE AND SEAT

1. Remove oil pressure regulating valve plug from timing gear cover.



RG7554

2. Remove oil pressure regulating valve and spring.
3. Check valve cone for excessive wear and damaged sealing face.
4. Check oil pressure regulating spring free length and compression strength using D01168AA Spring Compression Tester. Replace parts if not within specification.

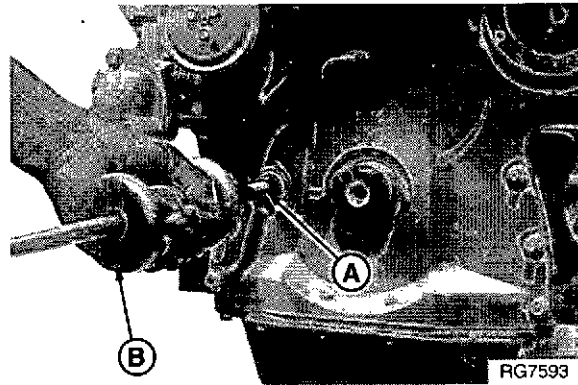


RG7555

PRESSURE REGULATING VALVE SPRING SPECIFICATIONS

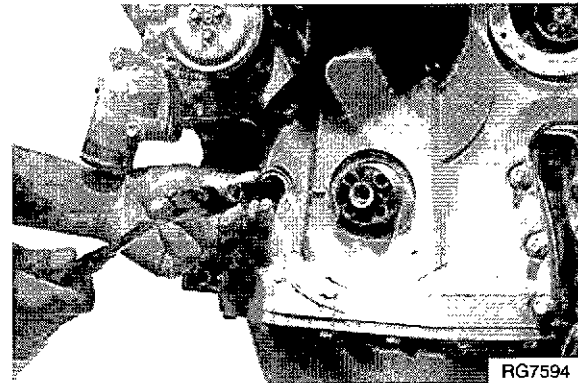
4-Cylinder Engines:	
Spring Free Length.....	11.5.5 mm (4.55 in.)
Spring Tension at 42.5 mm (1.68 in.).....	.45 N (9.1—11.1 lb-force)
6-Cylinder Engines:	
Spring Free Length.....	119 mm (4.68 in.)
Spring Tension at 42.5 mm (1.68 in.).....	.66 N (13.5—16.5 lb-force)

5. Pull valve seat out of cylinder block with JT01727 Collet (A) and JT01718 Slide Hammer (B) from D01061AA Blind-Hole Puller Set, or equivalent.

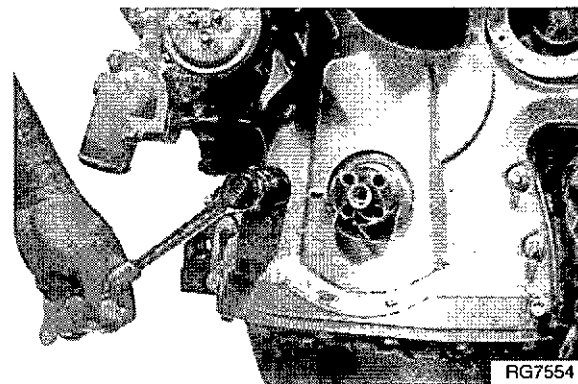


IMPORTANT: DO NOT drive against raised inner rim of valve seat so that valve seat bore is not damaged.

6. Drive valve seat into cylinder block with JD248A Oil Pressure Relief Valve Bushing Driver and JDG536 (OTC813) Handle until the seat bottoms in bore.

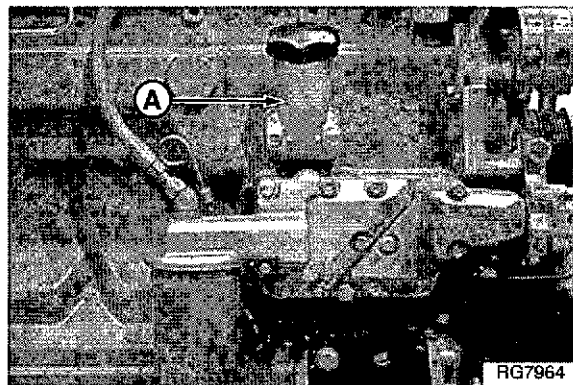


7. Install valve, spring, washer, and plug in timing gear cover. Tighten plug to 95 N·m (70 lb-ft).



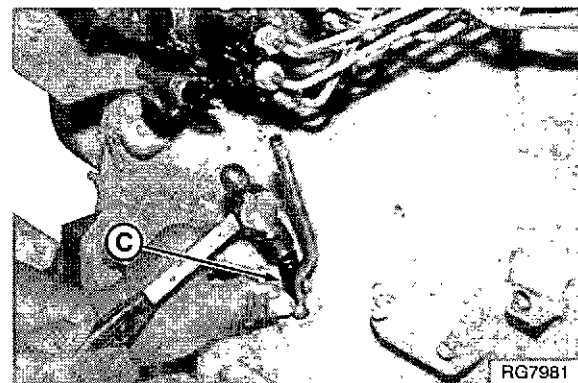
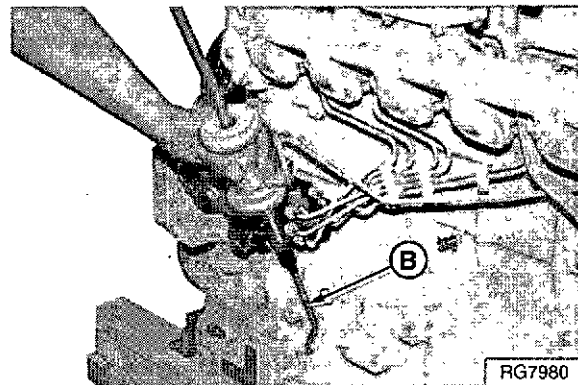
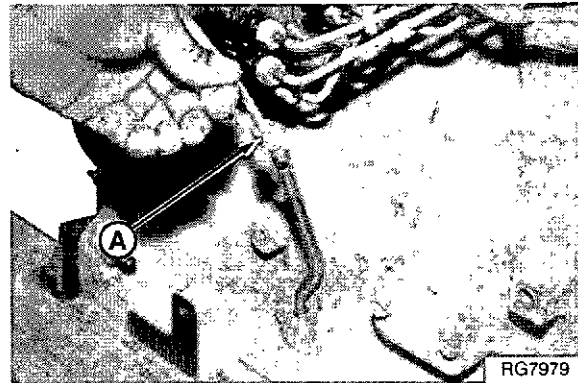
REMOVE AND INSTALL OIL FILL TUBE

1. Remove oil fill tube (A).
2. Inspect and replace tube as needed.
3. Using a new gasket, install oil fill tube.
4. Apply LOCTITE 242 Thread Lock and Sealer to threads of cap screws.
5. Tighten cap screws to 35 N·m (26 lb-ft).



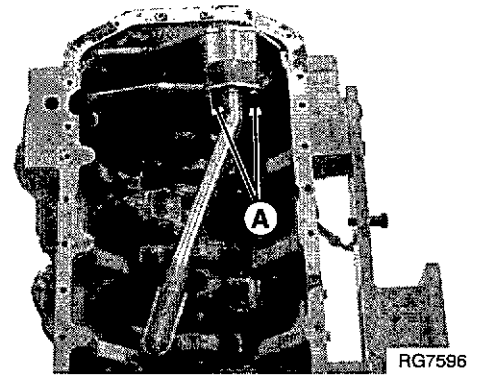
REMOVE AND INSTALL DIPSTICK TUBE WITH OIL PAN INSTALLED

1. Remove dipstick (A).
2. Using No. 33856 (5/16 in.) Collet, No. 28250 Actuator Pin, and D01299AA Slide Hammer, remove dipstick tube (B) from block.
3. Coat end of new dipstick tube with LOCTITE 680 Retaining Compound.
4. Orient dipstick tube with first bend directed toward rear of engine and centerline plane of first bend angled 20 degrees toward the crankshaft centerline.
5. Using JDG965 Dipstick Driver (C), install dipstick tube until shoulder bottoms.
6. Install dipstick.

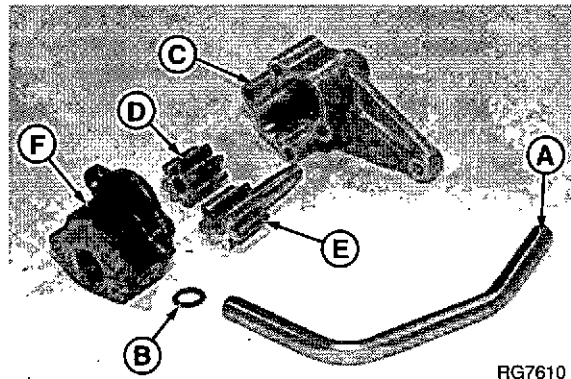


REPLACE OIL PUMP PICK-UP TUBE ASSEMBLY

1. Remove oil pan.
2. Loosen cap screws (A) and remove oil pump pick-up tube assembly.
3. Install new assembly with new O-ring and tighten cap screws to 47 N·m (35 lb-ft).
4. Reinstall oil pan. See INSTALL OIL PAN, as described later in this group.



ENGINE OIL PUMP ASSEMBLY



- A—Outlet Tube
- B—O-Ring
- C—Pump Housing
- D—Idler Gear
- E—Drive Gear
- F—Cover

REMOVE ENGINE OIL PUMP

1. Drain oil and disconnect turbocharger oil inlet line (A) at the turbocharger.
2. Remove oil pan.
3. Remove gasket from oil pan and oil pan rail.

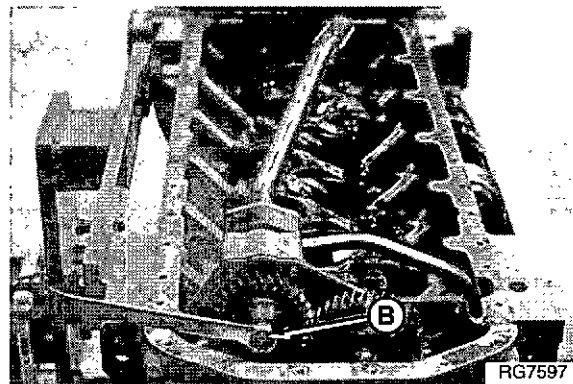
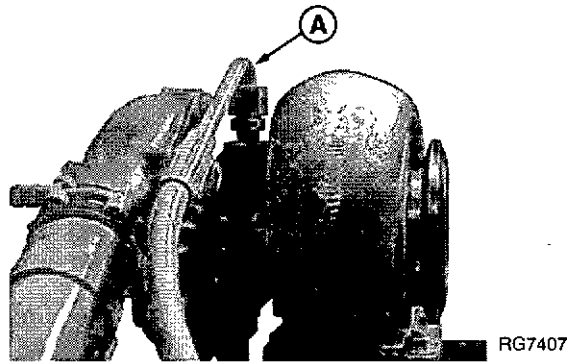
NOTE: To aid reassembly of 4-cylinder engines with balancer shafts, lock the crankshaft with No. 1 piston at TDC compression stroke.

4. Remove nut (B) and pull gear from tapered oil pump drive shaft.

To remove oil pump gear, loosen nut several turns and apply force between the front plate and gear on two sides of gear with small pry bars.

If above method does not work, loosen oil pump housing cap screws and strike the nut on end of shaft with a small lead hammer while applying force to gear until gear is free of tapered shaft.

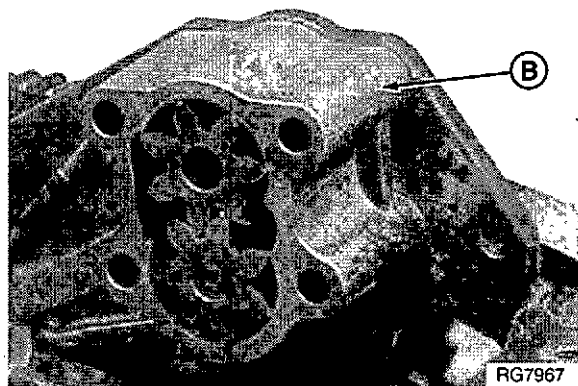
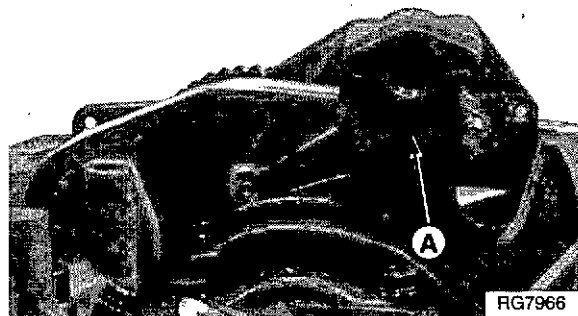
5. Remove oil pump pick-up tube, as described earlier in this group.



6. Remove upper two cap screws and remove cover (A).

NOTE: The lower idler gear cap screw has to be removed to remove the oil pump housing.

7. Remove oil pump housing assembly (B).



INSPECT AND MEASURE CLEARANCES

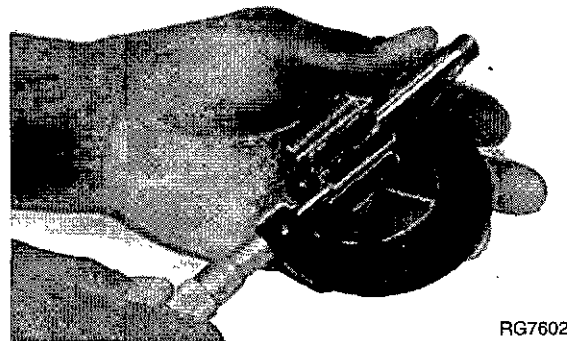
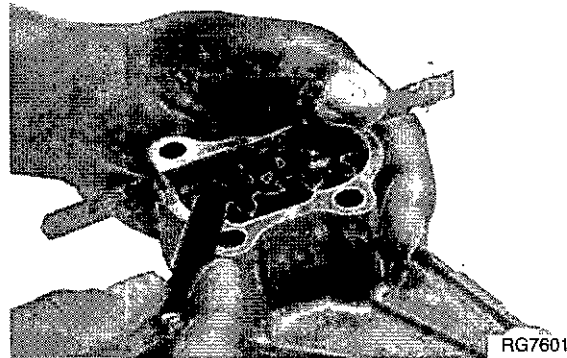
Inspect oil pump components for excessive wear.
Replace parts or oil pump assembly, as necessary.

1. Check gear-to-pump cover axial clearance.

AXIAL CLEARANCE SPECIFICATIONS

Thickness of Gears 35.975—36.025 mm
(1.4163—1.4183 in.)

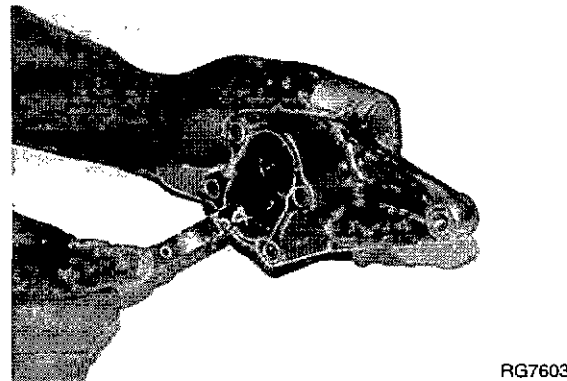
Axial Clearance 0.045—0.165 mm
(0.0018—0.0065 in.)



2. Check gear-to-pump housing radial clearance.

RADIAL CLEARANCE SPECIFICATIONS

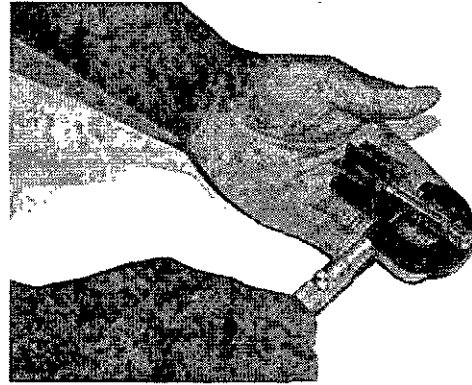
Radial Clearance 0.131—0.211 mm
(0.005—0.008 in.)



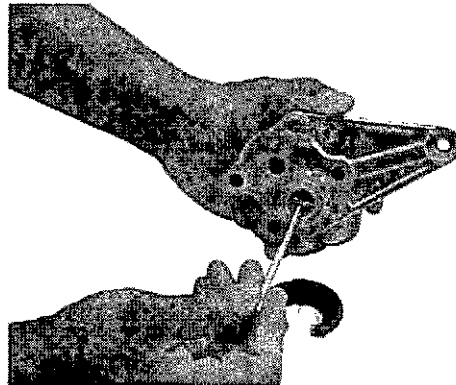
3. Check housing and cover bore ID and shaft OD.
Inspect cover and housing for evidence of gear rub.
Light contact is acceptable.
4. Measure bushing ID in housing and bore in cover.

PUMP SHAFT OD AND BORE ID SPECIFICATIONS

Drive Shaft OD	16.017—16.037 mm (0.6306—0.6314 in.)
Bushing ID in housing	16.052—16.102 mm (12.316—12.332 in.)



RG7605

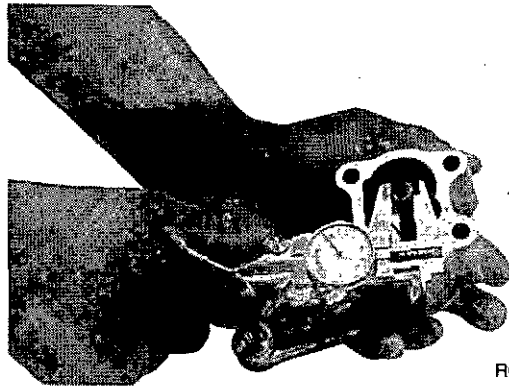


RG7606

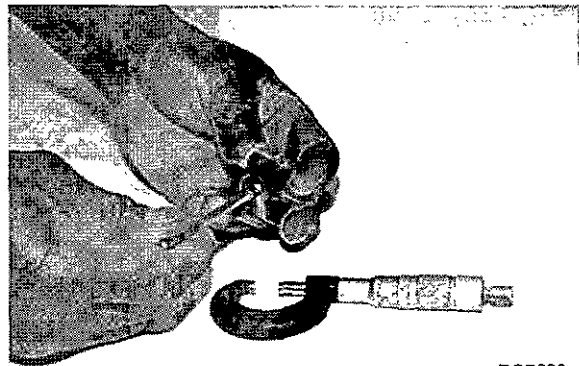
5. Measure idler shaft OD and idler gear ID

IDLER SHAFT OD AND IDLER GEAR ID SPECIFICATIONS

Idler Shaft OD	12.316—12.332 mm (0.4849—0.4855 in.)
Idler gear ID	12.355—12.363 mm (0.4864—0.4867 in.)



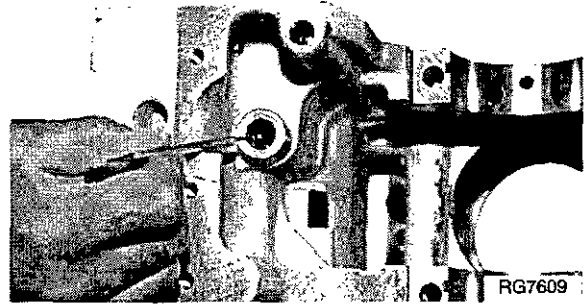
RG7607



RG7608

COMPLETE OIL PUMP DISASSEMBLY

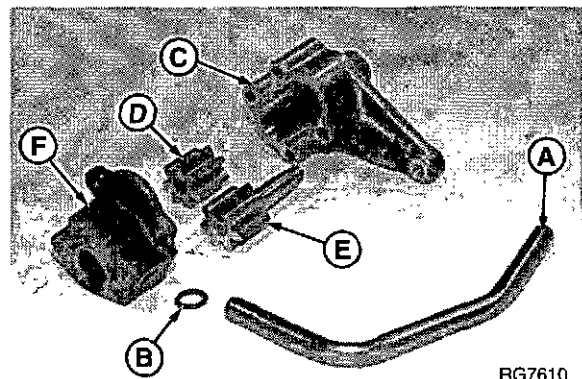
1. Remove O-ring from pump housing and cylinder block (for outlet tube).
2. Remove O-ring from oil pick-up tube.
3. Clean oil pump parts in solvent. Dry with compressed air.
4. Inspect pick-up tube. Check flange-to-pick-up tube weld for cracks. If cracks or other defects are found, replace pick-up tube. See REPLACE OIL PUMP PICK-UP TUBE ASSEMBLY, earlier in this group.



ASSEMBLE ENGINE OIL PUMP

IMPORTANT: Lubricate gears and shaft with clean engine oil before assembling.

1. Install new O-ring (B) in pump cover (F).
2. Put idler gear (D) and drive gear (E) in pump housing (C).

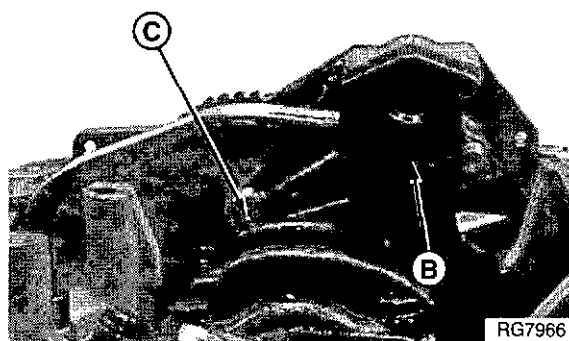
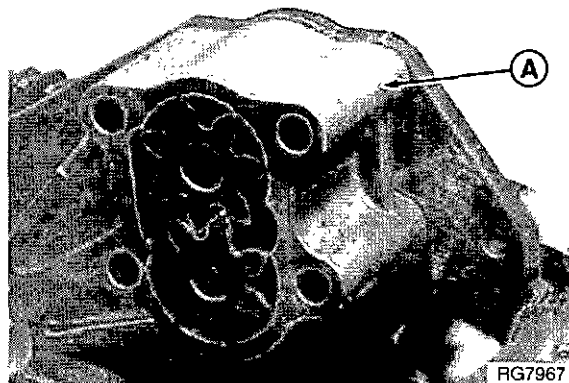


- A—Outlet Tube
- B—O-Ring
- C—Pump Housing
- D—Idler Gear
- E—Drive Gear
- F—Cover

INSTALL ENGINE OIL PUMP

NOTE: This procedure is for installing the oil pump with timing gear cover installed. If timing gear cover is removed from engine, refer to **INSTALL AND TIME BALANCER SHAFTS** in Group 16 (for 4-cylinder engines only).

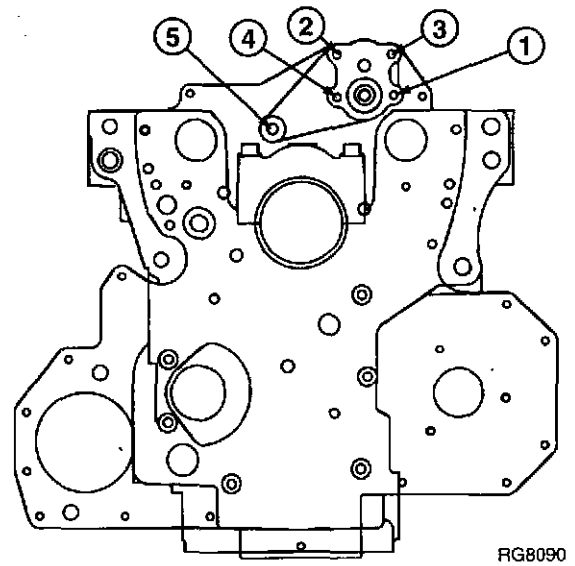
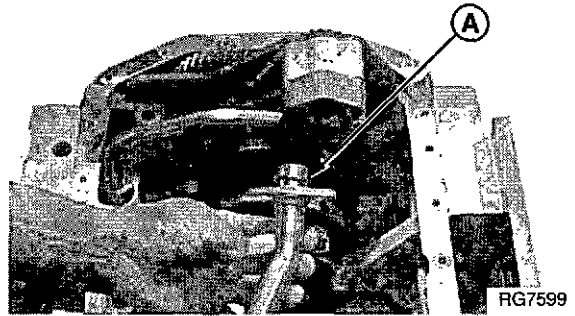
1. On 4-cylinder engines with balancer shafts, lock No. 1 piston at TDC compression stroke.
2. Install new O-rings in cylinder block and oil pump cover (for outlet tube). Install tube into cover and block.
3. Install oil pump housing with gears (A) onto front plate. Install lower idler gear cap screw (C) into leg of housing finger tight.
4. Swing (position) oil pump cover (B) onto pump housing and install two lower cap screws finger tight.



5. Install new O-ring (A) on neck of pick-up tube.
Install pick-up tube.
6. Tighten four cap screws and lower idler gear cap screw to specified torque according to sequence shown.

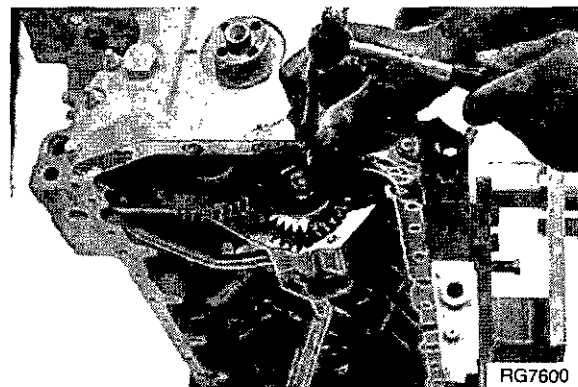
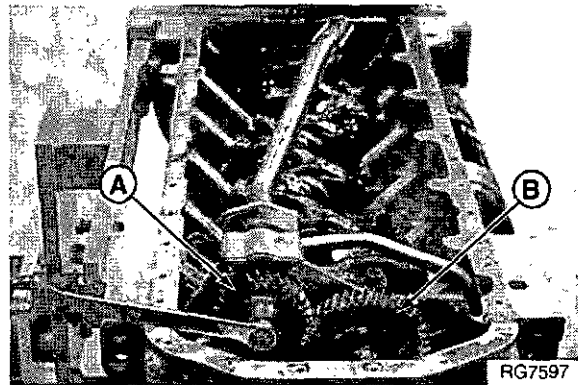
TORQUE SPECIFICATIONS

Oil Pump Pick-up Tube	35 N·m (26 lb-ft)
Lower Idler Gear	80 N·m (59 lb-ft)



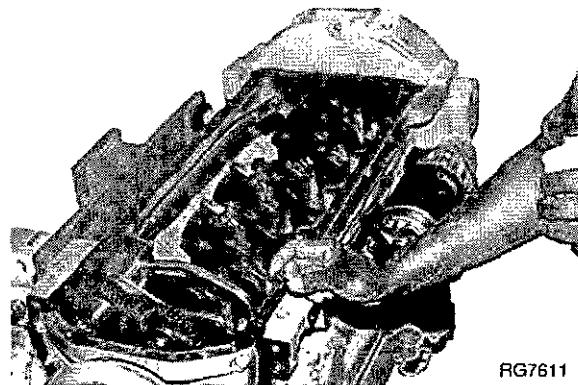
Viewed from rear of engine

7. Install oil pump drive gear (A) so that it meshes with lower idler gear (B) and balancer shaft gear (4045 engines only) without altering gear train timing.
8. Install new retaining nut and tighten to 50 N·m (37 lb-ft).
9. Stake nut to shaft by applying three center punch marks near ID of the nut.



INSTALL OIL PAN

1. Apply LOCTITE 515 Flexible Form-In-Place Gasket on oil pan rail where flywheel housing, front plate, and timing gear cover attach to cylinder block.
2. Install oil pan gasket.
3. Install oil pan and tighten cap screws to 35 N·m (26 lb-ft).



4. Install aluminum or copper washer on drain plug with raised center against plug. Install plug in oil pan. Tighten drain plug to 47 N-m (35 lb-ft)

If equipped with elbow drain fittings, the threads and sealing surfaces must be free of oil film to insure an effective seal. Apply LOCTITE 592 Pipe Sealant with TEFLON to fitting except for the leading one to three threads. Install and tighten fitting.

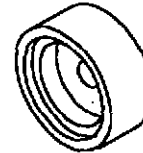
5. Fill engine crankcase with correct grade and viscosity engine oil. (See Group 02.)

SPECIAL OR ESSENTIAL TOOLS

NOTE: Order tools according to information given in the U.S. SERVICEGARD™ Catalog or in the European Microfiche Tool Catalog (MTC).

Water Pump Bearing Installer JDG956

Install water pump bearing.



RG7950

SERVICE EQUIPMENT AND TOOLS

NOTE: Order tools from the U.S. SERVICEGARD™ Catalog or from the European Microfiche Tool Catalog (MTC). Some tools may be available from a local supplier.

Name	Use
D01045AA Bushing, Bearing, and Seal Driver Set	Remove inner seal in water pump housing.
D01047AA 17-1/2 and 30-Ton Puller Set	Remove pulley from water pump shaft.

OTHER MATERIAL

Number	Name	Use
LOCTITE 515 (TY6304)	Flexible Form-In-Place Gasket (General Purpose)	Thermostat cover gaskets.
PT507	Multi-Purpose Grease	Thermostat housing O-rings.

COOLING SYSTEM SPECIFICATIONS

ITEM	SPECIFICATION	WEAR LIMIT
Clearance between bearing housing and impeller	1.016—1.270 mm (0.040—0.050 in.)	_____
Bearing Shaft OD:		
Impeller End	12.025—12.038 mm (0.4734—0.4739 in.)	_____
Pulley End	39.997—40.013 mm (1.5747—1.5753 in.)	_____
Impeller Bore	11.973—11.999 mm (0.4714—0.4724 in.)	_____
Pump Housing Bearing Bore	61.961—61.987 mm (2.4394—2.4404 in.)	_____
Impeller (with fins on both sides)-to-End of Shaft	2.46—2.58 mm below end of shaft (0.096—0.102 in.)	_____
Impeller (with fins on one side)-to-End of Shaft	flush ± 0.13 mm (0.005 in.) with end of shaft	_____
Minimum Clearance between Housing and Impeller	0.27 mm (0.010 in.)	_____
Adjustable Fan Drive:		
Bearing Housing ID		
Option Code 2301 and 2302	38.018—38.038 mm (1.4968—1.4976 in.)	_____
Option Code 2303 and 2304	47.538—47.558 mm (1.8716—1.8724 in.)	_____
Bearing OD:		
Option Code 2301 and 2302	38.087—38.100 mm (1.4995—1.5000 in.)	_____
Option Code 2303 and 2304	47.612—47.625 mm (1.8745—1.8750 in.)	_____
Shaft OD:		
Option Code 2301 and 2302	18.948—18.961 mm (0.7460—0.7465 in.)	_____
Option Code 2303 and 2304	25.387—25.400 mm (0.9995—1.0000 in.)	_____

COOLING SYSTEM SPECIFICATIONS—CONTINUED

ITEM	SPECIFICATION	WEAR LIMIT
Hub ID:		
Option Code 2301 and 2302	18.910—18.936 mm (0.7445—0.7455 in.)	_____
Option Code 2303 and 2304	25.337—25.363 mm (0.9975—0.9985 in.)	_____ _____ _____
Fan Drive Rear Housing Face-to-Hub Front Face:		
Option Code 2301 and 2303	110.85—110.87 mm (4.364—4.365 in.)	_____
Option Code 2302 and 2304	106.65—106.67 mm (4.199—4.200 in.)	_____ _____ _____
Thermostat Opening Temperature:		
82° C (180° F) Thermostat(s)	80°—84°C (175—182°F)	_____
Deaeration Method	Across thermostats in housing. Air must be bled from system when refilled with coolant. See operator's manual.	

COOLING SYSTEM SPECIFICATIONS—CONTINUED

	TORQUES
Water Pump-to-Timing Gear Cover	16 N·m (12 lb-ft)
Water Pump Inlet Elbow-to-Water Pump	35 N·m (26 lb-ft)
Water Pump Pulley-to-Water Pump	16 N·m (12 lb-ft)
Fan Pulley-to-Fan Pulley Hub:	
M8 cap screws	35 N·m (26 lb-ft)
M10 cap screws	70 N·m (52 lb-ft)
Fan Drive Assembly-to-Timing Gear Cover	70 N·m (52 lb-ft)
Water Manifold or Thermostat Housing-to-Cylinder Head	70 N·m (52 lb-ft)
Heating Element Retaining Nut	34 N·m (25 lb-ft)
Fan Belt Tensioner-to-Timing Gear Cover	50 N·m (37 lb-ft)
Cold Advance Switch (Sensor)	5 N·m (3.5 lb-ft)

DIAGNOSING COOLING SYSTEM MALFUNCTIONS

- **Engine Overheats:**

- Loose or broken fan belt
- Dirty radiator
- Low coolant level
- Low oil level
- Engine overloaded
- Defective head gasket
- Incorrect timing (engine/injection pump)
- Faulty thermostats
- Faulty water pump
- Corroded coolant passages
- Improper grade of fuel
- Excessive fuel delivery

- **Low Coolant Level:**

- Improper maintenance
- Improper operation
- Damaged radiator
- Water pump seal leakage
- Leakage
- Faulty radiator cap

REMOVE WATER MANIFOLD/ THERMOSTAT COVER AND THERMOSTAT(S)

NOTE: On some engines, the water manifold/thermostat housing is an integral part of the cylinder head.

1. Partially drain coolant from system.
2. Remove thermostat cover-to water pump tube (A) and seal.

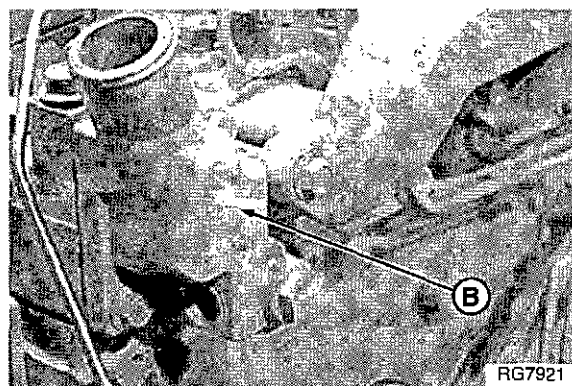
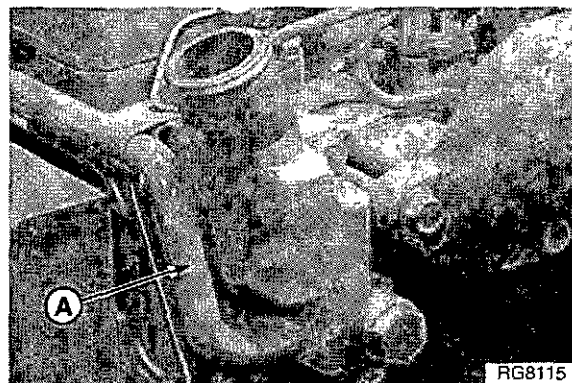
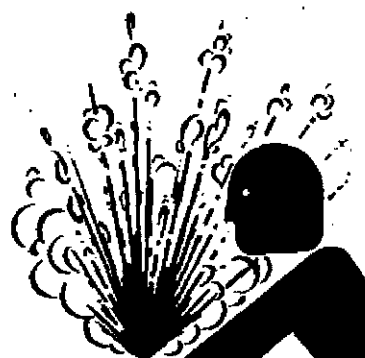


CAUTION: Explosive release of fluids from pressurized cooling system can cause serious burns. Do not drain coolant until coolant temperature is below operating temperature. Always loosen cooling system filler cap, radiator cap, or drain valve slowly to relieve pressure.

3. Visually inspect area around water manifold/thermostat cover for leaks.
4. Remove water manifold/thermostat cover (B) with gasket.

NOTE: Engines may be equipped with one or two thermostats.

5. Remove thermostat(s).
6. Remove and discard all gasket material. Clean gasket surfaces.
7. Clean and inspect cover for cracks or damage.



TEST THERMOSTAT(S)

1. Inspect thermostat(s) for debris or damage, and test each thermostat using an approved testing procedure. See **INSPECT THERMOSTAT AND TEST OPENING TEMPERATURE** in Group 105 for testing procedure. Thermostat(s) should start to open within the range specified. Replace if defective.

THERMOSTAT OPENING TEMPERATURE SPECIFICATIONS

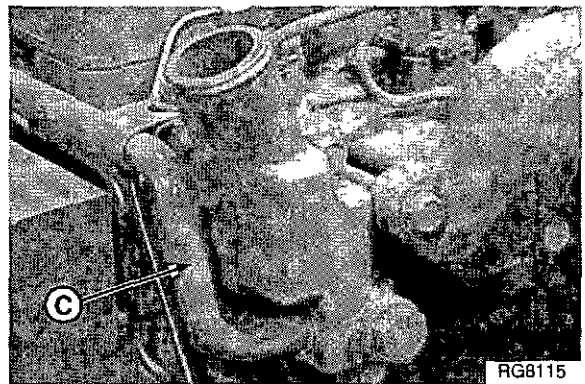
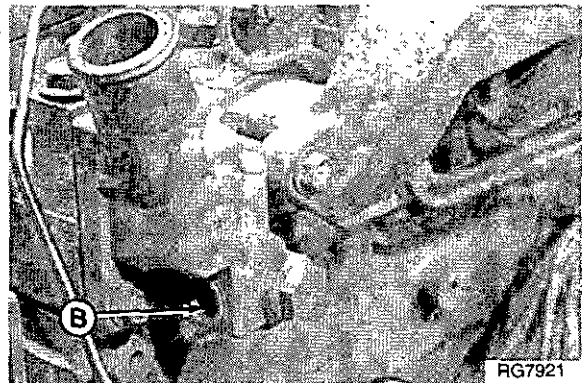
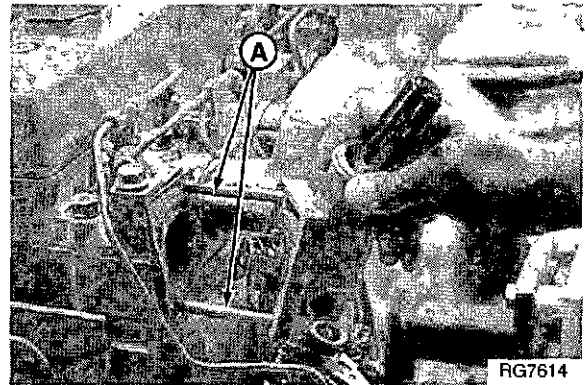
82°C (180°F) Thermostats 80—84°C (175—182°F)

NOTE: Deaeration is accomplished by a jiggle wire or groove in thermostat flange area (positioned at top).

INSTALL WATER MANIFOLD/ THERMOSTAT COVER AND THERMOSTAT(S)

1. Using guide studs (A) to keep gasket in place, install a new gasket on cylinder head.
2. Using a screwdriver to hold thermostat in place, install thermostat(s) and water manifold/thermostat cover. Tighten cover cap screws to 70 N·m (52 lb-ft).
3. Lubricate new O-ring with multi-purpose grease. Install seal (B) in thermostat cover.
4. Install water manifold/thermostat cover-to-water pump tube (C). Tighten clamps.
5. Fill cooling system and check for leaks.

IMPORTANT: Air must be expelled from cooling system when filling. Loosen temperature sending unit fitting at rear of cylinder head or plug in thermostat housing to allow air to escape when filling system. Tighten fitting or plug when all air has been expelled.

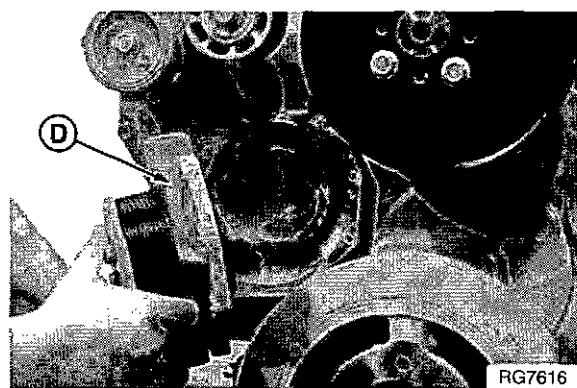
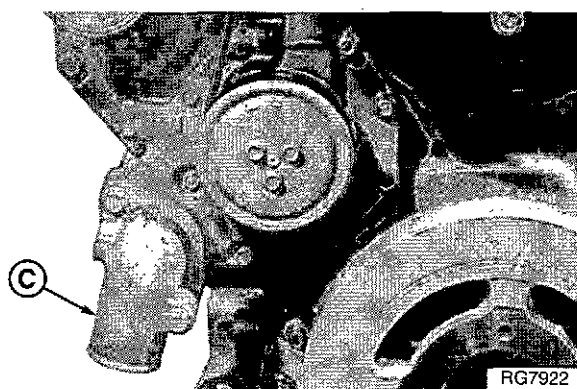
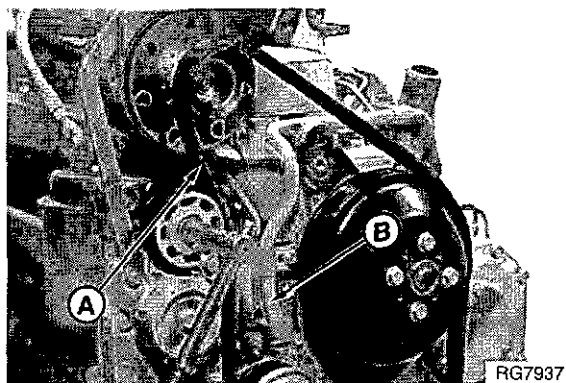


REMOVE WATER PUMP



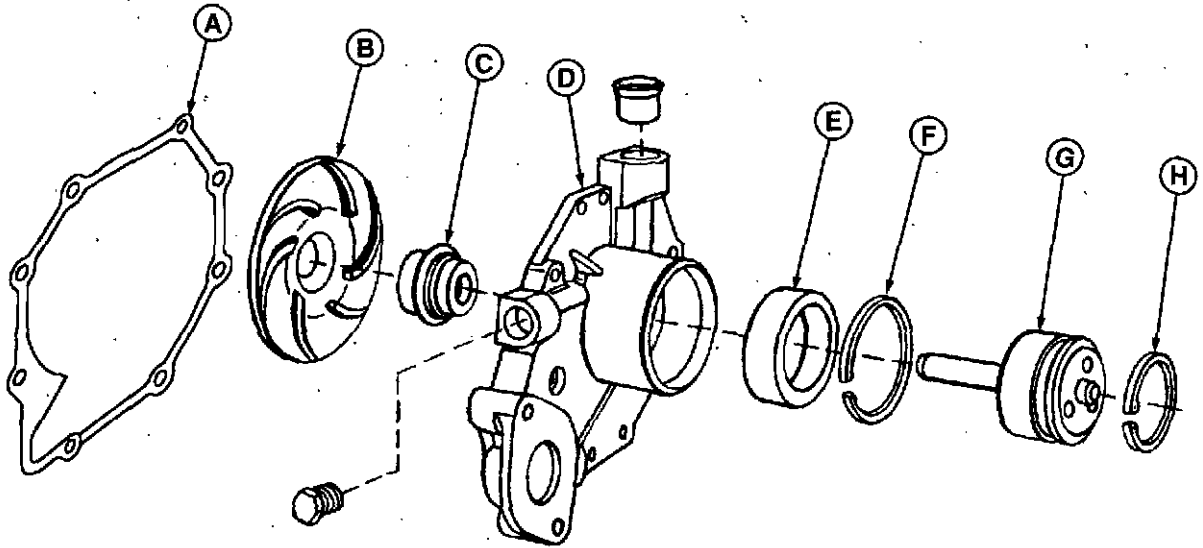
CAUTION: Explosive release of fluids from pressurized cooling system can cause serious burns. Do not drain coolant until the coolant temperature is below operating temperature. Always loosen cooling system filler cap, radiator cap, or drain valve slowly to relieve pressure.

1. Drain coolant.
2. Remove fan (shown removed).
3. Release tension on belt (A) using a breaker bar and socket.
4. Remove poly-vee belt from pulleys.
5. Remove thermostat housing-to-water pump tube (B).
6. Remove water pump inlet elbow (C) and O-ring, if desired.
7. Remove water pump (D).
8. Remove pulley from water pump.



A—Belt
B—Thermostat Housing-to-Water Pump Tube
C—Inlet Elbow
D—Water Pump

WATER PUMP ASSEMBLY

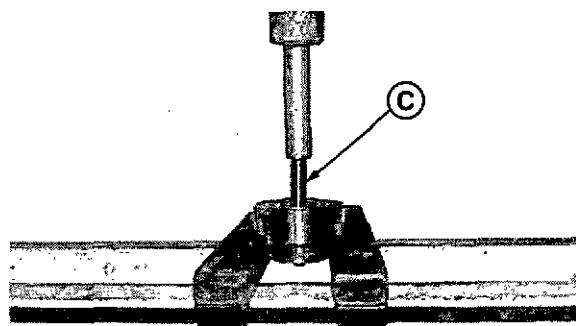
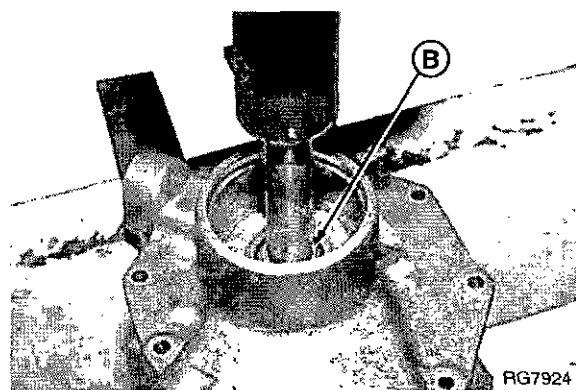
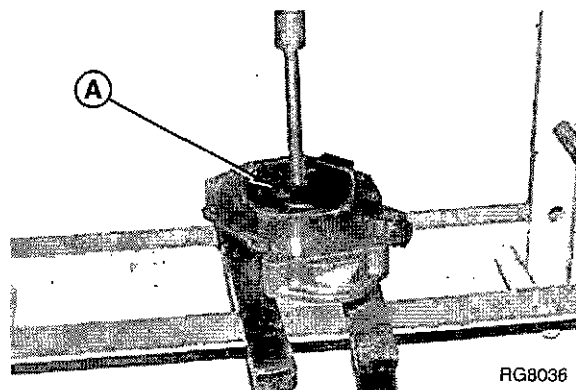


RG8114

- A—Gasket
- B—Impeller
- C—Seal
- D—Housing
- E—Bearing
- F—External Snap Ring
- G—Shaft
- H—Internal Snap Ring

DISASSEMBLE WATER PUMP

1. Using appropriate external snap ring pliers, remove internal snap ring from front bore of pump housing.
2. Support nose of water pump housing and press shaft through impeller (A) until impeller is free from shaft and bearing/shaft assembly is removed from housing. Discard impeller.
3. Drive or press seal (B) from pump housing.
4. Support inner bearing race and press shaft (C) out of bearing. Discard bearing.

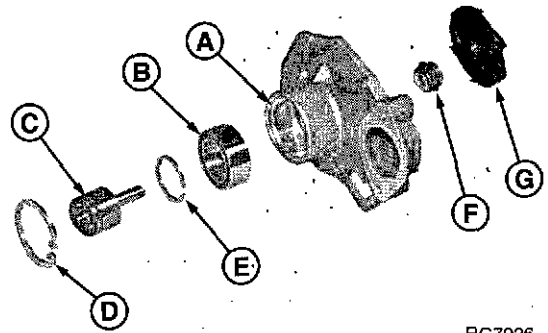


INSPECT, CLEAN, AND MEASURE WATER PUMP PARTS

1. Inspect water pump housing (A) for cracks or damage.
2. Remove gasket material from housing and clean with solvent. Dry with compressed air.
3. Clean out weep hole in housing. Inspect weep hole for oil or coolant leakage.

— Oil leakage indicates a damaged sealed bearing (B).

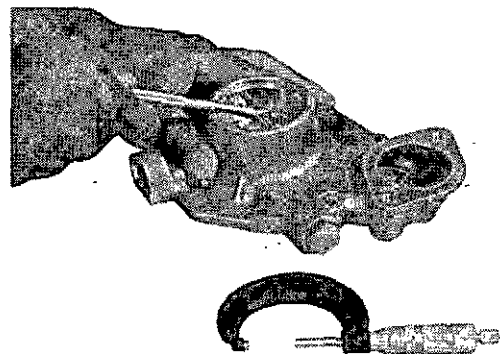
— Coolant leakage indicates a damaged housing seal (F).



RG7926

WATER PUMP SPECIFICATIONS

Impeller Bore	11.973—11.999 mm (0.4714—0.4724 in.)
Bearing Shaft OD (Impeller End)	12.025—12.038 mm (0.4734—0.4739 in.)
Bearing Shaft OD (Pulley End)	39.997—40.013 mm (1.5747—1.5753 in.)
Pump Housing Bearing Bore	61.961—61.987 mm (2.4394—2.4404 in.)



RG7927

- A—Housing
- B—Bearing
- C—Shaft
- D—Internal Snap Ring
- E—External Snap Ring
- F—Seal
- G—Impeller

ASSEMBLE WATER PUMP

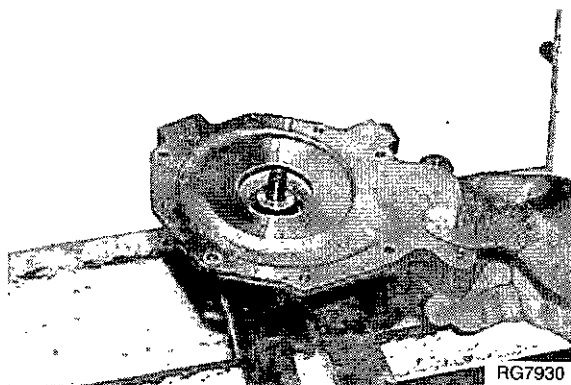
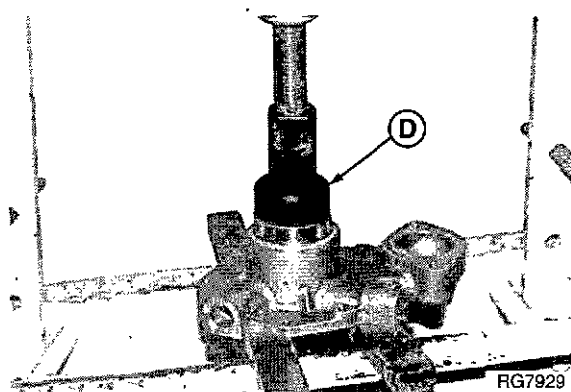
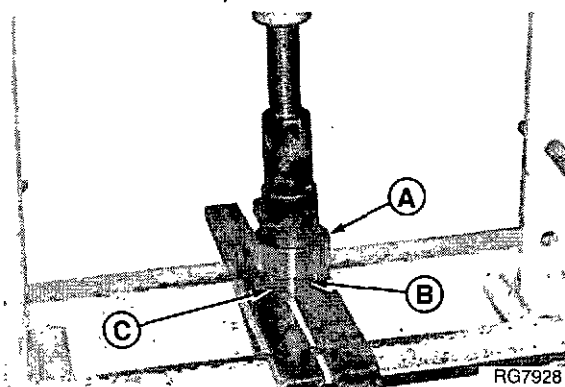
1. Thoroughly clean and inspect water pump mounting surface in timing gear cover before installing water pump assembly.
2. Using appropriate snap ring pliers, install external snap ring (C) into groove in shaft (B).
3. Using appropriate driver which bears on inner bearing race, install bearing (A) onto shaft against snap ring.

IMPORTANT: Do not push against end of bearing shaft. Push against outer race only, when installing bearing and shaft assembly into housing.

4. Using JDG956 Water Pump Bearing Installer (D), install bearing and shaft assembly into housing until it bottoms in housing bore.
5. Install large internal snap ring into groove in front bore of pump housing.

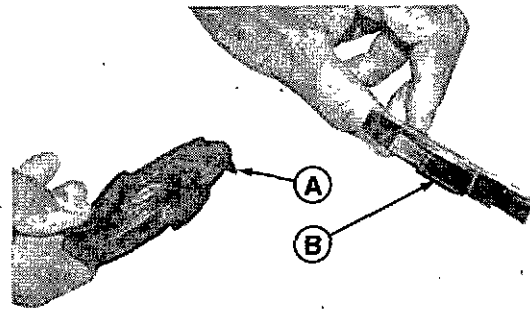
NOTE: Water pumps have a unitized (one-piece) water seal.

6. Using installation tool provided in seal kit, install seal (dry) onto water pump shaft and into housing until it is firmly seated.



- A—Bearing
- B—Shaft
- C—Snap Ring
- D—JDG956 Water Pump Bearing Installer

NOTE: Water pumps are available with two different types of impellers to assure adequate coolant flow for a given engine application. Fins can be present on both sides of impeller (A) or on just one side of impeller (B). Be sure to replace impeller with the same type of impeller to assure proper engine cooling.

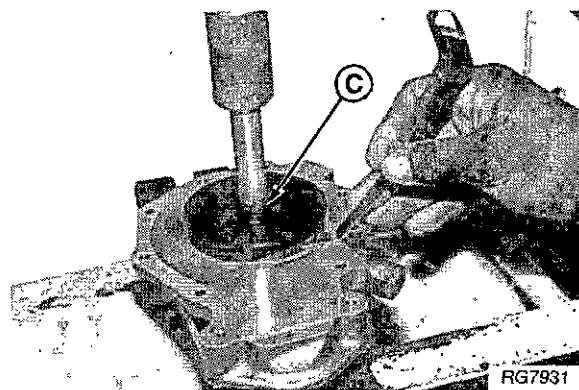


RG7932

7. Support front nose of water pump shaft.

IMPORTANT: When installing impeller, press only on brass bushing (C) as impeller could crack.

8. Using an appropriate driver, install impeller onto shaft to the specified dimension below.



RG7931

WATER PUMP IMPELLER SPECIFICATIONS

Impeller (with fins on both sides)-to-End of Shaft 2.46-2.58 mm (0.096-0.102 in.)
below end of shaft

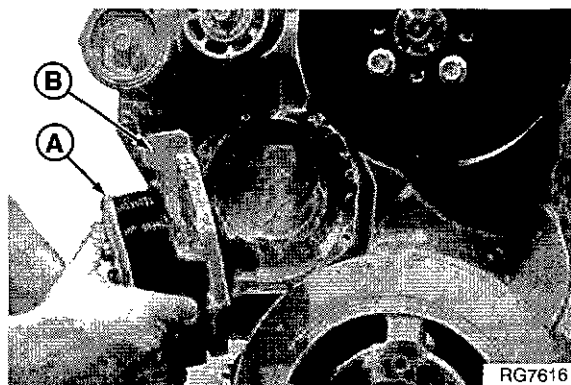
Impeller (with fins on one side)-to-End of Shaft flush ± 0.13 mm (0.005 in.)
with end of shaft

Minimum Clearance between Housing and Impeller 0.27 mm (0.010 in.)

9. Rotate impeller complete revolution by hand and check with feeler gauge for impeller-to-housing clearance.

INSTALL WATER PUMP

1. Install pulley (A) onto water pump (B). Tighten cap screws to 16 N·m (12 lb-ft).
2. Clean gasket surfaces. Using a new gasket, install water pump onto timing gear cover. Tighten cap screws to 16 N·m (12 lb-ft).
3. Using a new O-ring, install water pump inlet elbow (C), if removed. Tighten cap screws to 35 N·m (26 lb-ft).
4. Install poly-vee belts. Be sure that belt is correctly seated in all pulley grooves.



SPRING TENSION SPECIFICATION

Spring Tension 18—22 N·m (13—16 lb-ft)

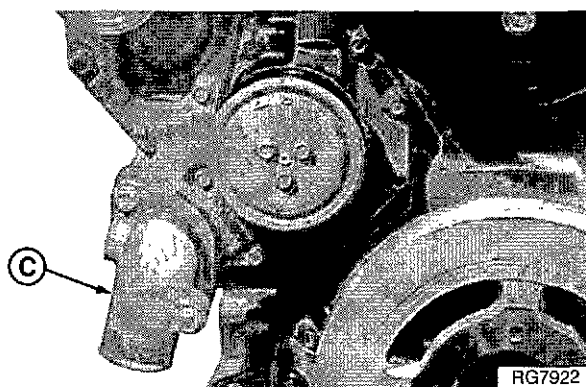
5. Install fan and tighten cap screws with lock washers to the following specification:

FAN-TO-PULLEY HUB TORQUE SPECIFICATIONS

M8 cap screws 35 N·m (26 lb-ft)

M10 cap screws 70 N·m (52 lb-ft)

6. Fill cooling system with proper coolant. (See Fuels, Lubricants, and Coolant—Group 02.)

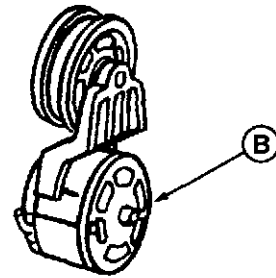
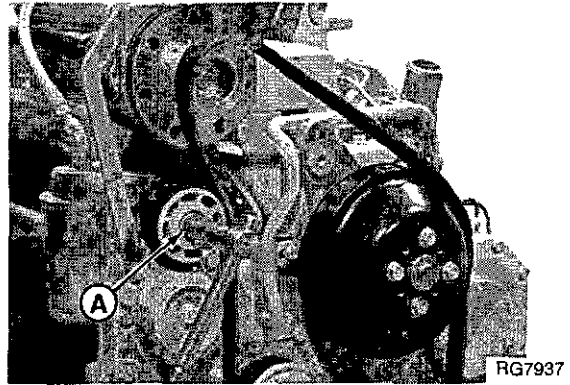


IMPORTANT: Air must be expelled from cooling system when refilled. Loosen temperature sending unit fitting at rear of cylinder head or plug in thermostat housing to allow air to escape when filling system. Tighten fitting or plug when all the air has been expelled.

REMOVE AND INSTALL AUTOMATIC (SPRING) BELT TENSIONER

NOTE: Belt tensioner cap screw (A) is left-hand threaded.

1. Release tension on belts using a breaker bar and socket.
2. Remove poly-vee belts from pulleys.
3. Remove belt tensioner.
4. Inspect sheave (B).
5. Install belt tensioner and tighten cap screws to 50 N·m (37 lb-ft).
6. Install poly-vee belts. Be sure that belt is correctly seated in all pulley grooves.



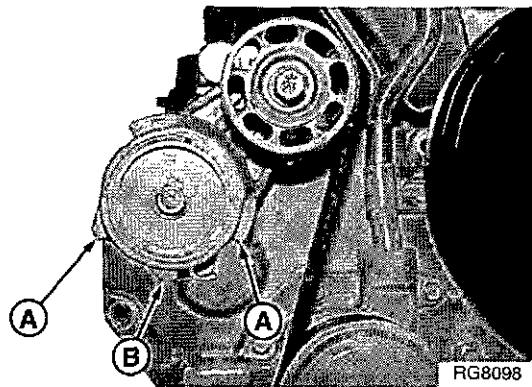
CHECKING BELT TENSIONER SPRING TENSION AND BELT WEAR

Belt drive systems equipped with automatic (spring) belt tensioners cannot be adjusted or repaired. The automatic belt tensioner is designed to maintain proper belt tension over the life of the belt. If tensioner spring tension is not within specification, replace tensioner.

• Checking Belt Wear

The belt tensioner is designed to operate within the limit of arm movement provided by the cast stops (A and B) when correct belt length and geometry is used.

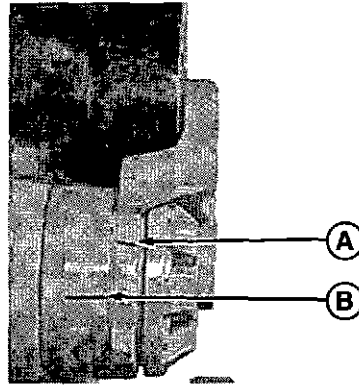
1. Visually inspect cast stops (A and B) on belt tensioner assembly.
2. If the tensioner stop on swing arm (A) is hitting the fixed stop (B), check mounting brackets (alternator, belt tensioner, etc.) and the belt length. Replace belt as needed.



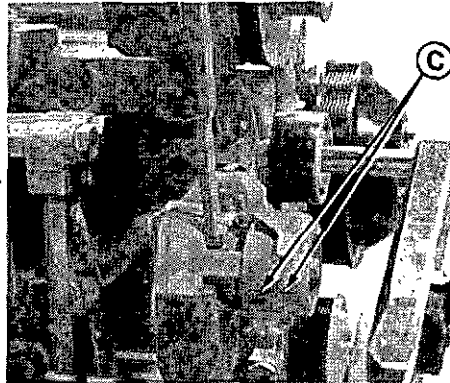
• **Checking Tensioner Spring Tension:**

A belt tension gauge will not give an accurate measure of the belt tension when automatic spring tensioner is used. Measure tensioner spring tension using a torque wrench and procedure outlined below:

1. Release tension on belt using a breaker bar and socket on tension arm. Remove belt from pulleys.
2. Release tension on tension arm and remove breaker bar.
3. Put a mark (A) on swing arm of tensioner as shown.
4. Measure 21 mm (0.83 in.) from (A) and put a mark (B) on tensioner mounting base.
5. Rotate the swing arm using a torque wrench until marks (A and B) are aligned (C).
6. Record torque wrench measurement and compare with specification below. Replace tensioner assembly as required.



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SPRING TENSION SPECIFICATION

Spring Tension 18—22 N·m (13—16 lb-ft)

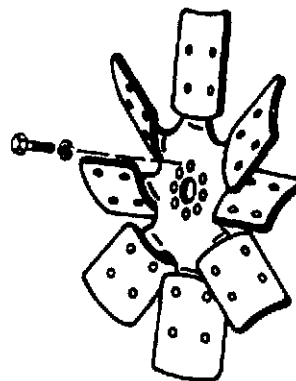
INSPECT AND INSTALL FAN ASSEMBLY

Several fan drive ratios are available allowing a closer matching of fan speed to application.

1. Inspect fan blades for bent or damaged condition. Bent blades reduce cooling system efficiency and throw the fan out of balance. Replace fan if blades are bent or damaged.

NOTE: Engines may be equipped with either suction-type fan or a blower-type fan, depending on application.

2. Install fan on pulley or pulley hub. Tighten cap screws (with lock washers) to specification.



RG4797

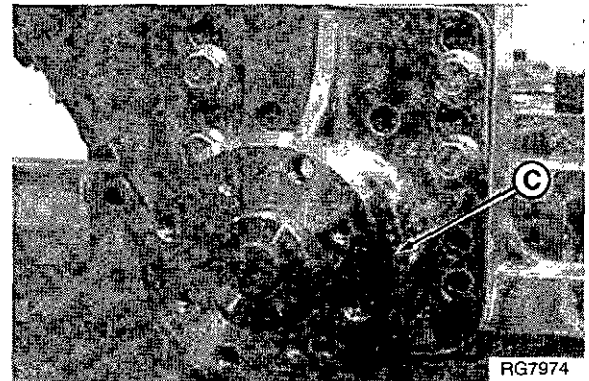
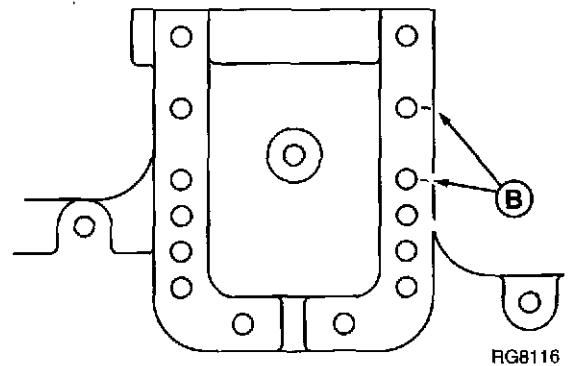
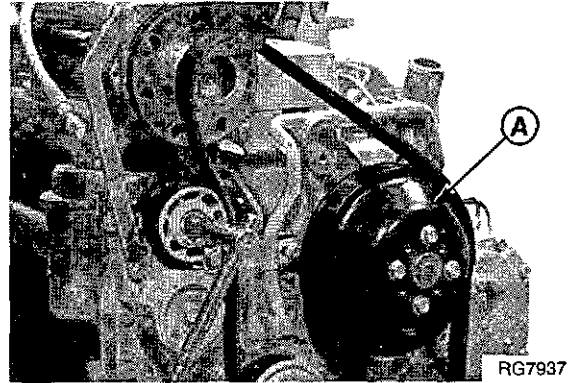
FAN-TO-PULLEY HUB CAP SCREW TORQUE SPECIFICATION

M8 Cap Screws	35 N-m (26 lb-ft)
M10 Cap Screws	70 N-m (52 lb-ft)

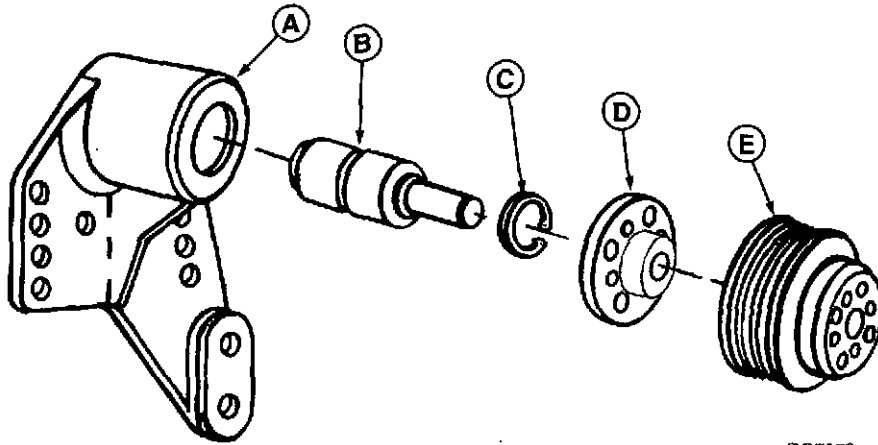
REMOVE AND INSPECT FAN DRIVE ASSEMBLY

Fan assemblies can be mounted in several positions to accommodate different application and engine cooling requirements.

1. Remove fan (shown removed).
2. Release tension on belt and remove poly-vee belt from pulleys.
3. Remove fan pulley (A).
4. Inspect pulley and grooves
5. Mark cap screw positions (B) on timing gear cover before removal to assure that fan pulley is installed in same position as removed to assure proper belt tension.
6. Remove hub (C) and fan drive.



REPLACE BEARINGS IN ADJUSTABLE FAN DRIVE ASSEMBLY



- A—Bearing Housing
- B—Bearing/Shaft
- C—Snap Ring
- D—Hub
- E—Pulley

• **To Disassemble Fan Drive Assembly:**

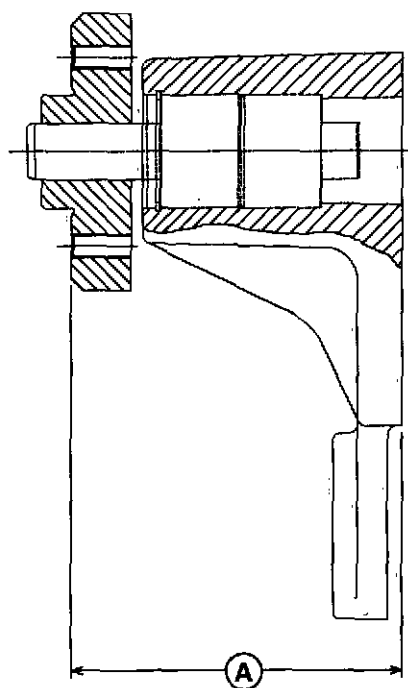
1. Support back side of fan hub (D) and press nose of bearing/shaft (B) out of hub.
2. Remove snap ring (C) from front bore of bearing housing (A).
3. Support front nose of bearing housing and press bearing/shaft out of housing. Discard bearing.
4. Thoroughly clean and inspect fan hub and bearing housing for cracks or any other damage.
5. Measure parts and compare with specifications given. Replace parts not within specification.

ADJUSTABLE FAN DRIVE SPECIFICATIONS

Bearing Housing ID:	
Option Code 2301 and 2302	38.018—38.038 mm (1.4968—1.4976 in.)
Option Code 2303 and 2304	47.538—47.558 mm (1.8716—1.8724 in.)
Bearing OD:	
Option Code 2301 and 2302	38.087—38.100 mm (1.4995—1.5000 in.)
Option Code 2303 and 2304	47.612—47.625 mm (1.8745—1.8750 in.)
Shaft OD:	
Option Code 2301 and 2302	18.948—18.961 mm (0.7460—0.7465 in.)
Option Code 2303 and 2304	25.387—25.400 mm (0.9995—1.0000 in.)
Hub ID:	
Option Code 2301 and 2302	18.910—18.936 mm (0.7445—0.7455 in.)
Option Code 2303 and 2304	25.337—25.363 mm (0.9975—0.9985 in.)

• **To Assemble Fan Drive Assembly:**

1. Support rear face of bearing housing and drive bearing into housing by pressing on outer bearing shell until bearing bottoms in housing bore.
2. Install internal snap ring into front groove of housing bore.
3. Support shaft through rear housing bore and press fan hub onto shaft to dimensions given below.



RG8038

FAN DRIVE REAR HOUSING FACE-TO-HUB FRONT FACE DIMENSION (A)

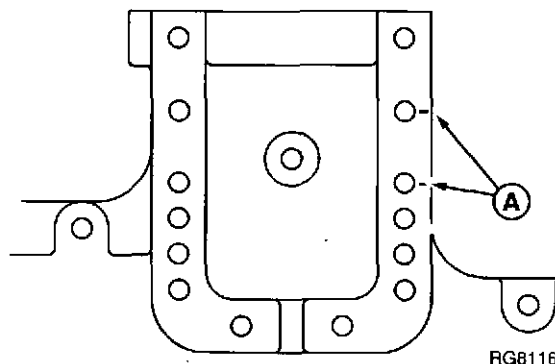
Option Code 2301 and 2303 110.85—110.87 mm
(4.364—4.365 in.)

Option Code 2302 and 2304 106.65—106.67 mm
(4.199—4.200 in.)

INSTALL FAN DRIVE ASSEMBLY

IMPORTANT: Be sure adjustable fan drive assembly is installed in correct position as removed to assure proper belt tension.

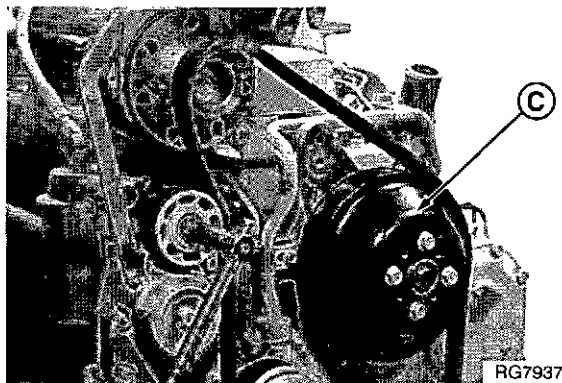
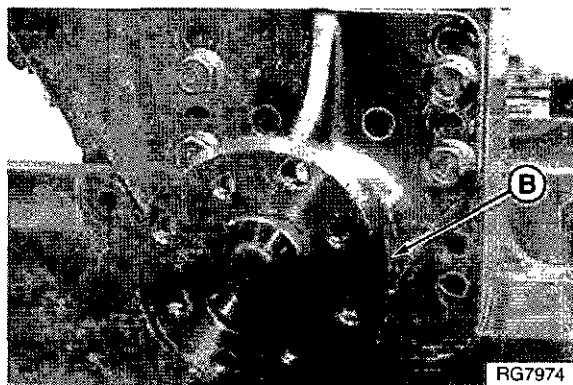
1. Install hub (B) with fan drive assembly, in positions (A) marked during disassembly, and tighten cap screws to 70 N·m (52 lb-ft).
2. Install fan pulley (C) and tighten cap screws to the following specification:



FAN PULLEY-TO-FAN PULLEY HUB TORQUE SPECIFICATIONS

M8 cap screws.....	35 N·m (26 lb-ft)
M10 cap screws.....	70 N·m (52 lb-ft)

3. Install poly-vee belt. Be sure that belt is correctly seated in all pulley grooves.



REMOVE AND INSTALL COOLANT HEATER—IF EQUIPPED



CAUTION: To avoid shock or hazardous operation, always use a three-wire heavy-duty electrical cord equipped with three-wire connectors. If a two-to-three contact adapter is used at the wall receptacle, always connect green wire to a good ground. Keep electrical connectors clean to prevent arcing.

Only plug coolant heater into electrical power if heating element is immersed in coolant. Sheath could burst and result in personal injury.

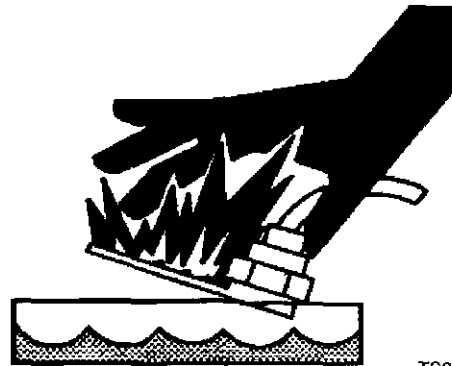
1. Unplug heater from electrical power source.
2. Drain cooling system.
3. Remove electrical cord, loosen nut, and pull heater element out of block.

NOTE: The heater element (G) cannot be repaired. If defective, replace it.

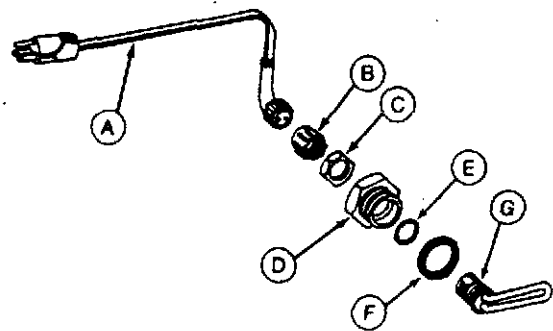
4. Assemble coolant heater (110 volt or 220 volt) as shown in illustration.
5. Place heater element in block so flats on the threaded part of the element are vertical. The element must not touch the internal walls of the block.

NOTE: If heater has been ordered as an attachment only, it will include a dust cover (B). The cover is used to protect the electrical connectors when cord assembly (A) has been removed.

6. Tighten retaining nut (C) to 34 N·m (25 lb-ft).
7. Install cord.



TS210



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- A—Cord
- B—Dust Cap
- C—Retaining Nut
- D—Adapter
- E—Gasket
- F—O-Ring
- G—Heater Element

OTHER MATERIAL

Number	Name	Use
PT569	NEVER-SEEZ Compound	Turbine housing-to-center housing cap screws and exhaust manifold-to-cylinder head cap screws.

AIR INTAKE AND EXHAUST SYSTEM SPECIFICATIONS

ITEM	SPECIFICATION
Intake Manifold Pressure (Turbocharger Boost)	See Group 110
Exhaust Adapter, Minimum End Play	0.8—1.6 mm (0.03—0.06 in.)
AiResearch/Garrett Turbocharger:	
Radial Bearing Clearance (Maximum)	
TA31, TA34, T300, and T350	0.08—0.18 mm (0.003—0.007 in.)
Axial Bearing End Play (Maximum):	
TA31, TA34, T300, and T350	0.025—0.102 mm (0.001—0.004 in.)

AIR INTAKE AND EXHAUST SYSTEM SPECIFICATIONS—CONTINUED

	TORQUES
Turbocharger-to-Exhaust Manifold	70 N·m (52 lb-ft)
Exhaust Adapter-to-Exhaust Manifold	47 N·m (35 lb-ft)
Exhaust Manifold-to-Cylinder Head	70 N·m (52 lb-ft)*
Exhaust Elbow-to-Exhaust Manifold	47 N·m (35 lb-ft)
Oil Inlet Line-to-Turbocharger	27 N·m (20 lb-ft)
Oil Return Line-to-Turbocharger:	
AiResearch/Garrett Turbocharger	
TA31, TA34, T300, and T350	35 N·m (26 lb-ft)
Turbine Housing-to-Center Housing:	
AiResearch/Garrett Turbocharger	
Initial	10 N·m (7 lb-ft)
Final	17 N·m (13 lb-ft)
Compressor Housing-to-Center Housing:	
Initial	10 N·m (7 lb-ft)
Final	17 N·m (13 lb-ft)

On 6-cylinder engines, tighten cap screws on cylinders No. 3 and No. 4 first.

EXTENDING TURBOCHARGER LIFE

Turbochargers are designed to last the life of the engine, but, because they operate at such high speeds (100,000 rpm or more); a moment's carelessness can cause them to fail in seconds.

The major causes of turbocharger failures are attributed to:

- **Lack of lube oil (quick starts and hot shutdowns)
Oil contamination**
- **Ingestion of foreign objects**
- **Restricted oil drainage**
- **Low oil level**
- **Operation on excessive side slopes**
- **Abnormally high exhaust temperatures**

- **Lack of Lube Oil**

Oil not only lubricates the turbocharger's spinning shaft and bearings, it also carries away heat. When oil flow stops or is reduced, heat is immediately transferred from the hot turbine wheel to the bearings, which are also heating up because of the increased friction due to the lack of oil. This combination causes the turbocharger shaft temperature to increase rapidly.

If oil flow does not increase and the process continues, bearings will fail. Once the bearings fail (which can happen in just seconds) seals, shaft, turbine and compressor wheels can also be damaged.

The principle causes of turbocharger bearing lubrication problems are low oil pressure, a bent, plugged or undersized oil lube supply line, plugged or restricted oil galleries in the turbocharger, or improper machine start-up and shutdown procedure.

Oil levels and pressure should always be closely monitored and all worn hoses and lines should be replaced. The turbocharger oil supply line should be checked frequently to make sure it is not kinked or bent and it should always be replaced with a line of equal size, length and strength.

The easiest way to damage a turbocharger is through improper start-up and shutdown procedures. Always idle the engine for at least 30 seconds (no load) after start-up and before shutdown. Warming the engine up before applying a load allows oil pressure to build up and lines to fill with oil.

Idling the engine before shutdown allows the engine and turbocharger to cool. "Hot" shutdowns can cause the turbocharger to fail because after high-speed operation the turbocharger will continue to rotate long after the engine has been shut off and oil pressure has dropped to zero. This will cause heat to build up and possible bearing damage. It can also cause carbon and varnish deposits to form.

• **Oil Contamination**

A second cause of turbocharger failures is contaminated oil. It can be caused by a worn or damaged oil filter or not changing the lube oil at recommended intervals. Expecting the oil filter to remove dirt, sand, metal chips, etc. from the oil before they reach the engine or turbocharger can be a costly mistake because contaminated oil may completely bypass the engine oil filter if the oil filter or oil cooler is clogged, if the filter element is improperly installed, or if the oil is thick during cold weather.

Four good ways of avoiding oil contamination are:

- Always inspect the engine thoroughly during major overhaul. Look especially for any sludge or debris left in lube oil galleries.
- Change lube oil at recommended intervals. Analysis of oil samples at filter change periods can help identify potentially harmful contaminants in the oil.
- Clean the area around the oil fill cap before adding oil.
- Use a clean container when adding oil.

• **Ingestion of Foreign Objects**

The third cause of turbocharger damage is the ingestion of foreign objects. Foreign objects or particles can be ingested and cause damage to the turbocharger on both compressor and turbine sides. This is easy to avoid.

On the compressor side, foreign objects usually take the form of dust, sand, or shreds of air cleaner element that enter through improperly installed air cleaner elements. Leaky air inlet piping (loose clamps or torn rubber joints) or torn pleats in dry-type air cleaner elements also create problems.

The result is erosion of compressor blades that can cause the delicately balanced wheel to wobble.

IMPORTANT: Whenever an internal engine failure (valve, valve seat, piston) occurs, a thorough inspection of the turbocharger MUST BE performed before returning engine to service.

- **Restricted Oil Drainage**

A fourth cause of turbocharger damage is restricted lube oil drainage. The lubricating oil carries away heat generated by friction of the bearings and from the hot exhaust gases. If drainage back to the sump is impeded, the bearings will overheat with damage that will ultimately lead to failure.

There are two primary reasons for restricted drainage. A blocked drain tube, due to either damage or a buildup of sludged oil, or high crankcase pressure, which can be due to restricted crankcase breather or excessive engine blowby.

Periodically check both the turbocharger oil drain tube and engine breather tube for damage or restriction. Correction of these conditions leads to longer turbocharger life.

- **Abnormally High Exhaust Temperatures**

A fifth cause of turbocharger damage is abnormally high exhaust temperatures. Elevated exhaust temperatures cause coking of oil which can lead to bearing failure. Extreme over-temperature operation can cause wheel burst.

There are two basic causes of over-temperature. The first is restricted air flow and the second is overpowering the engine. In either case the engine has more fuel than available air for proper combustion, this overfueled condition leads to elevated exhaust temperatures.

Causes of restricted air flow can include damaged inlet piping, clogged air filters, excessive exhaust restriction, or operation at extreme altitudes. Overpowering generally is due to improper fuel delivery or injection timing. If overtemperature operation has been identified, an inspection of the air inlet and exhaust systems should be performed. Also, check the fuel delivery and timing.

REMOVE TURBOCHARGER

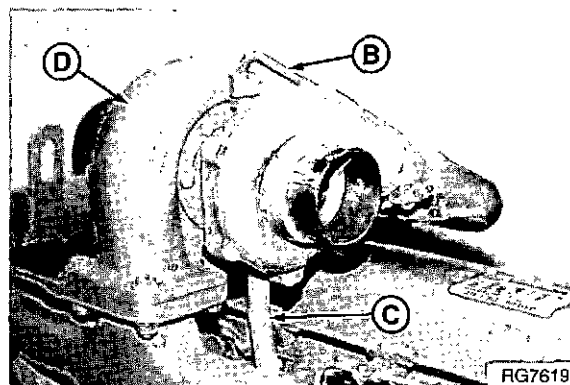
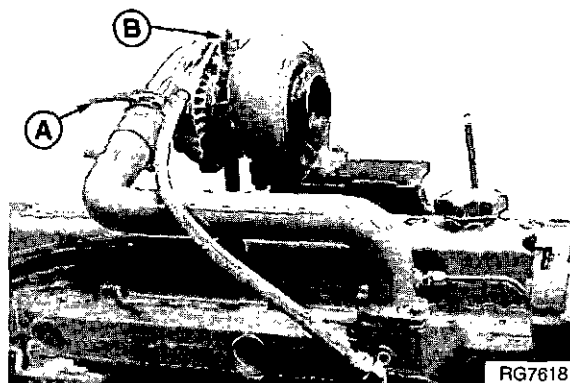


CAUTION: After operating engine, allow exhaust system to cool before removing turbocharger.

Thoroughly clean exterior of turbocharger and surrounding area to prevent entry of dirt into the air intake system during removal.

IMPORTANT: When cleaning turbocharger, do not spray directly into compressor cover or turbine housing. If turbocharger inspection is required, do not clean exterior prior to removal. Doing so may wash away evidence of a potential failure mode. See **TURBOCHARGER SEVEN-STEP INSPECTION** later in this group.)

1. Remove air intake hose and exhaust elbow (shown removed). Loosen hose clamp (A).
2. Disconnect oil inlet line (B) and oil return pipe (C) from turbocharger (D).
3. Remove mounting cap screws and nuts and lift turbocharger from exhaust manifold. Remove stainless steel gasket.
4. Place turbocharger on a clean flat surface. Cap or plug all air intake and exhaust openings.
5. Perform turbocharger seven-step inspection as described later, if failure mode has not yet been determined. See **TURBOCHARGER SEVEN-STEP INSPECTION**.



A—Hose Clamp
B—Oil Inlet Line
C—Oil Return Pipe
D—Turbocharger

TURBOCHARGER FAILURE ANALYSIS

The following is a guide for diagnosing the cause of turbocharger failures after removal from the engine.

COMPRESSOR HOUSING INLET DEFECTS

Problem	Possible Cause	Suggested Remedy
Foreign Object Damage	Objects left in intake system.	Disassemble and inspect intake system for foreign objects (this group). Inspect engine for internal damage.
	Leaking and/or defective intake system.	Inspect air intake system connections including air filter; repair as required (this group). Inspect air intake related engine components.
	Bearing failure.	Determine if engine and/or operator contributed to lack of lubrication, contaminated lubrication, excessive temperature, or debris generating engine failure in progress. Correct as required.
Compressor Wheel Rub	Manufacturing defects.	Correct as required.

COMPRESSOR HOUSING OUTLET DEFECTS

Oil and/or Dirt in Housing	Restricted air intake system.	Inspect and clean air cleaner.
	Prolonged periods of low RPM engine idling.	Check with operator to confirm conditions. (See operator's manual.)
	Defective oil seal ring.	Repair as required. (This group.)
	Restricted oil drain line.	Inspect and clear oil drain line as required.

TURBINE HOUSING INLET DEFECTS

Oil in Housing	Internal engine failure.	Inspect and repair engine as required.
	Oil leaking from compressor housing seal.	Verify that oil is in compressor housing and refer to "Compressor Housing Outlet Defects" as listed earlier in this chart.
Center Wall Deteriorated	Excessive operating temperature.	Check for restricted air intake.
		Check engine for overfueling.
		Check injection pump timing.

TURBOCHARGER FAILURE ANALYSIS—CONTINUED**TURBINE HOUSING OUTLET DEFECTS**

Problem	Possible Cause	Suggested Remedy
Turbine Wheel Rub	Bearing failure.	Determine if engine and/or operator contributed to lack of lubrication, contaminated lubrication, excessive temperature, or debris generating engine failure in progress. Correct as required.
	Manufacturing defect.	Correct as required (this group).
Foreign Object Damage	Internal engine failure.	Inspect and repair engine as required
	Objects left in intake system.	Disassemble and inspect air intake system,(this group).
	Leaking air intake system.	Correct as required, (this group).
Oil and/or Excessive Carbon	Internal engine failure.	Verified by oil in turbine housing. Correct as required.
	Turbine seal failure.	Inspect for excessive heat from overfueling and/or restricted air intake.
	Prolonged periods of low RPM engine idling.	Verify with operator to run engine underload or at a higher RPM. (Operator's Manual.)
	Restricted oil drain line.	Inspect and clear oil drain line as required.

EXTERNAL CENTER HOUSING AND JOINT DEFECTS

Leaks from Casting	Defective casting.	Replace turbocharger, (this group).
	Defective gasket.	Verify that leaks are not occurring at gasket joints.
Leaks from Joints	Loose attaching screws.	Tighten to specifications in CTM, (this group).
	Defective gasket.	Inspect and repair as required.

TURBOCHARGER FAILURE ANALYSIS—CONTINUED

INTERNAL CENTER HOUSING DEFECTS

Excessive Carbon Build up in Housing or on Shaft	Hot engine shut-down.	Review proper operation with operator as shown in operator's manual.
	Excessive operating temperature.	Restricted air intake; Overfueling or Mistimed engine.
	Restricted oil drain line.	Inspect and clean oil drain lines as required.
	Operating engine at high speeds and loads immediately after start-up.	Idle engine for a few minutes to allow oil to reach bearings before applying heavy loads.

TURBOCHARGER SEVEN-STEP INSPECTION

The following inspection procedure is recommended for systematic failure analysis of a suspected failed turbocharger. This procedure will help to identify when a turbocharger has failed, and why it has failed so the primary cause of the failure can be corrected.

Proper diagnosis of a non-failed turbocharger is important for two reasons. First, identification of a non-failed turbocharger will lead to further investigation and repair of the cause of a performance complaint.

Second, proper diagnosis eliminates the unnecessary expense incurred when a non-failed turbocharger is replaced.

The seven recommended inspection steps, which are explained in detail on following pages, are:

- Compressor Housing Inlet and Compressor Wheel.
- Compressor Housing Outlet.
- Turbine Housing Inlet.
- Turbine Housing Outlet and Turbine Wheel.
- External Center Housing and Joints.
- Internal Center Housing.
- Turbocharger Bench Test.

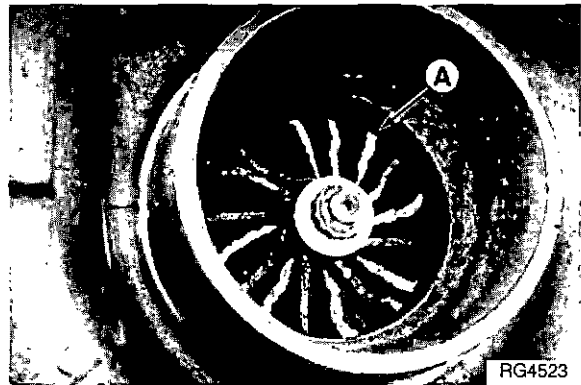
NOTE: To enhance the turbocharger inspection, an inspection sheet (Form No. DF-2280 available from Distribution Service Center—English only) can be used that lists the inspection steps in the proper order and shows potential failure modes for each step. Check off each step as you complete the inspection and record any details or problems obtained during inspection. Retain this with the work order for future reference.

• **Compressor Housing Inlet and Compressor Wheel**

1. Check compressor inlet and compressor wheel (A) for foreign object damage.

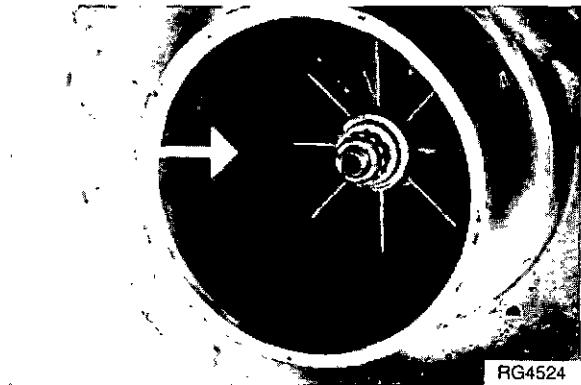
NOTE: Foreign object damage may be extensive or minor. In either case, the source of the foreign object must be found and corrected to eliminate further damages.

2. Mark findings on your checklist and continue the inspection.



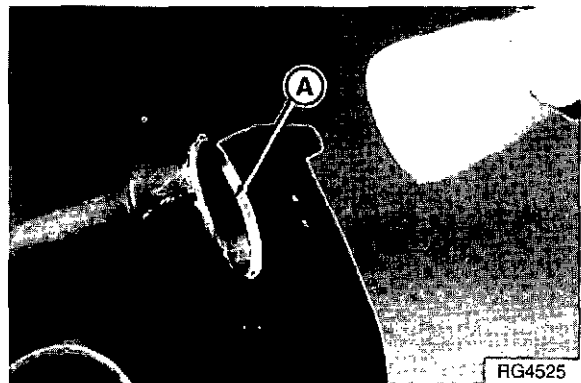
NOTE: You will need a good light source for this check.

3. Check compressor inlet for wheel rub on the housing (arrow). Look very closely for any score marks on the housing itself and check the tips of the compressor wheel blades for damage.



• **Compressor Housing Outlet**

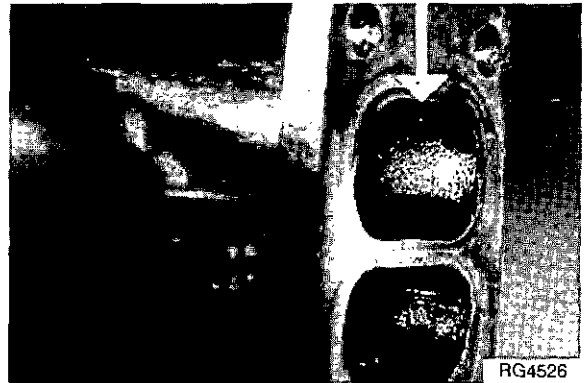
1. Check compressor housing outlet (A). The outlet should be clean and free of dirt or oil.
2. Mark it on your checklist if dirt or oil is found and continue the inspection.



• **Turbine Housing Inlet**

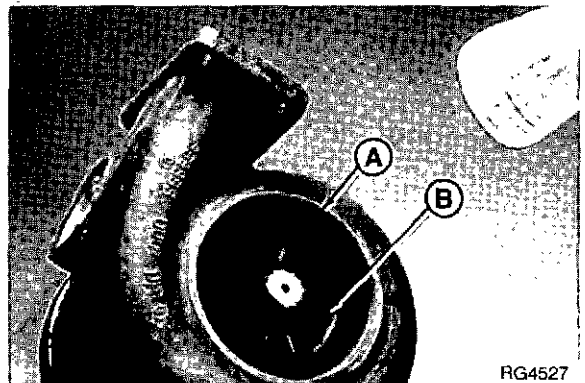
1. Check the turbine housing inlet ports (arrow) for oil in housing, excessive carbon deposit or erosion of center walls.

NOTE: If the inlet is wet with oil, or has excessive carbon deposits, an engine problem is likely. Center wall erosion (cracking or missing pieces), indicate excessive exhaust temperature.

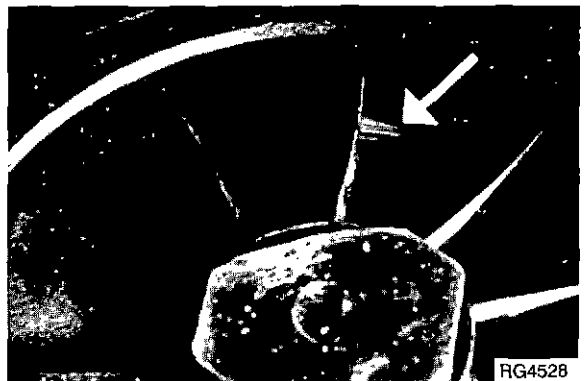


• **Turbine Housing Outlet and Turbine Wheel**

1. Use a flashlight to look up inside the turbine housing outlet (A) and check blades (B) for foreign object damage.



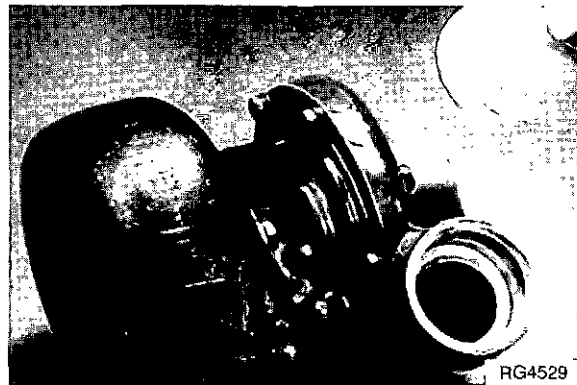
2. Inspect the wheel blades and housing for evidence of wheel rub (arrow). Wheel rub can bend the tips of the blades with the housing showing wear or damage.



- **External Center Housing and Joints**

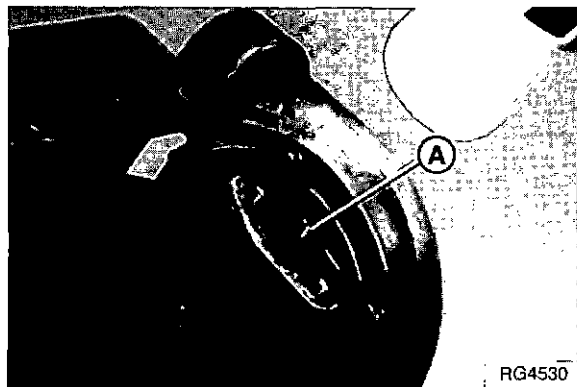
1. Visually check the outside of the center housing, all connections to the compressor, and turbine housing for oil.

NOTE: If oil is present, make sure it is not coming from a leak at the oil supply or return line.

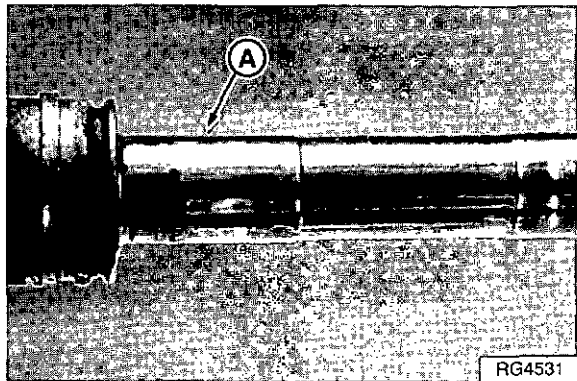


- **Internal Center Housing**

1. Using a flashlight, look through the oil return hole (A), to check the condition of the shaft and/or bearings. There should not be excess carbon deposits on the shaft or in the housing.

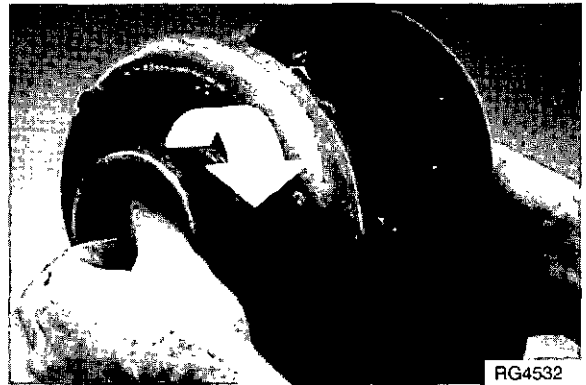


2. Excessive "blueing" or "coking" of oil along the complete length of the shaft (A) indicates a possible lack of lubrication caused by an engine failure, or improper operation, such as hot shutdowns.



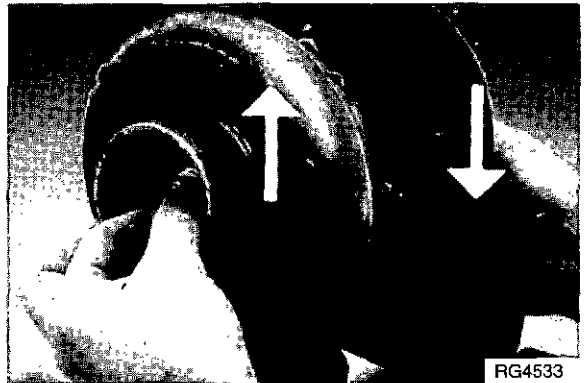
• **Turbocharger Bench Test**

1. Mount the turbocharger in a vise.
2. Rotate the shaft, using both hands, to check rotation and clearance. The shaft should turn freely, however, there may be a slight amount of drag.

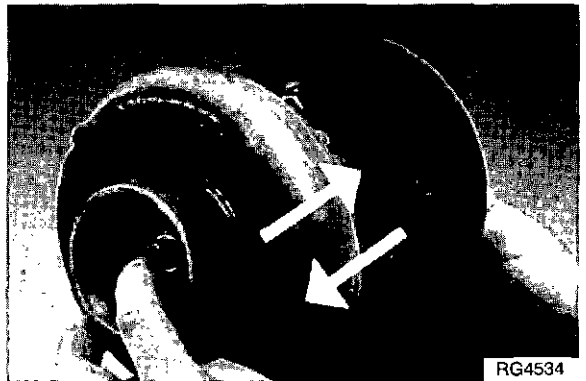


3. Next, pull up on the compressor end of the shaft and press down on the turbine end while rotating shaft. Neither the compressor wheel nor the turbine wheel should contact the housing at any point.

NOTE: There will be some "play" because the bearings inside the center housing are free floating.



4. Next, check shaft endplay by moving the shaft back and forth while rotating. There will be some endplay but not to the extent that the wheels contact the housings.



NOTE: These diagnostic procedures will allow you to determine the condition of the turbocharger. If the turbocharger has failed, analysis of your inspection notes should direct you to the specific areas of the engine to correct the problems causing the turbocharger failure (See **TURBOCHARGER FAILURE ANALYSIS**, outlined earlier in this group). It is not unusual to find that a turbocharger has not failed. If your turbocharger passes all the inspections, the problem lies somewhere else.

IMPORTANT: Before you finalize your conclusion that the turbocharger has not failed, it is strongly recommended that the following procedures of checking radial bearing clearance and axial bearing endplay with a dial indicator be performed. These procedures are not required if a failure mode has already been identified.

PERFORM RADIAL BEARING CLEARANCE TEST

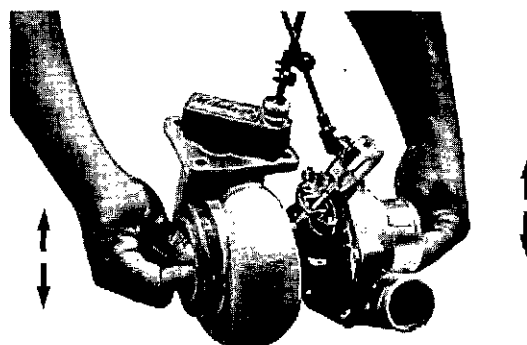
This test will give an indication of the condition of the radial bearings within the center housing and rotating assembly.

NOTE: Prelube center housing bearings prior to performing radial clearance test. (See **PRELUBE TURBOCHARGER**, later in this group.)

1. Position dial indicator with extension adapter onto center housing so that tip rests on shaft extending through oil return cavity.
2. Grasp rotating shaft at both ends and move the shaft toward the indicator then away from the indicator (arrows) by applying moderate force.
3. Observe and record total indicator movement.

The bearing clearance specification is 0.08—0.18 mm (0.003—0.007 in.).

If total indicator reading is not within specification, replace turbocharger.



RG7622

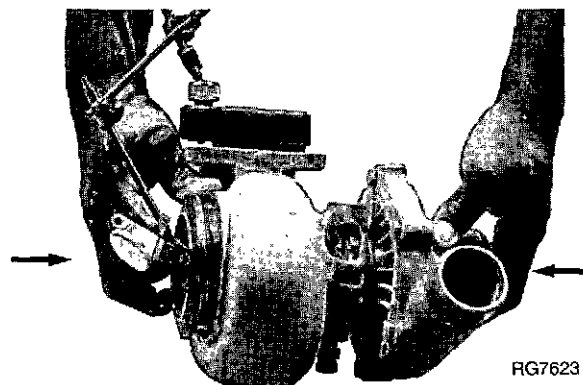
PERFORM AXIAL BEARING END PLAY TEST

This test will give an indication of the condition of the axial bearing within the center housing and rotating assembly.

1. Mount magnetic base dial indicator so that indicator tip rests on end of shaft. Preload indicator tip and zero dial on indicator.
2. Move shaft axially back and forth by hand.
3. Observe and record total dial indicator movement.

The bearing end play specification is 0.025—0.102 mm (0.001—0.004 in.).

If bearing end play is not within specification, replace turbocharger.



REPAIR TURBOCHARGER

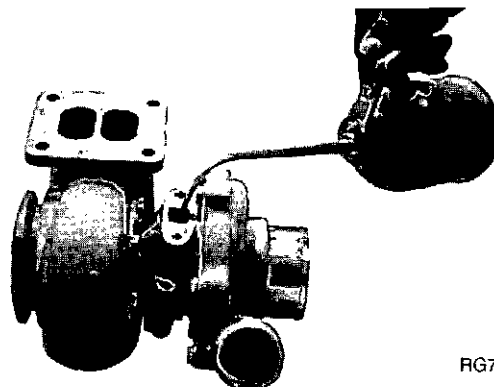
Turbochargers used on the engines covered in this manual are available through service parts as a complete remanufactured assembly only. Individual components for repair are not available.

PRELUBE TURBOCHARGER

IMPORTANT: DO NOT spin the rotor assembly with compressed air. Damage to bearings can occur, when using compressed air.

Fill oil inlet or drain port with clean engine oil and spin rotating assembly (by hand) to properly lubricate bearings.

If turbocharger is to be stored for an extended period of time, lubricate internally and install protective covers on all openings.



RG7624

INSTALL TURBOCHARGER

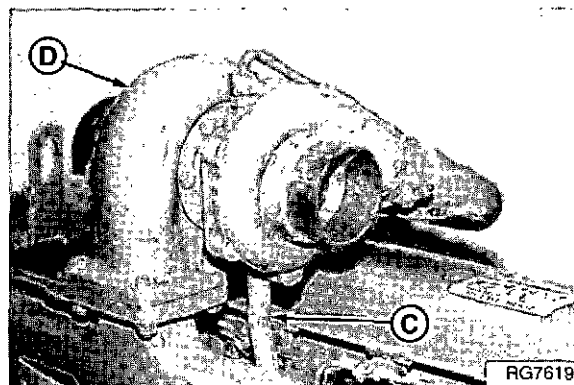
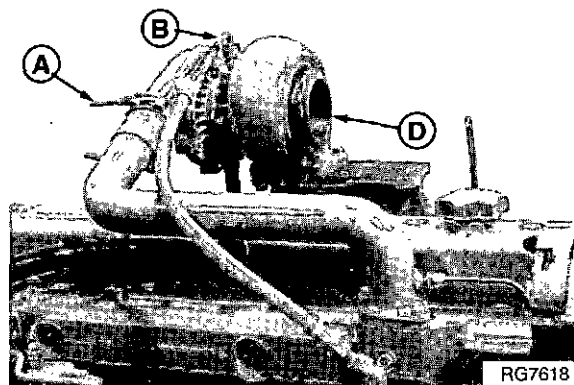
IMPORTANT: If turbocharger failed because of foreign material entering the air intake system, be sure to examine the system and clean as required to prevent a repeat failure.

If not done previously, prime (prelube) the turbocharger rotating assembly prior to mounting turbocharger on engine. Prelube center housing with clean engine oil through the oil drain hole. Turn rotating assembly by hand to lubricate bearings.

1. Position turbocharger (D) and new stainless steel gasket onto exhaust manifold. Tighten stud nuts to 70 N·m (52 lb-ft).
2. Install oil return pipe (C) to turbocharger. Tighten oil return pipe cap screws to 35 N·m (26 lb-ft). Connect turbocharger oil inlet line (B) and tighten to 27 N·m (20 lb-ft).
3. Connect air inlet hose-to-turbocharger compressor housing. Tighten hose clamp (A) on air inlet line.

IMPORTANT: Since the greatest suction force occurs between air cleaner and turbocharger, ensure that hose connections are tight to prevent entry of dirt into system.

4. Install exhaust adapter and exhaust elbow. The exhaust adapter must have a minimum end play of 0.8—1.6 mm (0.03—0.06 in.). Tighten cap screws to 47 N·m (35 lb-ft).



A—Hose Clamp
B—Oil Inlet Line
C—Oil Return Pipe
D—Turbocharger

TURBOCHARGER BREAK-IN

IMPORTANT: A new or repaired turbocharger DOES NOT have an adequate oil supply for immediate start-up of engine. Perform the steps below to prevent damage to turbocharger bearings.

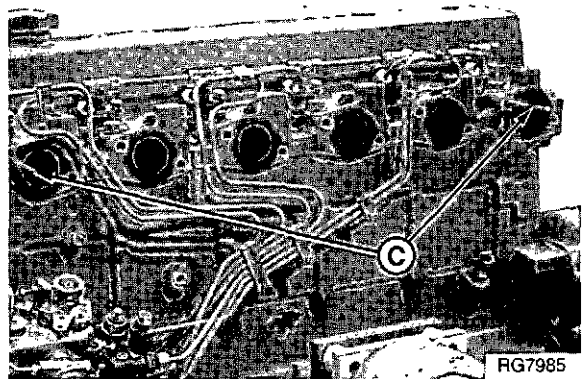
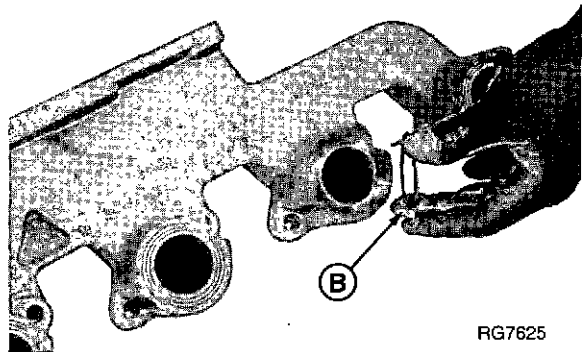
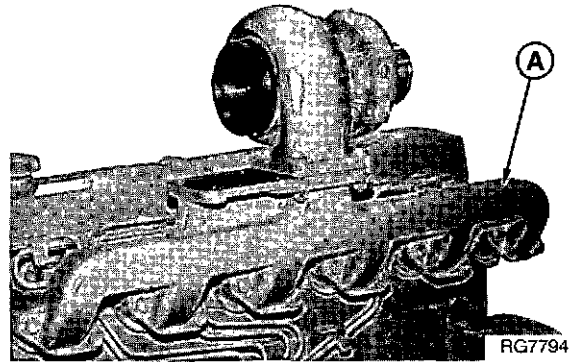
1. Either push the throttle lever to the "STOP" position, hold the engine shut-off knob out, or disconnect electrical wire from injection pump.
2. Crank engine over with starting until oil pressure gauge needle registers within the "GREEN" zone of pressure gauge.

IMPORTANT: DO NOT crank engine longer than 30 seconds at a time to avoid damage to starting motor.

3. Start and run engine at low idle while checking oil inlet and air piping connections for leaks.

REMOVE, INSPECT, AND INSTALL EXHAUST MANIFOLD

1. Remove turbocharger (if equipped), exhaust elbow, or exhaust pipe if desired. Turbocharger can be removed with exhaust manifold (A). (See REMOVE TURBOCHARGER, earlier in this group.)
2. Remove exhaust manifold using guide studs (C).
3. Inspect exhaust manifold and stainless steel gaskets (B).
4. Thoroughly clean passages in exhaust manifold.
5. Inspect each exhaust manifold for cracks or damage. Inspect machined mounting surfaces for burrs or other defects which might prevent gaskets from sealing properly. Replace parts as needed.
6. Install stainless steel gaskets on exhaust manifold.
7. Using guide studs, install exhaust manifold.
8. Apply PT569 NEVER-SEEZ® Compound to cap screws. Tighten exhaust manifold-to-cylinder head cap screws to 70 N·m (52 lb-ft). **On 6-cylinder engines**, tighten cap screws on No. 3 and No. 4 cylinders first.



REMOVE AND INSTALL AIR-TO-AIR AFTERCOOLER

Refer to machine technical manual for removal, inspection, and installation procedures.

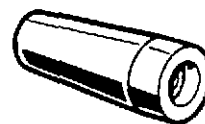
SPECIAL OR ESSENTIAL TOOLS

NOTE: Order tools according to information given in the U.S. SERVICEGARD™ Catalog or in the European Microfiche Tool Catalog (MTC).

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1

Nozzle Carbon Stop Seal Installer JD258

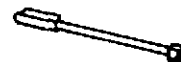
Used to install carbon stop seal in injection nozzle groove.



RG6254

Nozzle Bore Cleaning Tool JDE39

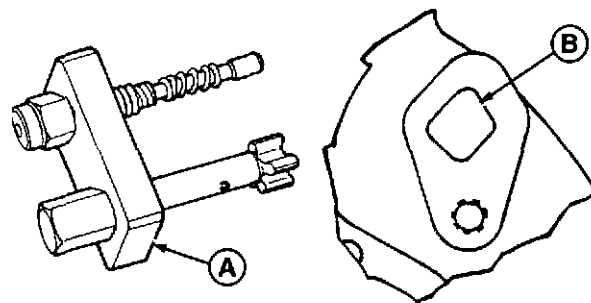
Clean injection nozzle bore in cylinder head.



RG5084

Flywheel Turning Tool (A) JD281A

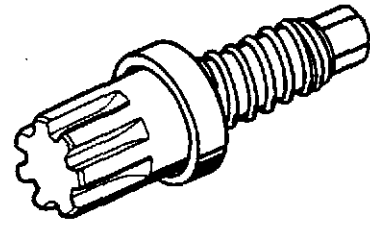
Used on engines with 142-tooth flywheel ring gear and a diamond-shaped tool guide bore (B) in flywheel housing. Tool has its own spring-loaded timing pin which threads into flywheel housing.



RG6252

Flywheel Turning Tool JDG820

Used to rotate flywheel on engine, with 129-tooth flywheel ring gear and a 29.9 mm (1.18 in.) ID flywheel housing guide bore diameter, to check damper radial runout and time engine. JDE81-1 may be used also if JDG820 is not available.

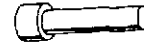


RG7056

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2

Timing Pin JDE81-4

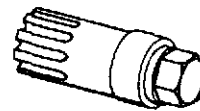
Lock engine at TDC when installing injection pump or timing valve train. Use with JDG820, JDE81-1, or JDE83 Flywheel Turning Tool.



RG5068

Flywheel Turning Tool JDE83

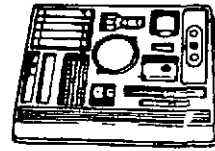
Used to rotate flywheel on engines with 142-tooth flywheel ring gear and a 26.5 mm (1.04 in.) ID flywheel housing guide bore diameter. Use with JDE81-4 Timing Pin.



RG6251

Injection Nozzle Cleaning Kit JDF13 (JDE105)

Clean 9.5 mm injection nozzles.

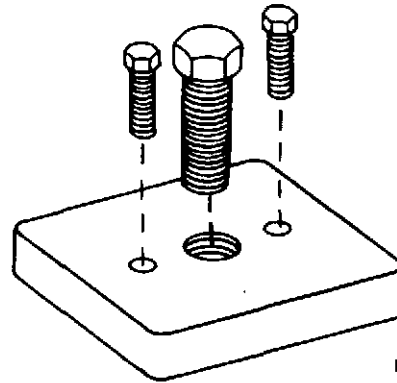


RG5224

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3

Injection Pump Drive Gear Puller JDG670A

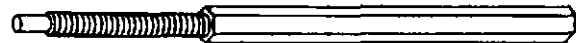
Remove drive gear from tapered shaft on Stanadyne DB2 (with retained drive shafts) and DB4 fuel injection pumps. Also used to remove drive gear on Lucas injection pumps.



RG6032

Injection Pump Timing Pin. JDG886

Used to lock Nippondenso in-line fuel injection pump timing prior to removal of pump.

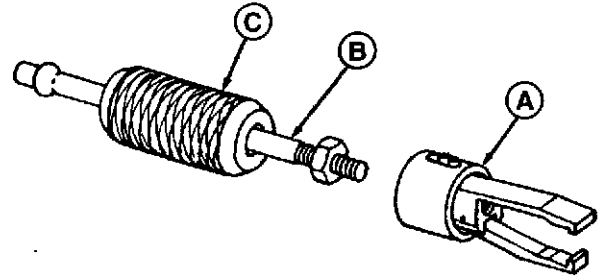


RG7212

Injection Nozzle Puller JDE38B

Remove Stanadyne 9.5 mm injection nozzles.

NOTE: If JDE38A Nozzle Puller is on hand, order JDG716 Adapter and use with slide handle from JDE38A.



RG6436

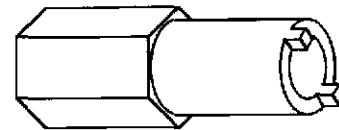
JDG716 Adapter can be used with slide handle from JDE38 or JDE38A to remove 9.5 mm injection nozzles without removing the rocker arm cover.

NOTE: JDG716-1 Repair Kit is available if leg of JDG716 Adapter is damaged.

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Injection Nozzle Wrench JDG949

Used to loosen or tighten lift adjusting screw on injection nozzle.



RG7644

SERVICE EQUIPMENT AND TOOLS

NOTE: Order tools from the U.S. SERVICEGARD™ Catalog or from the European Microfiche Tool Catalog (MTC). Some tools may be available from a local supplier.

Name	Use
Bosch Bench Mounted Nozzle Tester (JT25510); or, OTC Portable Nozzle Tester (D01109AA)	Check nozzle opening pressure.
Fuel Injection Nozzle Tester Adapter Set (D01110AA)	Check nozzle opening pressure.
JDG966 Crankshaft Front/Rear Rotation Adapter	Rotate crankshaft from front and rear with flywheel removed.

OTHER MATERIAL

Number	Name	Use
LOCTITE 242 (TY9370)	Thread Sealant	Fuel line fittings and supply pump mounting cap screws, between fuel pump and cylinder block gasket, and timing hole cover cap screws.
LOCTITE 595* (TY15130)	Superflex Sealant	Use on injection pump cover and pump timing gear cover ONLY when a traditional gasket is not available through service parts.
ROS16489	Lapping Compound	Use on nozzle valve for cleaning in the guide area ONLY.

Use DD14928 Sealing Compound Kit when servicing an engine within the European Market/Service Area. Follow manufacturer's directions on package when using and storing sealant.

FUEL SYSTEM SPECIFICATIONS

ITEM	SPECIFICATION
Rotary Fuel Injection Pump Dynamic (TIME TRAC®) Timing: All Models	See Group 115.
In-Line Fuel Injection Pump Static Timing	Lock No. 1 cylinder at TDC compression stroke. Align mark on injection pump drive hub with pointer mark. Install pump, recheck alignment of marks.
Injection Pump Timing-to-Engine	TDC
Overflow Valve Opening Pressure on In-Line Pump	130—180 kPa (1.3—1.8 bar) (19—26 psi)
Engine Operating Speeds	See Applicable Machine TM

TIME TRAC® is a registered trademark of Stanadyne Automotive Corp.

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FUEL SYSTEM SPECIFICATIONS—CONTINUED

Item	Naturally Aspirated Engines	Turbocharged Engines
Fuel Injection Nozzles		
—Number of nozzle tip orifices	4	4
—Diameter of nozzle tip orifice	0.27 mm (0.0106 in.)	0.29 mm (0.0116 in.)
—Nozzle Tip Spray Angle	72°	72°
Opening pressure of a new or reconditioned nozzle with new internal parts:		
—For setting	22400—22800 kPa (224—228 bar) (3250—3300 psi)	25900—26200 kPa (259—262 bar) (3750—3800 psi)
—For checking (minimum)	21800 kPa (218 bar) (3160 psi)	25200 kPa (252 bar) (3660 psi)
Minimum acceptable opening pressure of a used nozzle being checked (minimum)	19850 kPa (198 bar; 2880 psi)	22950 kPa (230 bar; 3330 psi)
Maximum opening pressure difference between cylinders	700 kPa (7 bar; 100 psi)	700 kPa (7 bar; 100 psi)
Nozzle valve/seat tightness condition at pressure test of 2800—3500 kPa (28—35 bar) (400—500 psi) below opening pressure	Nozzle tip still dry after 5 seconds (A slight dampness is permissible on used nozzles.	Nozzle tip still dry after 5 seconds. (A slight dampness is permissible on used nozzles)
Return leakage at pressure test of 10300 kPa (103 bar) (1500 psi)	3—10 drops/30 seconds	3—10 drops/30 seconds
Valve needle lift (based on zero lift)	1/2 turn counterclockwise	3/4 turn counterclockwise
Fuel Supply Pump:		
—Vacuum/Pressure Test	28—41 kPa (0.28—0.41 bar) (4—6 psi)	28—41 kPa (0.28—0.41 bar) (4—6 psi)

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FUEL SYSTEM SPECIFICATIONS—CONTINUED

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8

Item	Naturally Aspirated Engines	Turbocharged Engines
Aneroid Pressure Test (on Rotary-Type Pump):		
Lever Lift-Off	76—102 mm Hg (3—4 in. Hg) 10—14 kPa (1.5—2.0 psi)	76—102 mm Hg (3—4 in. Hg) 10—14 kPa (1.5—2.0 psi)
Aneroid Pressure Test (on Rotary-Type Pump):		
Lever at Full Travel	330—380 mm Hg (13—15 in. Hg) 44—51 kPa (6.4—7.4 psi)	330—380 mm Hg (13—15 in. Hg) 44—51 kPa (6.4—7.4 psi)

FUEL SYSTEM SPECIFICATIONS—CONTINUED

TORQUES

Rotary Fuel Injection Pumps:

Pump drive gear-to-pump shaft, hex. nut:	
Stanadyne Model DB2	122 N·m (90 lb-ft)
Stanadyne Model DB4	203 N·m (150 lb-ft)
Lucas Model DP201	122 N·m (90 lb-ft)
Lucas Model DP203	81 N·m (60 lb-ft)
Pump-to-front plate hex nuts	27 N·m (20 lb-ft)
Pump drive gear access cover	24 N·m (18 lb-ft)
Fuel pressure lines-to-nozzles	27 N·m (20 lb-ft)
Fuel pressure lines-to-injection pump:	
Stanadyne	27 N·m (20 lb-ft)
Lucas	27 N·m (20 lb-ft)
Fuel supply line-to-injection pump	30 N·m (22 lb-ft)
Fuel return line-to-injection pump	16 N·m (12 lb-ft)
Pump drive gear cover cap screw	2 N·m (1.7 lb-ft) (18 lb-in.)
Adjusting screw lock nut for slow and fast idle speeds	4.5 N·m (3.5 lb-ft) (42 lb-in.)

In-Line Fuel Injection Pump:

Pump-to-front plate	70 N·m (52 lb-ft)
Pump drive gear-to-pump hub	48 N·m (35 lb-ft)
Injection line connectors	27 N·m (20 lb-ft)
Supply pump-to-injection pump	5—7 N·m (4—5 lb-ft) (45—60 lb-in.)
Leak-off connectors	27 N·m (20 lb-ft)
Pump drive gear cover cap screws	2 N·m (1.7 lb-ft) (18 lb-in.)

Shut-off solenoid valve

	15—20 N·m (11—15 lb-ft)
--	-------------------------

Fuel injection nozzles:

Pressure adjusting screw lock nut	10 N·m (7 lb-ft)
Lock nut of lift adjusting screw	5 N·m (3.5 lb-ft)

Fuel injection nozzle clamp-to-cylinder head

	40 N·m (30 lb-ft)
--	-------------------

Fuel leak-off hex nut

	5 N·m (3.7 lb-ft) (44 lb-in.)
--	-------------------------------

Fuel supply pump-to-cylinder block cap screw

	30 N·m (22 lb-ft)
--	-------------------

Primary fuel filter/water separator mounting

	35 N·m (26 lb-ft)
--	-------------------

Final fuel filter mounting base-to-bracket

	35 N·m (26 lb-ft)
--	-------------------

Fuel filter mounting bracket-to-cylinder head

	35 N·m (26 lb-ft)
--	-------------------

FUEL SYSTEM—GENERAL INFORMATON

- Engines may be equipped with a Stanadyne or Lucas rotary-type injection pump or a Nippondenso in-line injection pump. Engines with rotary pumps are dynamically timed at the factory. See Group 115.
- Some injection pumps are equipped with an aneroid.
- Engines may be equipped with a primary fuel filter/water separator.
- All engines use 9.5 mm pencil-type nozzles.
- On rotary pumps, the fuel supply pump is a separate component mounted on upper right-hand side of engine block and is actuated by a pin in block that rides on engine camshaft lobe.
- On rotary pumps, a cold start switch may be installed in the thermostat housing/water manifold and is connected to a wiring harness from the pump. This switch helps during cold start-up operation.
- On in-line pumps, the fuel supply pump is a component mounted on the side of the pump actuated by lobe on injection pump camshaft.
- All engines are equipped with a round final fuel filter. Hand primer on top of filter element is optional.

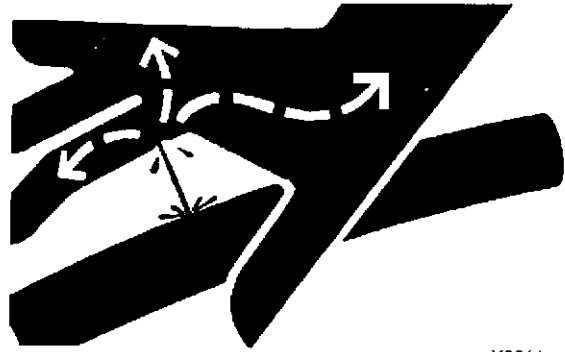
RELIEVE FUEL SYSTEM PRESSURE



CAUTION: Escaping diesel fuel under pressure can have sufficient force to penetrate the skin, causing serious injury. Before disconnecting lines, be sure to relieve pressure. Before applying pressure to the system, be sure ALL connections are tight and lines, pipes and hoses are not damaged. Keep hands and body away from pinholes and nozzles which eject fluid under pressure. Use a piece of cardboard or wood, rather than hands, to search for suspected leaks.

If ANY fluid is injected into the skin, it must be surgically removed within a few hours by a doctor familiar with this type injury or gangrene may result. Doctors unfamiliar with this type of injury may call the Deere & Company Medical Department in Moline, Illinois, or other knowledgeable medical source.

Any time the fuel system has been opened up for service (lines disconnected or filters removed), it will be necessary to bleed air from the system. (See BLEED FUEL SYSTEM in Group 115.)



X9811

REMOVE FINAL FUEL FILTER AND PRIMARY FUEL FILTER/WATER SEPARATOR MOUNTING BRACKETS

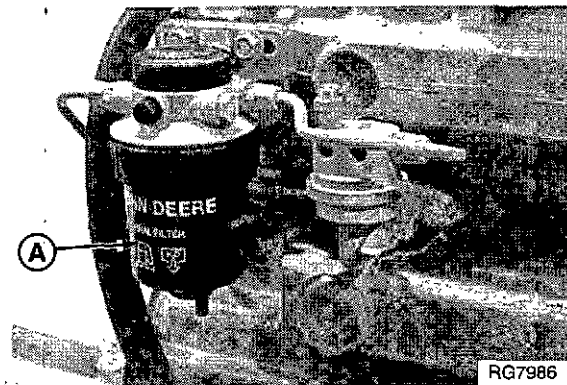
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Refer to operator's manual for proper servicing and (hourly) replacement intervals.

Some engines maybe equipped with a final fuel filter (A) and an optional primary fuel filter/water separator (B).

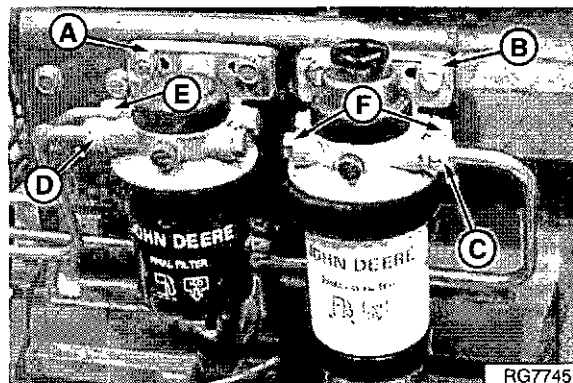


A—Final Fuel Filter
B—Primary Fuel Filter/Water Separator



A—Final Fuel Filter

1. Thoroughly clean fuel filter/water separator assembly and surrounding area to keep from getting dirt and debris into fuel system.
2. Connect a drain line to filter drain adapters and drain all fuel from system.
3. Remove final fuel filter and primary (round) fuel filter/water separator, if desired. See REPLACE PRIMARY FUEL FILTER/WATER SEPARATOR, as described later in this group.
4. Disconnect fuel lines from all ports.
5. Remove final fuel filter base (A).
6. If equipped, remove primary fuel filter base (B).
7. Replace parts as necessary.
8. Install mounting brackets and tighten to torque specifications provided below.



A—Final Fuel Filter Base
 B—Primary Fuel Filter Base
 C—Primary Filter Outlet to Supply Pump
 D—Final Filter Outlet to Injection Pump
 E—Final Filter Inlet from Supply Pump
 F—Primary Filter Inlet from Pump

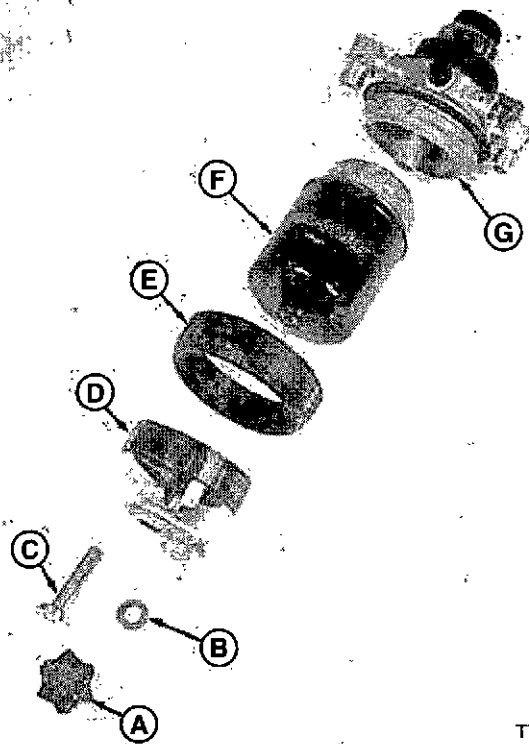
TORQUE SPECIFICATIONS

Fuel Filter Base Mounting	
Bracket-to-Cylinder Head	35 N-m (26 lb-ft)
Primary Fuel Filter/Water Separator	
Mounting Base-to-Bracket	35 N-m (26 lb-ft)
Final Fuel Filter Mounting Base-to-Bracket	35 N-m (26 lb-ft)

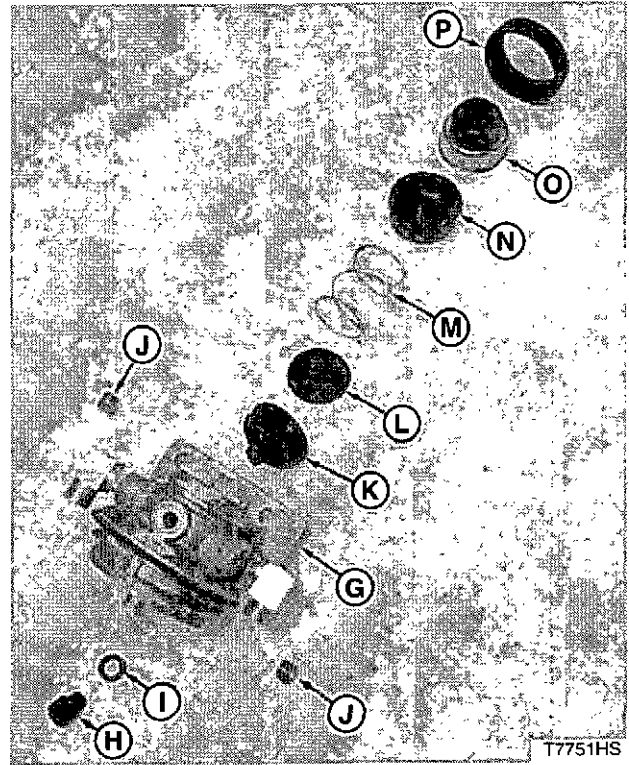
9. Install water separator and fuel filters. See REPLACE PRIMARY FUEL FILTER/WATER SEPARATOR, as described later in this group.
10. Connect fuel lines to all ports.
11. Bleed the fuel system as detailed in Group 115.

PRIMARY FUEL FILTER/WATER SEPARATOR ASSEMBLY

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14



T7751HR



T7751HS

Primary Filter/Water Separator Assembly

Filter Base Assembly

- | | |
|------------------------|------------------------------|
| A—Drain Adapter | E—Retaining Ring |
| B—Packing | F—Filter Element |
| C—Cap Screw | G—Filter Base with Seal Ring |
| D—Water Separator Bowl | H—Vent Plug |

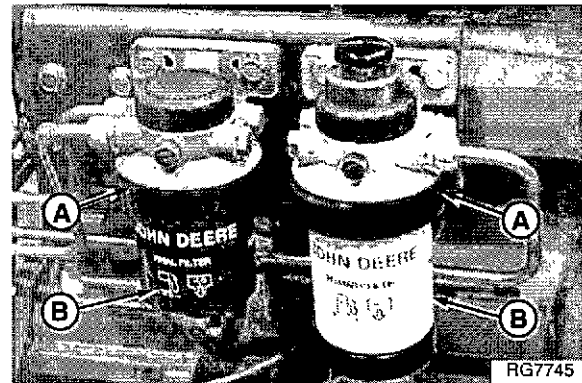
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|-----------------|------------------|
| I—Packing | M—Spring |
| J—Plug (2 used) | N—Spring Cover |
| K—Diaphragm | O—Pump Knob |
| L—Spring Seat | P—Retaining Ring |

REPLACE FINAL FUEL FILTER AND PRIMARY FUEL FILTER/WATER SEPARATOR

NOTE: Refer to operator's manual for proper servicing and (hourly) replacement intervals.

Replacement of primary and final fuel filter elements are similar, differences will be noted.

1. Thoroughly clean fuel filter/water separator assembly and surrounding area, if not previously done.



NOTE: Lifting up on retaining ring (A) as it is rotated helps to get it past raised locators.

2. Connect a drain line to filter drain adapters and drain all fuel from filters.
3. Firmly grasp the retaining ring and rotate it counterclockwise 1/4 turn. Remove ring with filter element (B).
4. Inspect filter mounting base for cleanliness. Clean as required.
5. Remove water separator bowl, if equipped. Drain and clean separator bowl. Dry with compressed air.
6. Install water separator bowl, if equipped, onto new filter element. Tighten securely.

NOTE: The fuel filter must be indexed properly and the key on canister must be oriented in slot of mounting base for correct installation.

7. Thoroughly inspect filter base seal ring. Replace as needed.
8. Install new filter element onto mounting base and position element using a slight rocking motion. Be sure element is properly indexed on mounting base.
9. Install retaining ring onto mounting base and tighten about 1/3 turn until ring "snaps" into the detent. DO NOT overtighten the retaining ring.
10. Bleed fuel system. (See BLEED THE FUEL SYSTEM, in Group 115.)

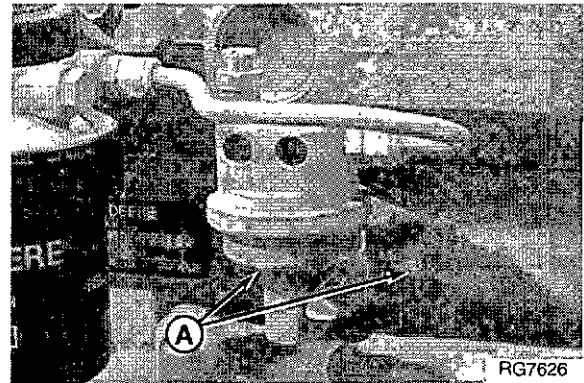
REMOVE FUEL SUPPLY PUMP

IMPORTANT: A backup wrench must always be used when disconnecting fittings or fuel lines from supply pump to avoid damage to fittings.

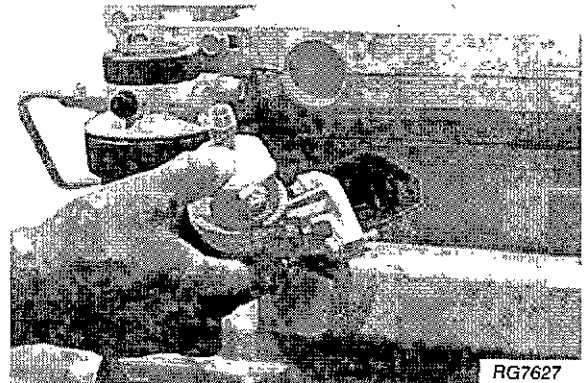
1. Disconnect fuel lines and cap connections on fuel supply pump and fuel lines to keep debris out of fuel system.
2. Remove cap screws (A) and remove fuel supply pump assembly from cylinder block.

NOTE: The fuel supply pump is driven by a push rod (B) that rides on an eccentric camshaft lobe. The cylinder head must be removed to remove this push rod.

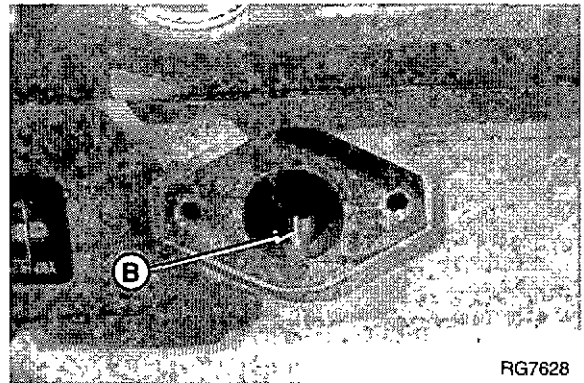
3. Cover opening on cylinder block to prevent dirt from entering the engine.
4. Inspect face of pump lever for wear. If lever face is worn flat or concave, replace pump.



RG7626



RG7627



RG7628

BENCH TEST FUEL SUPPLY PUMP

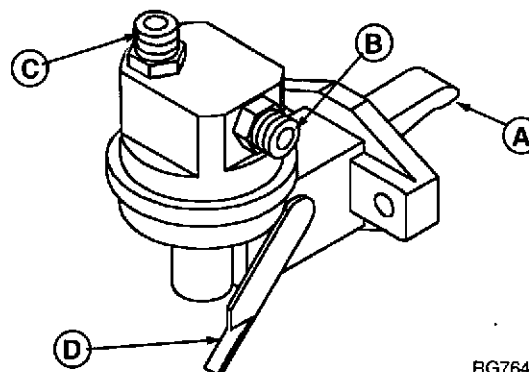
The following bench tests can be performed on a supply pump installed on the engine when the pump is suspected to be defective. (See MEASURE FUEL SUPPLY PUMP PRESSURE in Group 115.)

Perform the Vacuum/Pressure Test and Leakage Test, listed below. Replace the supply pump if either test shows the pump to be defective, there is no repair procedure.

- **Vacuum/Pressure Test:**

NOTE: This test will give a good indication of condition of both the inlet and outlet valves, as well as the diaphragm. The numerical values obtained on both the vacuum and pressure sides are not important; rather it is the needle movement that is important (very slow for a good pump; very fast or not at all for a defective pump).

1. Remove inlet and outlet fittings.
2. Install vacuum/pressure gauge to inlet side of pump (B).
3. Move primer lever (D) all the way downward. Release lever and at the same time observe gauge:
 - The gauge needle should read the same value each time, and then very slowly return to "0". This indicates that the inlet valve and diaphragm are in good condition. Proceed to next step.
 - If the gauge needle does not move at all, or the needle rapidly returns to "0", the pump is defective and must be replaced.
4. Remove vacuum/pressure gauge and install onto outlet side of pump (C).
5. Move priming lever all the way to upward position. Release lever and at same time observe gauge reading:
 - The gauge needle should initially read 28—41 kPa (0.28—0.41 bar) (4—6 psi), then return to "0" very slowly. This indicates that the outlet valve and diaphragm are in good condition. Supply pump is operating properly and should be reinstalled on engine.
 - If the gauge needle initially reads same value as above and then returns immediately back to "0", the pump is defective and must be replaced.



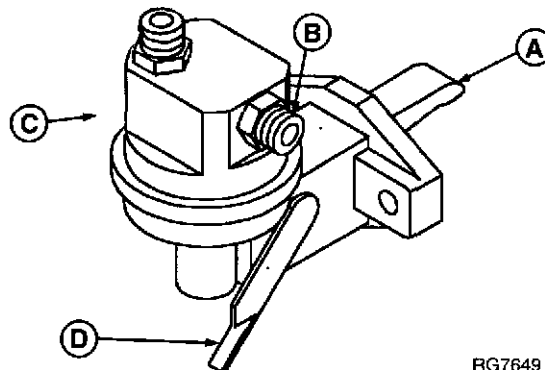
RG7649

- A—Lever
- B—Inlet Side of Pump
- C—Outlet Side of Pump
- D—Primer Lever

• **Leakage Test:**

The leakage test should be performed if a supply pump suspected of leaking fuel externally, or internally into the engine crankcase.

1. Install an air line on inlet side of pump (B) and apply 140 kPa (1.4 bar) (20 psi) pressure.
 2. Hold finger over outlet side of pump (C) or install a plug. Submerge pump into a container of clean diesel fuel.
- If air bubbles occur around banded connection holding the two halves of pump together (indicating leakage), replace pump.
 - If the diaphragm is bad, there will be leakage through vent holes (if equipped) and around the rocker arm. Replace pump as necessary.



RG7649

- A—Lever
- B—Inlet Side of Pump
- C—Outlet Side of Pump
- D—Primer Lever

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18

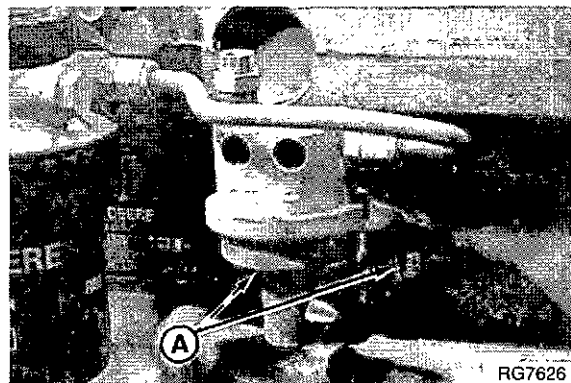
INSTALL FUEL SUPPLY PUMP

IMPORTANT: Apply LOCTITE 242 Thread Lock and Sealer (TY9370) to threads of supply pump mounting screws (A) and fuel line fittings when reinstalling supply pump. DO NOT allow sealant to get into fuel system.

1. Install the fuel supply pump to cylinder block with pumping lever resting on top of push rod, using a new O-ring. Tighten cap screws to 30 N·m (22 lb-ft).

IMPORTANT: ALWAYS use a backup wrench when installing fittings and/or fuel lines onto supply pump to avoid damage to fittings.

2. Connect fuel lines and tighten securely.
3. Bleed fuel system. (See BLEED THE FUEL SYSTEM in Group 115.)



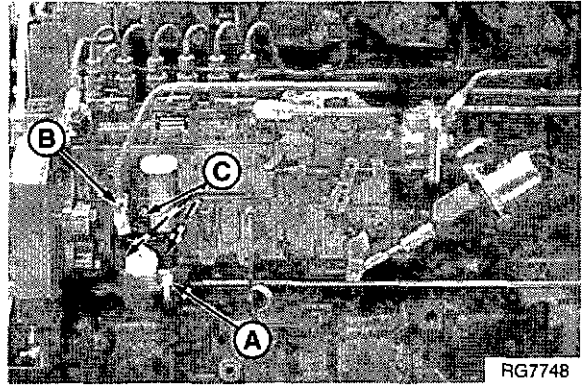
REMOVE FUEL SUPPLY PUMP ON IN-LINE FUEL INJECTION PUMP

NOTE: To diagnose fuel supply pump malfunctions or test for leaks, refer to Group 115.

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Thoroughly clean exterior of supply pump. Also clean around supply pump mounting area on injection pump housing.

1. Disconnect fuel inlet line (A), and outlet line (B). Cap all line openings so contaminants do not enter fuel system.
2. Remove mounting nuts (C).
3. Pull fuel supply pump straight out from injection pump housing. Cover supply pump mounting bore so debris cannot enter injection pump.



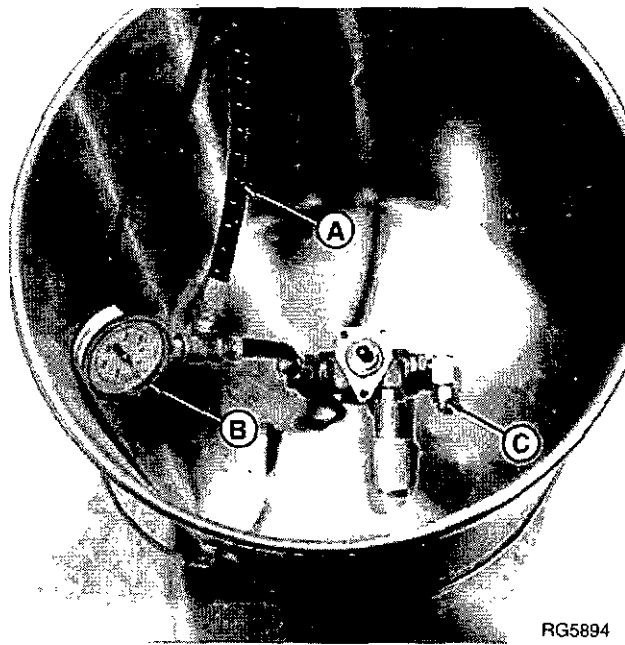
TEST FUEL SUPPLY PUMP FOR LEAKS

Fuel delivery pressure should be checked before removing supply pump from injection pump. (See CHECK FUEL SUPPLY PUMP OPERATION, in Group 115.)

1. Connect compressed air line (A) to a pressure gauge (B) and to supply pump inlet fitting. Air line should have a regulating valve to control pressure.
2. Cap or plug supply pump outlet fitting (C).
3. Submerge supply pump in a container of clean diesel fuel. Regulate air pressure to 200 kPa (2.0 bar) (29 psi).
4. Move roller tappet in and out by hand. No air bubbles should appear around roller tappet.

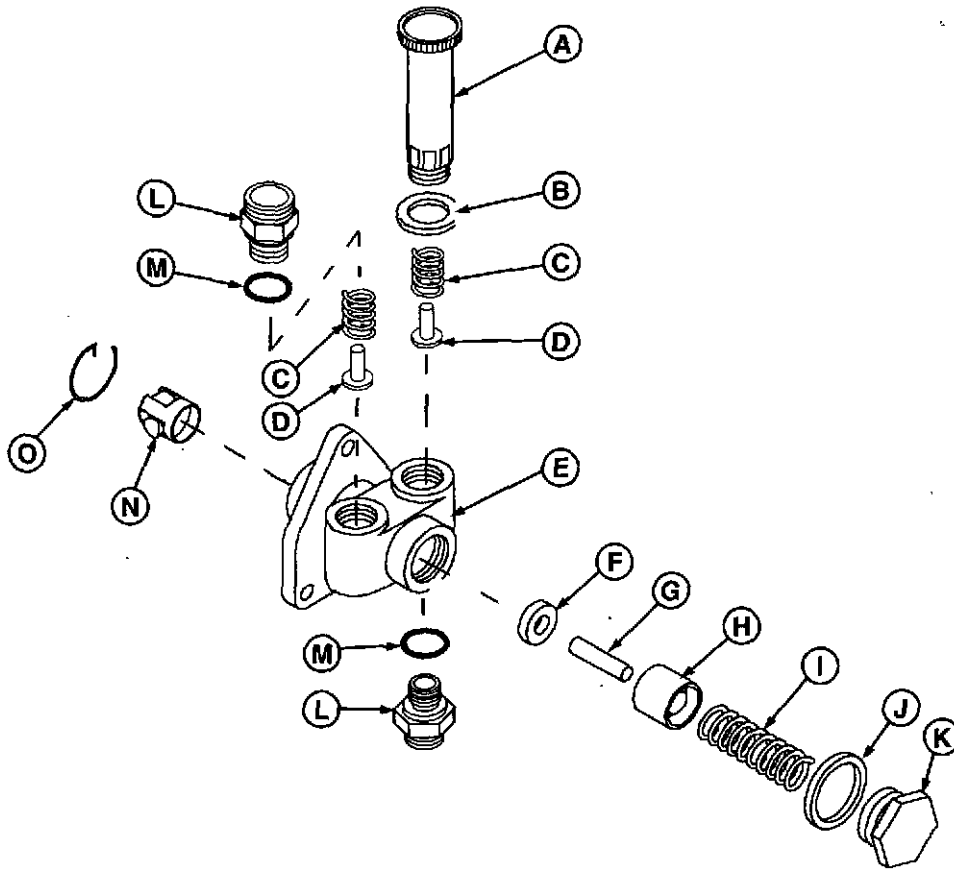
NOTE: *If bubbles appear, it is an indication that either the O-ring seal is defective or spindle or tappet is worn (or possibly both).*

IMPORTANT: Serious injection pump or engine damage could occur, if enough diesel fuel leaks past spindle and seal. Fuel leakage past spindle dilutes engine oil.



RG5894

DISASSEMBLE FUEL SUPPLY PUMP



RG8070

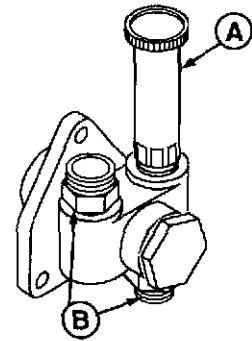
A—Hand Primer
 B—Washer (4 used)
 C—Spring (2 used)
 D—Valve

E—Pump Housing
 F—O-Ring/Spindle Seal
 G—Pressure Spindle
 H—Plunger

I—Spring
 J—Washer
 K—Plug
 L—Flex Fitting

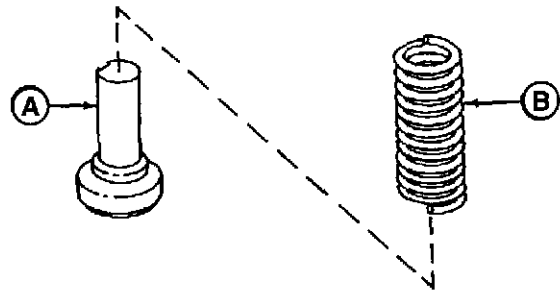
M—O-Ring
 N—Roller/Tappet Assembly
 O—Snap Ring

1. Remove hand primer (A) and flex fittings (B) from housing. Discard O-rings.



RG8071

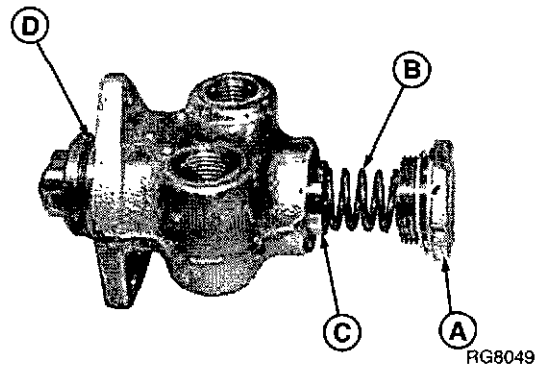
2. Remove valves (A) and springs (B).



RG2323

3. Remove plug (A), spring (B), and plunger (C) from pump housing. Discard copper washer.
4. Remove snap ring (D) from outer circumference of pump housing neck.

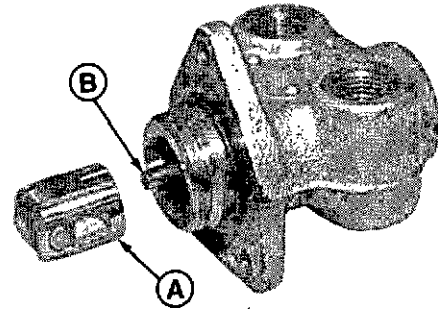
NOTE: Snap ring has a tang on one end which extends vertically down through a hole in pump housing to retain roller tappet assembly.



RG8049

- A—Plug
- B—Spring
- C—Plunger
- D—Snap Ring

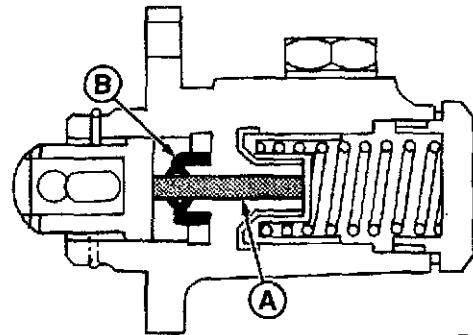
5. Remove roller tappet (A) and spindle (B) from pump housing. Remove and discard O-ring on spindle.



RG8052

NOTE: Spindle/seal O-ring (B) is pressed into pump housing. This seal keeps diesel fuel from leaking past spindle (A) and entering injection pump crankcase.

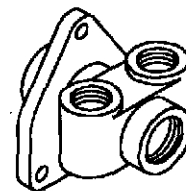
6. Remove spindle seal from housing using needle nose pliers. Discard seal.



RG4029

INSPECT AND REPAIR FUEL SUPPLY PUMP COMPONENTS

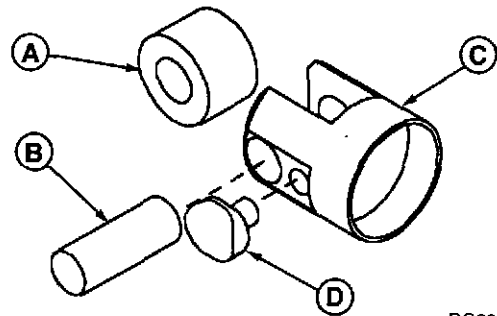
1. Inspect supply pump housing for cracks and wear. Be sure valve seating areas are not pitted. Replace housing as necessary.
2. Check roller tappet and plunger bore for wear and scoring. Remove any deposits in housing with a suitable solvent. Rinse housing in clean diesel fuel.
3. Check condition of threads for inlet and outlet fittings. Pump elbow fittings have 1/2-20 threads.



RG8050

4. Inspect roller (A) OD for excessive wear. Be sure roller turns freely on pin (B) and in tappet (C).
5. Inspect sliding blocks (D). Edges should be square and unpitted. Blocks should slide in and out of tappet easily.
6. Inspect tappet for wear and scoring. Remove any deposits with a suitable solvent.

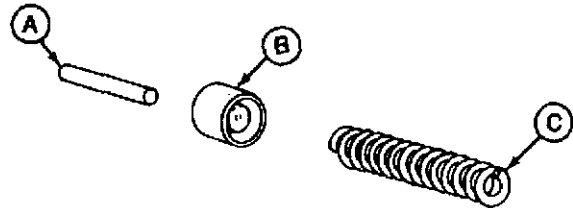
Be sure land on tappet that contacts pressure spindle is flat and undamaged.



RG8051

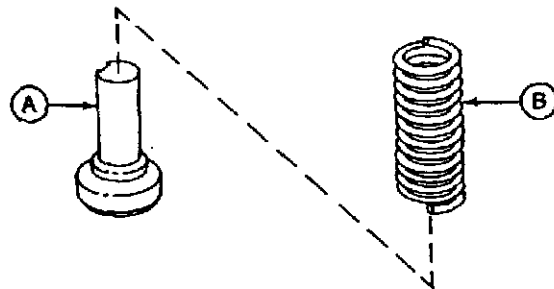
- A—Roller
- B—Pin
- C—Tappet
- D—Sliding Block (2 used)

7. Inspect pressure spindle (A) and plunger (B) for pits and burrs. Replace parts as necessary.
8. Inspect spring (C) for cracks and distortion. Replace parts as necessary.



RG2322

9. Inspect valves (A), especially valve face, for cracks, pits and wear. Replace as necessary.
10. Spring (B) should not be bent or broken.



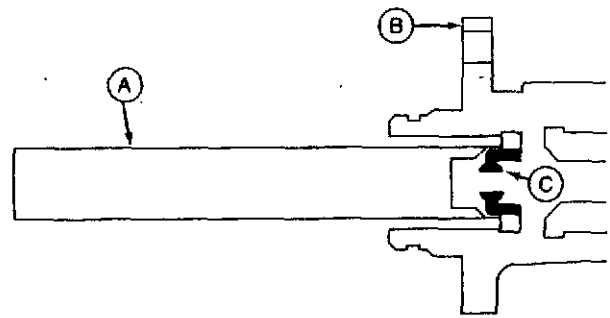
RG2323

ASSEMBLE FUEL SUPPLY PUMP

IMPORTANT: Hands should be wet with diesel fuel when assembling internal components of fuel supply pump.

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26

1. Install new spindle seal (C) into pump housing (B) using JDF15 Driver (A). Be sure seal is started straight in housing bore and drive until driver contacts housing.
2. To assemble supply pump, reverse disassembly procedure using new O-rings.



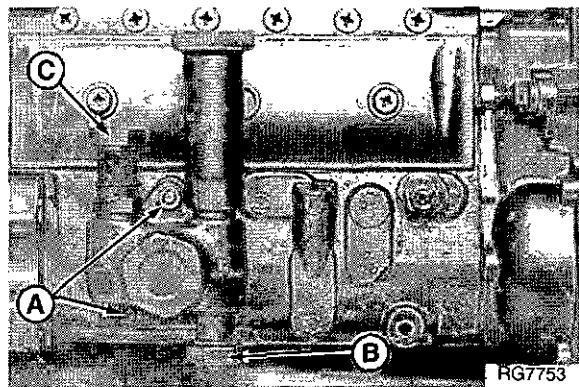
RG2013

Perform leak test described in Group 115.

INSTALL FUEL SUPPLY PUMP ON IN-LINE FUEL INJECTION PUMP

IMPORTANT: Before installing supply pump, test pump to make sure fuel will not leak around spindle and spindle seal. (See **TEST MECHANICAL FUEL SUPPLY FOR LEAKS**, in Group 115.)

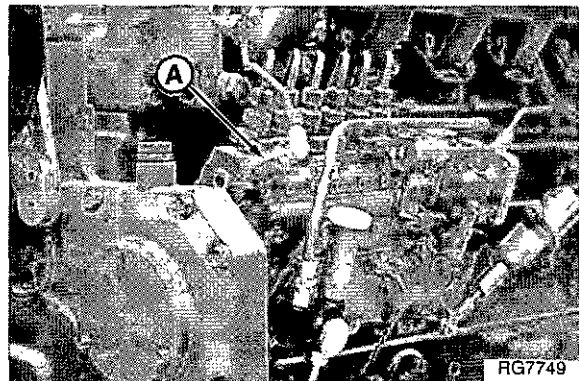
1. Put a new O-ring in counterbore of injection pump housing next to fuel supply pump mounting face.
2. Position pump over mounting studs (A). Tighten mounting studs 5–7 N·m (4–5 lb-ft) (45–60 lb-in.).
3. Install fuel inlet (B) and outlet lines (C) when engine is installed in vehicle. Tighten all connections securely.
4. Bleed fuel system. (See **BLEED THE FUEL SYSTEM** in Group 115.)



SERVICE INJECTION PUMP OVERFLOW VALVE

NOTE: Overflow valve (A) can be serviced with injection pump installed.

There is no adjustment on valve to regulate housing pressure. If suspected that valve is pump to an ADS shop replace valve to restore proper operation.

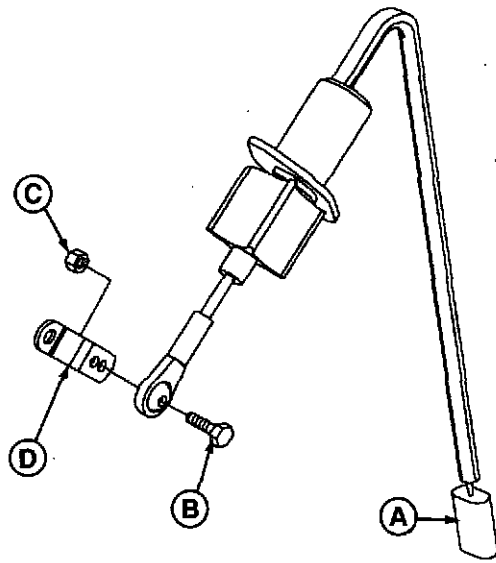


REMOVE AND INSTALL FUEL SHUTOFF SOLENOID

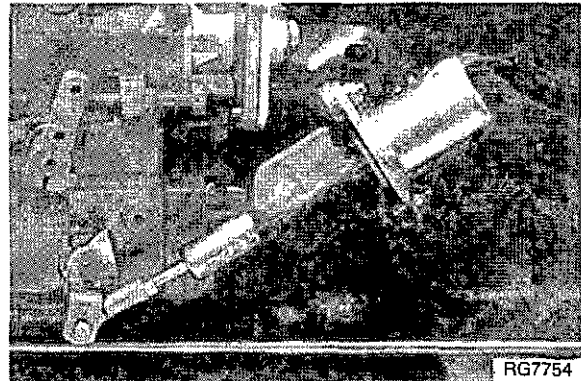
1. Disconnect electrical wiring connector (A) on solenoid lead.
2. Remove cap screw (B).
3. Remove fuel shutoff solenoid assembly from mounting bracket.
4. Fuel shutoff solenoid linkage should move freely back and forth.

NOTE: *Electric fuel shutoff solenoids are factory adjusted to a specified length and should not require additional adjustment. See machine technical manual for fuel shutoff solenoid diagnostics.*

To install fuel shutoff solenoid, reverse removal procedure. Tighten cap screw to 15–20 N·m (11–15 lb-ft). Connect electrical wiring connector.



RG7755



RG7754

- A—Electrical Wiring Connector
- B—Cap Screw
- C—Washer
- D—Fuel Shut-off Lever

FUEL INJECTION PUMP TIMING

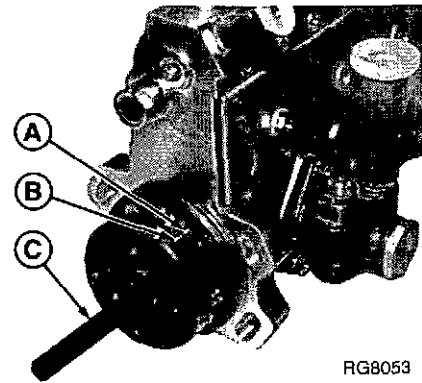
Rotary fuel injection pumps on John Deere Diesel Engines are dynamically timed at the factory.

- Dynamic Timing, which involves a sensor installed within the No. 1 fuel line and connected to a pulse-activated timing meter to determine precisely at what point injection occurs. Another form of dynamic timing employs the use of a timing light along with a fixed reference mark on engine block and a timing mark on crankshaft damper or pulley which aligns with fixed reference mark when light flashes.

In-line fuel injection pumps are static lock-pin timed.

- Static Lock-Pin Timing, which is accomplished by locking engine at No. 1 TDC compression stroke. Align pump timing mark on drive hub (B) and stationary timing pointer (A). Lock the pump at this position with JDG886 Injection Pump Timing Pin (C).

See Group 115 for timing procedures.



RG8053

REMOVE STANADYNE MODEL DB2 AND DB4 INJECTION PUMP

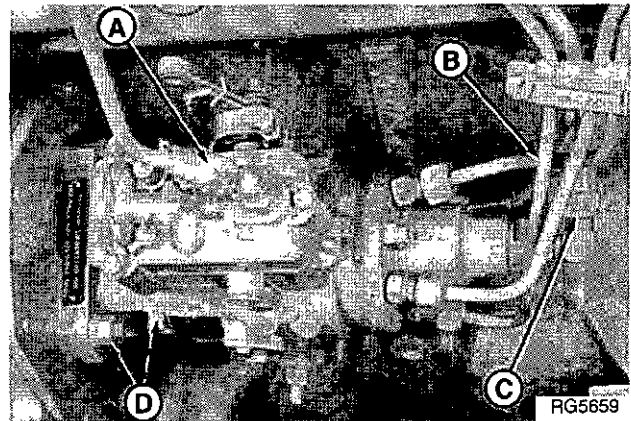
All Stanadyne DB2 and DB4 injection pumps will have a retained drive shaft (shaft stays in the pump when pump is removed from engine).

IMPORTANT: Never steam clean or pour cold water on a fuel injection pump while the pump is running or while it is warm. Doing so may cause seizure of internal rotating pump parts.

1. Clean the fuel injection pump, lines and area around the pump with cleaning solvent or a steam cleaner.
2. Disconnect shut-off cable and speed control linkage, if equipped. Disconnect electrical connection to shut-off solenoid or throttle positioning solenoid, if equipped. Disconnect cold start switch, if equipped. Tag electrical wires for correct reassembly.

IMPORTANT: ALWAYS use a backup wrench when loosening or tightening fuel lines at injection pump so that discharge fittings are not altered to prevent possible internal pump damage.

3. Disconnect fuel return line (A) and fuel supply line (C).
4. Disconnect all fuel delivery (pressure) lines (B) from injection pump using a suitable 17 mm deep-well crowsfoot socket.



A—Fuel Return Line
B—Fuel Delivery (Pressure) Lines
C—Fuel Supply Line
D—Mounting Stud Nuts

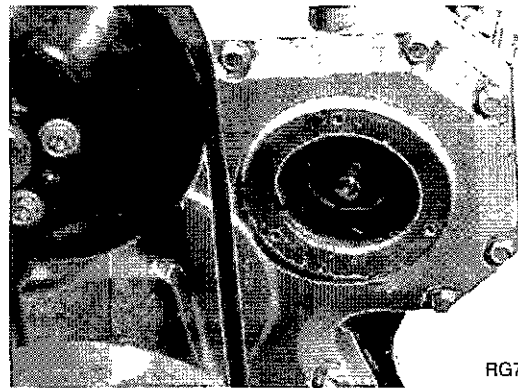
- Remove injection pump drive gear cover (shown removed). Remove drive gear retaining nut and washer from end of pump shaft. Be careful not to let washer fall inside timing gear cover.

NOTE: The injection pump drive gear fits snugly onto a tapered drive shaft and is indexed by a hollow pin or Woodruff key installed in drive shaft.

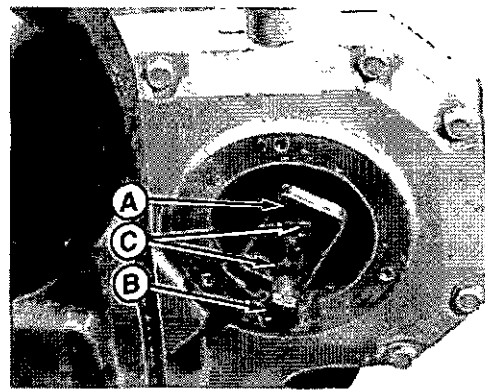
- Attach JDG670A Drive Gear Puller (A) to injection pump drive gear as shown.

NOTE: Replace 6 mm Grade 12.9 cap screws (C) as needed.

- Evenly tighten the two 6 mm, Grade 12.9 screws (threaded in drive gear) and snugly tighten center forcing screw (B) against end of pump shaft.
- Tighten center forcing screw until pump drive gear is free from tapered shaft. Remove JDG670A Puller from drive gear.



RG7630

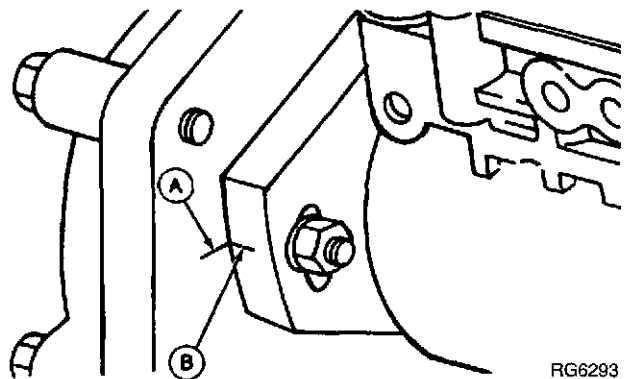


RG7757

- Check to make sure that timing marks on back side of front plate (A) and injection pump flange (B) are present and properly aligned. This assures that repaired or replacement pump can be properly timed to engine when installed.

If timing mark is not clearly visible on front plate, scribe a visible reference mark as accurately as possible in-line with mark on pump flange.

- Remove three injection pump mounting stud nuts. Remove injection pump from mounting studs. Place pump on a clean flat surface and inspect shaft O.D. and drive gear as outlined later in this group. (See INSPECT INJECTION PUMP DRIVE GEAR I.D. AND SHAFT O.D. later in this group).



RG6293

INSPECT INJECTION PUMP DRIVE GEAR I.D. AND SHAFT O.D.

IMPORTANT: Use a good light source to thoroughly inspect gear I.D. and shaft O.D.

1. Inspect injection pump drive gear I.D. full 360° for metal transfer as a result of slippage on shaft.
2. Inspect injection pump drive shaft O.D. full 360° for presence of metal transfer from gear slippage. Also, check to see if index pin in shaft is not damaged, indicating gear slippage.

If there is clear evidence of metal transfer on pump shaft O.D., in drive gear I.D., or if index pin in pump shaft is damaged, injection pump and drive gear **MUST BE** replaced.

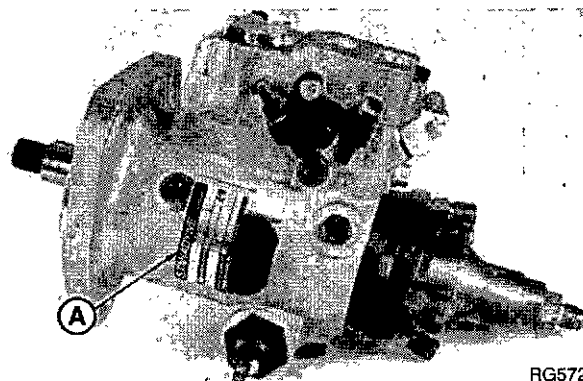
IMPORTANT: When replacing injection pump drive gear or installing a new pump, the tapered surfaces of the pump drive shaft O.D. and drive gear I.D. **MUST BE** cleaned to remove protective coatings and oily residue. Use a suitable cleaner that does not leave a residue. Mating surfaces **MUST BE ASSEMBLED DRY** and **LUBRICANTS MUST NOT BE USED.**

REPAIR STANADYNE FUEL INJECTION PUMP

IMPORTANT: Do not disassemble the fuel injection pump further than necessary for installing available repair parts—not even for cleaning.

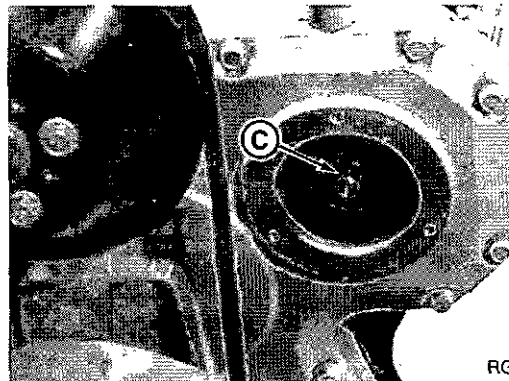
Be sure that injection pump serial number tag (A) is in place and that all identification numbers are legible so that pump is set to the correct specification for its intended application.

For injection pump repair and testing, have an authorized ADS diesel injection repair station perform the work. Unauthorized repairs made to fuel injection pumps will void warranty.



RG5724

INSTALL STANADYNE MODEL DB2 AND DB4 INJECTION PUMP



Injection pump mounting flange timing mark (B) and front plate timing mark (A) presence and alignment **MUST BE** verified before removing pumps from engine. When pump is reinstalled on engine, time pump by aligning these two (external) marks. **DO NOT** reference internal timing marks (on pump cam ring and governor weight retainer) for accurate pump timing.

1. Lubricate a new square sealing ring with clean engine oil, install ring into groove on front face of pump mounting flange. Slide injection pump onto mounting studs while inserting pump shaft into drive gear.
2. Check pump shaft and index pin for proper alignment with pump drive gear key slot.

IMPORTANT: Shaft roll pin may be easily damaged if improperly assembled. Pump drive gear should not move when initially installing pump index pin into drive gear key slot.

3. Install injection pump partially onto mounting studs without engaging pump pilot hub into engine front plate.

IMPORTANT: DO NOT tighten hex nuts more than three full turns on mounting studs. Pump drive shaft index pin may be damaged if pin is not properly aligned with drive gear key slot and nuts are tightened more than three turns.

4. Install three flat washers, lock washers, and hex nuts onto pump mounting studs. Tighten nuts three turns only so that pump will not fall off mounting studs.

NOTE: The pump drive gear should begin to move forward (away from engine front plate) with the pump when flange is approximately 3.2 mm (1/8 in.) away from engine front plate.

5. Install pump mounting flange flush to engine front plate with drive gear held flush against front side of engine front plate.

IMPORTANT: DO NOT use tightening force of pump mounting stud nuts to pull pump shaft into drive gear I.D.

6. With the pump shaft index pin properly engaged in the drive gear key slot, finger tighten mounting stud nuts.
7. Push pump drive gear firmly onto shaft taper. Install washer and retaining nut (C) onto end of shaft. Tighten retaining nut to the following torque:

FUEL INJECTION PUMP DRIVE GEAR-TO-SHAFT RETAINING NUT TORQUE SPECIFICATIONS

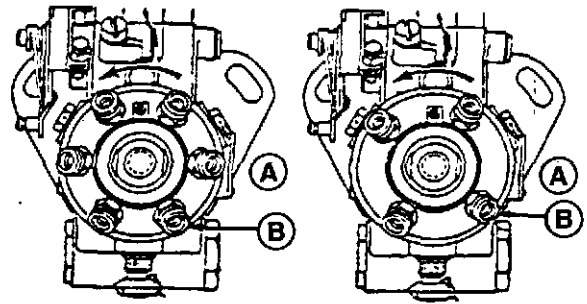
DB2 Pump	122 N·m (90 lb-ft)
DB4 Pump	203 N·m (150 lb-ft)

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34

8. Install access cover plate using a new O-ring, if needed. Apply LOCTITE 242 (TY9370) to cap screw threads and tighten to 2 N·m (1.7 lb-ft) (20 lb-in.).
9. Align timing mark on pump flange with timing mark on front plate.
10. Tighten three hex nuts securing the pump to the front plate to 27 N·m (20 lb-ft).
11. Connect injection pump pressure lines (E). Beginning with outlet (B) and continue around the pump head in counterclockwise direction, attaching lines in same order as engine firing (1-5-3-6-2-4 on 6-cylinder engines and 1-3-4-2 on 4-cylinder engines).
12. Tighten fuel delivery (pressure) lines at pump to 27 N·m (20 lb-ft), using a suitable 17 mm deep-well socket.

IMPORTANT: ALWAYS use a backup wrench when loosening or tightening fuel delivery lines at fuel injection pump, so that the pump discharge fittings are not altered. This prevents possible internal pump damage.

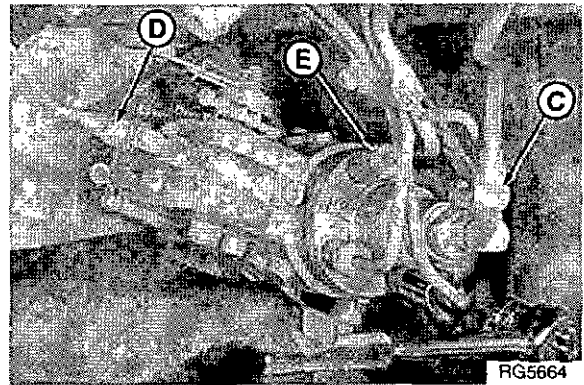
13. Connect fuel supply line (C) and fuel return line (D).
14. Connect fuel shut-off cable and speed control linkage, if equipped. Install and securely tighten electrical connections to shut-off solenoid and throttle positioning solenoid, if equipped. Connect cold start switch, if equipped.
15. Bleed air from fuel system as outlined in Group 115. Start engine, run for several minutes and check entire fuel system for leaks.



RG5565

6-Cylinder Engine (Left Illustration)

4-Cylinder Engine (Right Illustration)



RG5664

- A—Engine Block Side
- B—Outlet Connection to No. Cylinder
- C—Fuel Supply Line
- D—Fuel Return Line
- E—Fuel Delivery (Pressure) Lines

REMOVE LUCAS FUEL INJECTION PUMP

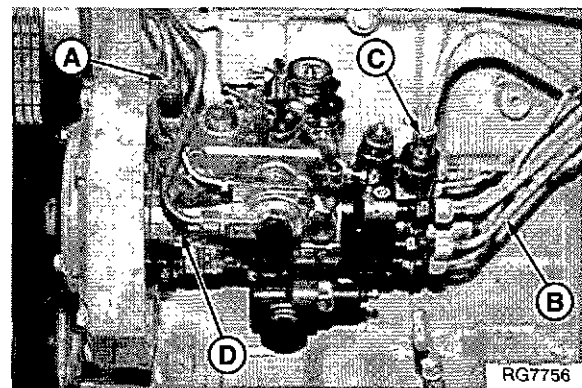
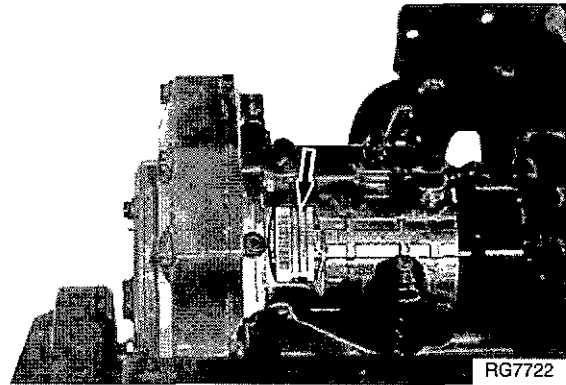
NOTE: The injection pump serial number tag (bold arrow) is located on the bottom of the pump.

IMPORTANT: Never steam clean or pour cold water on a fuel injection pump while the pump is running or while it is warm. Doing so may cause seizure of internal rotating pump parts.

1. Clean the fuel injection pump, lines and area around the pump with cleaning solvent or a steam cleaner.
2. Disconnect shut-off cable and speed control linkage, if equipped. Disconnect electrical connection to shut-off solenoid or throttle positioning solenoid, if equipped. Disconnect cold start switch, if equipped. Tag electrical wires for correct reassembly.

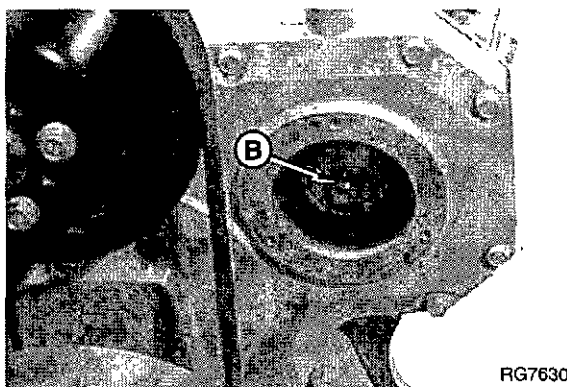
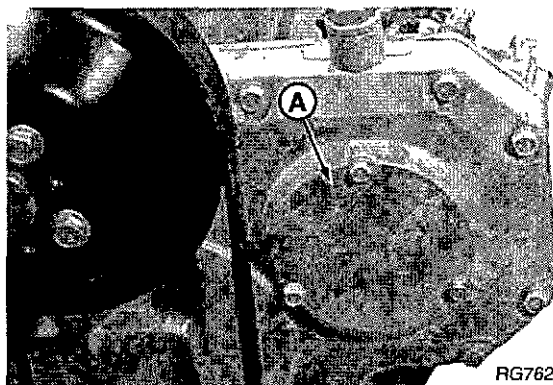
IMPORTANT: ALWAYS use a backup wrench when loosening or tightening fuel lines at injection pump so that discharge fittings are not altered to prevent possible internal pump damage.

3. Disconnect fuel return line (A) and fuel supply line (C).
4. Disconnect all fuel delivery (pressure) lines (B) from injection pump using a suitable 17 mm deep-well crowsfoot socket.



A—Fuel Return Line
B—Fuel Delivery (Pressure) Lines
C—Fuel Supply Line
D—Mounting Stud Nuts

5. Remove injection pump drive gear cover (A). Remove drive gear retaining nut (B) and washer from end of pump shaft. Be careful not to let washer fall inside timing gear cover.



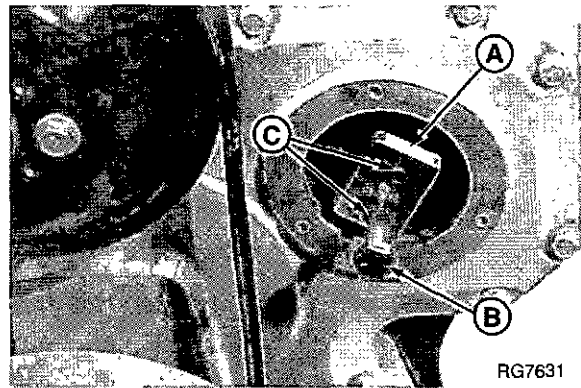
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NOTE: The injection pump drive gear fits snugly onto a tapered drive shaft and is indexed by a Woodruff key installed in drive shaft. Use JDG670A Drive Gear Puller (A) to remove drive gear from shaft.

6. Attach JDG670A Drive Gear Puller to injection pump drive gear as shown. Follow instructions provided with tool set.

NOTE: Replace 6 mm, Grade 12.9 cap screws (C) as needed.

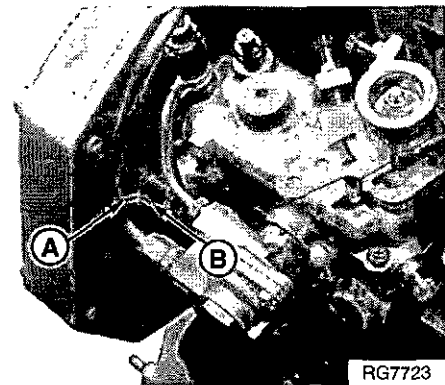
7. Evenly tighten the two 6 mm, Grade 12.9 screws (threaded in drive gear) and snugly tighten center forcing screw (B) against end of pump shaft.
8. Tighten center forcing screw until pump drive gear is free from tapered shaft. Remove JDG670A Puller from drive gear.



9. Check to make sure that timing marks on back side of front plate (A) and injection pump flange (B) are present and properly aligned. This assures that repaired or replacement pump can be properly timed to engine when installed.

If timing mark is not clearly visible on front plate, scribe a visible reference mark as accurately as possible in-line with mark on pump flange.

10. Remove injection pump mounting stud nuts. Remove injection pump from mounting studs.



REPAIR LUCAS FUEL INJECTION PUMP

IMPORTANT: DO NOT disassemble the Lucas fuel injection pump any further than necessary for installing available repair parts, not even for cleaning.

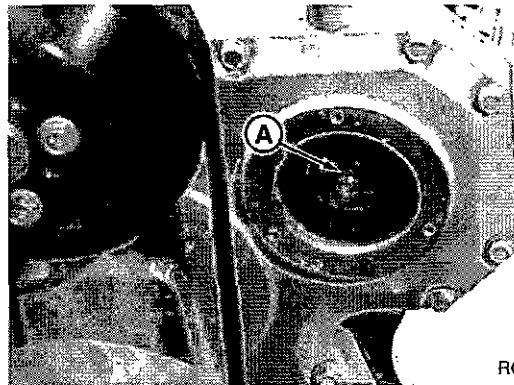
1. Have an authorized ADS Diesel Repair Station perform all injection pump testing, adjustments, and repairs.

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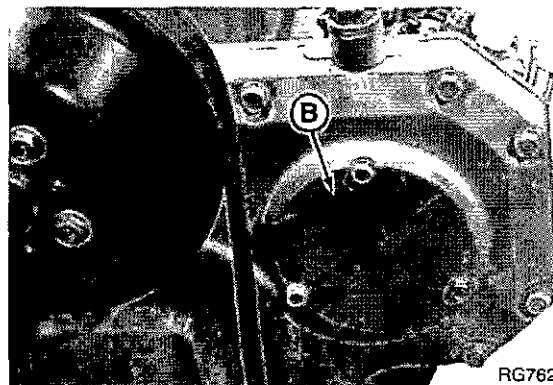
INSTALL LUCAS FUEL INJECTION PUMP

IMPORTANT: When replacing injection pump drive gear or installing a new pump, the tapered surfaces of the pump drive shaft O.D. and drive gear I.D. **MUST BE** cleaned to remove protective coatings and oily residue. Use a suitable cleaner that does not leave a residue. Mating surfaces **MUST BE** assembled dry. **LUBRICANTS MUST NOT BE USED.**



RG7630

1. Place a new O-ring onto front face of pump mounting flange with mounting slots aligned. Slide injection pump onto mounting studs while inserting pump shaft into drive gear.
2. Check pump shaft Woodruff key for proper alignment with pump drive gear key slot.
3. Install injection pump partially onto mounting studs with engaging pump pilot hub into engine front plate.
4. Install three flat washers, lock washers, and hex nuts onto pump mounting studs. Tighten nuts three turns only so that pump will not fall off mounting studs.
5. Install pump mounting flange flush to engine front plate with drive gear held flush against front side of engine front plate.
6. With the pump shaft key properly engaged in the drive gear key slot, finger tighten mounting stud nuts.
7. Push pump drive gear firmly onto shaft taper. Install washer and retaining nut (A) onto end of shaft. Tighten retaining nut to following specifications:



RG7629

FUEL INJECTION PUMP DRIVE GEAR-TO-SHAFT RETAINING NUT TORQUE SPECIFICATIONS

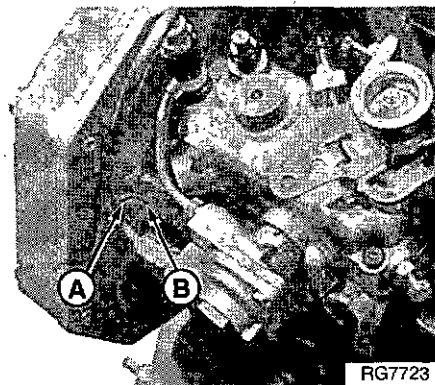
Model DP203.....81 N·m (60 lb-ft)

Model DP201.....122 N·m (90 lb-ft)

8. Install access cover plate (B) using a new O-ring, if needed. Apply LOCTITE 242 (TY9370) to cap screw threads and tighten to 2 N·m (1.7 lb-ft) (20 lb-in.).

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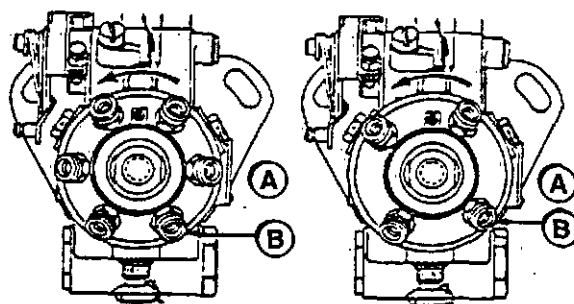
9. Align timing mark on the pump flange (B) with timing mark on front plate (A).
10. Tighten hex nuts securing the pump to the front plate to 27 N·m (20 lb-ft).



RG7723

11. Connect injection pump pressure lines (E). Beginning with outlet (B) and continue around the pump head in counterclockwise direction, attaching lines in same order as engine firing (1-5-3-6-2-4 on 6-cylinder engines and 1-3-4-2 on 4-cylinder engines).
12. Tighten fuel delivery (pressure) lines at pump to 27 N·m (20 lb-ft), using a suitable 17 mm deep-well socket.

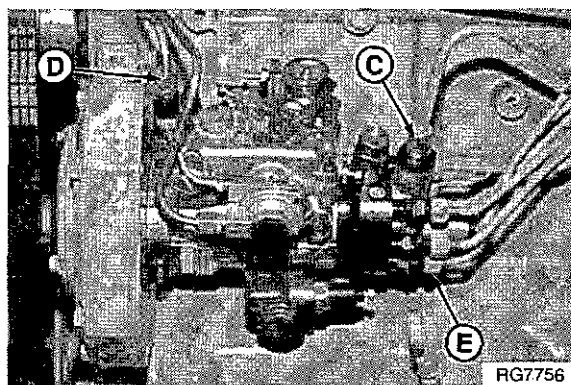
IMPORTANT: ALWAYS use a backup wrench when loosening or tightening fuel delivery lines at fuel injection pump, so that the pump discharge fittings are not altered. This prevents possible internal pump damage.



RG5565

6-Cylinder Engine (Left Illustration)
4-Cylinder Engine (Right Illustration)

13. Connect fuel supply line (C) and fuel return line (D).
14. Connect fuel shut-off cable and speed control linkage, if equipped. Install and securely tighten electrical connections to shut-off solenoid and throttle positioning solenoid, if equipped. Connect cold start switch, if equipped.
15. Bleed air from fuel system as outlined in Group 115. Start engine, run for several minutes and check entire fuel system for leaks.



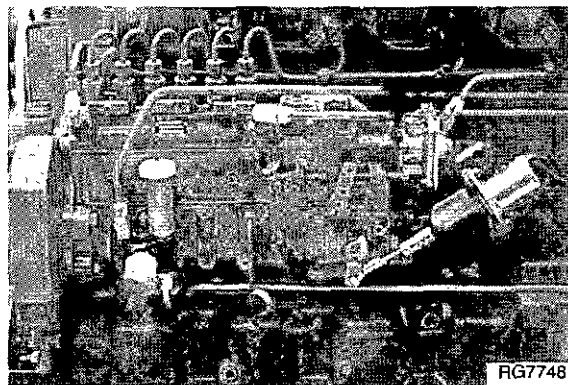
RG7756

A—Engine Block Side
B—Outlet Connection to No. 1 Cylinder
C—Fuel Supply Line
D—Fuel Return Line
E—Fuel Delivery (Pressure) Lines

REMOVE IN-LINE FUEL INJECTION PUMP

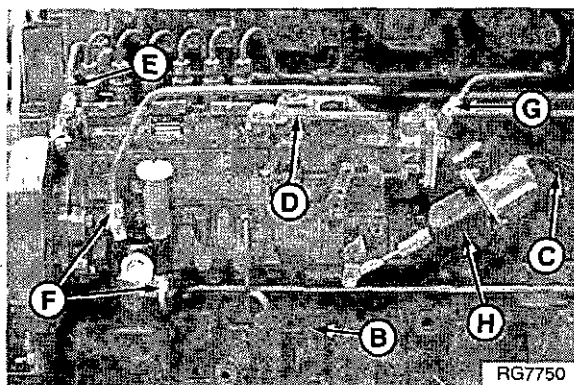
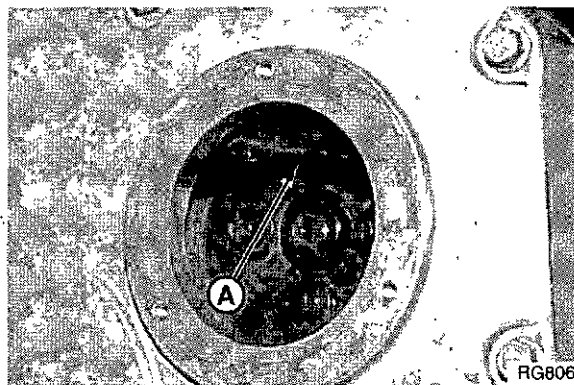
IMPORTANT: Never steam clean or pour cold water on an injection pump while pump is running, or while it is still warm. To do so may cause seizure of pump parts.

1. Clean injection lines and area around the injection pump with cleaning solvent or a steam cleaner.
2. Rotate engine flywheel (in normal running direction) until No. 1 piston is at "TDC" of its compression stroke. At this point, JDE81-4 Timing Pin should enter hole in flywheel.



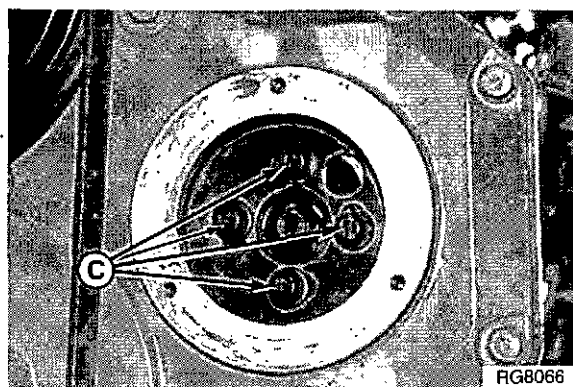
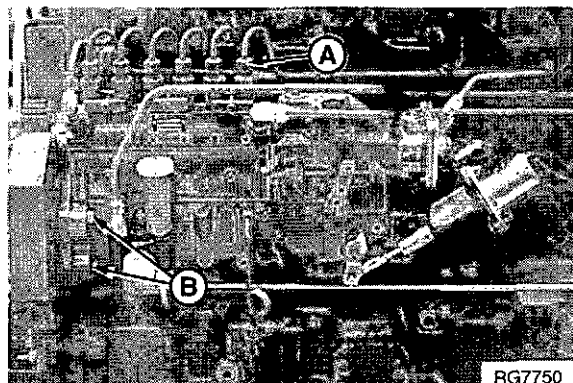
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3. Remove injection pump drive gear cover and O-ring.
4. Install JDG886 Injection Pump Timing Pin through injection pump drive gear into injection pump hub until it bottoms. In some instances, it may be necessary to rotate the pump drive hub slightly to get the pin installed.
5. Disconnect injection pump lube line (B).
6. Disconnect fuel shutoff solenoid electrical connector (C).
7. Remove fuel inlet line (D). Remove fuel leak-off line (E).
8. Disconnect fuel supply pump lines (F).
9. Disconnect aneroid line (G).



- A—JDG886 Injection Pump Timing Pin
- B—Injection Pump Lube Line
- C—Fuel Shutoff Solenoid Electrical Connector
- D—Fuel Inlet Line
- E—Fuel Leak-off Line
- F—Fuel Supply Pump Lines
- G—Aneroid Line
- H—Fuel Shutoff Solenoid

10. Remove fuel injection line nuts (A).
11. Remove four injection pump drive gear cap screws (C).
12. Remove four mounting stud nuts (B) which secure injection pump to cylinder block.
13. Carefully remove injection pump from mounting studs and place it on a clean flat surface.



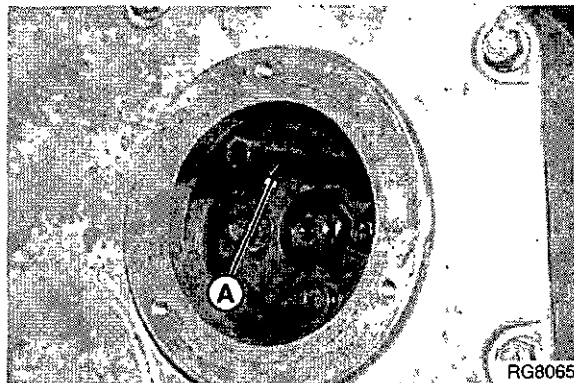
REPAIR IN-LINE FUEL INJECTION PUMP

IMPORTANT: Do not disassemble fuel injection pump further than necessary for installing available service parts, not even for cleaning.

Be sure that injection pump serial number tag is in place and that all identification numbers are legible so that pump is set to the correct specifications for its intended use.

NOTE: Remove JDG886 Injection Pump Timing Pin (A) when sending an injection pump out for repair.

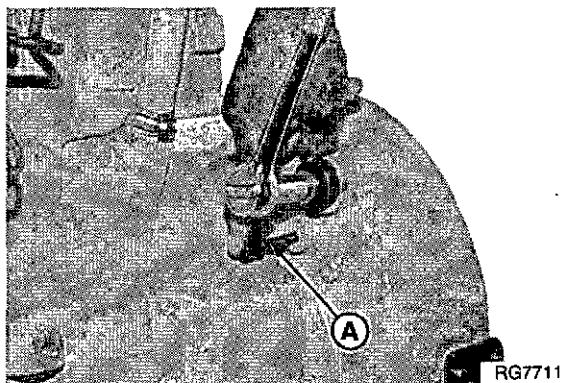
For injection pump repair and testing, have an authorized diesel injection repair station perform the work. Unauthorized repairs made to the injection pump will void warranty.



INSTALL IN-LINE FUEL INJECTION PUMP

1. If engine was rotated after injection pump was removed, rotate flywheel until JDE81-4 Timing Pin (A) enters flywheel at No. 1 cylinder's "TDC" compression stroke.

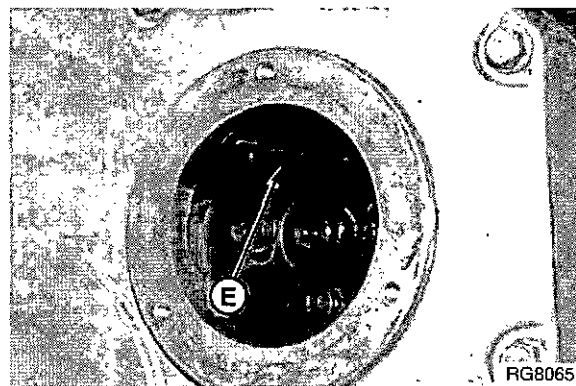
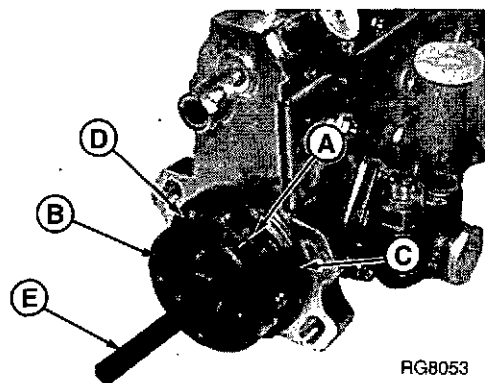
NOTE: When No. 1 cylinder is at "TDC" compression stroke, intake and exhaust valves for No. 1 cylinder will be closed and both rocker arms will be loose.



2. Rotate injection pump drive hub until marks on drive hub (B) and pointer (A) are aligned.

NOTE: It may be necessary to rotate pump hub slightly to allow JDG886 Injection Pump Timing Pin (E) to enter bearing plate.

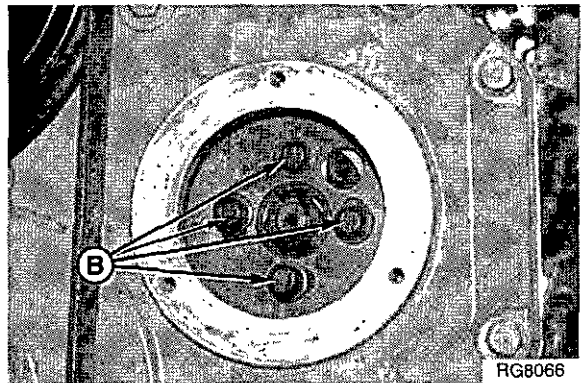
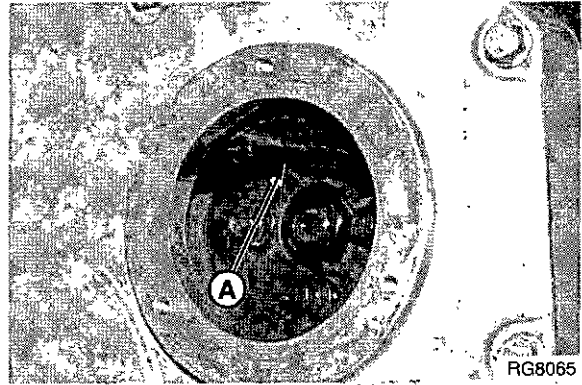
3. Thread JDG886 Timing Pin into drive hub as shown, and tighten until it bottoms against bearing plate (D).
4. Install a new O-ring (C) on bearing plate. Lightly lubricate O-ring with AR54749 Soap Lubricant to aid in pump installation and prevent O-ring damage.
5. Install injection pump using moderate forward pressure and slight rocking motion to work O-ring into mounting bore. Injection pump flange should seat solidly against cylinder block.
6. Install mounting stud nuts and tighten to 70 N·m (52 lb-ft).



- A—Pointer
- B—Drive Hub
- C—O-Ring
- D—Bearing Plate
- E—JDG886 Injection Pump Timing Pin

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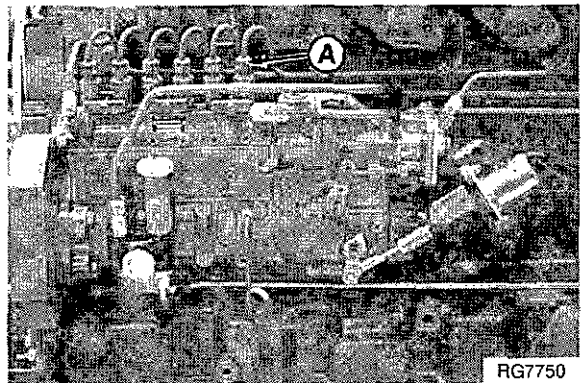
7. Carefully install drive gear on pump drive hub, position gear so mounting cap screws are approximately centered in mounting slots. This will allow for minor adjustment of pump timing, should the need arise.
8. Install drive gear-to-pump hub cap screws (B) and tighten to 47 N·m (35 lb-ft).
9. Remove JDG886 Injection Pump Timing Pin (A) from injection pump hub.
10. Install injection pump drive gear cover using a new O-ring, if needed. Tighten cap screws to 27 N·m (20 lb-ft).



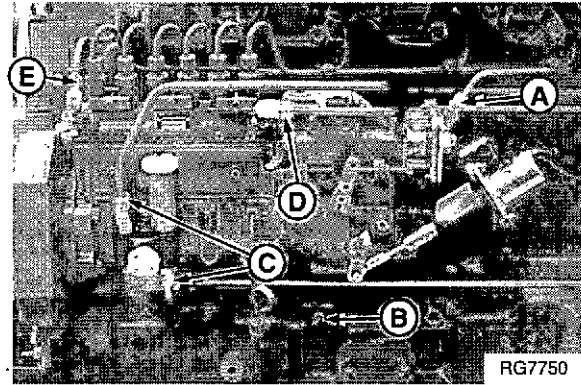
NOTE: Remove protective caps and plugs that were installed on fuel system components during injection pump removal.

11. Connect fuel delivery lines (A). Tighten line nuts to 27 N·m (20 lb-ft).

IMPORTANT: DO NOT move delivery valve fittings while tightening line nuts. If delivery valve and barrel housing rotates while tightening a fuel line nut, injection pump fuel delivery will be altered. The injection pump will have to be recalibrated on a test stand by an authorized diesel repair station.



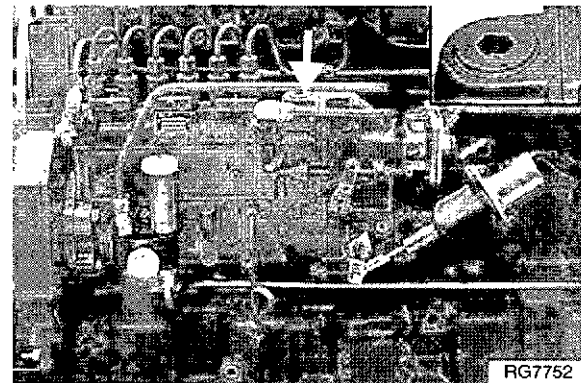
12. Connect aneroid line (A).
13. Connect fuel supply pump lines (C).
14. Connect fuel inlet line (D) and leak-off line (E).
15. Connect injection pump oil line (B) to cylinder block fitting.
16. Connect fuel shutoff solenoid connector.



RG7750

- A—Aneroid Line
- B—Injection Pump Oil Line
- C—Fuel Supply Pump Lines
- D—Fuel Inlet Line
- E—Leak-Off Line

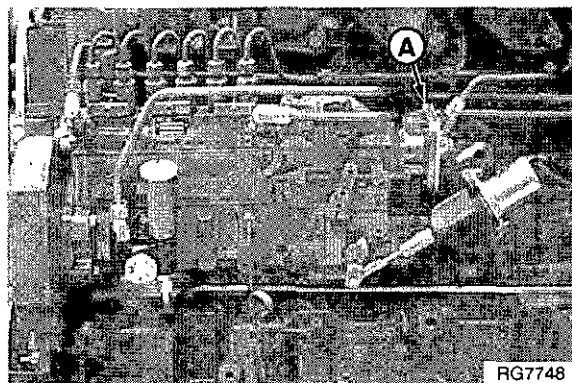
17. Remove oil fill plug (arrow) from governor housing and add 1/2 pint of clean engine oil.
18. Bleed fuel system. (See BLEED THE FUEL SYSTEM in Group 115.)
19. Connect throttle levers and adjust engine speeds as required. (See ADJUST ENGINE SPEEDS in Group 115.)



RG7752

REPAIR ANEROID — IN-LINE INJECTION PUMP

For aneroid (A) repair and adjustment, have an authorized diesel repair station perform the work.



The aneroid controls fuel delivery when intake manifold pressure is about 100 kPa (1.00 bar) (15 psi) or less. Therefore, all final adjustments are to be made on the test stand with aneroid mounted on injection pump.

IMPORTANT: Correct aneroid adjustments are essential for satisfactory engine performance. Whenever aneroid has been disassembled or adjustments have been altered, injection pump (including aneroid) must be calibrated on test stand before releasing pump for service.

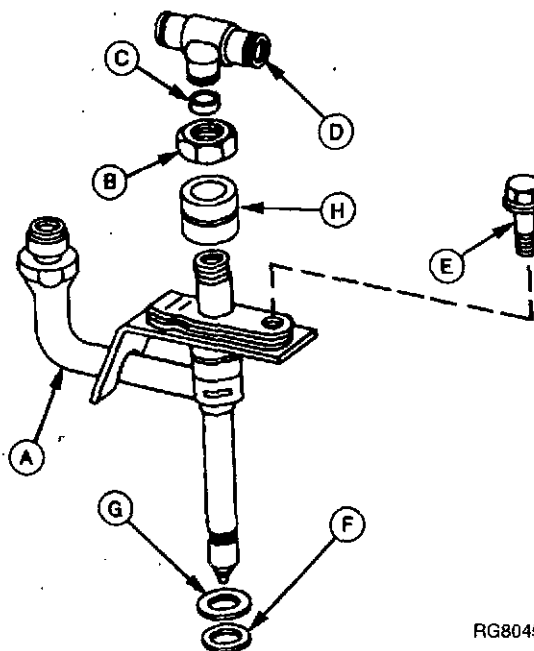
ESTABLISHING ROTARY FUEL INJECTION PUMP TIMING MARK ONTO REPLACEMENT FRONT PLATE

IMPORTANT: Replacement front plates do not have a rotary injection pump timing mark. It is extremely important that timing be accurately established by dynamically timing the engine. Refer to Group 115.

REMOVE FUEL INJECTION NOZZLES

General Nozzle Service Precautions:

- Before removal, thoroughly remove all dirt from the cylinder head around fuel injection nozzles. Clean with compressed air to prevent dirt from entering the cylinders. Plug the bore in the cylinder head after each nozzle has been removed. Cap fuel line openings as soon as they are disconnected.
- Immediately fit protective caps over the nozzle tips and the line connections to avoid handling damage and getting debris in fuel system.
- Do not bend the fuel delivery lines, as this may affect their durability. When loosening the fuel pressure lines, hold male union of nozzle line stationary with a backup wrench.

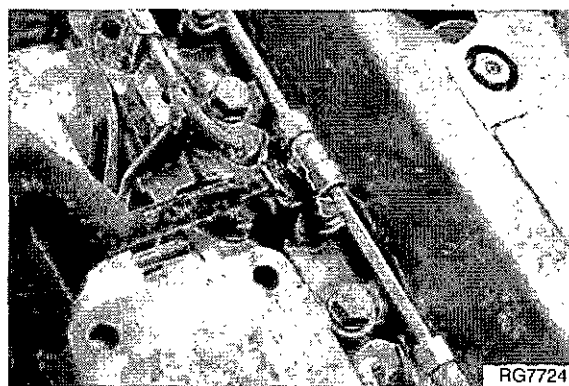


RG8045

- A—Nozzle Assembly
- B—Tube Nut
- C—Packing
- D—Leak-Off T-Fitting
- E—Cap Screw
- F—Carbon Stop Seal
- G—Upper Sealing Washer
- H—Spacer

NOTE: When all fuel injection nozzles have to be removed, disconnect leak-off line and remove as a complete assembly. For individual nozzle removal, remove only the section of leak-off line necessary for nozzle removal.

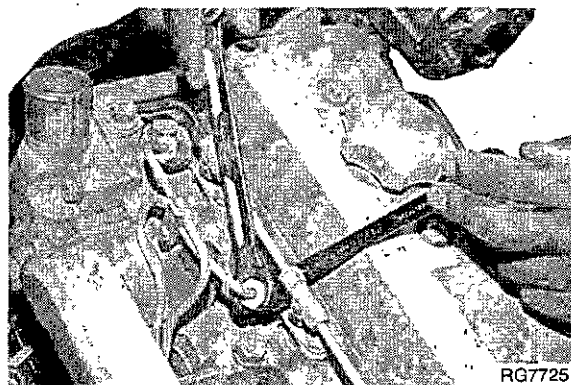
1. Loosen tube nuts at each nozzle to remove leak-off lines and T-fittings as an assembly.



RG7724

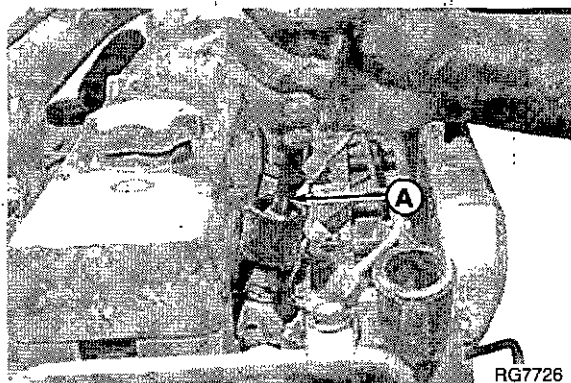
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2. Disconnect fuel injection line from nozzle using a backup wrench on nozzle connection as shown.
3. Remove cap screw securing nozzle in cylinder head nozzle bore.



4. Pull injection nozzle out of cylinder head using JDE38B Injection Nozzle Puller Set (A) or JDG716 Adapter and slide handle from JDE38 or JDE38A Puller Set.

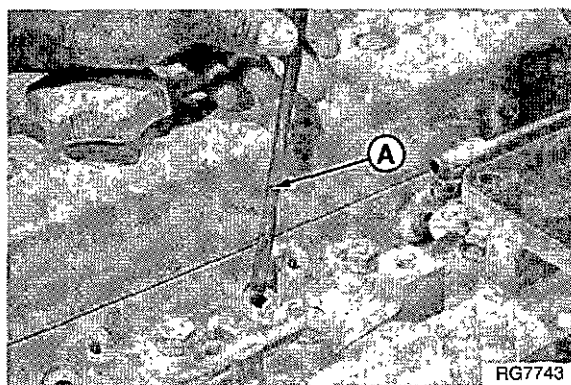
IMPORTANT: Do not use screwdrivers, pry bars, or similar tools for this as they might damage the injection nozzle beyond repair.



CLEAN FUEL INJECTION NOZZLE BORE

IMPORTANT: Always turn tool clockwise in bore to prevent dulling of cutting edges, even when removing tool from bore.

1. Clean injection nozzle bore using JDE39 Nozzle Bore Cleaning Tool (A). Blow debris from bore using compressed air, and plug the bore to prevent entry of foreign material.

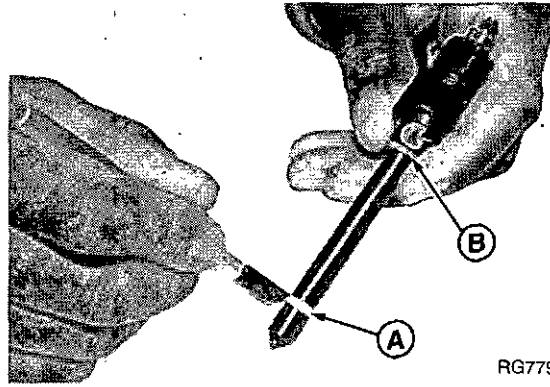


CLEAN FUEL INJECTION NOZZLES

1. Remove carbon stop seal (A) from groove in nozzle body using razor blade or sharp knife and remove upper sealing washer (B). Discard seal and washer.
2. Place nozzle in solvent or clean diesel fuel, so carbon stop seal groove is submerged, and soak for a while.

IMPORTANT: Do not scrape or disturb the teflon coating on the nozzle body above the carbon stop seal groove. This coating will become discolored during normal operation, but this is not harmful. Do not use a motor-driven brush to clean nozzle body.

3. After soaking, clean nozzle tip with ROS16488 Brass Wire Brush. Never use a steel wire brush or scraper.



RG7798

DIAGNOSE FUEL INJECTION NOZZLE MALFUNCTION

Problem	Possible Cause	Suggested Remedy
Failed Carbon Stop Seal Washer	Nozzle replaced without using new seal or washer.	Install new seal or washer.
	Carbon stop seal groove not cleaned when new seal was installed.	Clean groove. Install new seal.
Incorrect Opening Pressure	Improper adjustment.	Adjust opening pressure.
	Broken spring.	Replace spring.
Nozzle Will Not Open	Plugged orifices.	Clean.
	Chipped orifices.	Replace nozzle.
	Bottomed lift screw.	Adjust lift screw.
Poor Spray Pattern	Plugged orifices.	Clean.
	Chipped orifices.	Replace nozzle.
	Cracked nozzle tip.	Replace nozzle.
Poor Atomization	Plugged orifice.	Clean.
	Chipped orifice.	Replace nozzle.
	Cracked nozzle tip.	Replace nozzle.
	Valve not free.	See "Inconsistent Chatter".
Inconsistent Chatter	Spring components misaligned.	Adjust opening pressure.
	Varnish on valve.	Clean guide area.
	Deposits in seat area.	Clean seat.
	Bent valve.	Replace nozzle.
	Distorted body.	Replace nozzle.

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DIAGNOSE FUEL INJECTION NOZZLE MALFUNCTION—CONTINUED

Problem	Possible Cause	Suggested Remedy	
No Chatter	Spring components misaligned.	Adjust opening pressure.	
	Varnish on valve.	Clean guide area.	
	Deposits in seat area.	Clean seat.	
	Bent valve.	Replace nozzle.	
	Valve seat eroded or pitted.	Lap valve to seat. Replace nozzle as necessary.	
	Tip seat pitted.	Lap tip to seat. Replace nozzle as necessary.	
	Seat interference angle worn.	Replace nozzle.	
	Distorted body.	Replace nozzle.	
	Seat Leakage	Deposits in seat area.	Clean seat.
		Valve seat eroded or pitted.	Lap valve to seat. Replace nozzle as necessary.
Tip seat pitted.		Lap tip to seat. Replace nozzle as necessary.	
Valve not free.		See "Inconsistent Chatter".	
		See "No Chatter".	
Distorted body.		Replace nozzle.	
Cracked tip.		Replace nozzle.	
High Leak-Off	Wear or Scratched at Guide	Lap valve to guide. Replace nozzle.	
Low Leak-Off	Varnish on valve.	Clean guide area.	
	Insufficient clearance.	Clean nozzle. Lap valve to guide. Replace nozzle as necessary.	

TEST FUEL INJECTION NOZZLES



CAUTION: The nozzle tip should always be directed away from the operator. Fuel from the spray orifices can penetrate clothing and skin causing serious personal injury. Enclosing the nozzle in a clear glass beaker is recommended.

Before applying pressure to the nozzle tester, be sure that all connections are tight, and that the fittings are not damaged. Fluid escaping from a very small hole can be almost invisible. To search for suspected leaks, use a piece of cardboard or wood, rather than hands.

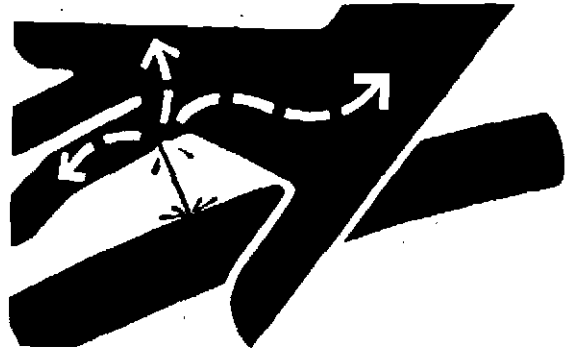
If ANY fluid is injected into the skin, it must be surgically removed within a few hours by a doctor familiar with this type injury or gangrene may result.

1. Connect injection nozzle to nozzle tester. When using the Bosch tester (JT25510), use the KJD10109 Fuel Line and connect line to tester and nozzle.
2. Use Y900-3, Y900-5 Adapters (C) and Y900-2 Fuel Line (B) from D01110AA Adapter Set to connect nozzles to D01109AA Nozzle Tester.
3. Position tip of nozzle below top of beaker (D) and back out 30° from vertical. This is necessary to contain all spray in beaker, as nozzle spray pattern is at an angle to the nozzle centerline. Leave connections slightly loose.

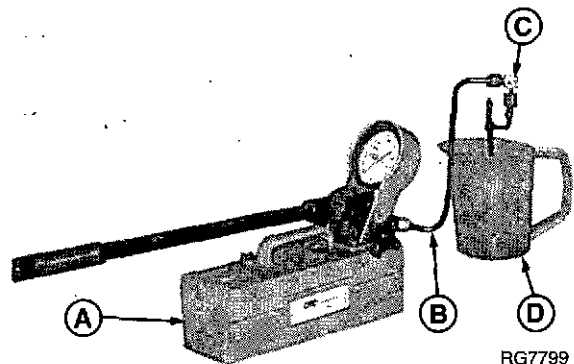
NOTE: Rapid operation of pump handle will result in inaccurate cranking pressure readings and cause undue wear on gauge.

4. Pump handle several strokes to flush air from lines and to determine the pumping rate required for proper fuel atomization. Tighten all connections securely after all air has been expelled from nozzle and line.

IMPORTANT: Make sure that nozzle tester is in good condition and that gauge works properly. Service nozzle tester as recommended in the operating instructions provided with tester.



X9811



RG7799

A—Nozzle Tester
B—Fuel Line
C—Adapters
D—Beaker

• **Opening Pressure Test**

NOTE: Actual nozzle opening pressure is less important than equal opening pressure of all nozzles. For maximum variation between nozzles see FUEL SYSTEM SPECIFICATIONS, at beginning of this group.

1. Actuate the nozzle tester rapidly several times to allow the valve to seat rapidly.
2. Open gauge valve, actuate the tester and raise the pressure to a point where the gauge needle falls rapidly. This is the nozzle opening pressure, and should be as specified for a new or used nozzle.

IMPORTANT: If any of the nozzle opening pressures are not within specified range, reset pressure and valve lift **BEFORE** checking chatter and spray pattern. Otherwise, these characteristics may be affected. (See **ADJUST FUEL INJECTION NOZZLES** later in this group.)

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• **Chatter Test**

1. Close gauge shut-off valve and operate nozzle tester at a pumping rate that will cause the nozzle to chatter. Nozzle should chatter softly, and spray pattern should be broad and finely atomized.

NOTE: Until the chattering range is reached, fuel will emerge in non-atomized streams.

If nozzle fails to chatter, the nozzle valve may be bent or tight in it's guide due to accumulated lacquer deposits. Disassemble nozzle and correct as detailed later in this group.

2. Using the pumping rate for proper atomization, operate tester for ten strokes. The nozzle must atomize on at least eight of the ten strokes without consecutive misses.

If the nozzle fails to meet this requirement, repeat procedure. Nozzles which do not meet the requirement after second test should be considered unacceptable and should be either repaired or replaced.

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• **Spray Pattern Test**

1. Close gauge shut-off valve and operate nozzle tester at a pumping rate that will cause the nozzle to chatter.

2. Observe spray pattern and check for plugged orifices.

NOTE: Partially clogged, chipped, or eroded orifices will cause the spray to deviate from the correct angle. Spray will be streaky, rather than finely atomized.

If nozzle fails to chatter or spray properly, disassemble, clean and recondition as outlined later in this group.

• **Leakage Test**

1. Check nozzle for fuel leakage past valve seat by positioning nozzle on nozzle tester with nozzle tip down.
2. Operate pump handle rapidly to firmly seat valve. Wipe the nozzle tip dry with a clean, lint-free cloth

3. Slowly raise pressure at nozzle to about 2800—3500 kPa (28—35 bar) (400—500 psi) under specified opening pressure and hold at that pressure. Watch for an accumulation of fuel around the nozzle tip orifices.

If fuel drips from nozzle within 5 seconds, nozzle must be lapped.

• **Valve Stem and Guide Wear Test**

1. Position nozzle with tip slightly above the horizontal plane.

NOTE: Leakage rate based on use of No. 2 diesel fuel or an equivalent viscosity of test oil at 18°—24° C (65°—75° F) ambient temperature.



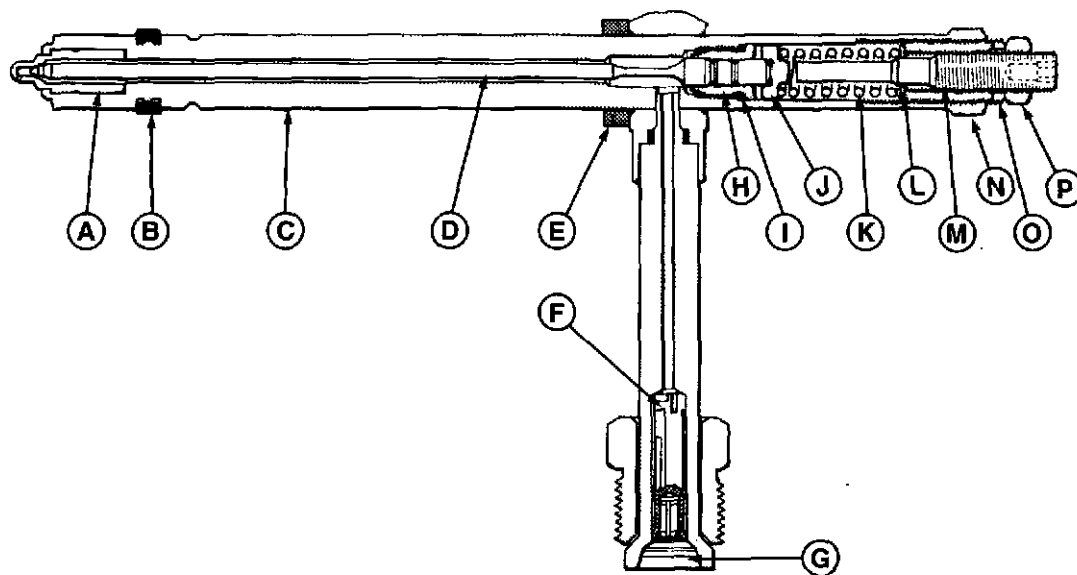
CAUTION: Completely enclose spray zone in a glass beaker to avoid possible personal injury from spray.

2. Slowly raise pressure to 10 300 kPa (103 bar) (1500 psi) on test gauge

3. Look for leakage from the return end of nozzle. After one drop, leakage should be 3—10 drops in 30 seconds.

If nozzle leakage is not within specified range, nozzle must be reconditioned as outlined later in this group.

DISASSEMBLE FUEL INJECTION NOZZLES



RG7800

A—Nozzle Tip
 B—Carbon Stop Seal
 C—Nozzle Body
 D—Nozzle Valve

E—Upper Sealing Washer
 F—Edge-Type Filter
 G—Fuel Inlet
 H—Upper Guide

I—Upper Seal
 J—Spring Seat
 K—Spring
 L—Spring Washer
 M—Lift Adjusting Screw

N—Lock Nut
 O—Pressure Adjusting
 Screw
 P—Lock Nut

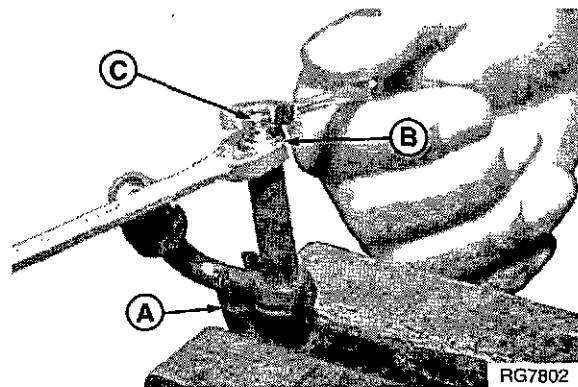
General Nozzle Repair Notes:

NOTE: Disassembly of nozzles is not recommended unless servicing is indicated by nozzle operation and testing.

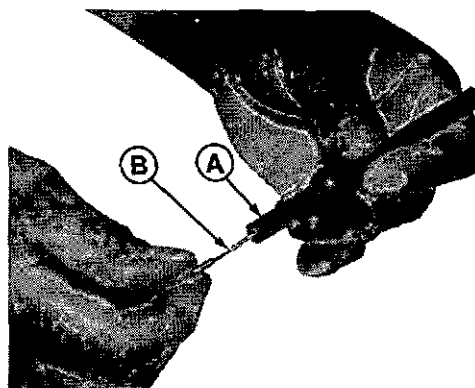
- Since dirt and water are the worst contaminants in the fuel injection system, the working area, tools and cleaning materials must be kept spotlessly clean. Whenever possible, work in an isolated, dust-free area.
- Cover the work bench with clean paper before beginning disassembly of injection nozzles.
- As parts are disassembled, place them in a pan of clean diesel fuel and leave there until needed. Do not permit these parts to strike each other.
- Use a separate pan of clean fuel for washing parts before assembly.

To Disassemble Fuel Injection Nozzle:

1. Place nozzle in ROS17787 Holding Fixture or nozzle index clamp (A) and secure fixture or clamp in a vise.
2. Loosen pressure adjusting lock nut (B).
3. Back out lift adjusting screw lock nut (C) and lift assembly.
4. Invert nozzle and allow pressure adjusting spring seat and lift adjusting assembly to fall into your hand. Do not bend stem during removal.



5. If valve does not slide freely from body (A), use No. 16481 Valve Retractor (B) to remove valve.
6. Remove locating clamps and spacer from nozzle body.



RG7803

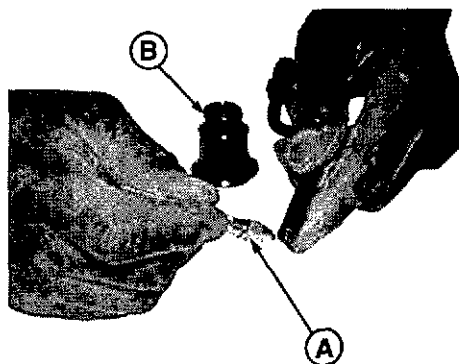
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INSPECT AND CLEAN FUEL INJECTION NOZZLE BODY

NOTE: Unless otherwise indicated, all tools required for nozzle cleaning can be found in the ROS16494 Nozzle Cleaning Kit.

Clean carbon stop seal groove and nozzle tip with a nozzle cleaning wire inserted in holder (A).

Inspect tip for cracks and spray orifices for chipping and erosion using ROS16487 Inspection Magnifier (B).



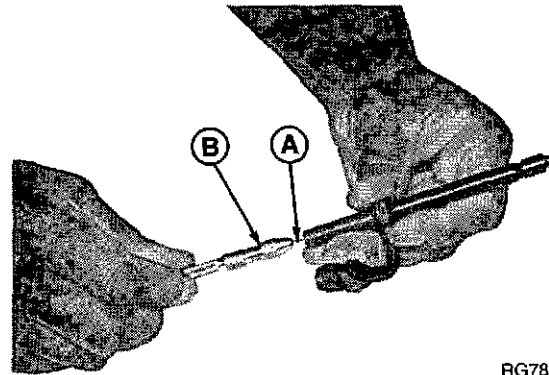
RG7804

To clean carbon from nozzle orifices:

1. Begin with a cleaning wire 0.07—0.10 mm (0.003—0.004 in.) smaller than the nominal orifice size given in specifications.

NOTE: Stoning the wire to provide a flat surface on one side will help in reaming carbon from a clogged hole.

2. Clamp the wire in ROS16483 Pin Vise. Wire should not protrude from the vise more than 0.8 mm (1/32 in.).
3. Insert wire in orifice and rotate.
4. Use ROS17712 Scraper to clean deposits from valve seating area.
5. Grasp ROS16476 Sac Hole Drill (A) with No. 16481 Valve Retractor (B).
6. For final cleaning, use a cleaning wire 0.03 mm (0.001 in.) smaller than the nominal orifice size and repeat Steps 2 and 3.



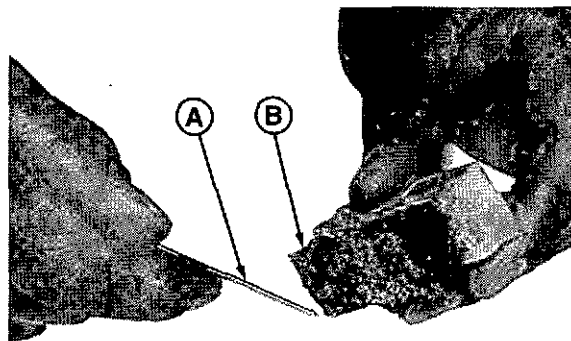
RG7805

INSPECT AND CLEAN VALVE AND VALVE SEAT

IMPORTANT: NEVER use a steel wire brush on nozzle parts.

Use ROS16488 Brass Wire Brush (B) to remove deposits from seating area on tip of nozzle valve (A).
Use a ROS16544 Felt Pad to remove varnish deposits.

Inspect guide area of valve scratches which could cause sticking. This area will generally be polished on one side during operation. Visible vertical marks are normal.

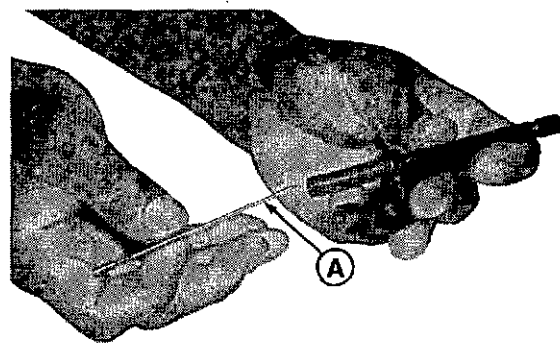


RG7806

• **Inconsistent Chatter or No Chatter**

A nozzle which during test had spotty chatter or showed definite signs of sticking accompanied by low return leakage, may be corrected by polishing the valve guide area as follows:

1. Place a small amount of ROS16489 Lapping Compound on the nozzle valve (A) in guide area only. DO NOT use any other compound for this purpose.
2. Slide valve into body.
3. Grip top of the valve with No. 16481 Retractor and rotate valve in the guide by turning retractor. The amount of lapping required can be accomplished in 10—20 turns by hand. The valve should be raised and lowered in the guide every 3—4 revolutions and direction of rotation changed for best results.



RG7807

IMPORTANT: Never attempt to rotate the valve in a motor driven chuck for this purpose.

4. Wash nozzle body and valve thoroughly in clean fuel before reassembly.

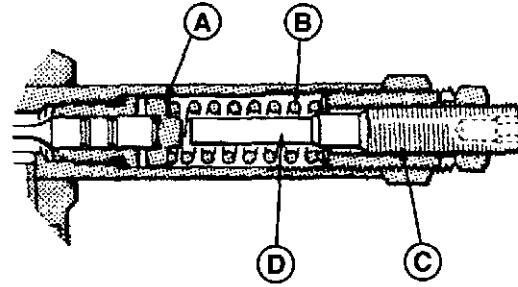
• **Seat Leakage**

Seat leakage may be caused by dirt, carbon or fuel deposits in valve area. Inspect valve seat and clean as follows:

1. Apply a small amount of ROS16489 Lapping Compound to valve tip and insert valve in nozzle body.
2. Gripping valve with No. 16481 Retractor, rotate valve 3 to 5 turns to clean up seat.
3. Wash valve and nozzle body thoroughly in clean fuel.

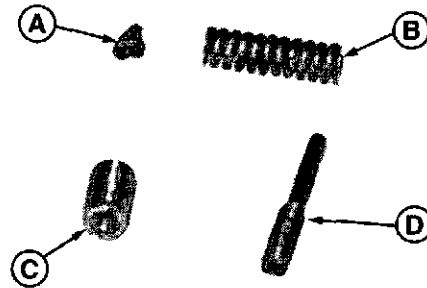
INSPECT VALVE ADJUSTING MECHANISM

1. Inspect lift adjusting screw (D). Replace if bent or otherwise damaged.
2. Inspect pressure adjusting screw (C). Replace if worn or damaged.
3. Inspect pressure adjusting spring (B). Replace if broken or distorted.
4. Inspect spring seat (A) for wear. Replace as necessary.
5. Replace nozzle clamp if bent.



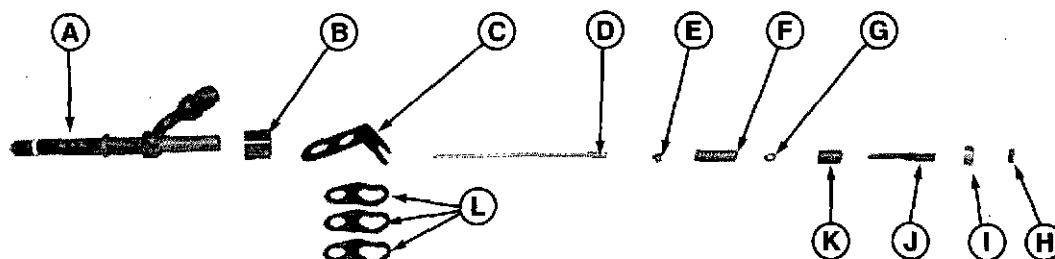
RG7810

- A—Spring Seat
- B—Pressure Adjusting Spring
- C—Pressure Adjusting Screw
- D—Lift Adjusting Screw



RG7808

ASSEMBLE FUEL INJECTION NOZZLES



RG8042

A—Nozzle Body
B—Spacer
C—Indexing Clamp

D—Nozzle Valve
E—Spring Seat
F—Pressure Adjusting Spring

G—Washer
H—Lift Adjusting Screw Lock Nut
I—Pressure Adjusting Screw Lock Nut

J—Lift Adjusting Screw
K—Pressure Adjusting Screw
L—Hold-Down Clamps

1. Install nozzle spacer (B) onto upper nozzle body (A). Position nozzle locating clamp (C) over upper nozzle body with flanges pointing downward. Install three remaining clamps (L) onto nozzle body.
2. Dip valve (D) in clean fuel and insert into nozzle body.
3. Thread lift adjusting screw (J) into pressure adjusting screw (K) until top just enters screw.
4. Invert adjusting screw assembly and assemble spring seat (E) and spring (F) to adjusting screw.
5. Tilt body, DO NOT allow valve to fall out, and install spring and adjusting screws to body. Be careful not to dislodge spring or seat during initial assembly.
6. Turn pressure adjusting screw down as far as possible by hand; usually about ten full turns. Adjust nozzle as detailed later in this group.

IMPORTANT: Wear rubber gloves when assembling nozzles.

ADJUST FUEL INJECTION NOZZLES

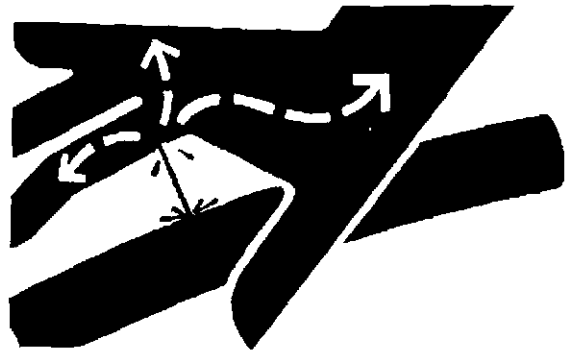


CAUTION: Nozzle tip should always be directed away from operator. Fuel from spray orifices can penetrate clothing and skin causing serious personal injury. Enclosing nozzle in a glass beaker is recommended.

Before applying pressure to nozzle tester, be sure all connections are tight, and fittings are not damaged. Fluid escaping from a very small hole can be almost invisible. Use a piece of cardboard or wood, rather than hands, to search for suspected leaks.

If ANY fluid is injected into the skin, it must be surgically removed within a few hours by a doctor familiar with this type injury or gangrene may result.

1. Connect nozzle to nozzle tester. (See TEST INJECTION NOZZLES earlier in this group.)



X9811

• **Adjust Nozzle Opening Pressure**

Close pressure gauge valve and flush nozzle by operating pump rapidly.

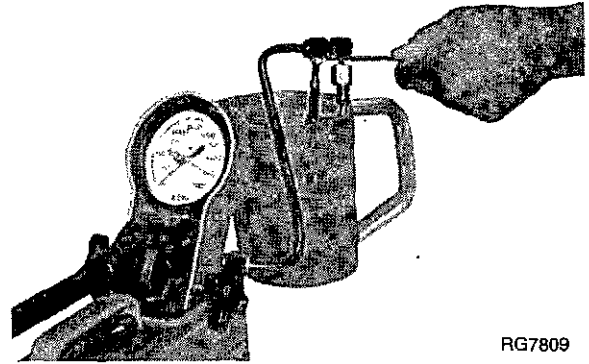
Raise pressure on pump until nozzle opens (gauge drops sharply).

Refer to nozzle opening pressure specification, given in Fuel System Specifications at beginning of this group.

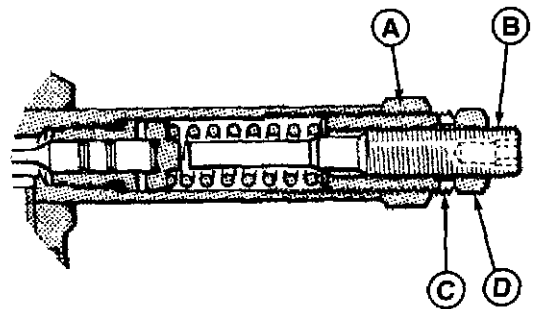
If opening pressure is incorrect:

1. Remove nozzle from tester and install in ROS17787 Holding Fixture.
2. Remove lift adjusting lock nut (D).
3. Loosen pressure adjusting screw lock nut (A), using JDG949 Nozzle Wrench.
4. Reconnect nozzle to tester with tip pointing downward.
5. Back out lift adjusting screw (B) far enough (two or three turns) to prevent bottoming when pressure adjusting screw (C) is turned.
6. Turn pressure adjusting screw in (clockwise) to increase opening pressure, or out (counterclockwise) to decrease opening pressure.

NOTE: It is desirable to set opening pressure to the high limit of specification. If required, repeat procedure to obtain proper result.



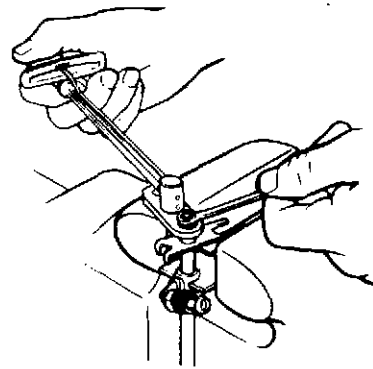
RG7809



RG7810

- A—Pressure Adjusting Screw Lock Nut
- B—Lift Adjusting Screw
- C—Pressure Adjusting Screw
- D—Lift Adjusting Lock Nut

7. Remove nozzle from tester and secure in holding fixture. While holding pressure adjusting screw, tighten pressure adjusting screw lock nut to 10 N·m (7 lb-ft) using the ROS18958 (English size) or No. 24374 (metric size) Torque Wrench Adapter.



RG7811

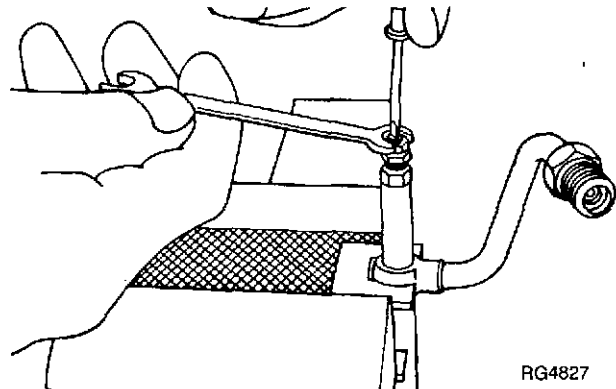
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• **Adjust Nozzle Valve Lift**

1. Reconnect nozzle to tester. While pumping fuel through nozzle, hold pressure adjusting screw and slowly turn lift adjusting screw in (clockwise) until valve ceases to open.

IMPORTANT: DO NOT manually bottom the valve with excessive force as bending of the valve may result.

2. Check for valve bottoming by raising pressure to 1380—3450 kPa (14—34 bar) (200—500 psi) above nozzle opening pressure.



RG4827

Although some fuel may collect at nozzle tip, a rapid dribble should not occur.

3. Remove nozzle from tester and install in holding fixture.
4. Carefully turn lift adjusting screw out specified amount. A tolerance of 1/8 turn is permissible. (See FUEL SYSTEM SPECIFICATIONS earlier in this group.)

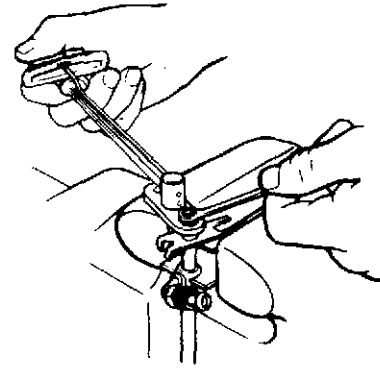
Hold pressure adjusting screw stationary while tightening lock nut. Use ROS18958 Torque Wrench Adapter on English-type lock nuts; No. 24374 on metric-type lock nuts.

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5. Tighten pressure adjusting screw lock nut to 5 N·m (3.5 lb-ft) (42 lb-in.).
6. Recheck nozzle opening pressure.

If nozzle chatter is incorrect after servicing, valve parts may be misaligned. To correct, screw pressure adjusting screw through its range of adjustment several times and reset valve lift. Recheck nozzle for chatter.

7. Clean nozzle with ROS16488 Brass Wire Brush.

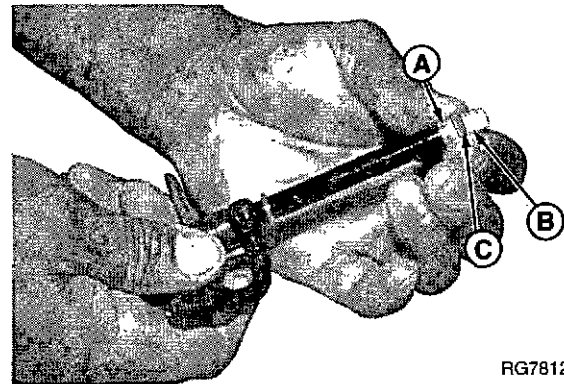


RG7811

INSTALL SEALS ON FUEL INJECTION NOZZLE

IMPORTANT: Each time an injection nozzle is removed from the cylinder head, replace carbon stop seal (C) with a new one.

1. Position JD258 (ROS16477) Pilot Tool (A) over nozzle tip.
2. Install a new seal washer (B) onto nozzle body.
3. Position a new carbon stop seal on pilot tool. Slide the carbon seal until it seats in its groove on nozzle body.



RG7812

NOTE: If nozzle is not going to be installed at this time, install a No. 16189 Nozzle Protector Cap over nozzle tip. Plug all other openings in nozzle to prevent contamination.

INSTALL FUEL INJECTION NOZZLES

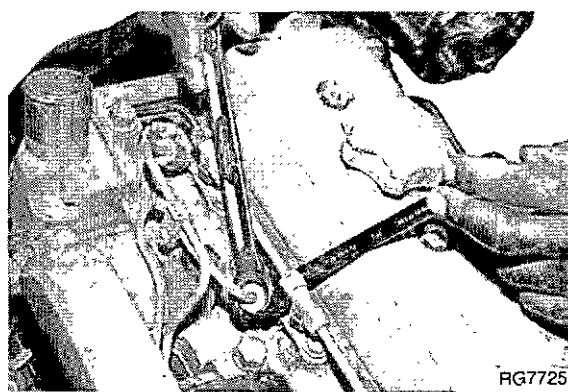
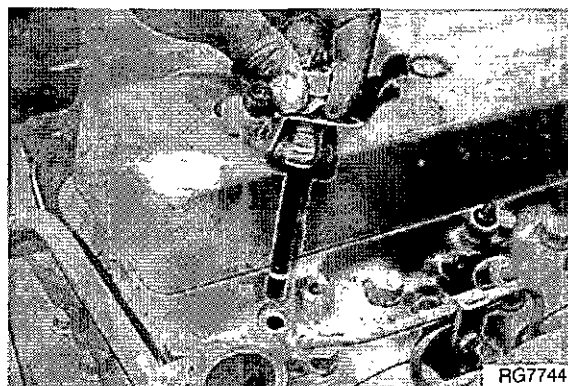
NOTE: If nozzle bore in cylinder head must be cleaned, use JDE39 Nozzle Bore Cleaning Tool. (See REMOVE FUEL INJECTION NOZZLES earlier in this group.)

IMPORTANT: Before installing injection nozzles, make sure nozzles are clean and free from oil or grease.

1. Remove plug (if installed previously) from nozzle bore in cylinder head and blow out bore with compressed air.

NOTE: Make sure that the sealing surface of the cylinder head (on which the seal washer will be resting) is smooth and free of damage or dirt. This could prevent proper sealing. Dirt and roughness could also cause nozzle to be distorted when the attaching screw is tightened, making the valve stick.

2. Install nozzle with spacer and clamps in cylinder head using a slight twisting motion as nozzle is seated in bore. Illustration shows relationship of parts required for proper installation.
3. Align nozzle clamps and install cap screw. Do not tighten cap screw at this stage.
4. Connect fuel pressure line to nozzle. Leave connection slightly loose until air is bled from system.
5. Tighten nozzle hold-down clamp cap screws to 40 N-m (30 lb-ft).
6. Install leak-off line assembly.
7. Bleed air from loose injection line connection. Tighten connection using two wrenches to 34 N-m (25 lb-ft). (See BLEED THE FUEL SYSTEM in Group 115.)



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EFFECTS OF ALTITUDE AND TEMPERATURE ON ENGINE PERFORMANCE

Altitude, fuel temperature, air temperature, and humidity may affect engine performance. As a general rule, atmospheric changes will usually cause a decrease in engine power by the percentages shown in chart below.

ATMOSPHERIC CHANGE	% POWER DECREASE
Fuel Temperature Rise of 1° C (1.8° F) above 40° C (104° F)	0.29
Air Temperature Rise of 5.5° C (10° F) above 25° C (77° F)	0.50
Naturally Aspirated Engines:	
Altitude Rise of 300 m (1000 ft) above 180 m (600 ft) .....	.3.00**
Turbocharged Engines:	
Altitude Rise of 300 m (1000 ft) above 183 m (600 ft)	0.50*
Relative Humidity Rise of 10% above 0%	0.07

If engine required less fuel for acceptable performance at higher elevation, contact your local authorized fuel injection pump repair station for service.

**Engine may have to be defueled when a substantial percentage of operating time occurs at 2250 m (7500 ft) or higher.*

***Engine may have to be defueled when a substantial percentage of operating time occurs at 1500m (5000 ft) or higher.*

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1

PRELIMINARY ENGINE TESTING

Before tuning-up an engine, determine if a tune-up will restore operating efficiency. If in doubt, the following preliminary tests will help determine if the engine can be tuned-up. Choose from the following procedures only those necessary to restore the unit.

1. After engine has stopped for several hours, loosen crankcase drain plug and watch for any water to seep out. A few drops could be due to condensation, but any more than this would indicate problems which require engine repairs rather than just a tune-up.
2. With engine stopped, inspect engine coolant for oil film. With engine running, inspect coolant for air bubbles. Either condition would indicate problems which require engine repairs rather than just a tune-up.
3. Perform a dynamometer test and record power output. (See DYNAMOMETER TEST later in this group.) Repeat dynamometer test after tune-up. Compare power output before and after tune-up.
4. Perform compression test (See TEST ENGINE COMPRESSION PRESSURE in Group 105).

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2

GENERAL TUNE-UP RECOMMENDATIONS

As a general rule, an engine tune-up is not necessary if ALL recommended operator's manual hourly service procedures are performed on schedule. If your engine performance is not within the rated application guidelines, the following service procedures are recommended to help restore engine to normal operating efficiency.

Operation	Detailed Reference
Change engine oil and filter.	Operator's Manual
Lubricate PTO clutch internal levers and linkage, if equipped.	Operator's Manual
Replace fuel filter and water separator, if equipped.	Group 35/Operator's Manual
Clean crankcase vent tube.	Group 35/Operator's Manual
Check air intake system. Replace air cleaner elements.	This Group/Operator's Manual
Check exhaust system.	This Group
Check and service engine cooling system.	This Group/Operator's Manual
Check and adjust fan and alternator belts. Replace if necessary.	Group 25/Operator's Manual
Check electrical system.	This Group
Check crankshaft vibration damper (6-cylinder).	Group 15/Operator's Manual
Inspect turbocharger and check turbocharger boost pressure.	Group 110
Check fuel injection system: Check engine/injection pump timing; check and adjust speed advance; clean injection nozzles, and adjust opening pressure.	Group 35 and 115
Check engine oil pressure. Correct as necessary.	Group 105
Check engine valve clearance. Adjust if necessary.	Group 05
Check engine speeds. Correct as necessary.	Group 115
Check engine performance on dynamometer.	This Group

DYNAMOMETER TEST

IMPORTANT: Dynamometers should be periodically checked for accuracy and calibrated as necessary.

NOTE: High elevations may affect engine performance. (See EFFECTS OF ALTITUDE AND TEMPERATURE ON ENGINE PERFORMANCE, earlier in this group.)

1. Connect engine to dynamometer using manufacturer's instructions.
2. Operate engine at one-half load until coolant and crankcase oil temperatures are up to normal operating range.
3. Run engine at fast idle.

4. Gradually increase load on engine until speed is reduced to rated speed rpm.

NOTE: Refer to appropriate machine technical manual for average power ratings of specific applications. Allow $\pm 5\%$ for minimum and maximum power.

5. Read horsepower on dynamometer and record reading over a period of several minutes after engine stabilizes.
6. Compare readings taken with power rating level for your engine application, as listed in following module.

DYNAMOMETER TEST SPECIFICATIONS

Injection pump timing specifications are provided for OEM applications. For industrial applications refer to SP458 Specifications Handbook. For agricultural applications, refer to DB1216 Specifications Handbook. If specifications are not listed in handbooks, refer to factory DTAC for assistance.

NOTE: The power specifications shown below apply to Dubuque and Saran-built engines.

Engine Model	Injection Pump Option Code	Original Injection Pump (Part No.)	Replaced By Injection Pump (Part No.)	Governor Regulation	Rated Speed (rpm)	Fast Idle (rpm)	Power Rating* kW (BHP)
4045DF150	1601	RE67557	—	STD	2500	2700	60 (80)
	1602	RE59809	—	STD	2500	2700	63 (84)
	1603	RE67558	—	3—5%	1800	1890	53 (71)
	1671	RE67559	—	STD	2500	2700	60 (80)
	1673	RE67560	—	3—5%	1800	1890	53(71)
	1674	RE67561	—	3—5%	1800	1890	53 (71)
4045TF150	1605	RE61668	—	STD	2500	2700	86 (115)
	1656	RE67562	—	3—5%	1800	1890	75 (100)
	1675	RE60091	—	STD	2500	2700	86 (115)
	1677	RE67563	—	3—5%	1800	1890	75 (100)
	1694	RE67863	—	STD	2500	2700	75 (100)
	1695	RE68739	—	STD	2500	2700	75 (100)
4045TF250	1606	RE64133	—	STD	2400	2600	93 (125)
	1608	RE67564	—	3—5%	1800	1890	84 (112)
	1667	RE59968	—	STD	2400	2600	93 (125)
	1682	RE67566	—	3—5%	1800	1890	84 (112)
	1683	RE60124	—	STD	2400	2600	93 (125)
6068DF150	1613	RE59861	—	STD	2500	2700	93 (125)
	1678	RE60101	—	STD	2500	2700	93 (125)
6068TF150	1614	RE61669	—	STD	2500	2700	127 (170)
	1680	RE60105	—	STD	2500	2700	127 (170)
	1681	RE67571	—	3—5%	1800	1890	112 (150)
	1688	RE67572	—	3—5%	1800	1890	112 (150)
	1696	RE67864	—	STD	2500	2700	116 (155)
	1697	RE68740	—	STD	2500	2700	116 (155)
6068TF250	1615	RE62366	—	STD	2400	2600	138 (185)
	1619	RE67573	—	3—5%	1800	1890	124 (166)
	1668	RE59969	—	STD	2400	2600	138 (185)
	1685	RE67574	—	3—5%	1800	1890	124 (166)
	1686	RE60131	—	STD	2400	2600	138 (185)

*Engine speeds listed are as preset to factory specification. In most cases, slow idle speed will be reset depending upon specific vehicle application requirements. Refer to your machine technical manual for engine speeds that are different from those preset at the factory.

ENGINE BREAK-IN GUIDELINES

Engine break-in should be performed when the following repairs have been made:

- Main bearings, rod bearings, crankshaft, or any combination of these parts have been replaced.
- Pistons, rings, or liners have been replaced.

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PERFORM ENGINE BREAK-IN

Use a dynamometer to perform the following preliminary break-in procedure. If necessary, preliminary engine break-in can be performed without a dynamometer if under controlled operating conditions.

IMPORTANT: DO NOT use John Deere PLUS-50® oil or engine oils meeting API CG4, API CF4, ACEA E3, ACEA E2, or CCMC D5 performance levels during break-in period of an engine that has had a major overhaul. These oils will not allow an overhauled engine to properly wear during the break-in period.

Do not add makeup oil until the oil level is BELOW the add mark. John Deere Break-In Oil should be used to make up any oil consumed during break-in period.

1. Fill engine crankcase to proper level with John Deere ENGINE BREAK-IN OIL during break-in operation. This oil is specifically formulated to enhance break-in of John Deere diesel engines.

IMPORTANT: During preliminary break-in, periodically check engine oil pressure and coolant temperature. Also check for signs of fuel, oil, or coolant leaks.

2. Start engine, run at loads and speeds shown in following chart for time limits given.

PRELIMINARY ENGINE BREAK-IN AFTER MAJOR OVERHAUL

Time	Load	Engine Speed
1 minute	No load	850 rpm
2 minutes	No load	Fast Idle
15 minutes	1/2—3/4 load	2000 rpm to rated speed
10 Minutes	Full load	Rated speed

3. After preliminary break-in, run engine 1—2 minutes at 1500 rpm, with no load before shut-down.
4. Check and readjust valve clearance as necessary. Cylinder head retorquing is not required.
5. Operate the engine at heavy loads with minimal idling during the break-in period.

If the engine has significant operating time at idle, constant speeds, and/or light load usage, an additional 100 hour break-in period is recommended using a new change of John Deere ENGINE BREAK-IN OIL and new John Deere oil filter.

As a general rule, makeup oil should not need to be added during 100-hour break-in period. However, if makeup oil is required in the first 100-hour break-in, an additional 100-hour break-in period is required. Use a new change of John Deere ENGINE BREAK-IN OIL and a new John Deere oil filter.

CHECK CRANKCASE VENTILATION SYSTEM

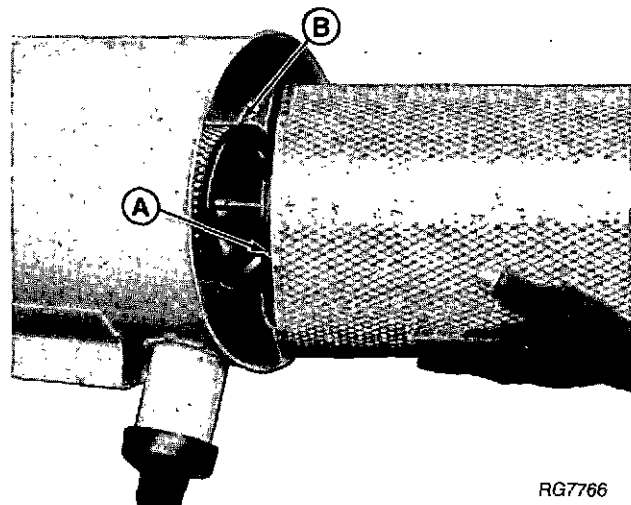
1. Inspect crankcase ventilation system for restrictions. Lack of ventilation causes sludge to form in crankcase. This can lead to clogging of oil passages, filters, and screens, resulting in serious engine damage.
2. Clean crankcase vent tube or hose (A) with solvent and compressed air if restricted.



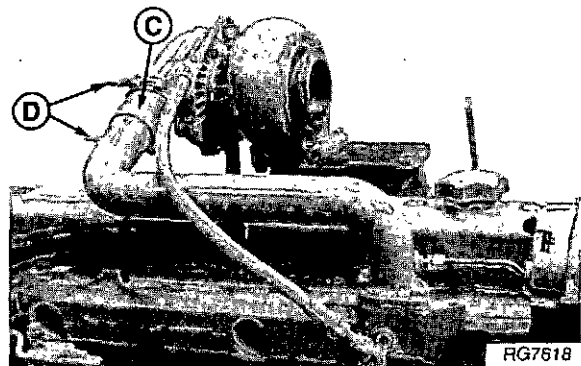
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CHECK AIR INTAKE SYSTEM

1. Replace air cleaner primary filter element (A). Replace secondary element (B) if primary element has holes in it.
2. Check condition of air intake hose(s) (C). Replace hoses that are cracked, split, or otherwise in poor condition.
3. Check hose clamps (D) for tightness. Replace clamps that cannot be properly tightened. This will help prevent dust from entering the air intake system which could cause serious engine damage.

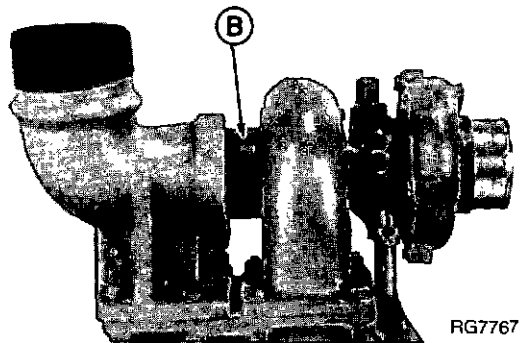
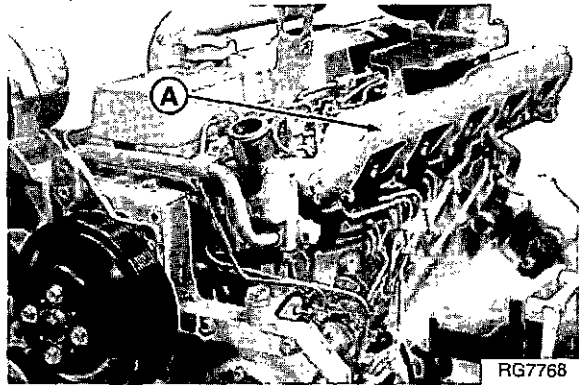


- A—Primary Filter Element
- B—Secondary Element
- C—Air Intake Hose(s)
- D—Hose Clamps



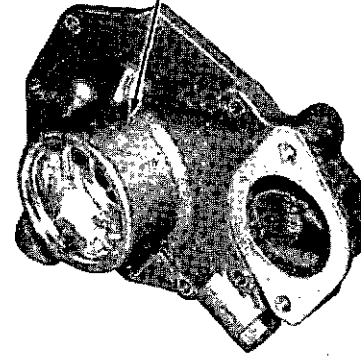
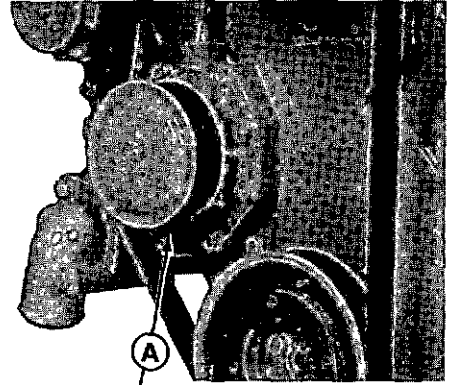
CHECK EXHAUST SYSTEM

1. Inspect exhaust system for leaks or restrictions. Check manifold (A) for cracks. Repair or replace as necessary.
2. On turbocharged engines, check exhaust adapter (B) to make sure it has end play and rotates freely. Correct as necessary.



CHECK AND SERVICE COOLING SYSTEM

1. Remove trash that has accumulated on or near radiator.
2. Visually inspect entire cooling system and all components for leaks or damage. Repair or replace as necessary.
3. Inspect radiator hoses for signs of leakage or rot. Replace hoses as necessary.
4. Inspect the water pump weep hole (A) for any restrictions.
5. Insert a heavy gauge wire deep into weep hole to make sure hole is open.

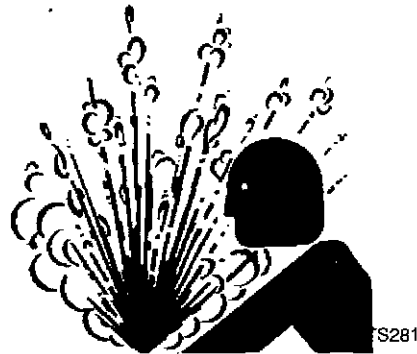


RG7990



CAUTION: Do not drain coolant until it has cooled below operating temperature. Always loosen block drain valve slowly to relieve any excess pressure.

6. Remove and check thermostat(s) (B). (See REMOVE, TEST, AND INSTALL THERMOSTATS in Group 25.)
7. Drain coolant at drain valve (C) and flush cooling system. (See FLUSHING AND SERVICING COOLING SYSTEM in Group 02.)

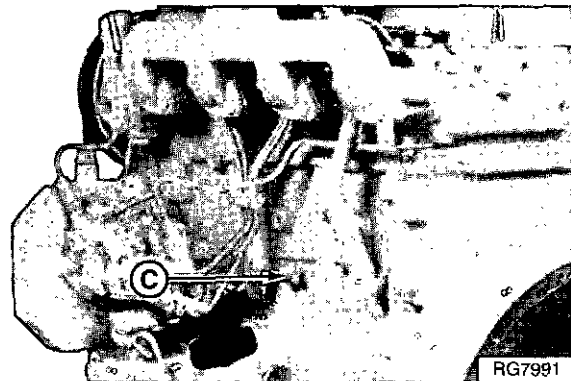
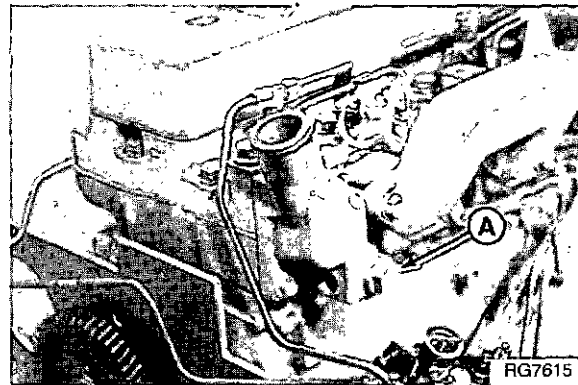


IMPORTANT: Air must be expelled from cooling system when system is refilled. Loosen temperature sending unit fitting at rear of cylinder head or plug in thermostat housing (A) to allow air to escape when filling system. Retighten fitting or plug when all the air has been expelled.

8. Fill cooling system with recommended concentration of coolant, clean soft water, and inhibitors. (See ENGINE COOLANT RECOMMENDATIONS/SPECIFICATIONS in Group 02.)
9. Run engine until it reaches operating temperature. Check entire cooling system for leaks.
10. After engine cools, check coolant level.

NOTE: Coolant level should be even with bottom of radiator filler neck.

11. Check system for holding pressure. (See PRESSURE TEST COOLING SYSTEM AND RADIATOR CAP in Group 105.)



CHECK ELECTRICAL SYSTEM



CAUTION: Battery gas can explode. Keep sparks and flames away from batteries. Use a flashlight to check battery electrolyte level.

Never check battery charge by placing a metal object across the posts. Use a voltmeter or hydrometer.

Always remove grounded (-) cable clamp from battery first and replace it last, when disconnecting and reconnecting battery.



TS204

1. Clean batteries and cables with damp cloth. If corrosion is present, remove it and wash terminals with a solution of ammonia or baking soda in water. Then flush area with clean water.
2. Coat battery terminals and connectors with petroleum jelly mixed with baking soda to retard corrosion.
3. Test batteries. If batteries are not near full charge, try to find out why.
4. On low-maintenance batteries, check level of electrolyte in each cell of each battery. Level should be to bottom of filler neck. If water is needed, use clean, mineral-free water.

If water must be added to batteries more often than every 250 hours, alternator may be overcharging.

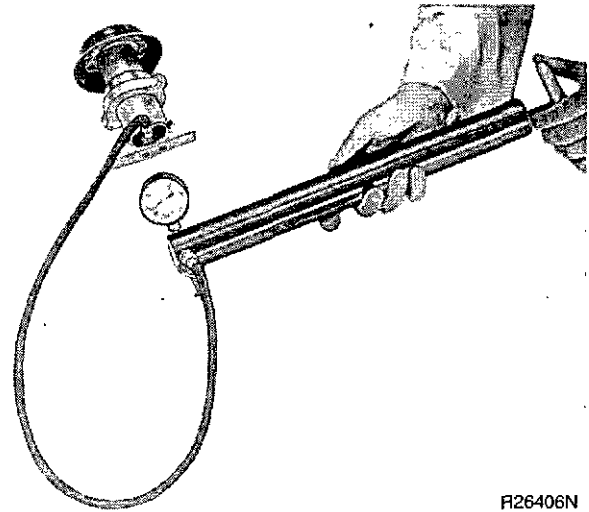
NOTE: Water cannot be added to maintenance-free batteries.

5. If batteries appear to be either undercharged or overcharged, check alternator and charging circuit. Follow diagnosis and testing procedures outlined in CTM77.
6. Check poly-vee belt wear. (See Group 30.)
7. Check operation of starting motor and gauges.

SPECIAL OR ESSENTIAL TOOLS

NOTE: Order tools according to information given in the U.S. SERVICEGARD™ Catalog or in the European Microfiche Tool Catalog (MTC).

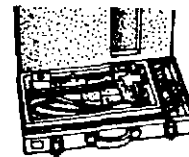
Cooling System Pressure Pump D05104ST
Used to pressure test radiator cap and cooling system.



R26406N

Compression Test Set JT01674
(formerly D14546BA)
or FKM10021

Used to check cylinder's compression pressure. Use adapter and gauge/hose assembly from set.

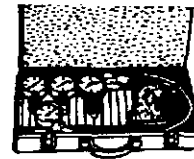


RG5161

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Universal Pressure Test Kit JT05470
(D15027NU)
or FKM10002

Used to check oil and fuel pressure.

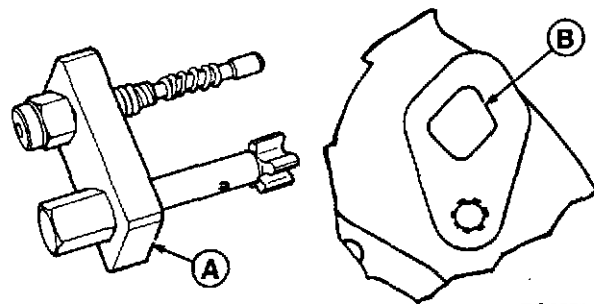


RG5162

105 Flywheel Turning Tool (A).....JD281A

2

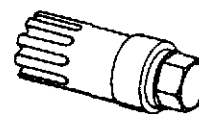
Used on engines with 142-tooth flywheel ring gear and a diamond shaped tool guide bore (B) in flywheel housing. Tool has it's own spring loaded timing pin which threads into flywheel housing.



RG6252

Flywheel Turning ToolJDE83

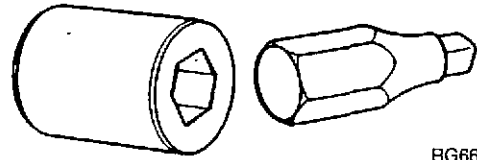
Used to rotate flywheel on engines with 142-tooth flywheel ring gear and a 26.5 mm (1.04 in.) ID flywheel housing guide bore diameter. Use with JDE81-4 Timing Pin.



RG6251

Oil Galley Plug Tool JDG782

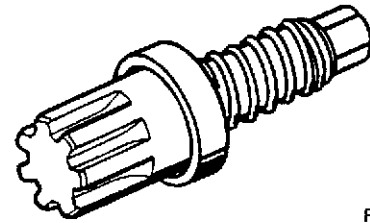
Used to remove and install oil galley plug.



RG6612

Flywheel Turning Tool JDG820

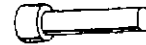
Used to rotate flywheel on engine, with 129-tooth flywheel ring gear and a 29.9 mm (1.18 in.) ID of flywheel housing guide bore diameter, to check damper radial runout and time engine. JDE81-1 may be used also if JDG820 is not available.



RG7056

Timing Pin JDE81-4

Lock engine at TDC when installing injection pump or timing valve train. Use with JDG820, JDE81-1, or JDE83 Flywheel Turning Tool.



RG5068

SERVICE EQUIPMENT AND TOOLS

NOTE: Order tools from U.S. SERVICEGARD™ Catalog or from the European Microfiche Tool Catalog (MTC). Some tools may be available from a local supplier.

Name	Use
JDG966 Crankshaft Front/Rear Rotation Adapter	Rotate crankshaft from front and rear with flywheel removed.

105
4

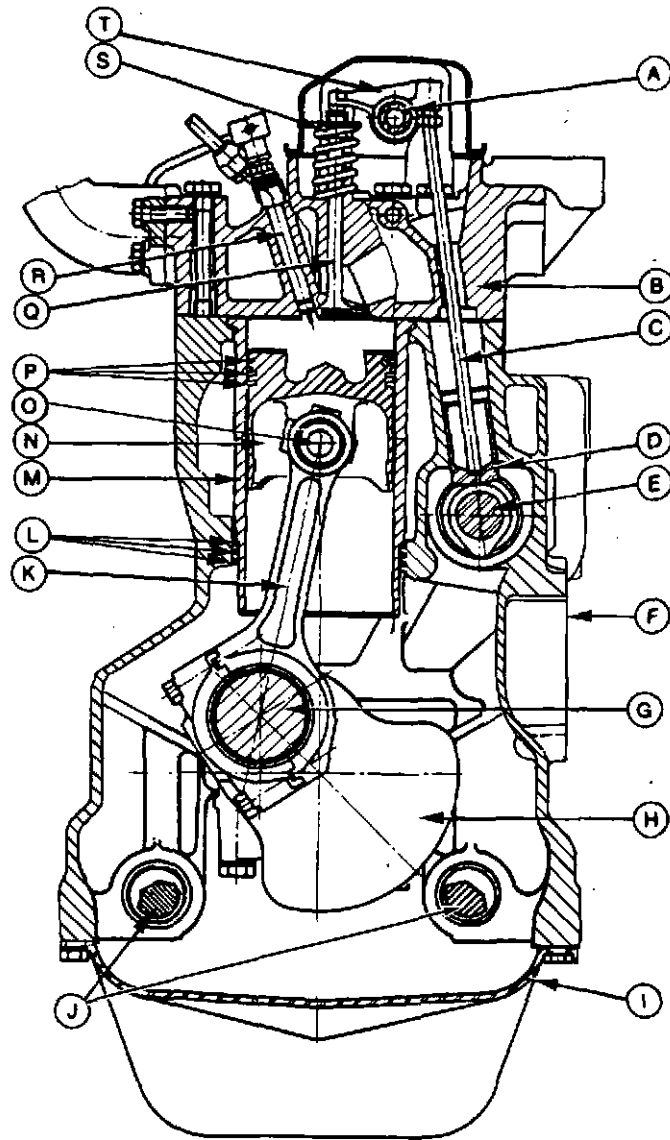
ENGINE TEST SPECIFICATIONS

ITEM	SPECIFICATION
Engine Compression Pressure at 150—200 rpm Cranking Speed:	
Minimum	2400 kPa (24 bar) (350 psi)
Maximum Difference between Cylinders	340 kPa (3.4 bar) (50 psi)
Engine Oil Pressure at 93°C (200°F) Sump Temperature:	
Minimum at slow idle rpm (4- and 6-cylinder)	100 kPa (1.0 bar) (14 psi)
Minimum at rated speed*	275 kPa (2.75 bar) (40 psi)
Engine Blow-By at Crankcase Vent Tube:	
4-Cylinder "D" Engines	4.0 m ³ /h (141 cu ft/h)
6-Cylinder "D" Engines	6.0 m ³ /h (225 cu ft/h)
4-Cylinder "T" Engines	6.0 m ³ /h (225 cu ft/h)
6-Cylinder "T" Engines	8.0 m ³ /h (282 cu ft/h)
Cooling System Leakage Test Pressure**	70 kPa (0.7 bar) (10 psi)

*Gauge fluctuations and tolerance extremes can result in readings up to 586 kPa (5.86 bar) 85 psi.

**Test pressures recommended for all Deere OEM cooling systems. On specific vehicle applications, test cooling system and pressure cap according to the recommended pressure for that vehicle.

ENGINE—SECTIONAL VIEW



RG7635

As viewed from flywheel end

- | | | | |
|--------------------|----------------------------|-----------------------|-------------------------|
| A—Rocker Arm Shaft | F—Cylinder Block | K—Connecting Rod | P—Piston Rings |
| B—Cylinder Head | G—Crankshaft | L—Liner Packing Rings | Q—Valve |
| C—Push Rod | H—Crankshaft Counterweight | M—Cylinder Liner | R—Fuel Injection Nozzle |
| D—Cam Follower | I—Oil Pan | N—Piston | S—Valve Spring |
| E—Camshaft | J—Balancer Shafts* | O—Piston Pin | T—Rocker Arm |

* 4-Cylinder Engines Only

GENERAL ENGINE DESCRIPTION

Engines are vertical, in-line, valve-in-head, 4-cycle (stroke) diesel engines.

Direct fuel injection is provided by a rotary-type injection pump or an in-line injection pump and 9.5 mm injection nozzles mounted in cylinder head. The camshaft gear-driven injection pump is timed to the crankshaft by the timing gear train.

Some engines are equipped with a turbocharger. The turbocharger uses energy from exhaust gases to compress intake air and force it into the combustion chamber.

The cylinder block is a one-piece casting. The block is available in structural and non-structural configurations.

The camshaft is timed to the crankshaft through the timing gear train. The camshaft rotates in honed bores in the cylinder block. All engines use a bushing in No. 1 camshaft bore. The camshaft lobes determine the duration and lift of each valve, and operate the fuel supply pump on rotary-type injection pumps.

Intake and exhaust valves are operated by camshaft followers, push rods and rocker arm assembly. Valve seat inserts in cylinder head are used for intake and exhaust valves.

The crankshaft is a one-piece, heat treated, nodular-iron or steel forging which operates in replaceable two-piece main bearings. Crankshafts are dynamically balanced and are machined with undercut and rolled fillets. Two-piece main thrust bearing inserts are used to control crankshaft end-play.

Cylinder liners are "wet" sleeve type and are individually replaceable. O-rings seals are used at the lower connection between cylinder block and liners.

Pistons are made of high-grade cast aluminum alloy with internal ribbing. The skirt is cam ground to allow for expansion during operation. The piston crown has a cut-out combustion bowl with a truncated cone center. All piston rings are located above the piston pin. Two compression rings and one oil control ring are used. The top compression ring is a keystone shaped ring located close to the top of the piston for improved engine performance.

The hardened, fully-floating piston pins are held in place by snap rings. Spray jets (piston cooling orifices) in cylinder block spray pressurized oil on the underside of the piston to lubricate piston pins and cool pistons.

The forged steel connecting rods have replaceable pin bushing and bearing inserts. Some connecting rods have a tapered pin-end while others have a straight pin-end.

The engine is equipped with a gear driven oil pump and full-flow oil filter. The oil filter has an internal bypass valve which opens if the filter element becomes restricted. Engines are equipped with an oil cooler mounted on the right side of the cylinder block. The engine is equipped with a pressure regulator valve to relieve excessive pressure build-up in the main oil gallery, and a bypass valve to prevent oil starvation if the oil cooler and filter become plugged.

Balancer shafts are used on four-cylinder engines to reduce vibration. The two shafts rotate on bushings in cylinder block and are counter-rotating at twice engine speed.

The engine has a pressurized cooling system, consisting of radiator, water pump, multi-blade fan, and one or two thermostats.

HOW THE ENGINE LUBRICATION SYSTEM WORKS

The engine lubrication system consists of a positive displacement gear-driven oil pump (A), full-flow oil filter (F), oil cooler (I), oil pressure regulating valve (Y), and an oil by-pass valve (Z).

The oil pump pulls oil from the oil pan sump through a strainer and a suction line (B). The pump forces oil through the outlet tube (C) into a vertical drilling in the cylinder block, and up to the oil cooler and filter. After flowing through the cooler and filter, oil flows into the main oil gallery (N).

The main oil gallery runs the length of the cylinder block and delivers oil to oil passages (M) that feed the camshaft bushings (Q) and main bearing bushings (L). The cross-drillings (X) intersect with those same oil passages and feed oil to the balancer shaft bushings (J).

From the main bearings, oil flows to the connecting rod bearings (O) through drilled cross-passages (K) in the crankshaft between the main journals and connecting rod journals. Oil from the main bearing also supplies oil to the piston cooling orifices (P).

Oil from the piston cooling orifices sprays on the underside of the piston to keep the piston crown cool. The oil spray also provides splash lubrication for the piston pin and bushing (R) by splashing oil into a hole drilled in the top end of the connecting rod.

At the rear of the cylinder block, oil flows from the rear camshaft bore (Q), up through the cylinder head, and into the rocker arm shaft (S). Oil flows through the rocker arm shaft and lubricates each of the rocker arms (V). Oil drips from the rocker arms to lubricate the adjusting screws, push rods, and camshaft followers.

At the front of the cylinder block, oil flows from the oil passage into a machined groove (W) in the front face of the block. This groove connects with the upper idler gear shaft to provide oil to the idler gear bushing. The lower idler gear bushing is splash lubricated.

The turbocharger oil supply line (T) supplies oil to the turbocharger from filtered side of oil filter adapter. Oil returns from the turbocharger through the drain line (U).

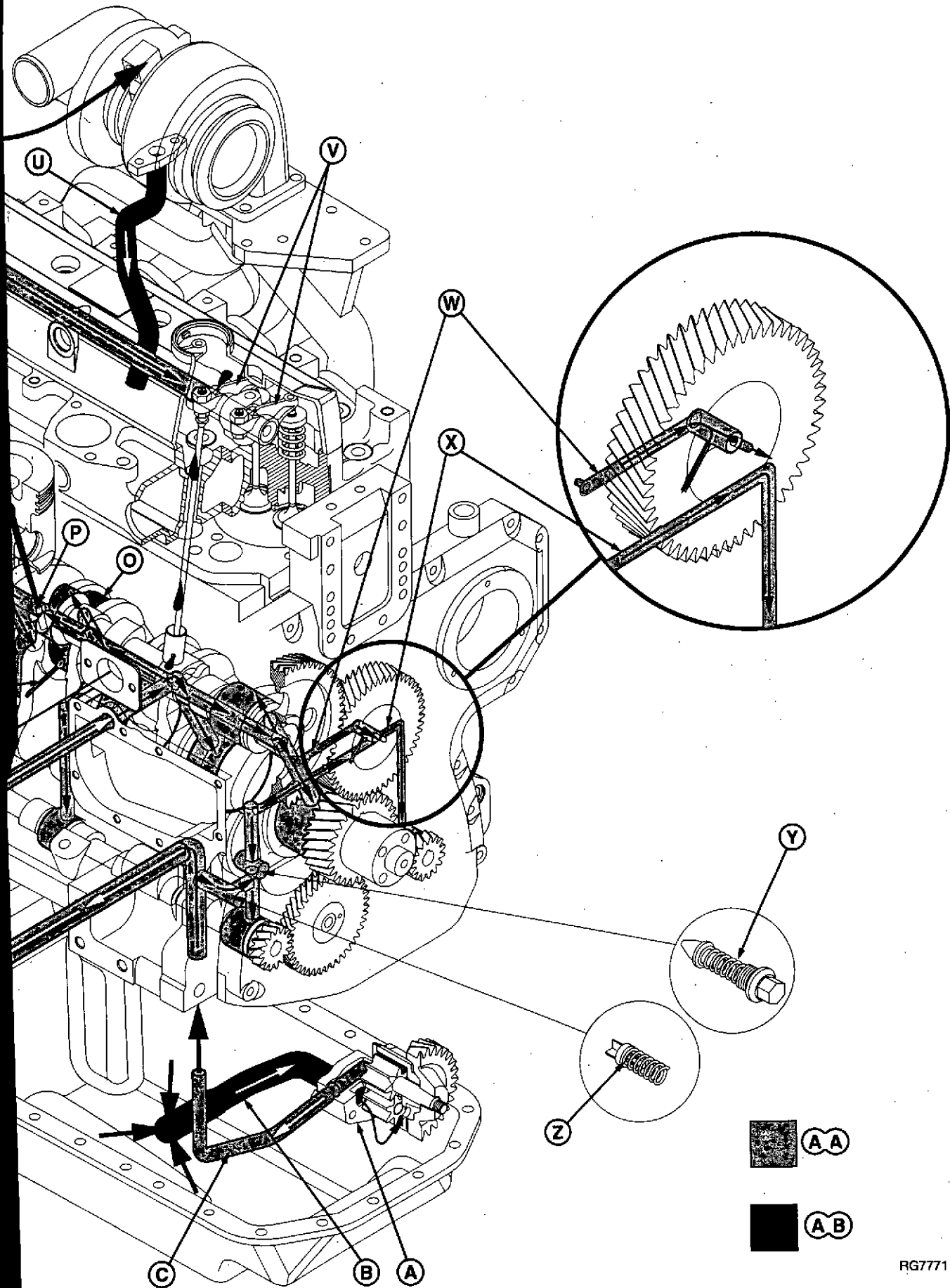
A—Oil Pump
 B—Oil Suction Line
 C—Oil Outlet Tube
 D—Oil Cooler Housing
 E—Coolant Passage Adapter
 F—Oil Filter
 G—Oil Filter Header/Adapter
 H—Oil Fill Tube
 I—Oil Cooler
 J—Balancer Shaft Bushings

K—Crankshaft Drilled Cross-Passages
 L—Main Bearing Bushings
 M—Oil Passages
 N—Main Oil Gallery
 O—Connecting Rod Bearings
 P—Piston Cooling Orifice
 Q—Camshaft Bushings

R—Piston Pin and Bushing
 S—Rocker Arm Shaft
 T—Turbocharger Oil Supply Line
 U—Turbocharger Drain Line
 V—Rocker Arms
 W—Machined Groove
 X—Cross-Drillings
 Y—Oil Pressure Regulating Valve

Z—Oil ByPass Valve
 AA—Pressurized Oil
 AB—Pressure-Free Oil
 AC—High-Mount Vertical Oil Filter Assembly
 AD—Low-Mount Rear Vertical Oil Filter Assembly
 AE—Low-Mount Front Vertical Oil Filter Assembly

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J
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RG771

Engines

HOW THE COOLING SYSTEM WORKS

The cooling system includes the radiator, water pump (A), and thermostat(s) (H).

Coolant is circulated from the water pump into the coolant passage adapter (B) and circulates around the oil cooler plates (D). From the oil cooler, coolant flows into the main coolant gallery (E). From the gallery coolant flows into the coolant jacket (F), around the cylinder liners, up through the block deck passages (G), and into the cylinder head. In the cylinder head, the coolant flows through passages (H) around the intake and exhaust ports, valve seats, and injection nozzles. Coolant flows toward the front end of the cylinder head and exits through the water manifold /thermostat housing (J). Engines may be equipped with a dual thermostat assembly (K).

During the warm-up period, thermostat(s) (I) are closed and coolant is directed through a bypass circuit (L) into suction side of water pump. The coolant continues circulating through the cylinder block, cylinder head, and water pump to provide a uniform and fast warm-up period.

Once the engine has reached operating temperature, the thermostat(s) open and allow coolant to flow through the upper radiator hose to the radiator top tank (M). Coolant circulates through the radiator, dissipates heat, and then flows out of the radiator through the lower hose and into the suction side (O) of the water pump. Coolant continues flowing through the engine and radiator circuit until the coolant temperature drops below the thermostat opening temperature.

A—Water Pump
B—Coolant Passage Adapter
C—Oil Cooler Drain Plug
D—Oil Cooler Plates
E—Main Coolant Gallery

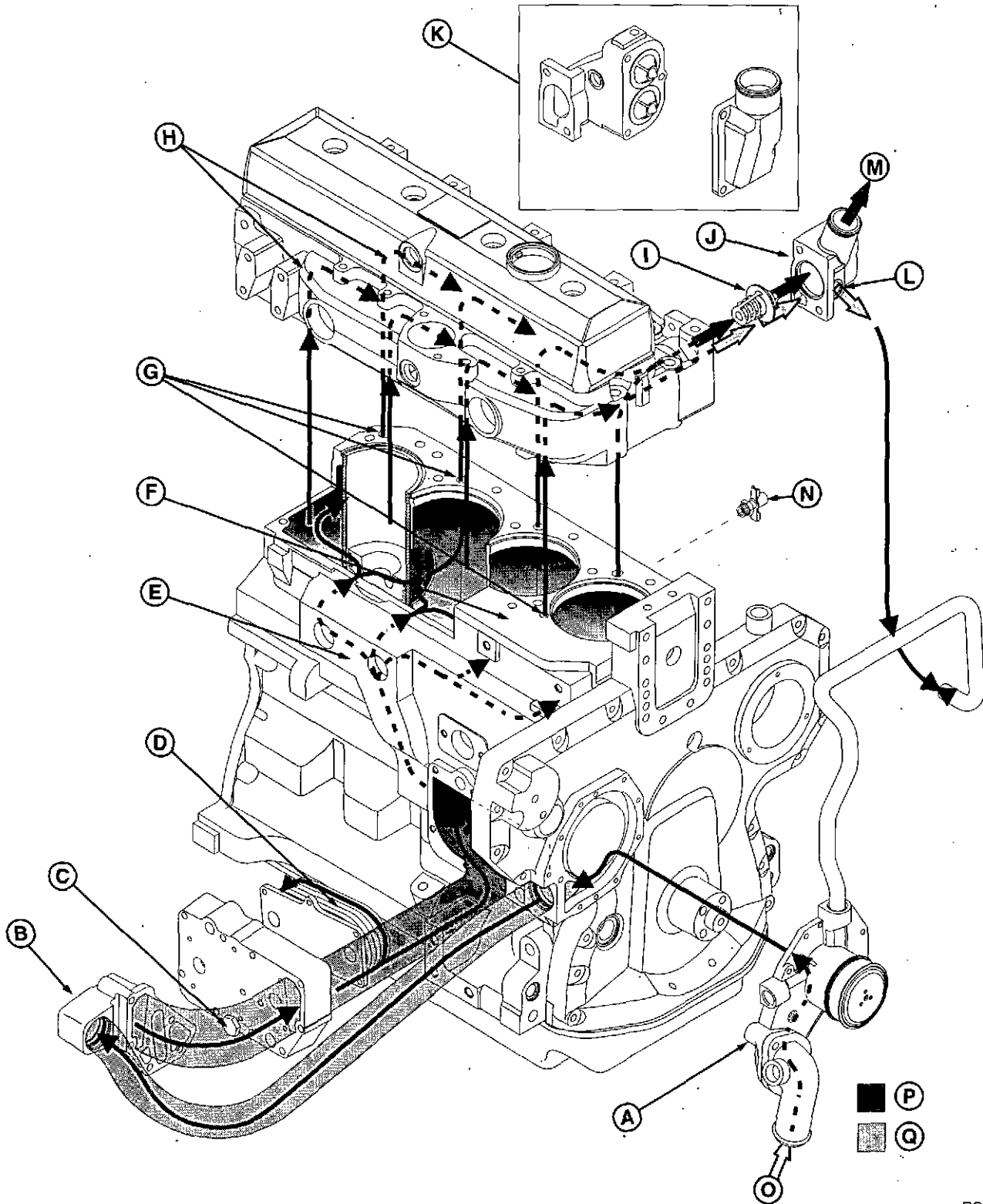
F—Coolant Jacket
G—Block Deck Passages
H—Passages
I—Thermostat(s)

J—Water Manifold/
Thermostat Housing
K—Dual Thermostat
Assembly
L—Bypass Circuit
M—To Radiator Top Tank

N—Drain Valve
O—Suction Side of Water
Pump
P—High Temperature Coolant
Q—Low Temperature Coolant

105
10

HOW THE COOLING SYSTEM WORKS—CONTINUED



105
11

RG7772

HEAD GASKET JOINT CONSTRUCTION AND OPERATION

The head gasket joint consists of the following components:

- Cylinder head gasket
- Cylinder head (A)
- Cylinder block (E)
- Cylinder liners (C)
- Cylinder head cap screws (B)

The head gasket must form an air-tight seal between cylinder liners and cylinder head that can withstand the temperatures and pressures of the combustion process. The gasket must also form a liquid-tight seal between the cylinder head and cylinder block to retain coolant and oil in their respective passages. The gasket is constructed of thin, formed sheets of steel-inserted, non-asbestos material (F). The surface of gasket is treated to improve liquid sealing and anti-stick characteristics. A fire ring combustion seal (G) is located at each cylinder bore and is held in place by a U-shaped stainless steel flange (H).

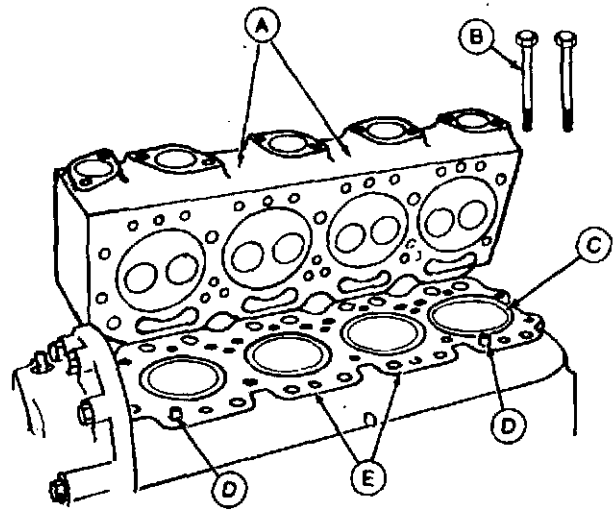
The cylinder head and block must be flat to provide an even clamping pressure over the entire surface of gasket, and must have the proper surface finish to keep gasket material from moving in the joint. Dowels (D) are used to properly locate head gasket on block.

The cylinder liners must protrude evenly from top of cylinder block the specified amount to provide adequate clamping force on fire ring of each cylinder.

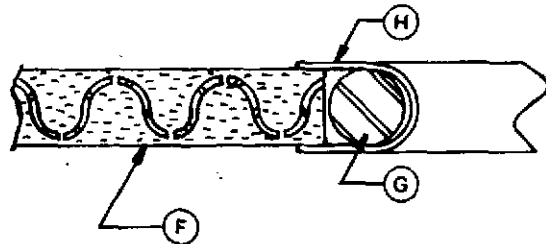
The cap screws must be proper length, made of proper material, and be tightened to proper torque in order to provide an adequate clamp load between other joint components.

Each of the above components contributes to the integrity of the head gasket joint. If any of these components do not conform to specifications, gasket joint may fail resulting in combustion leaks, coolant leaks, or oil leaks.

Operating conditions such as coolant, oil, and combustion temperatures, and combustion pressures can reduce the ability of the head gasket joint to function properly. Failure of head gasket and mating parts may occur when coolant and oil temperatures become excessive, or when abnormally high combustion temperatures and pressures persist.



RG6433



RG6430

- A—Cylinder Head
- B—Cylinder Head Cap Screws
- C—Cylinder Liners
- D—Dowel Pins
- E—Cylinder Block
- F—Gasket Body
- G—Fire Ring Combustion Seal
- H—Stainless Steel Flange

DIAGNOSING HEAD GASKET JOINT FAILURES

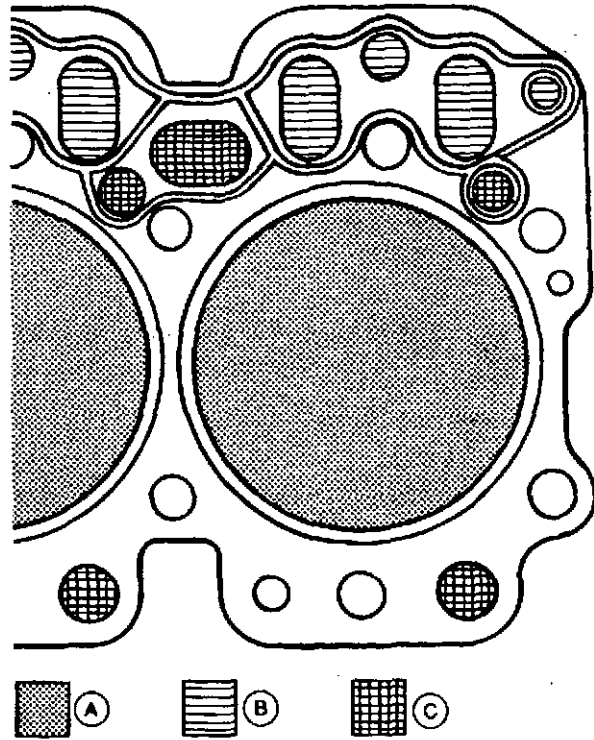
NOTE: Booklet DB1119—CYLINDER HEAD GASKET FAILURES for 6466 and 6076 Engines can be used as a guide for diagnosing head gasket failures on **POWERTECH** 4.5 L and 6.8 L Engines. However, use specifications provided in this manual (CTM104).

Head gasket failures generally fall into three categories:

- Combustion seal failures.
- Coolant seal failures.
- Oil seal failures.

Combustion seal failures occur when combustion gases escape between cylinder head and head gasket combustion flange, or between combustion flange and cylinder liner. Leaking combustion gases may vent to an adjacent cylinder, to a coolant or oil passage, or externally.

Coolant or oil seal failures occur when oil or coolant escapes between cylinder head and gasket body, or between cylinder block and gasket body. The oil or coolant may leak to an adjacent coolant or oil passage, or externally. Since oil and coolant passages are primarily on right hand (camshaft) side of engine, fluid leaks are most likely to occur in that area.



RG6432

- A—Combustion Sealing Area
- B—Oil Sealing Areas
- C—Coolant Sealing Areas

Follow these diagnostic procedures when a head gasket joint failure occurs, or is suspected.

1. Before starting or disassembling engine, conduct a visual inspection of machine, and note any of the following:

- Oil or coolant in head gasket seam, or on adjacent surfaces. Especially right rear corner of gasket joint.
- Displacement of gasket from normal position.
- Discoloration or soot from combustion gas leakage.
- Leaking radiator, overflow tank, or hoses.
- Leaking coolant from water pump weep hole.
- Damaged or incorrect radiator, fan, or shroud.
- Obstructed air flow or coolant flow.
- Worn or slipping belts.
- Damaged or incorrect pressure cap.
- Presence of oil in coolant.
- Low coolant levels or improper coolant.
- Unusually high or low oil levels.
- Oil degradation, dilution, or contamination.
- Correctly specified injection pump.
- Indications of fuel or timing adjustments.
- Unburned fuel or coolant in exhaust system.

2. Obtain coolant and oil samples for further analysis.

3. Start and warm up engine if it can be safely operated. Examine all potential leakage areas again as outlined previously. Using appropriate test and measurement equipment, check for the following:

- White smoke, excessive raw fuel, or moisture in exhaust system.
- Rough, irregular exhaust sound, or misfiring.
- Air bubbles, gas entrainment in radiator or overflow tank.
- Loss of coolant from overflow.
- Excessive cooling system pressure.
- Coolant overheating.
- Low coolant flow.
- Loss of cab heating (air lock).

4. Shut engine down. Recheck crankcase, radiator, and overflow tank for any significant differences in fluid levels, viscosity, or appearance.

5. Compare your observations from above steps with the following diagnostic charts. If diagnostic evaluations and observations provide conclusive evidence of combustion gas, coolant, or oil leakage from head gasket joint, the cylinder head must be removed for inspection and repair of gasket joint components.

Combustion Seal Leakage

Symptoms:

- Exhaust from head gasket crevice
- Air bubbles in radiator/overflow tank
- Coolant discharge from overflow tube
- Engine overheating
- Power loss
- Engine runs rough
- White exhaust smoke
- Loss of cab heat
- Gasket section dislodged, missing (blown)
- Coolant in cylinder
- Coolant in crankcase oil
- Low coolant level

Possible Causes:

- Insufficient liner standout
- Excessive liner standout differential between cylinders
- Low head bolt clamping loads
- Rough/damaged liner flange surface
- Cracked/deformed gasket combustion flange
- Out-of-flat/damaged/rough cylinder head surface
- Missing/mislocated gasket fire ring
- Block cracked in liner support area
- Excessive fuel delivery
- Advanced injection pump timing
- Hydraulic or mechanical disturbance of combustion seal

NOTE: Cracked cylinder head or liners may also allow combustion gas leakage into coolant.

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15

Coolant Seal Leakage

Symptoms:

- Coolant discharge from head gasket crevice
- Coolant in crankcase oil
- Low coolant level
- High oil level
- Coolant discharge from crankcase vent

Possible Causes:

- Excessive liner standout
- Excessive liner standout differential between cylinders
- Low head bolt clamping loads
- Out-of-flat/damaged/rough block surface
- Out-of-flat/damaged/rough cylinder head surface
- Oil or coolant overheating
- Cracks/creases in gasket body surfaces
- Damage/voids in elastomer beading

NOTE: Cracked cylinder head, liners, liner packings, defective oil cooler or aftercooler may also allow coolant leakage into crankcase.

Oil Seal Leakage

Symptoms:

- Oil discharge from head gasket crevice
- Oil in coolant
- Low crankcase oil level
- Reduced oil to rocker arms (noisy)

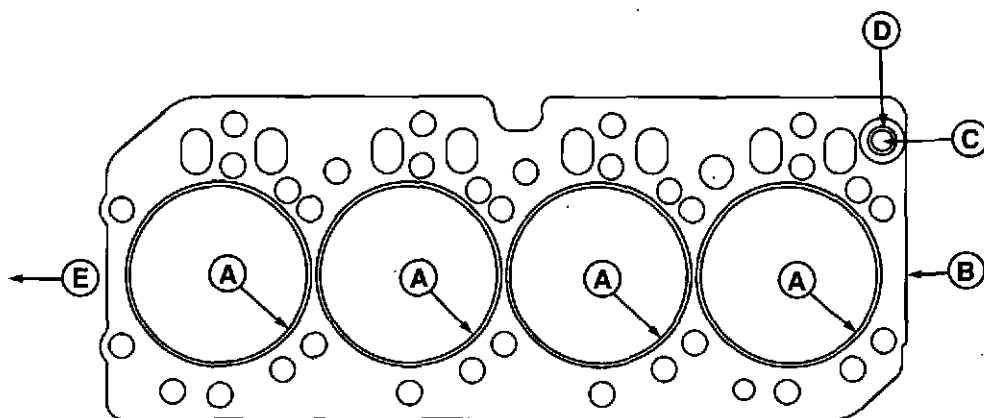
Possible Causes:

- Excessive liner standout
- Excessive liner standout differential between cylinders
- Low head bolt clamping loads
- Out-of-flat/damaged/rough block surface
- Out-of-flat/damaged/rough cylinder head surface
- Oil or coolant overheating
- Cracks/creases in gasket body surfaces
- Damage/voids in elastomer beading
- Damaged/missing O-ring seal at oil port to rocker arms

NOTE: Defective oil cooler may also allow oil leakage into coolant.

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16

HEAD GASKET INSPECTION AND REPAIR SEQUENCE



RG8117

- A—Combustion Seals (Flanges)
- B—Gasket Body
- C—Rocker Arm Oil Port
- D—Elastomer Beading Strip
- E—Front of Engine

The following inspection procedures are recommended whenever a head gasket joint failure occurs, or when joint disassembly takes place.

1. Review historical data relating to machine operation, maintenance and repair, along with diagnostic observations. Note all areas requiring further inspection and analysis.
2. Remove rocker arm cover and check for presence of coolant in the oil.
3. Record head cap screw torques prior to removal. Upon removal, check cap screw length differences.
4. Remove cylinder head using appropriate lifting devices to prevent handling damage to head gasket. (See REMOVE CYLINDER HEAD in Group 05.)
5. Observe surfaces of removed head gasket.
 - Examine combustion seals (A) for the following:
 - Flange severed/expanded/cracked/deformed.
 - Adjacent body area burned/eroded.
 - Fire ring severed/displaced/missing.
 - Flange sealing pattern eccentric/contains voids.
 - Discoloration of flange and adjacent body areas.
 - Flange surfaces rough/abraded/channelled.
 - Examine gasket body (B) for the following:
 - Combustion gas erosion paths or soot deposits originating at combustion seals.
 - Extreme discoloration/hardening/embrittlement in localized areas.
 - O-ring seal missing/damaged in port area (C).
 - Elastomer missing/damaged in port area (D).
 - Oil or coolant paths from port areas.
 - Localized areas of low compression.
6. Before cleaning components, inspect head, block, and liners for evidence of combustion gas and fluid leakage. Inspect cylinders and valve ports for unusual deposits.

7. Clean block, head, liners, and cap screws. (See Groups 05 and 10.)
8. Proceed with the following dimensional checks and visual inspections:

Cylinder Head (See Group 05.)

- Check surface flatness/finish.
- Inspect for surface damage.
- Check cylinder head thickness, if resurfacing.

Cylinder Block and Liners (assembled and clamped)
(See Group 05 or 10.)

- Check liner standout at four places on each liner.
- Check liner standout difference between cylinders.

Cylinder Block (See Group 10.)

- Check surface flatness/finish.
- Inspect for surface damage.
- Check liner counterbore depth (if liner is removed).
- Check top deck to crankshaft centerline dimension.
- Inspect cap screw bosses, must be clean/intact.

Cylinder Liner (See Group 10.)

- Check liner flange flatness/finish.
- Check liner flange thickness (if liner is removed).
- Inspect flange for damage.

Cylinder Head Cap Screws (See Group 05.)

- Inspect for corrosion damage.
- Inspect condition of threads.
- Inspect for straightness.
- Check length.

9. When inspections and measurements have been completed, determine most probable causes of joint failure. Make all necessary repairs to joint components, cooling system, and fuel injection system.

10. Reassemble the engine according to procedures and specifications in the repair groups of this manual.

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DIAGNOSING ENGINE MALFUNCTIONS

- **Will Not Crank**

Electrical System Malfunction

- Weak battery
- Corroded or loose battery connections
- Defective main switch or start safety switch
- Starter solenoid defective
- Starter defective

- **Hard to Start or Will Not Start**

Electrical System Malfunction

- Loose or corroded battery connections
- Weak battery
- Excessive resistance in starter circuit

Fuel System Malfunction - See Group 115

- Empty fuel tank
- Improper fuel
- Water, dirt or air in fuel system
- Plugged fuel filter
- Stuck shut-off control
- Dirty or faulty fuel injection nozzles
- Defective fuel injection pump
- Defective fuel transfer pump
- Fuel injection pump incorrectly timed

Service Problem

- Too high viscosity crankcase oil

- **Engine Runs Irregularly or Stalls Frequently**

Basic Engine Problem

- Coolant temperature too low
- Improper valve clearance
- Cylinder head gasket leaking
- Worn or broken compression rings
- Valves sticking or burned
- Exhaust system restricted
- Engine compression too low
- Engine overheating
- Worn camshaft lobes

Fuel System Malfunction - See Group 115

- Defective fuel injection pump
- Low fuel supply
- Fuel injection nozzles defective or leaking
- Fuel filter or fuel lines restricted
- Defective fuel transfer pump
- Fuel injection pump incorrectly timed

- **Engine Misfiring**

Service Problem

- Water in fuel
- Mixture of gasoline and diesel fuel

Fuel System Malfunction - See Group 115

- Air in fuel system
- Defective fuel injection nozzles
- Defective fuel injection pump
- Fuel injection nozzles improperly installed
- Leaking fuel injection nozzle seals
- Worn or defective fuel transfer pump
- Fuel injection pump incorrectly timed

Basic Engine Problem

- Engine overheated
- Lobes of camshaft worn
- Weak valve springs
- Pre-ignition
- Engine compression too low
- Improper valve clearance
- Burnt, damaged or stuck valves

- **Lack of Engine Power**

Service Problem

- Air cleaner restricted or dirty
- Excessive resistance in air intake system
- Improper crankcase oil

Fuel System Malfunction - See Group 115

- Fuel filter restricted
- Defective fuel transfer pump
- Defective fuel injection pump
- Fuel injection pump incorrectly timed

Basic Engine Problem

- Engine overheated
- Engine clutch slipping
- Defective cylinder head gasket
- Lobes of camshaft worn
- Improper valve clearance
- Improper valve timing
- Burnt, damaged or stuck valves
- Weak valve springs
- Piston rings and cylinder liners excessively worn
- Engine compression too low
- Improper coolant temperature

DIAGNOSING ENGINE MALFUNCTIONS—CONTINUED

• **Engine Overheats**

Service Problem

- Lack of coolant in cooling system
- Radiator core and/or side screens dirty
- Cooling system limed up
- Engine overloaded
- Too low crankcase oil level

Basic Engine Problem

- Loose or defective fan belt
- Defective thermostat(s)
- Damaged cylinder head gasket
- Defective water pump
- Defective radiator cap

Fuel System Malfunction - See Group 115

- Fuel injection pump delivers too much fuel
- Fuel injection pump incorrectly timed

• **Excessive Oil Consumption**

Basic Engine Problem

- Oil control rings worn or broken
- Scored cylinder liners or pistons
- Excessive resistance in air intake system
- Oil flow through oil passages restricted
- Worn valve guides or stems
- Excessive oil pressure
- Piston ring grooves excessively worn
- Piston rings sticking in ring grooves
- Insufficient piston ring tension
- Piston ring gaps not staggered
- Excessive main or connecting rod bearing clearance
- Front and/or rear crankshaft oil seal faulty
- Glazed cylinder liners (insufficient load during engine break-in)

Service Problem

- Too low viscosity crankcase oil
- Crankcase oil level too high
- External oil leaks

• **Low Oil Pressure**

Service Problem

- Low crankcase oil level
- Improper crankcase oil
- Defective oil pressure warning switch or engine oil pressure indicator light
- Basic Engine Problem
- Leakage at internal oil passages
- Defective oil pump
- Excessive main and connecting rod bearing clearance
- Improper regulating valve adjustment
- Piston cooling orifice missing

• **High Oil Pressure**

Basic Engine Problem

- Oil pressure regulating valve bushing loose (wanders)
- Improperly operating regulating valve
- Stuck or damaged filter bypass valve

• **Excessive Fuel Consumption**

Service Problem

- Engine overloaded
- Air cleaner restricted or dirty

Basic Engine Problem

- Compression too low

Fuel System Malfunction - See Group 115

- Leaks in fuel system
- Fuel injection nozzles dirty or faulty
- Fuel injection pump defective (delivers too much fuel)
- Fuel injection pump incorrectly timed

• **Black or Grey Exhaust Smoke**

Service Problem

- Excess fuel
- Engine overloaded
- Air cleaner restricted or dirty
- Defective muffler (causing back-pressure)

Fuel System Malfunction - See Group 115

- Fuel injection nozzles dirty or faulty
- Incorrect engine timing

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DIAGNOSING ENGINE MALFUNCTIONS—CONTINUED

- **White Exhaust Smoke**

Basic Engine Problem

- Engine compression too low
- Defective thermostat(s) (does not close)

Fuel System Malfunction - See Group 115

- Defective fuel injection nozzles
- Fuel injection pump incorrectly times

- **Coolant in Crankcase**

Basic Engine Problem

- Cylinder head gasket defective
- Cylinder head or block cracked
- Cylinder liner seals leaking

- **Abnormal Engine Noise**

Basic Engine Problem

- Worn main or connecting rod bearings
- Excessive crankshaft end play
- Loose main bearing caps
- Foreign material in combustion chamber
- Worn connecting rod bushings and piston pins
- Scored pistons
- Worn timing gears
- Excessive valve clearance
- Worn cam followers
- Bent push rods
- Worn camshaft
- Worn rocker arm shaft
- Insufficient engine lubrication
- Worn turbocharger bearings

Fuel System Malfunction - See Group 115

- Fuel injection pump incorrectly timed

- **Detonation or Pre-Ignition**

Basic Engine Problem

- Oil picked up by intake air stream (intake manifold)
- Fuel System Malfunction - See Group 115
- Dirty or faulty fuel injection nozzles
 - Incorrect fuel injection pump timing
 - Fuel injection nozzle tip holes enlarged
 - Fuel injection nozzle tips broken
 - Carbon build-up in compression chamber

- **Water Pump Leaking**

- Seal ring or pump shaft worn

- **Coolant Temperature Below Normal**

- Defective thermostat(s)
- Coolant temperature gauge defective

- **Engine Vibrating**

- Fan blades bent or broken
- Water pump shaft worn
- Balancer shaft/gear broke (4-cylinder)

TEST ENGINE COMPRESSION PRESSURE

IMPORTANT: Compression pressures are affected by the cranking speed of the engine. Before beginning test, insure that batteries are fully charged and injection nozzle area is thoroughly cleaned.

1. Start engine and run at rated speed until it warms up to normal operating temperature. (From a cold start, operate engine 10—15 minutes at slow idle.)

Shut off fuel supply and remove fuel injection nozzles. (See Group 35.)

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- Install JT01679** Adapter with O-ring (or D14550BA* Adapter) in injection nozzle bore. Use JT02017 Holding Clamp** to hold JT01679 Adapter in position. Install hold down screw in clamp and tighten screw to 37 N·m (27 lb-ft). Attach JT01682** Test Gauge (or D14547BA*) to adapter.

NOTE: If using FKM10021 Compression Test Set, install 19.58—90.578 Adapter (A) in injection nozzle bore with R73788 nozzle spacer (B) and two R92352 nozzle seals (C). Attach test gauge FKM10022 to adapter.

- Push throttle lever to "STOP" position. Turn crankshaft for 10—15 seconds with starting motor (minimum cranking speed —150 rpm cold/200 rpm hot).
- Compare readings from all cylinders.

Compression pressure must be within specification.

ENGINE COMPRESSION PRESSURE TEST SPECIFICATIONS

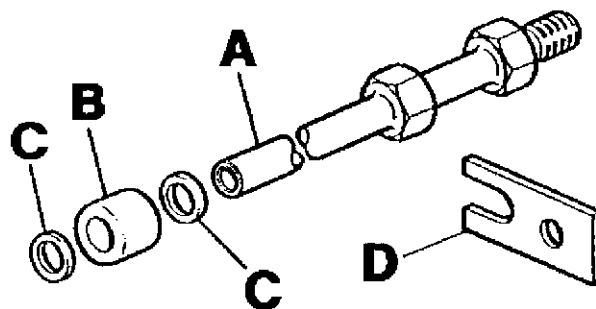
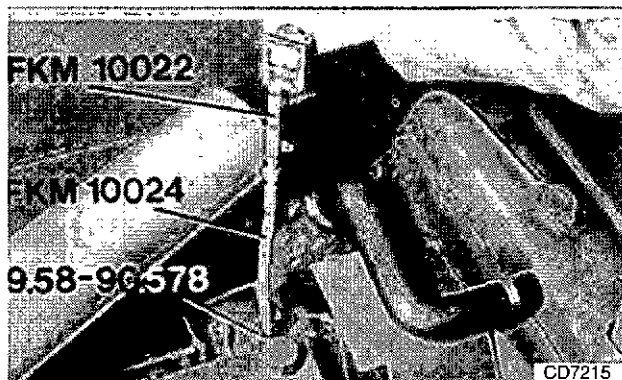
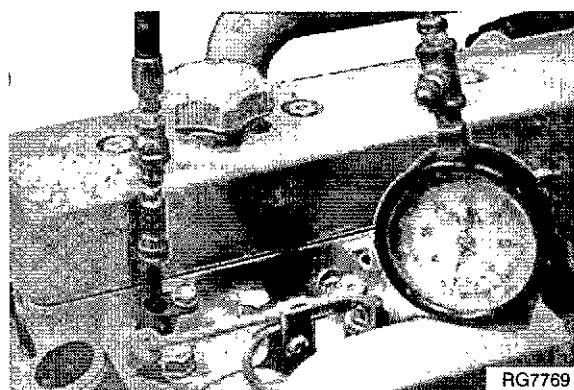
Engine Compression Pressure:
 Minimum 2400 kPa (24 bar) (350 psi)
 Maximum Difference Between Cylinders 350 kPa
 (3.5 bar) (50 psi)

NOTE: Pressure given was taken at 183 m (600 ft) above sea level. A 3.6 percent reduction in gauge pressure will result for each additional 300 m (1000 ft) rise in altitude.

All cylinders within an engine should have approximately the same pressure. There should be less than 340 kPa (3.4 bar) (50 psi) difference between cylinders.

*Part of D14546BA Compression Test Set

**Part of JT01674 Compression Test Set



A—19.58—90.578 Adapter
 B—R73788 Nozzle Spacer
 C—R92352 Nozzle Seal
 D—Holding Plate

5. If pressure is much lower than shown, remove gauge and apply oil to ring area of piston through injection nozzle bore. Do not use too much oil. Do not get oil on the valves.

6. Test compression pressure again.

If pressure is high, worn, or stuck rings are indicated, replace piston rings or install new piston and liner set as needed. (See Group 10.)

If pressure is low, valves could be worn or sticking. Recondition cylinder head as required. (See Group 05.)

7. Measure compression pressure in all remaining cylinders and compare readings. Recondition cylinders and valves as required.

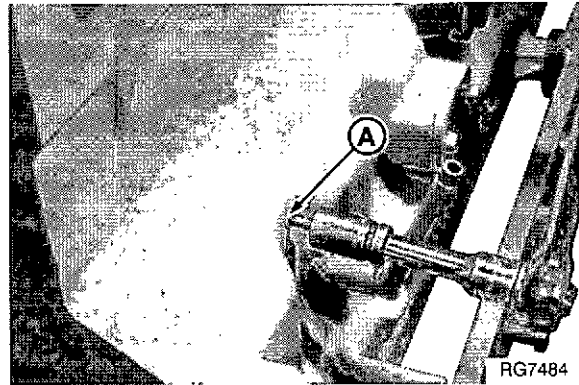
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CHECK ENGINE OIL PRESSURE

1. Remove main oil gallery plug (A) using JDG782 Oil Gallery Plug Tool.
2. Attach pressure gauge (B) to oil gallery.

IMPORTANT: To achieve an accurate oil pressure reading, warm up engine crankcase oil to 105°C (220°F) or high oil pressure readings will occur.

3. Start engine and run at speeds given below.
4. Measure oil pressure and compare readings.



OIL PRESSURE SPECIFICATIONS

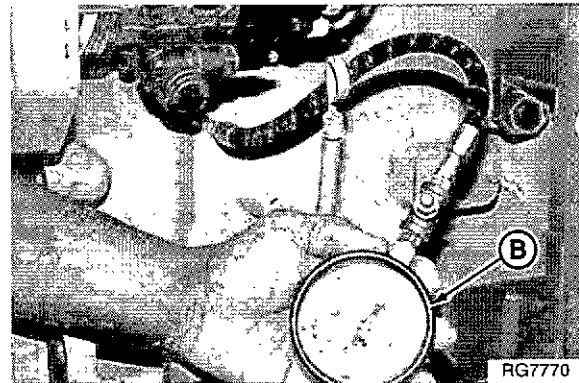
Minimum Pressure—No Load at Slow Idle and
93°C (200°F) Oil Temperature
(4- and 6-cylinder) 100 kPa (1.0 bar) (14 psi)

Minimum Pressure—Full Load at Rated Speed and
105°C (220°F) Oil Temperature 275 kPa
(2.75 bar) (40 psi)

NOTE: Tolerance extremes and gauge fluctuations can result in the gauge reading up to 586 kPa (5.86 bar) 85 psi. This is not detrimental to the engine.

The oil pressure regulating valve is designed so that adjustment of oil pressure should not be required.

5. Replace oil pressure regulating valve if oil pressure is not within specified range.

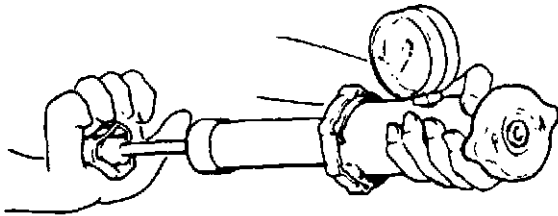


MEASURE ENGINE CRANKCASE PRESSURE (BLOW-BY)

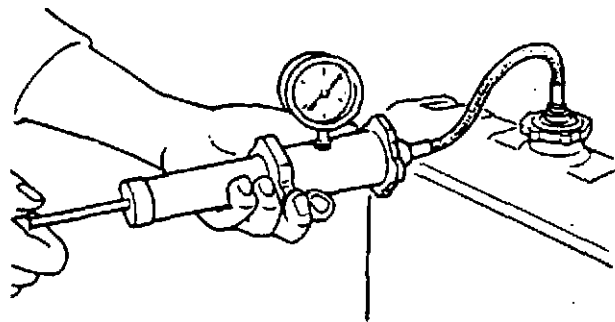
1. Place a hose with a standard gas gauge in end of crankcase vent tube.
2. Run engine at rated speed and load. Engine should be at operating temperature and run-in (with at least 100 operating hours).
3. Measure blow-by over a period of 5 minutes. Multiply figure obtained by 12 (hourly rate). Maximum engine blow-by is 17m³/h (600 ft³/h). See ENGINE TEST SPECIFICATIONS earlier in this group.
4. If blow-by is lower, there probably is no undue wear between piston rings and liners. If blow-by is higher, there could be excessive wear between piston rings and liners, resulting in loss of engine power. An overhaul of the engine should be considered only after other possible repair options (if any) are evaluated.

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PRESSURE TEST COOLING SYSTEM AND RADIATOR CAP



RG6557



RG6558



CAUTION: Explosive releases fluids from pressurized cooling system can cause serious burns.

Shut off engine. Only remove filler cap when cool enough to touch with bare hands. Slowly loosen cap to first stop to relieve pressure before removing completely.

• Test Radiator Cap:

1. Remove radiator cap and attach to D05104ST Pressure Pump as shown.
2. Pressurize cap to 70 kPa (0.7 bar) (10 psi)*. Gauge should hold pressure for 10 seconds within the normal range if cap is acceptable.

If gauge does not hold pressure, replace radiator cap.

3. Remove the cap from gauge, turn it 180°, and retest cap. This will verify that the first measurement was accurate.

• Test Cooling System:

NOTE: Engine should be warmed up to test overall cooling system.

1. Allow engine to cool, then carefully remove radiator cap.
2. Fill radiator with coolant to the normal operating level.

IMPORTANT: DO NOT apply excessive pressure to cooling system, doing so may damage radiator and hoses.

3. Connect gauge and adapter to radiator filler neck. Pressurize cooling system to 70 kPa (0.7 bar) (10 psi)*, using D05104ST Pressure Pump.
4. With pressure applied, check all cooling system hose connections, radiator, and overall engine for leaks.

If leakage is detected, correct as necessary and pressure test system again.

If no leakage is detected, but the gauge indicated a drop in pressure, coolant may be leaking internally within the system or at the block-to-head gasket. Have your servicing dealer or distributor correct this problem immediately.

*Test pressures recommended are for all Deere OEM cooling systems. On specific vehicle applications, test cooling system and pressure cap according to the recommended pressure for that vehicle.

INSPECT THERMOSTAT AND TEST OPENING TEMPERATURE

Visually inspect thermostat for corrosion or damage. Replace as necessary.

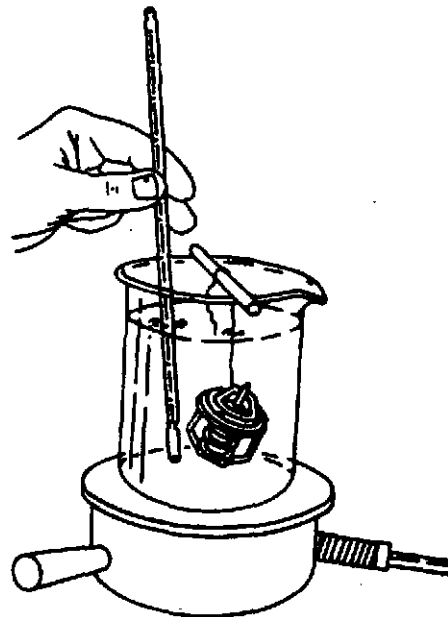
- Test thermostat as follows:



CAUTION: DO NOT allow thermostat or thermometer to rest against the side or bottom of container when heating water. Either may rupture if overheated.

1. Remove thermostats. (See REMOVE THERMOSTATS in Group 25.)
2. Suspend thermostat and a thermometer in a container of water.
3. Stir the water as it heats. Observe opening action of thermometer and compare temperatures with specification given in chart below.

NOTE: Due to varying tolerances of different suppliers, initial opening and full open temperatures may vary slightly from specified temperatures.



RG5971

THERMOSTAT TEST SPECIFICATIONS

Rating	Initial Opening (Range)	Full Open (Nominal)
71°C (160°F)	69—72°C (156—162°F)	84°C (182°F)
77°C (170°F)	74—78°C (166—172°F)	89°C (192°F)
82°C (180°F)	80—84°C (175—182°F)	94°C (202°F)
89°C (192°F)	86—90°C (187—194°F)	101°C (214°F)
90°C (195°F)	89—93°C (192—199°F)	103°C (218°F)
92°C (197°F)	89—93°C (193—200°F)	105°C (221°F)
96°C (205°F)	94—97°C (201—207°F)	100°C (213°F)
99°C (210°F)	96—100°C (205—212°F)	111°C (232°F)

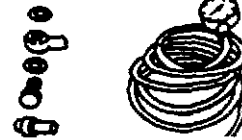
4. Remove thermostat and observe its closing action as it cools. In ambient air the thermostat should close completely. Closing action should be smooth and slow.
5. If any thermostat is defective on a multiple thermostat engine, replace all thermostats.

SPECIAL OR ESSENTIAL TOOLS

NOTE: Order tools according to information given in the U.S. SERVICEGARD™ Catalog or in the European Microfiche Tool Catalog (MTC).

Manifold Pressure Tester.....JDE147
or FKM10002

Kit to test intake manifold pressure (turbocharger boost)
on turbocharged engines.



RG5163

SERVICE EQUIPMENT AND TOOLS

NOTE: Order tools from the U.S. SERVICEGARD™ Catalog or from the European Microfiche Tool Catalog (MTC). Some tools may be available from a local supplier.

Name	Use
JDG576 Turbocharger Shield	Used to cover inlet on turbine on all turbocharged engines to protect blower when test running the engine with the air filter system disconnected.
D05022ST Water Vacuum Gauge Kit	Used to test air filter.

AIR INTAKE AND EXHAUST SYSTEM TEST SPECIFICATIONS

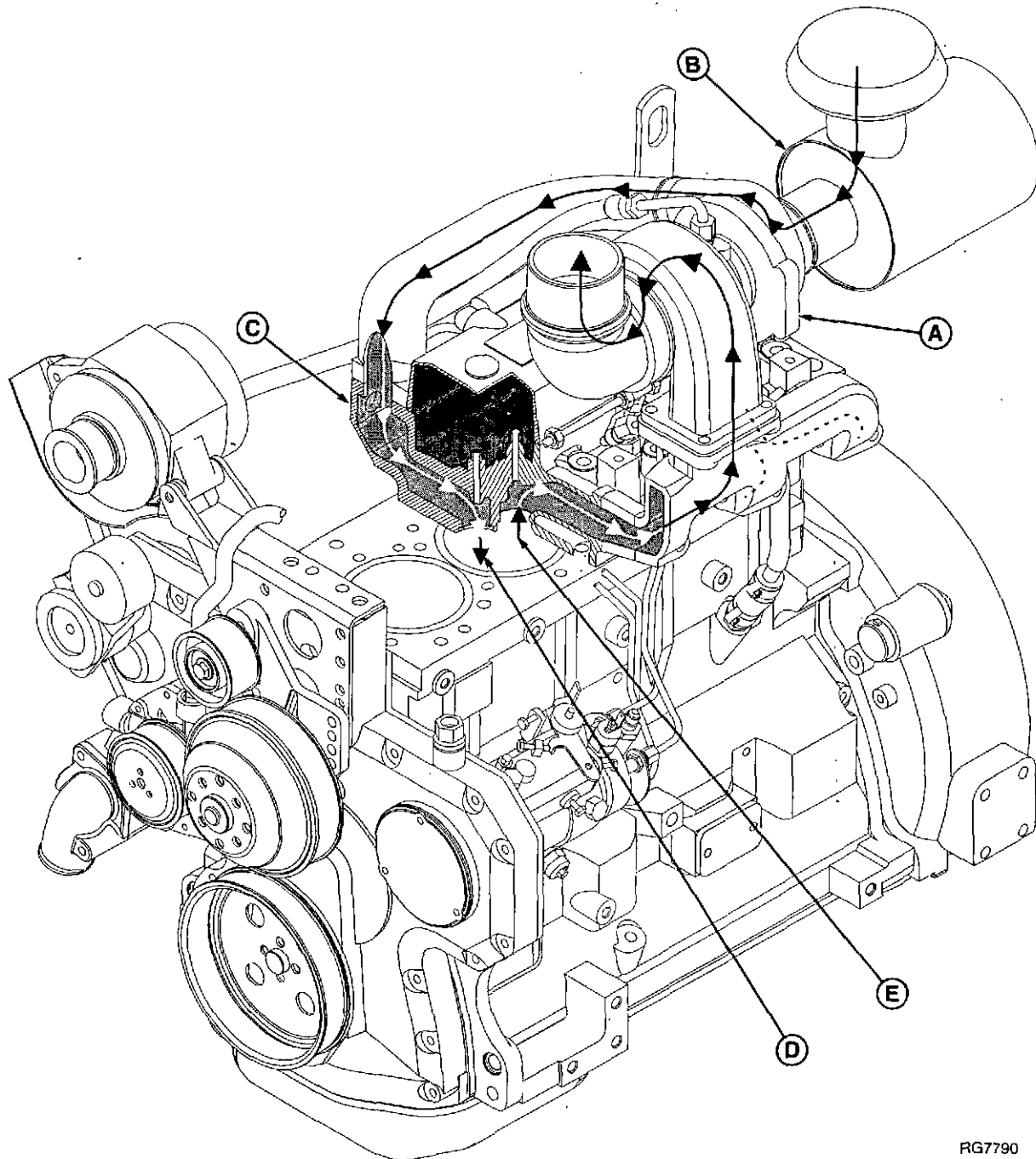
NOTE: The specifications given below apply to OEM engines only. As a general rule, minimum boost pressure should be 60 kPa (0.60 bar) (9 psi). For machine applications, consult the appropriate machine technical manual.

ITEM	SPECIFICATION
Intake Manifold Pressure (Turbocharger Boost) at engine rated speed and rated full load power:	
4045TF Engines	
Standard Governor (2200 rpm)	103—131 kPa (1.03—1.31 bar) (15—19 psi)
3—5% Governor (1800 rpm)	70—80 kPa (0.70—0.80 bar) (10—12 psi)
3—5% Governor (1500 rpm)	50—60 kPa (0.50—0.60 bar) (8—10 psi)
6068TF Engines	
Standard Governor (2400 rpm)	70—98 kPa (0.70—0.98 bar) (10—14 psi)
3—5% Governor (1800 rpm)	55—65 kPa (0.55—0.65 bar) (8—10 psi)

DIAGNOSING AIR INTAKE MALFUNCTIONS

Symptom	Problem	Solution
Engine Starts Hard or Won't Start	Air leak on suction side of system.	Check hose and pipe connections for tightness; repair as required. (See Group 30.)
Erratic Engine Operation	Air leak on suction side of system.	Check hose and pipe connections for tightness; repair as required. (See Group 30.)
Engine Emits Excessive Black Smoke	Air cleaner element restricted.	Clean or replace elements. (See operator's manual.)
	Turbocharger defective.	Repair or replace. (See Group 30.)
	Air leak in manifold.	Check hose and pipe connections for tightness; repair as required. (See Group 30.)
Engine Idles Poorly	Air leak on suction side of system.	Check hose and pipe connections for tightness; repair as required. (See Group 30.)
Engine Does Not Develop Full Power	Air cleaner restricted.	Clean or replace elements. (See operator's manual.)
	Air leak on suction side of system.	Check hose and pipe connections for tightness; repair as required. (See Group 30.)
	Turbocharger defective.	Repair or replace. (See Group 30.)
	Manifold pressure pipe to aneroid loose or broken.	Check hose and pipe connections for tightness; repair as required. (See Group 30.)
Turbocharger "Screams"	Air leak in manifold.	Check intake manifold gasket and manifold; repair as required. (See Group 30.)

HOW THE AIR INTAKE AND EXHAUST SYSTEM WORKS



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- A—Turbocharger
- B—Air Cleaner
- C—Intake Side of Cylinder Head
- D—Outside Intake Air
- E—Exhaust Air

RG7790

HOW THE AIR INTAKE AND EXHAUST SYSTEM WORKS—CONTINUED

Refer to illustration on previous page.

Engine suction draws dust-laden outside air (D) through an air inlet stack into the air cleaner (B). Air is filtered through dry type primary and secondary (safety) filter elements in the air cleaner canister. Clean air travels through the air intake hose to the turbocharger (A) and into the intake side of the cylinder head (C).

Exhaust (E), drives the turbocharger to deliver a larger quantity of air to meet the engine requirements than what could be delivered under naturally aspirated (non-turbocharged) conditions.

On some engines, an air-to-air aftercooler cools the turbocharger compressor discharge air by routing it through a heat exchanger before it enters the engine. The heat exchanger uses no liquid coolant but relies on air flow to cool the charge air.

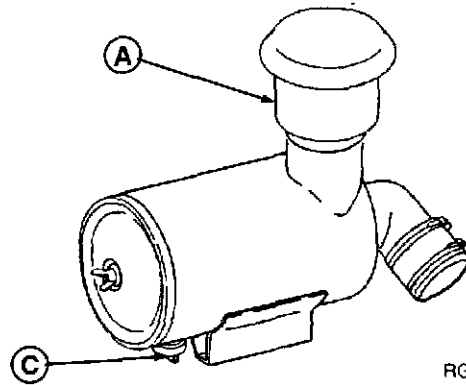
On some engines, the aftercooler functions as a heat exchanger. Engine coolant circulates through the aftercooler core and carries heat out of the aftercooler.

AIR CLEANER OPERATION

Under suction generated by the engine, unfiltered air flows through air inlet tube (A) and is forced into a high-speed centrifugal motion by tilted fins in the element. By this circulating action most of the dust and dirt particles are separated from the air and collected in the dust unloading valve (C).

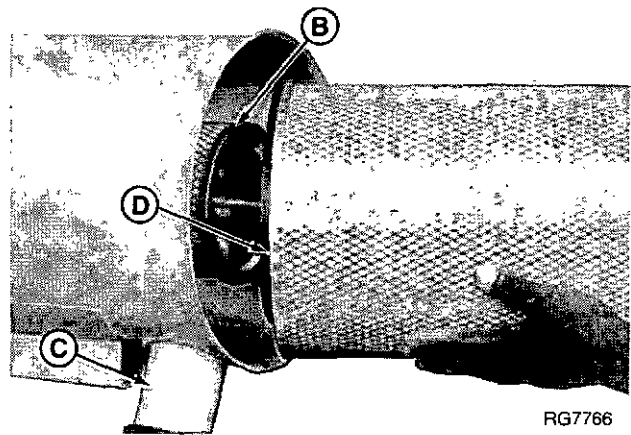
The remaining dirt is removed as the air flows through the primary element (D) and the secondary (safety) filter (B) before being drawn into the engine.

The secondary (safety) filter ensures that should primary element fail, no unfiltered air is drawn into the engine.



RG7775

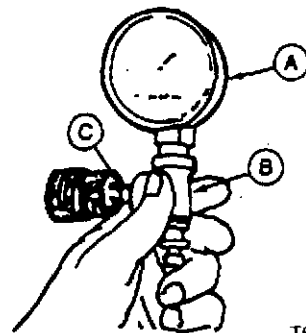
- A—Air Inlet Tube
- B—Secondary (Safety) Filter
- C—Dust Unloading Valve
- D—Primary Element



RG7766

AIR FILTER RESTRICTION INDICATOR SWITCH TEST

1. Remove air filter restriction indicator switch from air intake piping.
2. Install pipe nipple (C), tee fitting (B), and gauge (A) from D05022ST Water Vacuum Gauge Kit into air filter restriction indicator hole. Install air filter restriction indicator into tee fitting.
3. Start engine and slowly cover the air cleaner inlet with a piece of paper or cardboard.
4. Air restriction indicator must show red at 5.6—6.8 kPa (56—68 mbar) (22.7—27.3 in. water) (1.6—2.0 in. hg) vacuum.



T6188AQ

If air restriction indicator shows red at any other value than listed above, install a new indicator.

DIAGNOSING TURBOCHARGER MALFUNCTIONS

Before replacing the turbocharger, determine what caused the failure of the defective unit, and correct the condition. This will prevent an immediate repeat failure of the replacement unit. Refer to Air Intake and Exhaust System Group 30 for repair information.

- **Noise Or Vibration*:**

- Bearings not lubricated (insufficient oil pressure).
- Air leak in engine intake or exhaust manifold.
- Improper clearance between turbine wheel and turbine housing.
- Broken blades (or other wheel failures).

- **Engine Will Not Deliver Rated Power:**

- Clogged manifold system.
- Foreign material lodged in compressor, impeller, or turbine.
- Excessive dirt build-up in compressor.
- Leak in engine intake or exhaust manifold.
- Leak in intake manifold-to-aneroid pipe.
- Rotating assembly bearing failure.
- Damaged compressor or turbine blades.

- **Oil On Compressor Wheel Or In Compressor Housing (Oil Being Pushed or Pulled Through Center Housing):**

- Excessive crankcase pressure.
- Air intake restriction.
- Drain tube restriction.

- **Oil In Manifold Or Dripping From Housing:**

- Excessive crankcase pressure.
- Air intake restriction.
- Drain tube restriction.
- Damaged or worn journal bearings.
- Unbalanced rotating assembly:
 - Damage to turbine or compressor wheel or blade.
 - Dirt or carbon build-up on wheel or blade.
- Bearing wear:
 - Oil starvation or insufficient lubrication.
- Shaft seals worn.

- **Turbine Wheel Drag:**

- Carbon build-up behind turbine wheel caused by coked oil or combustion deposits.
- Dirt build-up behind compressor wheel caused by air intake leaks.
- Bearing seizure or dirty, worn bearings caused by excessive temperatures, unbalanced wheel, dirty oil, oil starvation, or insufficient lubrication.

**Do not confuse the whine heard during run down with noise which indicates a bearing failure.*

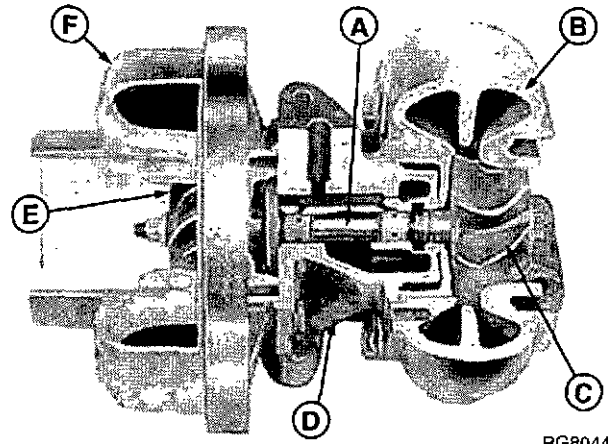
TURBOCHARGER OPERATION

The turbocharger, which is basically an air pump that is driven by exhaust gases, allows the engine to produce added power without increasing displacement. Turbochargers are specially matched for the power ratio requirements of each specific application.

The turbine wheel (C) is driven by the hot engine exhaust gases. These gases flowing through the turbine housing (B) act on the turbine wheel causing shaft (A) to turn.

Compressor wheel (E) brings in filtered air and discharges the compressed air into the intake manifold where it is then delivered to engine cylinders.

Engine oil under pressure from the engine lubrication system is forced through passages in center housing (D) to bearings.



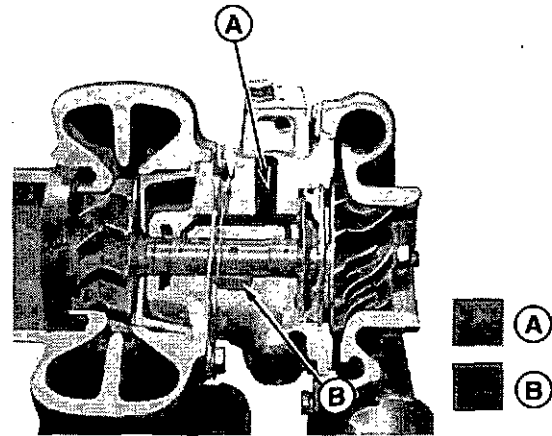
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- A—Shaft
- B—Turbine Housing
- C—Turbine Wheel
- D—Center Housing
- E—Compressor Wheel
- F—Compressor Housing

HOW THE TURBOCHARGER IS LUBRICATED

Engine oil under pressure from the engine lubrication system is pumped through a passage in the bearing housing and directed to the bearings, thrust plate, and thrust sleeve. Oil is sealed from the compressor and turbine by a piston ring at both ends of the bearing housing.

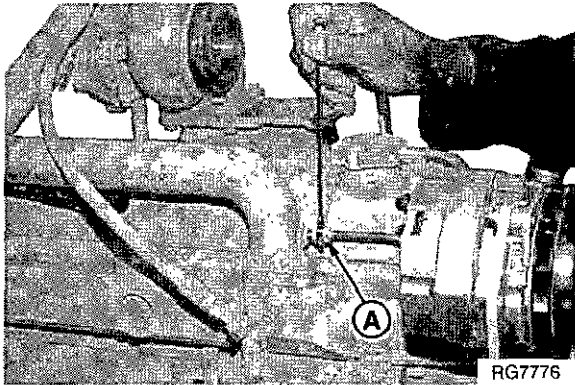
The turbocharger contains two floating bearings*. These bearings have clearance between the bearing OD and the housing bore as well as clearance between the bearing ID and the shaft OD. These clearances are lubricated by the oil supply (A) and the bearings are protected by a cushion of oil. Discharge oil (B) drains by gravity from the bearing housing to the engine crankcase.



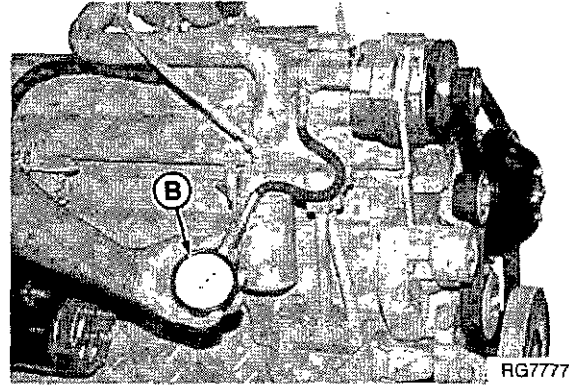
RG8099

A—Pressure Oil
B—Discharge Oil

CHECK INTAKE MANIFOLD PRESSURE (TURBOCHARGER BOOST)



RG7776



RG7777

NOTE: See AIR INTAKE AND EXHAUST SYSTEM TEST SPECIFICATIONS at the beginning of this group for all OEM (TF) engine specifications. Refer to the appropriate machine technical manual for specific machine applications.

1. Remove plug from intake manifold and install the appropriate fitting from JDE147 Manifold Pressure Test Kit or FKM10002 Universal Pressure Test Kit. Connect gauge and hose assembly to fitting. Be sure all connections are tight.
2. Before checking boost pressure, warm up engine to allow the lubricating oil to reach operating temperature.

IMPORTANT: Engine speed and load should be stabilized before taking a gauge reading. Be sure that gauge works properly and familiarize yourself with the use of the gauge.

Turbo-boost pressure checks are only a guide to determine if there is an engine problem (valve leakage, faulty nozzles, etc.). Low pressure readings are not a conclusive reason for increasing injection pump fuel delivery. Pump adjustment should be within the specifications as established by an authorized diesel repair station.

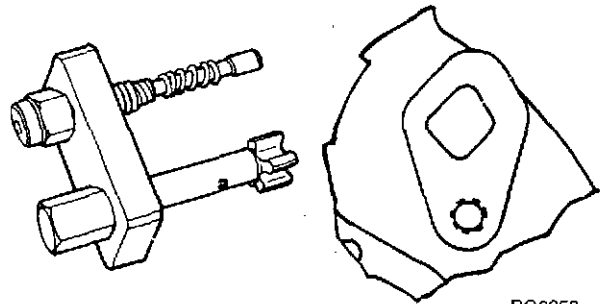
3. Observe pressure reading on gauge. Reading should be at least 60 kPa (0.6 bar) (9 psi) when engine is developing rated power at full load rated speed.
 - If boost pressure is too high, remove fuel injection pump and have it checked for high fuel delivery by an authorized diesel repair station.
 - If boost pressure is too low, check for the following:
 - Restricted air filter elements.
 - Restricted fuel filter elements.
 - Incorrect fast idle adjustment.
 - Incorrect injection pump timing.
 - Exhaust manifold leaks.
 - Intake manifold leaks.
 - Faulty fuel transfer pump.
 - Low compression pressure.
 - Faulty fuel injection nozzles.
 - Carbon build-up in turbocharger.
 - Turbocharger compressor or turbine wheel rubbing housing.
 - Low fuel injection pump fuel delivery.
 - Restricted exhaust.
4. After completing test, remove test equipment and reinstall nozzle adapter and plug. Tighten securely.

SPECIAL OR ESSENTIAL TOOLS

NOTE: Order tools according to information given in the U.S. SERVICEGARD™ Catalog or in the European Microfiche Tool Catalog (MTC).

Flywheel Turning Tool (A) JD281A

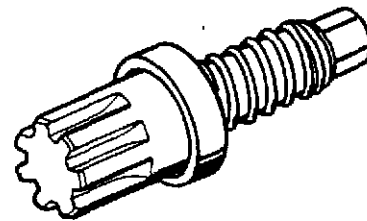
Used on engines with 142-tooth flywheel ring gear and a diamond-shaped tool guide bore (B) in flywheel housing. Tool has its own spring-loaded timing pin which threads into flywheel housing.



RG6252

Flywheel Turning Tool JDG820

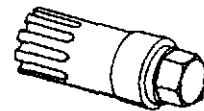
Used to rotate flywheel on engines, with 129-tooth flywheel ring gear and a 29.9 mm (1.18 in.) ID flywheel housing guide bore diameter, to check damper radial runout and time engine. JDE81-1 may be used also if JDG820 is not available.



RG7056

Flywheel Turning Tool JDE83

Used to rotate flywheel on engines with 142-tooth flywheel ring gear and a 26.5 mm (1.04 in.) ID flywheel housing guide bore diameter. Use with JDE81-4 Timing Pin.

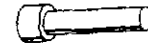


RG6251

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Timing Pin JDE81-4

Lock engine at TDC when installing injection pump or timing valve train. Use with JDG820, JDE81-1, or JDE83 Flywheel Turning Tool.



RG5068

TIME TRAC®Kit JT07158
(FKM10429A)

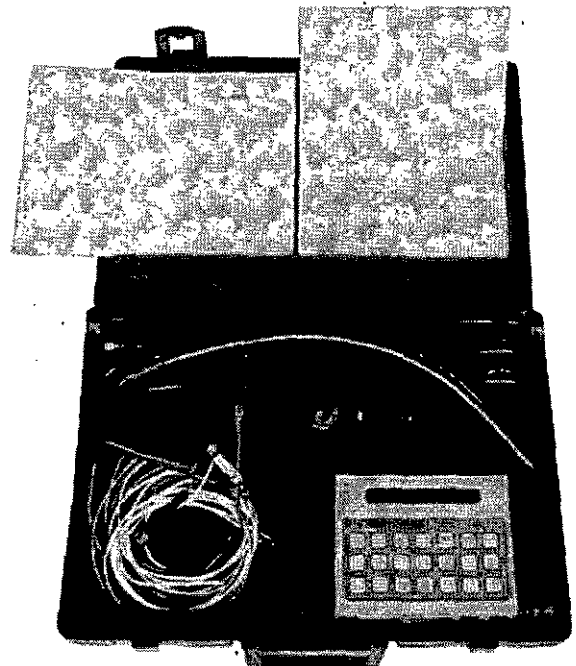
Used to perform the dynamic timing of engines.

- JT07158 Kit consists of the following:

- JT07170 Meter (26932)
- JT07171 Magnetic Pickup (30641)
- JT07172 Transducer Cable (30640)
- JT07173 SOI Clamp Assembly (28037)
- JT07174 Instruction Manual (28062)
- JT07175 Time Trac® Quick Reference Sheet (30642)
- JT07176 Carrying Case (26924)
- JT07177 6 mm Green Clamp-on Transducer (28026)
- JT07178 1/4 in. Clamp-on Black Transducer (28027)
- JDE81-4 Timing Pin
- JDG793 Threaded Magnetic Pickup Adapter
- JT07155 9/16 in. In-line SOI Sensor (29066)*
- JDG821 Tapered Adapter for Flywheel Housing without tapped hole*

- FKM10429A Kit consists of the following:

- FKM10429-1 Meter
- FKM10429-4 Sensor Clamp
- FKM10429-5 6 mm Clamp-on Transducer
- FKM10429-8 Instruction Manual
- JDE81-4 Timing Pin
- FKM10465-1 Magnetic Probe
- FKM10465-2 Transducer Cable
- FKM10465-3 1/4 in. Clamp-On Transducer
- JDG793 Flywheel Sensor Adapter (for threaded hole)
- JDG821 Flywheel Sensor Adapter (for smooth hole)



RG7246

* Optional Accessories

TIME TRAC® is a registered trademark of Stanadyne Automotive Corp.

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SERVICE EQUIPMENT AND TOOLS

NOTE: Order tools from the U.S. SERVICEGARD™ Catalog or from the European Microfiche Tool Catalog (MTC). Some tools may be available from a local supplier.

Name	Use
Pressure Gauge/0—200 kPa (0—2 bar) (0—30 psi), hose, and fittings.	Measure transfer pump pressure. <i>NOTE: Assemble test equipment from JT05470 Universal Pressure Test Kit or any other suitable equipment.</i>
JDG966 Crankshaft Front/Rear Rotation Adapter	Rotate crankshaft from front and rear when flywheel is removed.

FUEL SYSTEM TEST SPECIFICATIONS

ITEM	SPECIFICATION
Fuel Supply Pump Operating Pressure:	
Fuel static pressure	25—30 kPa (0.25—0.30 bar) (3.5—4.5 psi)
Minimum static pressure at 850 rpm engine speed	15 kPa (0.15 bar) (2.0 psi)
Minimum flow at 2400 rpm engine speed	1.5 L/min (0.42 gpm)
Engine Speeds (rpm)	For each machine application refer to the appropriate technical manual for slow idle, OEM applications, see FUEL INJECTION PUMP SPECIFICATIONS later in this group.

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3

FUEL SYSTEM TEST SPECIFICATIONS—CONTINUED

	TORQUES
Injection pump idle screw lock nuts	4.5 N·m (3.3 lb-ft)
Fuel return line.....	16 N·m (12 lb-ft)
Injection lines-to-pump	27 N·m (20 lb-ft)
Injection lines-to-nozzles	27 N·m (20 lb-ft)
Rotary injection pump-to-front plate mounting stud nuts	27 N·m (20 lb-ft)
In-line injection pump-to-front plate mounting stud nuts	70 N·m (52 lb-ft)
In-line injection pump timing hole cover screws	3.5 N·m (2.5 lb-ft)
Cold start switch	5 N·m (3.5 lb-ft)
Injection nozzle hold-down clamps	40 N·m (30 lb-ft)

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ROTARY FUEL INJECTION PUMP SPECIFICATIONS*

Injection pump timing specifications are provided for OEM applications. For industrial applications refer to SP458 Specifications Handbook. For agricultural applications, refer to DB1216 Specifications. If specifications are not listed in handbooks, refer to factory DTAC for assistance.

NOTE: The power specifications shown below apply to Dubuque and Saran-built engines.

Engine Model	Injection Pump Option Code	Original Injection Pump (Part No.)	Replaced By Injection Pump (Part No.)	Slow Idle (rpm)	Rated Speed (rpm)	Fast Idle (rpm)	Dynamic Timing (DBTDC)
4045DF150	1601	RE67557	—	850	2500	2700	9.5
	1602	RE59809	—	850	2500	2700	7
	1603	RE67558	—	—	1800	1890	7
	1671	RE67559	—	850	2500	2700	9.5
	1673	RE67560	—	—	1800	1890	7
	1674	RE67561	—	—	1800	1890	7
4045TF150	1605	RE61668	—	850	2500	2700	6
	1656	RE67562	—	—	1800	1890	6
	1675	RE60091	—	850	2500	2700	6
	1677	RE67563	—	—	1800	1890	6
	1694	RE67863	—	850	2500	2700	6
	1695	RE68739	—	850	2500	2700	6
4045TF250	1606	RE64133	—	850	2400	2600	4
	1608	RE67564	—	—	1800	1890	6
	1667	RE59968	—	850	2400	2600	4
	1682	RE67566	—	—	1800	1890	6
	1683	RE60124	—	850	2400	2600	4

**Engine speeds listed are as preset to factory specification. In most cases, slow idle speed will be reset depending upon specific vehicle application requirements. Refer to your machine technical manual for engine speeds that are different from those preset at the factory.*

ROTARY FUEL INJECTION PUMP SPECIFICATIONS*—CONTINUED

Engine Model	Injection Pump Option Code	Original Injection Pump (Part No.)	Replaced By Injection Pump (Part No.)	Slow Idle (rpm)	Rated Speed (rpm)	Fast Idle (rpm)	Dynamic Timing (DBTDC)
6068DF150	1613	RE59861	—	850	2500	2700	6
	1678	RE60101	—	850	2500	2700	6
6068TF150	1614	RE61669	—	850	2500	2700	5.5
	1680	RE60105	—	850	2500	2700	5.5
	1681	RE67571	—	—	1800	1890	8
	1688	RE67572	—	—	1800	1890	8
	1696	RE67864	—	850	2500	2700	7.3
	1697	RE68740	—	850	2500	2700	7.3
6068TF250	1615	RE62366	—	850	2400	2600	6.5
	1619	RE67573	—	—	1800	1890	7.5
	1668	RE59969	—	850	2400	2600	4
	1685	RE67574	—	—	1800	1890	7.5
	1686	RE60131	—	850	2400	2600	6.5

*Engine speeds listed are as preset to factory specification. In most cases, slow idle speed will be reset depending upon specific vehicle application requirements. Refer to your machine technical manual for engine speeds that are different from those preset at the factory.

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FUEL INJECTION PUMP—GENERAL INFORMATION

Most engines are equipped with a Stanadyne or Lucas rotary-type injection pump. Rotary injection pumps are dynamically timed at the producing factory and reference timing marks are accurately stamped on front plate and injection pump hub.

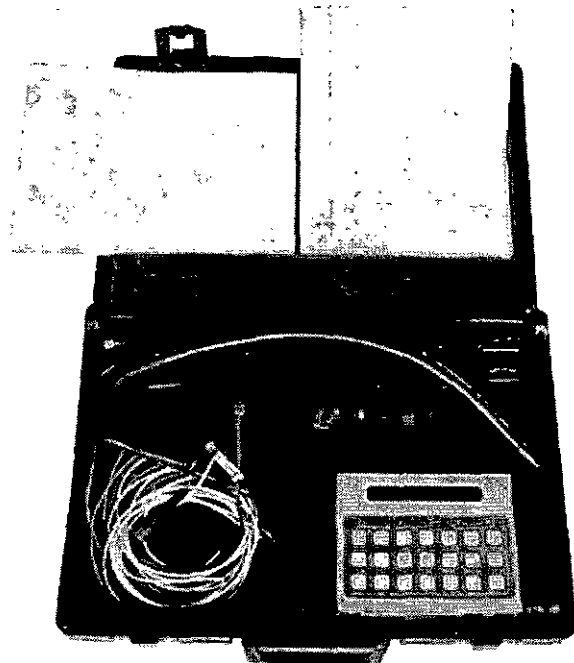
Higher horsepower engines use multiple-plunger, in-line type Nippondenso fuel injection pump with a mechanical flyweight governor and aneroid control.

In-line injection pumps are statically timed by locking engine at No.1 TDC compression and installing pump with injection pump drive hub lock-pinned.

CHECK AND ADJUST ROTARY INJECTION PUMP DYNAMIC TIMING USING JT07158 (OR FKM10429A) TIME TRAC KIT

The JT07158 (or FKM10429A) Time Trac Kit electronically indicates start of injection with respect to piston top dead center (TDC), and allows accurate setting of injection pump timing to provide optimum power, smoke, and exhaust emissions.

Timing engines with this timing kit improves consistency between engines and helps to control cylinder firing pressures which can be a factor in head gasket failures as well as improve overall engine performance efficiencies.



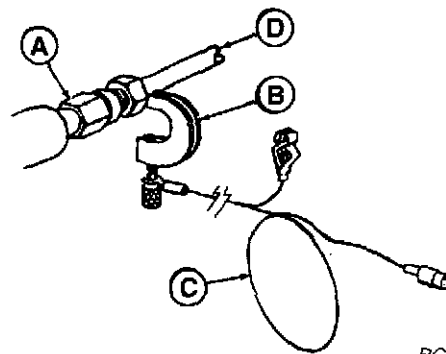
RG7246

• Install JT07158 (or FKM10429A) Time Trac Kit:

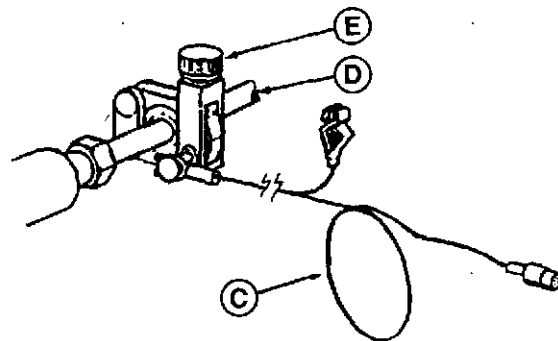
IMPORTANT: All transducers and sensors must be installed at nozzle end of No. 1 fuel injection line. If access to No. 1 line is restricted, sensor can be installed on No. 4 injection line (4-cylinder engines) and No. 6 injection line (6-cylinder engines).

Remove all paint from injection line where clamp-on transducer will be installed and be sure this location is thoroughly clean.

1. On engines with optional JT07155 In-Line SOI Sensor (A) installed between injection nozzle and fuel delivery line, install JT07173 SOI Clamp Assembly (B) onto clean sensor and tighten securely.
2. On engines without optional JT07155 In-Line Sensor, install JT07177 6 mm (green) Clamp-on Transducer (E) onto clean, paint-free injection line and tighten securely.
3. Assemble red lead of JT07172 Transducer Cable (C) onto in-line sensor or transducer, however equipped.
4. Attach spring clip to a solid ground. Plug connector into JT07170 meter port marked SR.



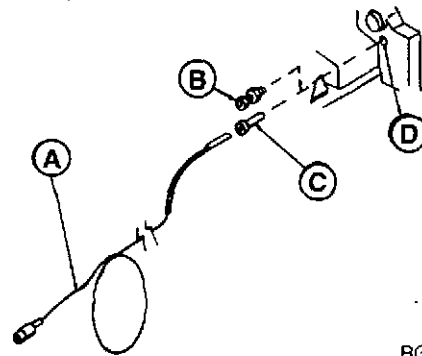
RG7285



RG7286

- A—JT07155 In-Line SOI Sensor
- B—JT07173 SOI Clamp Assembly
- C—JT07172 Transducer Cable
- D—Fuel Injection (Delivery) Line
- E—JT07177 6 mm (Green) Clamp-On Transducer

5. Use JDE81-4 Timing Pin in flywheel timing hole (D) to ensure engine is NOT stopped at TDC. Magnetic pick-up probe will enter TDC timing hole in flywheel and be damaged when engine is started. An air gap of 0.64 mm (0.025 in.) is recommended between tip of probe and flywheel face.
6. Install JDG793 Threaded Magnetic Pick-up Adapter (B) into flywheel housings with tapped hole until it bottoms. Insert probe of magnetic pickup (A) into adapter until it contacts flywheel. Back out hex head of adapter two flats and tighten lock nut; this will provide recommended air gap.
7. Install JDG821 Tapered Magnetic Pick-up Adapter (C) into flywheel housings without tapped hole. Lightly tap adapter to lock into position. Insert probe into adapter until it contacts the flywheel. Pull probe back out to provide 0.64 mm (0.025 in.) gap.
8. Plug magnetic pick-up connector into JT07170 meter port marked MP.



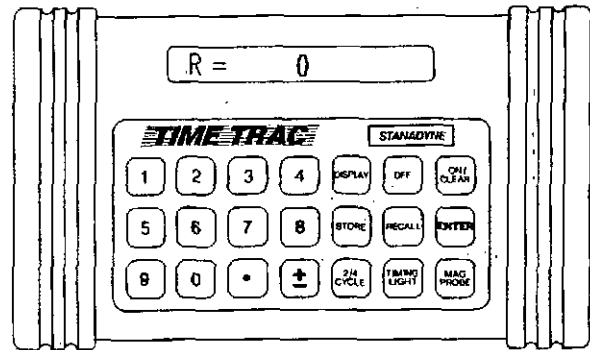
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- A—Magnetic Pick-Up
 B—JDG793 Threaded Magnetic Pick-Up Adapter
 C—JDG821 Tapered Magnetic Pick-Up Adapter
 D—Flywheel Timing Hole

• Check Rotary Injection Pump Rated Load
Dynamic Timing:

1. Engine OFF. Push ON/CLEAR button.

Display shows: R=0

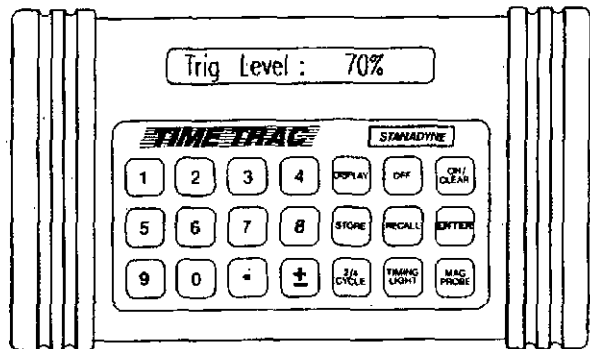


RG7031

2. Push MAG PROBE button.

Display shows: Trig Level: 30%

3. Change to 70% and push ENTER.

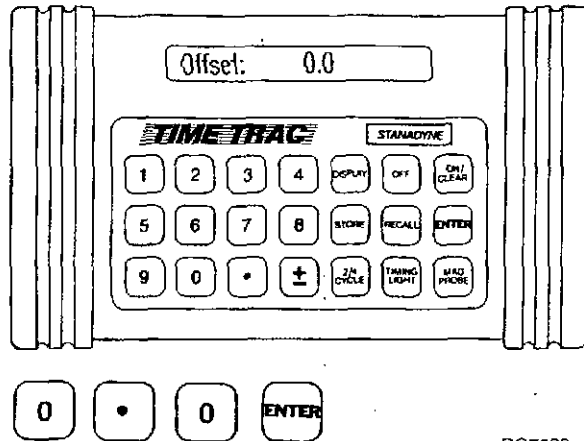


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Display shows: Offset: 20.0°

- Change to offset 0° and push ENTER.



RG7033

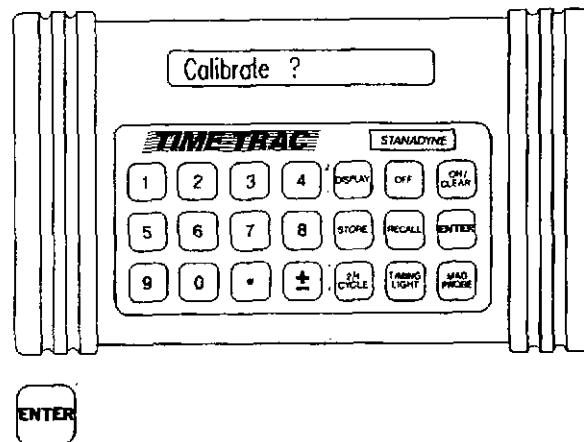
Display shows: Calibrate?

- Start engine and push ENTER.
- Run engine at 1300 rpm. Push ENTER.

Display shows: Calibrating then Engine RPM and timing.

NOTE: If display shows **NO PROBE**, the magnetic pick-up probe has not been installed properly [air gap exceeds 0.64 mm (0.025 in.)] or there is debris on the back of the flywheel. Check for proper air gap or clean the back side of the flywheel by inserting a soft wooden dowel into the engine timing pin hole with the engine running at low idle speed.

- Warm engine to normal operating temperature, check slow and fast idle rpm. (See ROTARYFUEL INJECTION PUMP SPECIFICATIONS earlier in this group.) Adjust speeds as necessary.



RG7129

IMPORTANT: Many machines have hydraulic pumps that have adequate flow to load engine well below rated load rpm. Some equipment may need to be driven in high gear or pull a load to bring engine speed to rated load rpm.

8. Run engine at wide open throttle (WOT) and load engine down gradually to rated speed rpm.

NOTE: A negative timing value indicates the clamp-on sensor signal is not adequate. Check sensor and lines for cleanliness and proper installation.

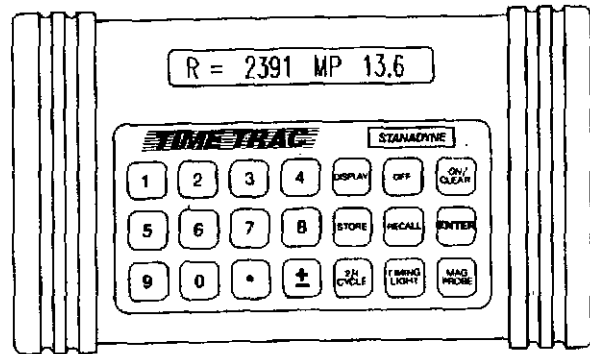
9. Record engine speed (rpm) and timing degrees.

IMPORTANT: Stop engine prior to making timing adjustments. Injection pump can seize if adjustment is made with engine running.

10. Stop engine.

If dynamic timing reading is more than 8 degrees retarded with pump flange and front plate timing marks at original location as shipped from factory, this may indicate the pump advance is not functioning. Check the following:

- Change fuel filter(s)
- Check transfer pump for positive fuel pressure to injection pump
- Check camshaft movement on injection pumps with rectangular timing window.
- Check pump drive shaft-to-gear key or pin to ensure key or pin has not sheared.
- If none of the above checks are conclusive, remove pump and have necessary repairs made at an authorized diesel repair station.



RG7037

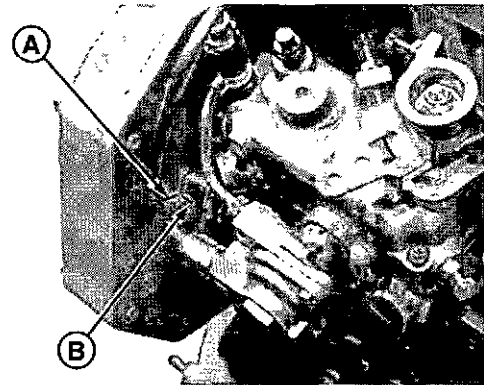
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• **Adjust Rotary Injection Pump Dynamic Timing:**

1. Loosen injection pump mounting flange nuts and adjust pump timing.

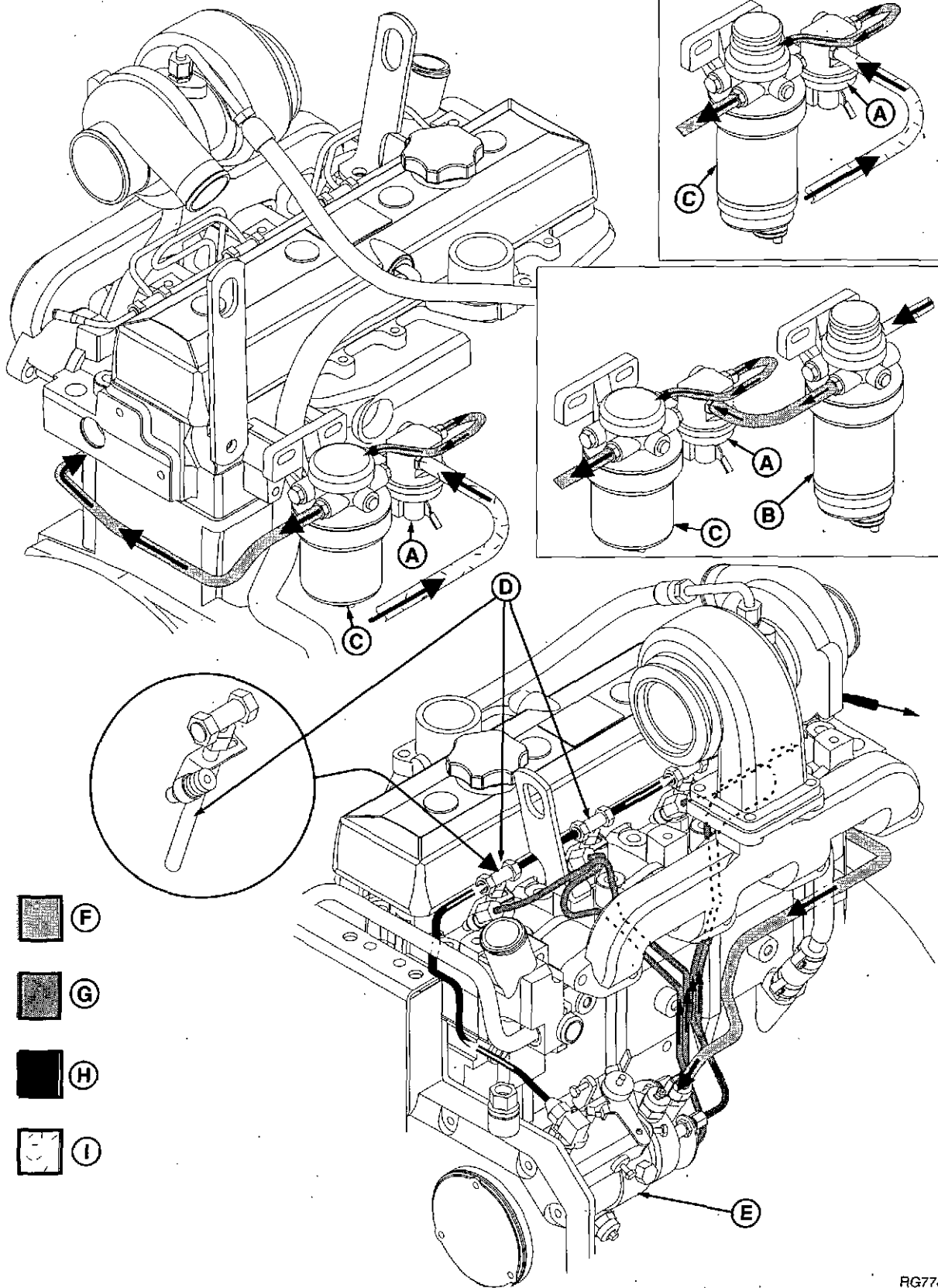
To advance pump timing, rotate top of pump clockwise view from rear (flywheel end) of engine. To retard timing, rotate top of pump counterclockwise. Pump flange movement of 1.524 mm (0.060 in.) is equivalent to 2 degrees of engine timing.

2. Tighten injection pump mounting flange nuts to 27 N·m (20 lb-ft). Start engine and check injection pump dynamic timing again. Adjust timing as needed.
3. Grind away original timing mark and stamp new timing mark (B) onto injection pump flange to align with timing mark (A) on front plate after all final adjustments have been made and satisfactory engine performance is achieved.



RG7723

FUEL SYSTEM OPERATION—ROTARY FUEL INJECTION PUMP



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RG7788

FUEL SYSTEM OPERATION—ROTARY FUEL INJECTION PUMP—CONTINUED

A—Fuel Supply (Transfer) Pump

B—Primary Fuel Filter/Water Separator

C—Final Fuel Filter

D—Fuel Injection Nozzles

E—Fuel Injection Pump

F—Supply Pump Pressure Fuel

G—Injection Pressure Fuel

H—Fuel Return Leak-off

I—Suction Fuel from Tank

Refer to illustration on previous page.

The fuel supply pump (A) draws fuel from the tank and pressurizes it. This pressure permits the fuel to flow through the optional primary filter (B) and final filter (C) and charge the transfer pump of the injection pump (E).

With the fuel injection pump charged with fuel by the fuel supply pump, the injection pump plungers pressurize the fuel to approximately 50 000 kPa (500 bar) (7255 psi). Delivery (pressure) lines are used to route this high pressure fuel to the fuel injection nozzles (D).

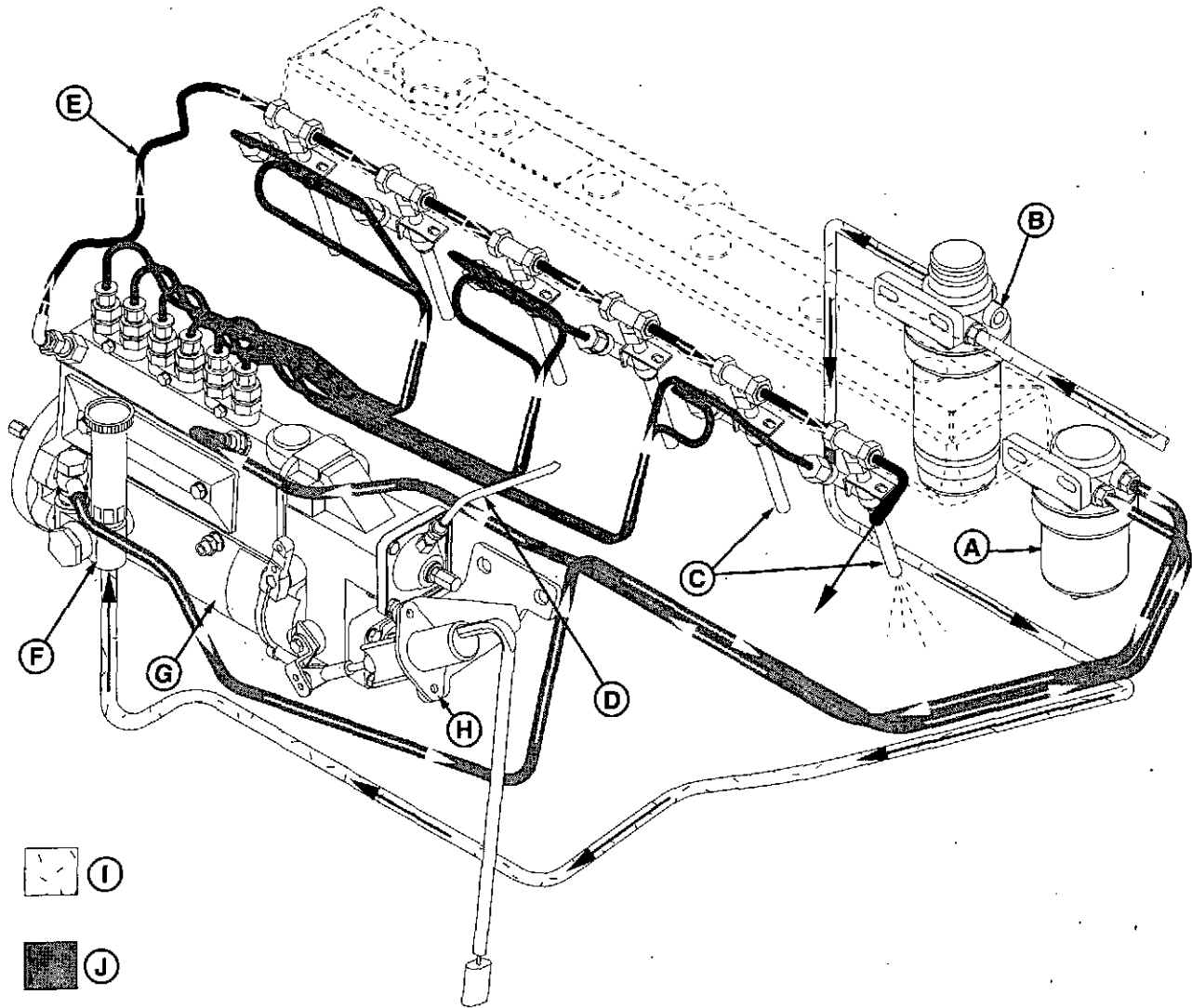
Fuel enters the injection nozzle at a pressure which easily overcomes the pressure required to open the nozzle valve. When the nozzle valve opens, fuel is forced out through the orifices in the nozzle tip and atomizes as it enters the combustion chamber.

Incorporated into the fuel system is a means of returning excess (or unused) fuel (H) back to the fuel tank. Excess fuel comes from two sources:





1. Fuel Injection Pump: A quantity of fuel greater than that required by the engine is supplied to the fuel injection pump.
2. Fuel Injection Nozzles: A small amount of fuel seeps past the nozzle valve for lubrication purposes.

To get the excess fuel back to the tank, a return line from the injection pump is connected to the middle of the nozzle leak-off line. Fuel from both sources is then returned to the tank by a return pipe connected to the front end of the leak-off pipe.

FUEL SYSTEM OPERATION—IN-LINE FUEL INJECTION PUMP



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-  (I)
-  (J)
-  (K)
-  (L)

RG7789

FUEL SYSTEM OPERATION—IN-LINE FUEL INJECTION PUMP—CONTINUED

A—Final Fuel Filter
B—Primary Fuel Filter/Water Separator
C—Injection Nozzles
D—Aneroid Inlet Line

E—Fuel Return (Leak-off) Line
F—Fuel Supply Pump
G—Fuel Injection Pump
H—Fuel Shut-off Solenoid

I—Suction Fuel from Tank
J—Supply Pump Pressure Fuel
K—Injection Pressure Fuel
L—Return (Leak-off) Line

Refer to illustration on previous page.

The supply pump (F) draws fuel from the vented fuel tank through the primary filter (B).

The supply pump pressurizes the fuel so that it flows through the filter to the injection pump galley. Supply pump output pressure will vary depending on load and application:

The galley is kept full by the supply pump. Injection pump plungers further pressurize the fuel. Injection pressure lines route the fuel to the nozzles (C).

The high pressure fuel (K) opens the nozzle valve and forces fuel out the small orifices in the nozzle tip. This atomizes the fuel as it enters the combustion chamber.

There are two sources of excess fuel incorporated into the system. The supply pump supplies more fuel to the pump than is required by the engine, and the nozzle requires excess fuel to lubricate the nozzle valve. A leak-off line (L) returns this excess fuel to the tank from both the pump and nozzles.

DIAGNOSE FUEL SYSTEM MALFUNCTIONS

Symptom	Problem	Solution
Fuel Not Reaching Injection Nozzles	Fuel filter restricted.	Replace fuel filter. (See Group 35.)
	Fuel line restricted.	Clean lines as required.
	Fuel too heavy at low temperatures.	Use correct grade of fuel.
	Air in system.	Correct problem and bleed fuel system (this group).
	Fuel tank valve shut off.	Open fuel tank valve.
	Low supply pump pressure.	Check fuel lines for restrictions; check pump output pressure (this group).
Engine Starts Hard or Won't Start	Fuel too heavy at low temperature.	Use correct grade of fuel. (See Fuels, Group 02.)
	Injection nozzles faulty or sticking.	Repair or replace as required. (See Group 35.)
	<i>Incorrect timing.</i>	<i>Adjust timing (this group).</i>
	Faulty injection pump.	Repair or replace.
	Water in fuel.	Drain water from filter (or separator if equipped). Install new filter.
	Fuel filter restricted.	See Group 35.
	Low supply pump pressure.	Check pump output pressure (this group).
	Injection pump return fuel line or fittings restricted.	Clean lines as required.
	Low cetane fuel.	Use correct grade of fuel. (See Group 02.)

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DIAGNOSE FUEL SYSTEM MALFUNCTIONS—CONTINUED

Symptom	Problem	Solution
Engine Starts and Stops	Air in system.	Correct problem and bleed fuel system. (See this group.)
	Fuel filter restricted.	Replace fuel filter.
	Fuel lines restricted.	Clean lines as required.
	Water in fuel.	Drain water from filter, (or separator if equipped). Install new filter. (See Group 35.)
	Injection pump return fuel line or fittings restricted.	Clean lines as required.
Erratic Engine Operations	Fuel filter restricted.	Replace fuel filter. (See Group 35.)
	Fuel too heavy at low temperatures.	Use correct grade of fuel. (See Group 02.)
	Injection nozzles faulty or sticking.	Repair or replace nozzles. (See Group 35.)
	Fuel lines restricted.	Clean as required.
	Incorrect timing.	Adjust timing (this group).
	Governor faulty.	Repair. (See Group 35.)
	Water in fuel.	Drain water from filter (or separator, if equipped). Install new filter.
	Injection pump return fuel line or fittings restricted.	Clean lines as required.
	Low cetane fuel.	Use correct grade of fuel. (See Group 02.)
	Injection nozzle return lines restricted.	Clean lines as required.

DIAGNOSE FUEL SYSTEM MALFUNCTIONS—CONTINUED

Symptom	Problem	Solution
Engine Emits Excessive Black Smoke	Injection nozzles faulty or sticking.	Repair. (See Group 35.)
	Injection pump timing incorrect.	Adjust timing (this group).
	Low cetane fuel.	Use correct grade of fuel. (See Group 02.)
	Over-fueling.	Repair injection pump. (See Group 35.)
Engine Emits Excessive Blue or White Smoke	Cranking speed too slow.	Check batteries and electrical system.
	Injection pump timing incorrect.	Adjust timing (this group).
	Injection nozzles faulty or sticking.	Repair. (See Group 35.)
	Excessive wear in liners and/or piston rings stuck.	See Group 10.
	Incorrect cetane fuel for ambient temperature.	Use correct grade of fuel. (See Group 02.)
	Engine running too "cold".	Check thermostat. (See Group 25.)
Engine Idles Poorly	Injection nozzles faulty or sticking.	Repair. (See Group 35.)
	Incorrect timing.	Adjust timing (this group).
	Pump slow idle speed not correctly adjusted.	Adjust slow idle speed (this group).
	Fuel lines restricted.	Clean as required.
	Water in fuel.	Drain water from filter, (or separator, if equipped). Install new filter. (See Group 35.)
	Injection pump return lines or fittings restricted.	Clean as required.
	Injection nozzle return lines clogged.	Clean as required.
	Low cetane fuel.	Use correct grade of fuel. (See Group 02.)

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DIAGNOSE FUEL SYSTEM MALFUNCTIONS—CONTINUED

Symptom	Problem	Solution
Engine Does Not Develop Full Power	Low cetane fuel.	Use correct grade of fuel. (See Group 02.)
	Incorrect timing.	Adjust timing (this group).
	Injection pump or governor faulty.	Repair. (See Group 35.)
	Fuel filter clogged.	Replace fuel filter. (See Group 35.)
	Injection nozzles faulty or sticking.	Repair. (See Group 35.)
	Defective supply pump.	Test (this group).
	Injection pump return fuel line or fittings restricted.	Clean as required.
	Water or gasoline in diesel fuel.	Drain water or replace with clean fuel. Install new filters (this group).
	Incorrect fast idle speed.	Adjust speed (this group).
Speed control linkage incorrectly adjusted.	Adjust (this group).	

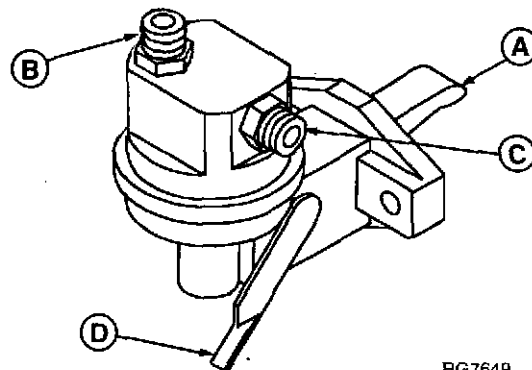
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FUEL SUPPLY PUMP OPERATION— ROTARY INJECTION PUMP

The Sofabex fuel supply pump used with Lucas and Stanadyne rotary fuel injection pumps uses an eccentric lobe on the engine camshaft to operate lever (A) on supply pump to pressurize fuel system.

Fuel flows from the fuel tank at gravity pressure to the inlet side (B) of the diaphragm-type pump. This pump increases the fuel pressure to 25—30 kPa (0.25—0.3 bar) (3.5—4.5 psi) at slow idle speed and forces fuel through the outlet side (C) to the filter and fuel injection pump. Minimum output pressure: 15 kPa (0.15 bar) (2 psi).

A hand primer lever (D) is provided for manually forcing fuel through the system to bleed air from fuel filter, etc.



RG7649

- A—Lever
- B—Inlet Side of Pump
- C—Outlet Side of Pump
- D—Primer Lever

DIAGNOSE FUEL SUPPLY PUMP MALFUNCTION—ROTARY INJECTION PUMP

Symptom	Problem	Solution
Low Supply Pump Pressure or Pump Not Functioning Correctly	Out of fuel.	Add fuel to tank.
	Fuel shut off at tank.	Open shut-off valve.
	Restricted fuel line.	Clean as required.
	Air leak in fuel line between pump and tank.	Repair as required.
	Loose or damaged fuel line connections.	Repair as required.
	Hand primer lever left in upward position.	Move lever toward engine block as far as it will go.
	Punctured or leaking diaphragm.	Replace pump. (See Group 35.)
	Worn or damaged valve assemblies.	Replace pump. (See Group 35.)
	Broken valve spring(s).	Replace pump. (See Group 35.)
	Foreign material under diaphragm (from vent holes).	Replace pump. (See Group 35.)
Wear or damage to hand primer linkage.	Replace pump. (See Group 35.)	

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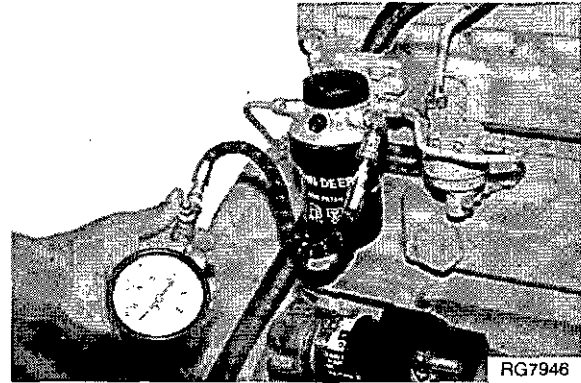
MEASURE FUEL SUPPLY PUMP PRESSURE—ROTARY INJECTION PUMP

FUEL SUPPLY PUMP OPERATING PRESSURE SPECIFICATIONS

Fuel Supply Pump Operating Pressure:

Normal 25—30 kPa (0.25—0.3 bar) (3.5—4.5 psi)
Minimum 15 kPa (0.15 bar) (2 psi)

1. Remove plug on fuel filter base.
2. Install test equipment as shown.
3. Start engine. Fuel pump should maintain positive minimum pressure of 15—30 kPa (0.15—0.3 bar) (2—4 psi). If pressure is low, replace filter element and recheck pressure.



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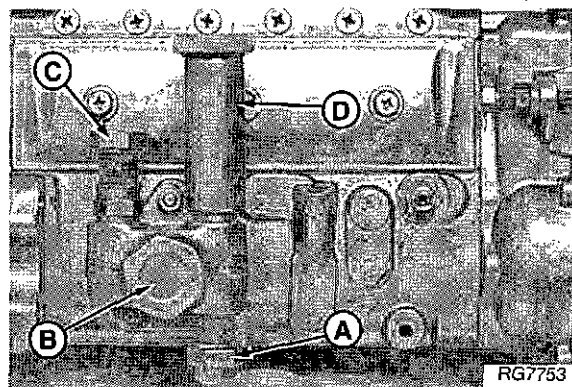
- **If pressure is still low, perform the following:**

1. Disconnect pump-to-filter fuel line at the filter.
2. With throttle set at no-fuel position (or injection pump shut-off solenoid wire disconnected) so engine will not start, turn engine over several times with starting motor.
3. If fuel spurts from the line, the pump is operating properly.

NOTE: Look for a possible restriction in filter/filter base. Make sure pressure gauge/hose assembly is not at fault.

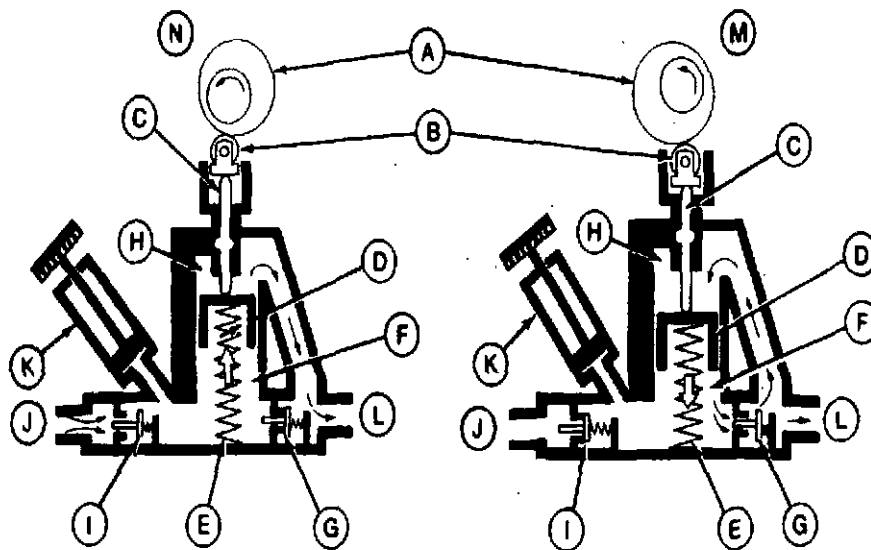
FUEL SUPPLY PUMP OPERATION— IN-LINE INJECTION PUMP

The plunger-type Nippondenso fuel supply pump is mounted on the side of the injection pump housing and is driven by the injection pump camshaft. Fuel enters the supply pump at (A), is pressurized by the plunger (B), and discharged through outlet (C). The hand primer (D) provides manual pump operation for bleeding the fuel system.



- A—Fuel Inlet
- B—Plunger
- C—Fuel Outlet
- D—Hand Primer

FUEL SUPPLY PUMP OPERATION—IN-LINE INJECTION PUMP— CONTINUED



RG5787

- | | | | |
|--------------------|--------------------|--------------------|-----------------------------------------|
| A—Camshaft | E—Plunger Spring | I—Suction Valve | M—Intermediate Stroke Position |
| B—Roller Tappet | F—Suction Chamber | J—Fuel Inlet | N—Suction and Discharge Stroke Position |
| C—Pressure Spindle | G—Pressure Valve | K—Hand Primer Pump | |
| D—Plunger | H—Pressure Chamber | L—Fuel Outlet | |

As the pump camshaft (A) rotates toward the "high cam" intermediate stroke position (M), the roller tappet (B) and pressure spindle (C) cause the plunger (D) to move against and compress the plunger spring (E).

Plunger movement forces the fuel out of the suction chamber (F), through the pressure valve (G), and into the pressure chamber (H). The amount of fuel discharged from the suction chamber is equal to the amount of fuel delivered for each stroke of the plunger. Towards the end of the intermediate stroke, the spring-loaded pressure valve closes again.

As the camshaft rotates toward the "low cam" or suction and discharge position (N), plunger spring pressure causes the plunger, pressure spindle, and roller tappet to follow the camshaft.

Movement of the plunger pushes the fuel from the pressure chamber, and delivers it to the fuel filters and injection pump. At the same time, plunger suction pressure is permitting fuel to enter the suction chamber through the suction valve (I). With the suction chamber charged with fuel, the pumping cycle begins again.

Fuel is allowed to flow in around the pressure spindle to lubricate the spindle as it moves back and forth in housing. To prevent the fuel from entering the pump crankcase, a rubber O-ring is positioned in the spindle bore of housing at the roller tappet end.

Unscrewing the knurled knob on the hand primer pump (K) and pulling upward causes the suction valve to open and fuel to flow into the suction chamber. When the hand plunger is pushed downward, the suction valve closes, and fuel is forced out of the pressure valve.

DIAGNOSE FUEL SUPPLY PUMP MALFUNCTIONS —IN-LINE INJECTION PUMP

IMPORTANT: Visually inspect the fuel inlet fitting and pump filter for possible plugging before disassembling to determine cause of malfunction.

Symptom	Problem	Solution
Low Supply Pump Output Pressure or Pump Not Functioning Correctly	Restriction at fuel inlet fitting.	Thoroughly clean fuel tank, lines, filters, and inlet fitting.
	Hand primer not screwed down tight, allowing dirt to enter hand primer plunger chamber.	Advise customer to tighten hand primer after use.
	Worn or pitted valves caused by foreign material lodging in valve.	Replace valves as required.
	Missing or broken spring(s).	Replace spring(s).
	Broken spindle.	Replace pump.
	Out of fuel.	Add fuel to fuel tank.
	Fuel shut off at tank.	Open fuel shut-off valve.
	Restricted fuel line.	Clean as required.
	Air leak in fuel line between pump and tank.	Repair as required.
	Loose or damaged fuel line connections.	Repair.
	Hand primer left in upward position.	Bleed fuel system, gently push hand primer down and tighten securely.
	Worn or damaged valve assemblies.	Repair or replace.
	Broken valve spring(s).	Repair or replace.
Diesel Fuel Leaking Into Injection Pump Crankcase	Worn spindle and/or pump housing.	Replace pump.
	Defective O-ring seal.	Replace O-ring seal.

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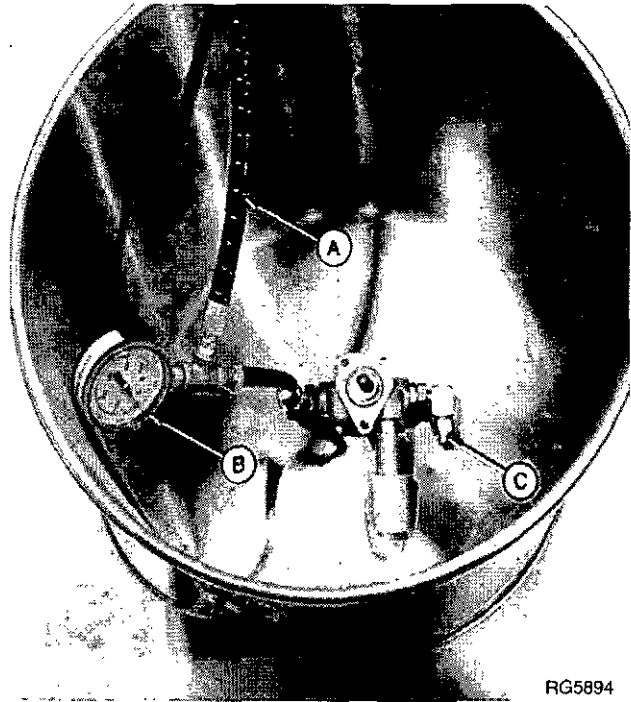
TEST FUEL SUPPLY PUMP FOR LEAKS— IN-LINE INJECTION PUMP

Fuel delivery pressure should be checked before removing supply pump from injection pump. (See FUEL SUPPLY PUMP OPERATION—IN-LINE INJECTION PUMP, earlier in this group).

1. Connect compressed air line (A) to a pressure gauge (B) and to supply pump inlet fitting. Air line should have a regulating valve to control pressure.
2. Cap or plug supply pump outlet fitting (C).
3. Submerge supply pump in a container of clean diesel fuel. Regulate air pressure to 200 kPa (2.0 bar) (29 psi).
4. Move roller tappet in and out by hand. No air bubbles should appear around roller tappet.

NOTE: *If bubbles appear, it is an indication that either the O-ring seal is defective or tappet is worn (or possibly both).*

IMPORTANT: Serious injection pump or engine damage could occur, if enough diesel fuel leaks past spindle and seal. Fuel leakage past spindle dilutes engine oil.



RG5894

CHECK FUEL SUPPLY PUMP OPERATION—IN-LINE INJECTION PUMP

NOTE: The following test procedure can best be performed under moderate air temperature conditions to reduce electrical loads when cranking the engine is required.

- **Test fuel supply pump and hand primer for leaks:**

1. Make a preliminary inspection of supply pump (A). Thoroughly clean area around pump. All connections must be tight and not leaking.
2. Start engine and bring to operating temperature. Shut off engine.

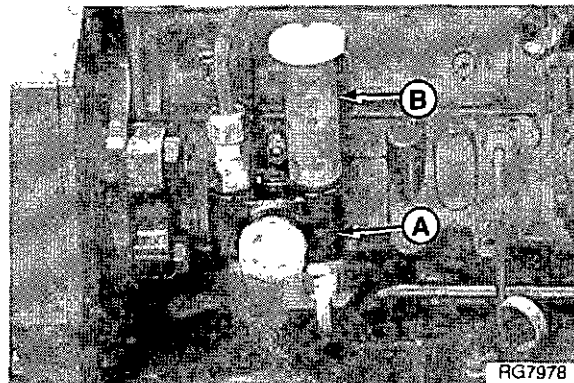
NOTE: If fuel leaks around hand primer (B) that is screwed down tight when engine is running, replace the hand primer.

3. Check operation of hand primer. With engine shut off, unscrew knob and operate hand primer through several strokes. Moderate to heavy leakage of fuel between plunger and barrel indicates seal is defective. Replace hand primer.

NOTE: Appearance of a slight quantity of fuel around the plunger is normal.

IMPORTANT: Be sure hand primer is seated all the way down in barrel before tightening to prevent internal thread damage.

4. Tighten hand primer knob, but do not overtighten. If knob will not tighten (indicating internal thread damage), replace hand primer.



RG7978

• **Test operation of suction side of pump:**

1. Disconnect suction and discharge lines at pump.
2. Drain all fuel from pump by operating hand primer. Then reconnect suction line to pump.
3. Operate hand primer until fuel flows from pump outlet (discharge). Fuel should flow within 15—25 strokes. If not, the suction line may be obstructed or leaking air; (replace in-line filter when used).

NOTE: When operating hand primer, a moderate resistance should be felt. When only a slight resistance (or no resistance) occurs, replace hand primer or repair pump (valves may be defective).

If fuel does not flow, and if no leak or obstruction is found, pump is defective. Repair or replace pump. (See Group 35).

• **Test operation of discharge side of pump:**

1. Suction line must be connected and discharge (pressure) line disconnected.
2. Tighten hand primer and place injection pump fuel shut-off control in "STOP" position to prevent engine from starting.
3. Crank engine with starting motor. Fuel should flow from pump outlet within 10 seconds. If not, the suction line may be obstructed or leaking air; (replace in-line filter when used).

- **Test pump output pressure while cranking engine:**

1. Connect a 0—400 kPa (0—4 bar) (0—60 psi) pressure gauge to one end of a pressure hose about 250—300 mm (10—12 in.) long. Connect other end of hose to pump outlet. All air must be out of system.

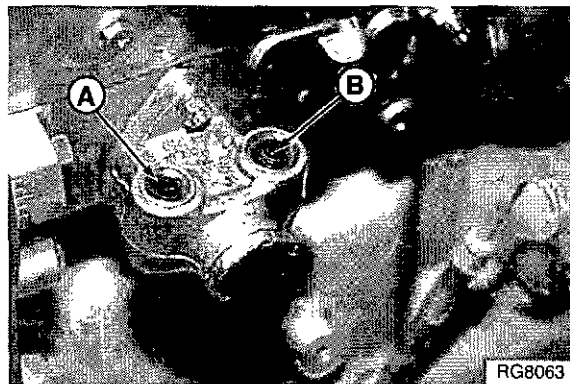
IMPORTANT: The starting motor must crank the engine at normal cranking speed. Use booster batteries if necessary.

2. Crank engine for 10 seconds with starting motor (approximately 300 engine rpm). Supply pump minimum outlet pressure should be 200 kPa (2.0 bar) (29.0 psi).
3. Compare measured output with the minimum pressure specifications.

If pressure is below the minimum specified and if no obstruction or leak is found, repair or replace the pump.

SERVICE FUEL SUPPLY PUMP

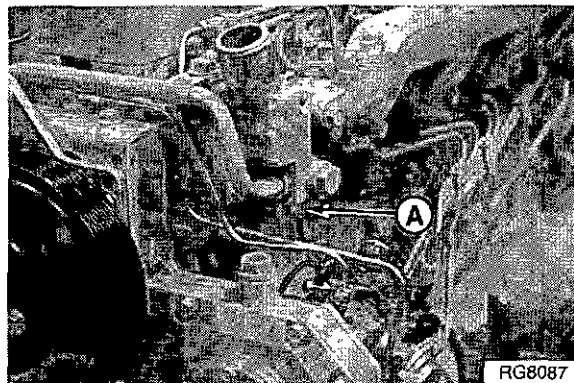
1. To gain access to the valves, remove hand primer, banjo fitting, and plug from top of supply pump (shown removed).
2. Remove valves (B) and springs (A).
3. Inspect valves and valve seats for foreign material, wear, or pitting. Valve springs must not be cracked or broken.
4. Reassemble parts, open tank shut-off valve, and check operation. If the pump operation is still not normal, the pump will have to be repaired or replaced. (See Group 35.)



COLD START SWITCH OPERATIONAL CHECK

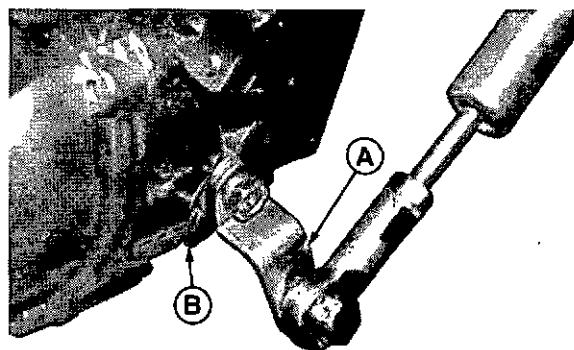
The cold start switch (A) is an option available on rotary injection pumps.

1. Disconnect cold start switch connector from pump wiring harness.
2. Remove cold start switch from thermostat housing/water manifold.
3. Submerge switch in water above 60° C (140° F) for a few minutes.
4. Remove switch and check for open or closed switch. On Lucas pumps, the switch should be closed. On Stanadyne pumps, the switch should be open.
5. Replace switch if defective.
6. Install switch in thermostat housing/water manifold and tighten to 5 N·m (3.5 lb-ft).
7. Connect cold start switch connector to pump wiring harness.



FUEL SHUT-OFF SOLENOID OPERATIONAL CHECK

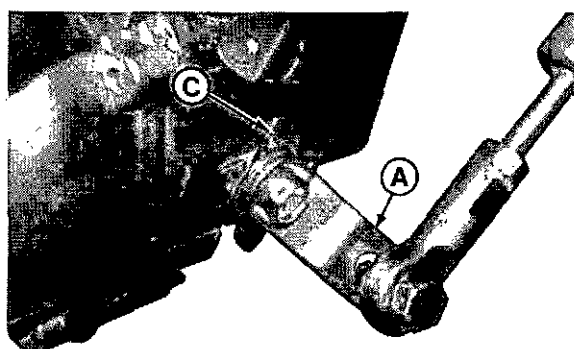
1. Observe fuel shut-off lever (A) when key switch is turned from "OFF" to "START" (engine running at slow idle) and then released to "ON" position.
2. Fuel shut-off lever should move from "NO FUEL" position (B) to "RUN" position (C) when starting motor begins to crank. The lever should remain at the "RUN" position after key switch is released to "ON" position.



RG8067

If fuel shut-off lever returns to "NO FUEL" position with key switch at "ON" position, check for:

- Loss of battery voltage to fuel shut-off winding. Check voltage and wiring connection to solenoid.
 - Binding of fuel shut-off lever, solenoid rod or linkage does not allow solenoid to lock in position. Repair or replace linkage.
 - Torn or leaking rubber boot allowing dirt or moisture to enter at spring end of solenoid rod.
 - Improperly adjusted fuel shut-off solenoid linkage. See FUEL SHUT-OFF SOLENOID LINKAGE ADJUSTMENT, later in this group.
3. Start engine and run at slow idle. Turn key switch to "OFF" position.
 4. Fuel shut-off lever should move to "NO FUEL" position and engine should stop.



RG8068

If the solenoid stops just short of the "NO FUEL" position, slight adjustment of the linkage is required. See FUEL SHUT-OFF SOLENOID LINKAGE ADJUSTMENT, later in this group.

If engine continues to run with key switch at "OFF" position, unplug shut-off solenoid 3-way connector.

- If solenoid moves lever to "NO FUEL" position, problem is in the electrical circuit.
- If solenoid does not shut off fuel to engine, check linkage for binding or excessive tightness. Replacement service kit is available with a swivel rod which is less sensitive to misalignment and binding.

FUEL SHUT-OFF SOLENOID RESISTANCE TEST

Disconnect shut-off solenoid 3-way WEATHER PACK™ connector.

1. Measure "PULL" coil resistance between black lead wire "C" and white lead wire "B".
2. Measure "HOLD" coil resistance between black lead wire "C" and red lead wire "A".

Replace solenoid if resistance is not within specification given below.

PULL AND HOLD COIL RESISTANCE SPECIFICATIONS

Solenoid Part Number	Pull Coil Resistance (Ohms)	Hold Coil Resistance (Ohms)
12-Volt System: RE67325	0.134—0.200	6.63—8.11
24-Volt System: RE67256	0.560—0.684	24.35—29.76

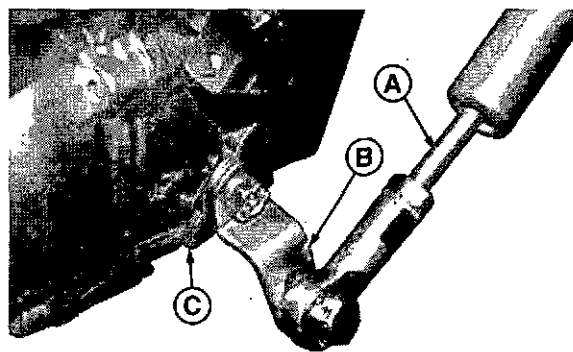
WEATHER PACK is a trademark of Packard Electric.

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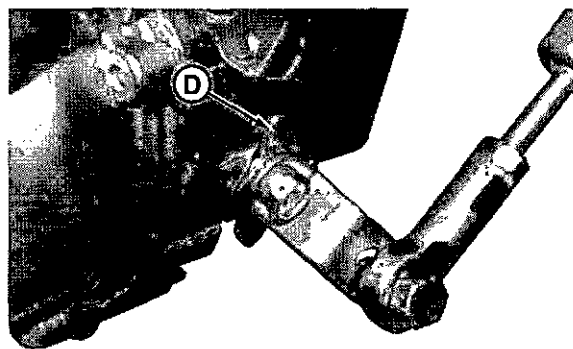
FUEL SHUT-OFF SOLENOID LINKAGE ADJUSTMENT

Shut-off solenoid linkage is factory adjusted and usually will not require additional field adjustment. ALWAYS check linkage and lever for alignment and binding before making adjustments.

1. Thoroughly lubricate all linkage and lever pivot points.
2. If necessary, adjust linkage (A) so that lever (B) contacts stop (C) with key switch "OFF" and engine not running.
3. Start engine and run at slow idle. Lever should contact stop (D) or nearly contact when the lever is being pushed up.



RG8067



RG8068

A—Link
B—Lever
C—Stop
D—Stop

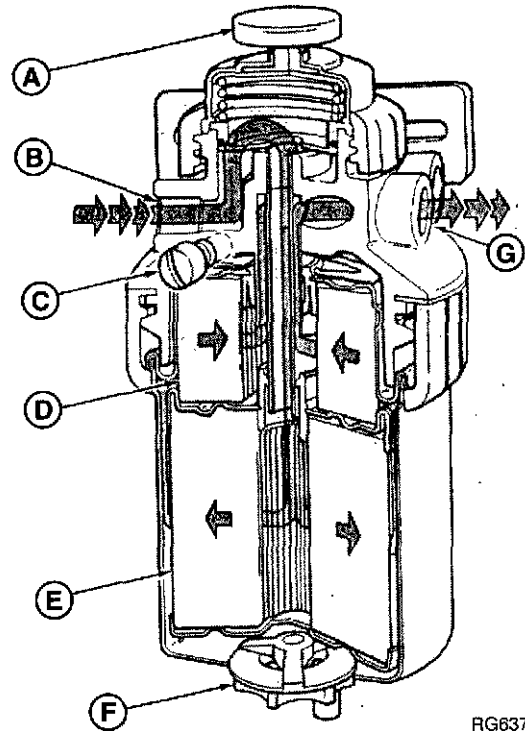
ROUND (PRIMARY) FUEL FILTER/WATER SEPARATOR OPERATION

Fuel enters the filter at inlet (B), then flows through a primary filter (E) and a secondary filter (D) before exiting filter through outlet (G) to the fuel injection pump. The filter elements are housed in a sediment bowl attached to the base with a threaded retaining ring.

Since water and contaminants settle at the bottom of the sediment bowl, a drain plug (F) is provided.

Air in the system can be expelled through the air vent when bleed screw (C) is loosened.

Priming pump (A) draws fuel from the fuel tank to fill the filter bowl when primary filter element is changed. Priming pump also supplies fuel from the filter to the injection pump.



RG6379

- A—Priming Pump
- B—Fuel Inlet
- C—Bleed Screw
- D—Secondary Filter
- E—Primary Filter
- F—Plug
- G—Fuel Outlet

BLEED THE FUEL SYSTEM

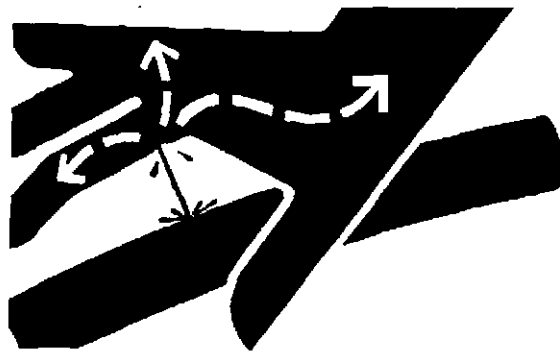


CAUTION: Escaping fluid under pressure can penetrate the skin causing serious injury. Avoid hazards by relieving pressure before disconnecting hydraulic or other lines. Tighten all connections before applying pressure. Search for leaks with a piece of cardboard. Protect hands and body from high pressure fluids.

If an accident occurs, see a doctor immediately. Any fluid injected into the skin must be surgically removed within a few hours or gangrene may result. Doctors unfamiliar with this type of injury may call the Deere & Company Medical Department in Moline, Illinois, or other knowledgeable medical source.

Any time the fuel system has been opened up for service (lines disconnected or filters removed), it will be necessary to bleed air from the system.

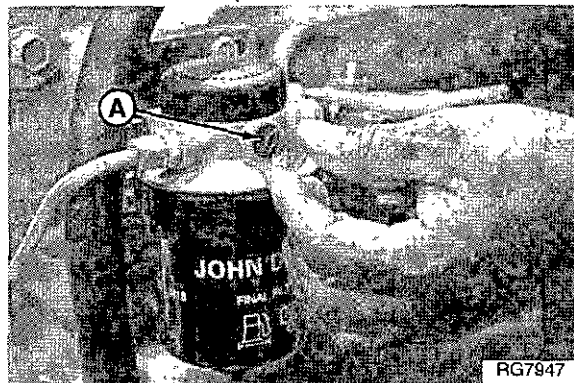
The fuel system may be bled at one of several locations. On some engine applications it may be necessary to consult your operator's manual and choose the location best for your engine/machine application.



X9811

• **At Final Fuel Filter:**

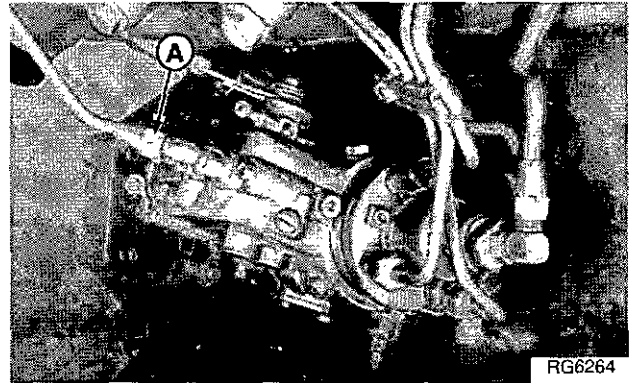
1. Open air bleed vent screw (A) two full turns by hand.
2. Pump the hand primer (if equipped) on filter mounting base until a noticeable amount of fuel and air comes out of vent opening. Continue pumping and close vent screw when fuel starts to flow.
3. Pump the hand primer several times until resistance is felt. Continue pumping and open air bleed vent screw again.
4. Close air bleed vent screw and pump the hand primer several times until resistance is felt again.



• **At Fuel Injection Pump:**

On Stanadyne rotary pumps:

1. Loosen fuel return line (A) at fuel injection pump.
2. Operate fuel supply pump primer lever.
3. As soon as fuel flow is free from air bubbles, tighten fuel return line to 16 N·m (12 lb-ft).



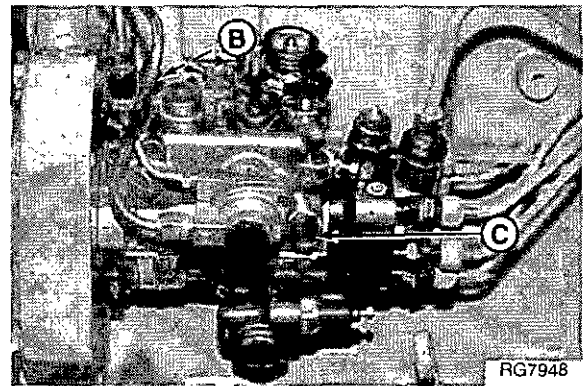
RG6264

On Lucas rotary pumps:

1. Loosen bleed screw (B) on pump cover.

NOTE: On Models DP200/201 Injection Pumps, bleed screw is located on top of cover near the fuel return line.

2. Operate supply pump primer lever or turn ignition switch to "ON".
3. Wait until fuel flow is free from air bubbles. Retighten bleed screw.



RG7948



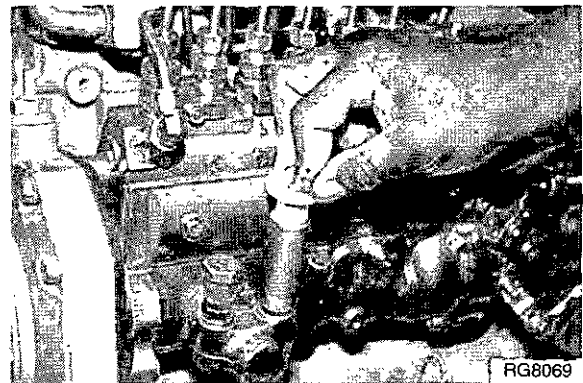
CAUTION: NEVER loosen screw (C) securing pump head, otherwise pump damage may occur.

On Nippondenso in-line pumps:

1. Unscrew hand primer on fuel supply pump until it can be pulled by hand.
2. Operate the hand primer until a smooth flow of fuel, free of bubbles, comes out of the filter plug hole.

IMPORTANT: Be sure hand primer is all the way down in barrel before tightening to prevent internal thread damage.

3. Simultaneously stroke the hand primer down and close the filter port plug. This prevents air from entering the system. Tighten plug securely. DO NOT overtighten.
4. Lock hand primer in position.



RG8069

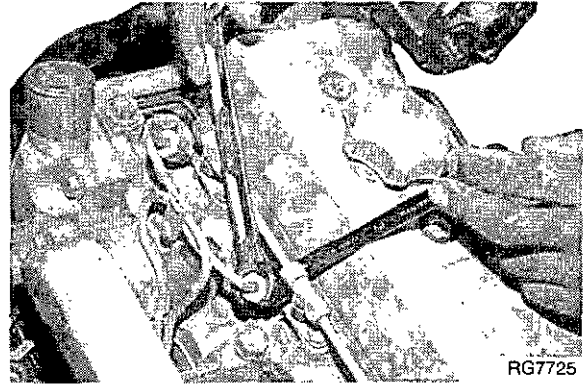
• **At Fuel Injection Nozzles:**

1. Place throttle lever in half-throttle position.

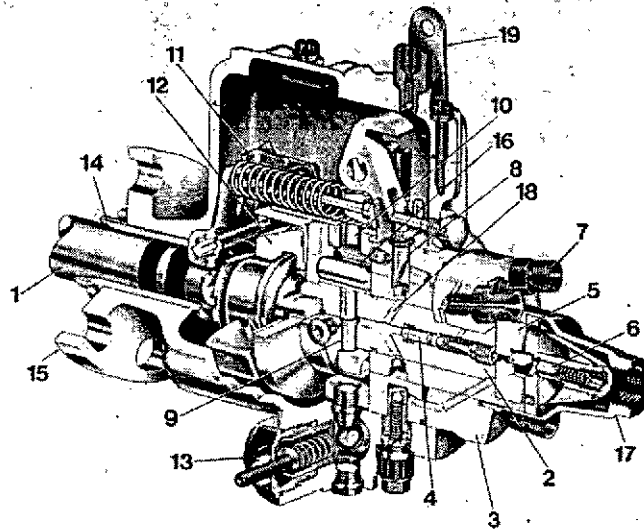
On engines equipped with electronic fuel shut-off solenoid, energize solenoid.

IMPORTANT: Always use a backup wrench when loosening or tightening fuel lines at nozzles and/or injection pump to avoid damage.

2. Using two open-end wrenches, loosen fuel line connection at injection nozzle.
3. Crank engine over with starting motor, (but do not start engine), until fuel free from bubbles flows out of loosened connection. Retighten connection to 27 N·m (20 lb-ft).
4. Repeat procedure for remaining injection nozzles (if necessary) until all air has been removed from fuel system.



STANADYNE ROTARY FUEL INJECTION PUMP OPERATION



DB2 Pump shown, DB4 Pump similar

- | | | | |
|---------------------|----------------------|------------------------|----------------------|
| 1—Drive Shaft | 6—Pressure Regulator | 11—Governor | 16—Rollers |
| 2—Distributor Rotor | 7—Discharge Fitting | 12—Governor Weights | 17—Supply Pump Inlet |
| 3—Hydraulic Head | 8—Metering Valve | 13—Automatic Advance | 18—Charging Ports |
| 4—Delivery Valve | 9—Pumping Plungers | 14—Drive Shaft Bushing | 19—Throttle Lever |
| 5—Supply Pump | 10—Internal Cam Ring | 15—Housing | |

Refer to illustration on previous page.

The main rotating components are the drive shaft (1), distributor rotor (2), supply pump (5) and governor (11).

The drive shaft engages the distributor rotor in hydraulic head (3). The drive end of rotor incorporates two pumping plungers (9).

The plungers are actuated toward each other simultaneously by an internal cam ring (10) through rollers (16) and shoes which are carried in slots at drive end of the rotor. The number of cam lobes normally equal the number of engine cylinders.

The supply pump at rear of rotor is a positive displacement vane-type pump enclosed in the end cap. The end cap also houses supply pump inlet (17), fuel strainer and pressure regulator (6). Supply pump pressure is automatically compensated for viscosity effects due to temperature changes and fuel grade variations.

The distributor rotor incorporates two charging ports (18) and a single axial bore (passage) with one discharge port to serve all head outlets (7) to the injection lines. The rotor rotates in bore of hydraulic head. Metering valve (8) bore, charging ports and discharge fittings are located in the head.

This pump contains its own mechanical governor. The centrifugal force of the weights (12) in their retainer is transmitted through a sleeve to a governor arm and through a positive linkage to the metering valve. The metering valve can be closed to shut off fuel through a solid linkage by an independently operated shut-off lever.

The automatic speed advance (13), advances or retards (hydraulically) the beginning of fuel delivery from the pump. The advance responds to changes in speed only, or to a combination of speed and load changes.

Fuel is drawn from the supply tank through filters into the pump inlet through the inlet filter screen by the vane type fuel transfer pump. Some fuel is bypassed through the pressure regulator assembly to the suction side.

Fuel under transfer pump pressure flows through the center of the transfer pump rotor, past the rotor retainer into a circular groove on the rotor. It then flows through a connecting passage in the head to the automatic advance and up through a radial passage and then through a connecting passage to the metering valve. The radial position of the metering valve, controlled by the governor, regulates flow of the fuel into the radial charging passages which incorporates the head charging ports.

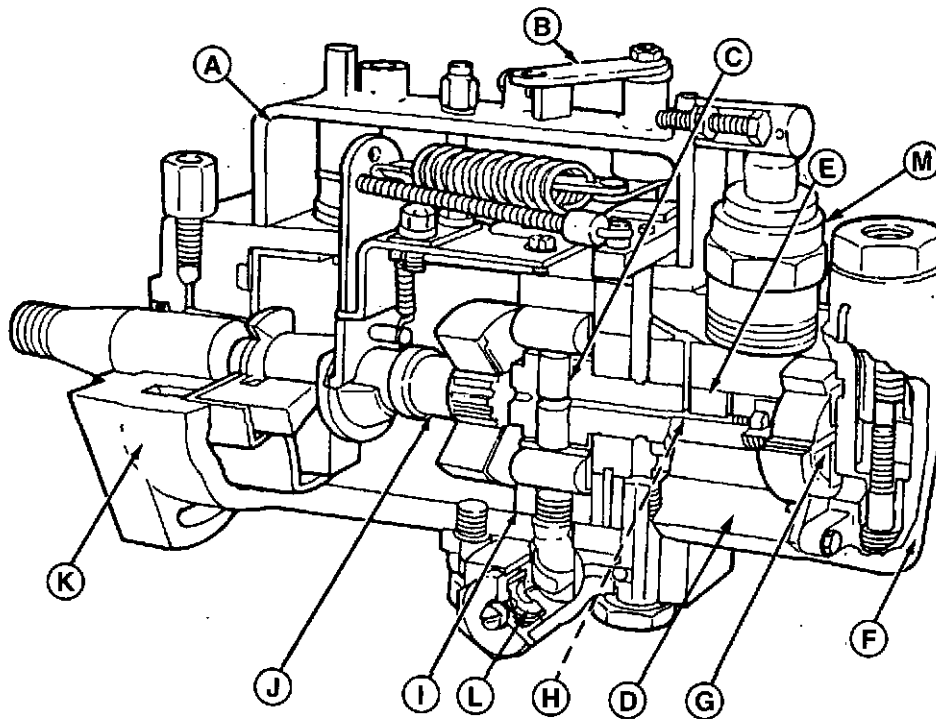
As the rotor revolves, the two rotor inlet passages register with the charging ports in the hydraulic head, allowing fuel to flow into the pumping chamber. With further rotation, the inlet passages move out of registry and the discharge port of the rotor registers with one of the head outlets. While the discharge port is opened, the rollers contact the cam lobes forcing the plungers together. Fuel trapped between the plungers is then pressurized and delivered by the nozzle to the combustion chamber.

Self-lubrication is an inherent feature of the pump's design. As fuel at transfer pump pressure reaches the charging ports, slots on the rotor shank allow fuel and any entrapped air to flow into the pump housing cavity.

Additionally, an air vent passage in the hydraulic head connects the outlet side of the transfer pump with the pump housing. This allows air and some fuel to be bled back to the fuel tank via the return line. The fuel thus bypassed fills the housing, lubricates the internal components, cools and carries off any small air bubbles. The pump operates with the housing completely full of fuel; there are no dead air spaces anywhere within the pump.

A cold start switch is optional and aids in cold start-up operation.

LUCAS ROTARY FUEL INJECTION PUMP OPERATION



RG8088

A—Governor Housing
 B—Throttle Lever
 C—Pumping Plungers

D—Hydraulic Head
 E—Distributor Rotor
 F—End Plate

G—Supply Pump
 H—Delivery Valve
 I—Internal Cam Ring

J—Drive Shaft
 K—Pump Housing
 L—Automatic Advance
 M—Electric Shutoff

Refer to illustration on previous page.

The Lucas fuel injection pump is a horizontally mounted distributor pump with mechanical governor and automatic hydraulic speed advance. The moving parts of the pump are simultaneously lubricated and cooled by diesel fuel flowing through the pump, no additional lubricant is required.

Diesel fuel for injection is fed to the cylinders by a single unit. The pumping plungers (C) and distributor rotor (E) is fitted with two opposed plungers controlled by an internal cam ring (I).

On the other end of the rotor, there is a supply pump (G) which delivers the fuel, drawn from the fuel filter, through the metering valve into the inlet bore in the pump hydraulic head (D), at a pressure that varies with engine speed.

As the rotor rotates, the inlet bore in pump head aligns with inlet bore in the rotor. Fuel coming from the transfer pump reaches the pump plunger chamber's through bore, regulated by the metering valve and forces the two plungers apart.

During further rotation of the distributor rotor, inlet bore in the pump head is closed and distributor channel in the rotor eventually aligns with one of the outlet bores in the pump head. Meanwhile the two pump plungers have reached the cam so that they move toward each other. The trapped, metered fuel is forced, (under high pressure) through a channel in the rotor and outlet opening in the pump head. Then, through pressurizing valve and pressure line, to the injection nozzle and into the appropriate cylinder.

A pressurizing valve is located at each outlet in the pump head where the pressure line leading to the fuel injection nozzle is connected. After injection, the pressure valve closes again, and with it's small relief piston, draws in a quantity of fuel from the pressure line.

A pressurizing valve is located at each outlet in the pump head where the pressure line leading to the fuel injection nozzle is connected. After injection, the pressure valve closes again, and with it's small relief piston, draws in a quantity of fuel from the pressure line.

The resulting relief in the pressure line causes a quick and firm closing of the nozzle valve. This prevents fuel from leaking into the combustion chamber.

The quantity of fuel which is needed at any given moment for each cylinder and combustion cycle is regulated by a metering valve. The metering valve is controlled by the speed control rod and throttle lever (B), and by the governor inside the governor housing (A). In the "NO-FUEL" ("OFF") position, the metering valve completely cuts the supply of fuel from supply pump to the rotor.

At slow idle speed or under full load, the supply pump feeds more fuel to the metering valve than is needed for injection. The excessive fuel flows through the pressure regulating valve back to the suction side of the transfer pump. A very small amount of this surplus fuel escapes through the top of the governor housing.

To obtain the best possible performance over the entire speed range, the fuel injection pump is fitted with an automatic, hydraulically operated speed advance (L). This speed advance is preset at the factory. The speed advance adjusts timing of the fuel injection pump in relation to engine speed and load.

The light load advance is standard on Model DP203 pumps and optional on DP201 pumps.

A cold advance switch is optional on these pumps. The switch consists of a housing to which is fitted a spring-loaded piston assembly, a "wax motor", and a spring-loaded ball valve. It is fitted top the spring end of the auto advance housing.

IMPORTANT: Remember that all adjustments to the injection pump, except for slow idle, MUST BE carried out on a test bench by a specialist injection pump repair station only. Internal adjustments in the field are not permitted, as this pump is a sealed unit.

DIAGNOSE ROTARY FUEL INJECTION PUMP MALFUNCTIONS

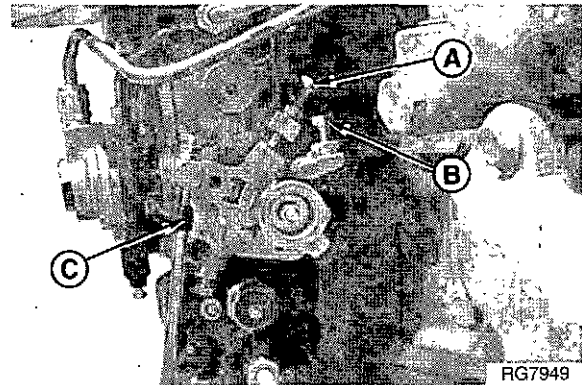
Symptom	Problem	Solution
Engine Starts Hard or Won't Start	Shut-off solenoid not functioning properly; or wiring lead loose or broken.	Repair.
	Injection pump not correctly timed.	Check pump timing (refer to this group).
	Defective injection pump.	Remove pump from engine and repair.
	Automatic advance faulty or not operating.	Adjust or repair.
Slow Idle Speed Irregular	Nozzle faulty or sticking.	Repair (See Group 35.)
	Automatic advance faulty or not operating.	Inspect and adjust or repair.
	Injection pump not properly timed.	Check pump timing (refer to this group).
	Defective injection pump.	Remove pump and repair.
Engine Horsepower Low	Pump not properly timed.	Check timing (refer to this group).
	Insufficient throttle arm travel.	Inspect and adjust.
	Automatic advance faulty or not operating.	Adjust or repair.
	Nozzle faulty or sticking.	Repair. (See Group 35.)
	Defective injection pump.	Remove pump and repair.

CHECK AND ADJUST ENGINE SPEEDS ON LUCAS PUMP

NOTE: Before checking and adjusting engine speed, make sure engine has reached its normal operating temperature.

- **Check Slow And Fast Idle Speeds:**

1. Start engine and run at 50% load and rated speed until engine reaches normal operating temperature.
2. Stop engine and disconnect speed control rod from fuel injection pump throttle lever (C).



NOTE: Refer to **FUEL INJECTION PUMP SPECIFICATIONS**, earlier in this group, for slow and fast idle speeds.

3. Start engine and move injection pump lever to slow idle position against slow idle adjusting screw (A). Using a tachometer, read and record engine speed. Compare reading with specifications. Adjust slow idle as necessary as detailed below.
4. Move injection pump lever to fast idle position against fast idle adjusting screw (B). Using a tachometer, read and record engine speed. Compare reading with specifications.

IMPORTANT: If fast idle is not within specification, have an authorized diesel repair station, servicing dealer, or engine distributor adjust as necessary.

- **Adjust Slow Idle Speed:**

1. Move pump throttle lever to slow idle position against slow idle adjusting screw (A). See specifications for specified engine speeds.

Loosen slow idle screw lock nut. Turn adjusting screw clockwise to increase speed and counterclockwise to decrease engine speed.

**ADJUST VARIABLE SPEED ON
GENERATOR SET ENGINES (LUCAS
PUMPS ONLY)**

See your authorized Lucas Repair Station for speed droop adjustment. This service requires that an internal pump adjustment be made.

CHECK AND ADJUST ENGINE SPEEDS ON STANADYNE PUMP

NOTE: Before checking and adjusting engine speed, make sure engine has reached its normal operating temperature.

• Check Slow And Fast Idle Speeds:

1. Start engine and run at 50% load and rated speed until engine reaches normal operating temperature.
2. Stop engine and remove control rod pin (B, if used). Disconnect speed control rod (or control cable) from fuel injection pump throttle lever.

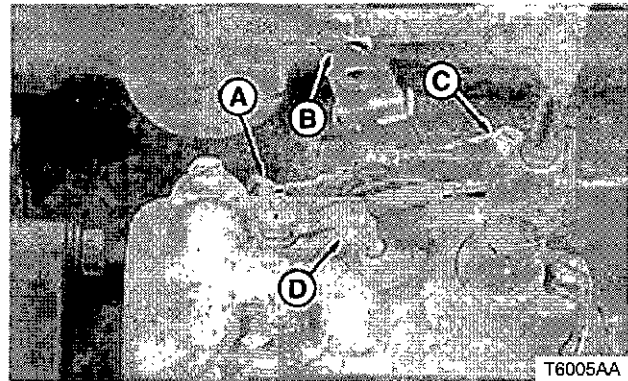
NOTE: Refer to **FUEL INJECTION PUMP SPECIFICATIONS**, earlier in this group, for slow and fast idle speeds.

3. Start engine and move injection pump lever to slow idle position against slow idle adjusting screw (A or D). Using a tachometer, read and record engine speed. Compare reading with specifications. Adjust as necessary as detailed below.
4. Move injection pump lever to fast idle position against fast idle adjusting screw (C). Using a tachometer, read and record engine speed. Compare reading with specifications.

IMPORTANT: If fast idle is not within specification, have an authorized diesel repair station, servicing dealer, or engine distributor adjust as necessary.

• Adjust Slow Idle Speed:

1. Move pump throttle lever in slow idle position against slow idle adjusting screw (A or D). See specifications for specified engine speeds.
2. Loosen slow idle screw lock. Turn adjusting screw clockwise to increase speed and counterclockwise to decrease engine speed.



A—Slow Idle Adjusting Screw*
 B—Control Rod Pin
 C—Fast Idle Adjusting Screw
 D—Slow Idle Adjusting Screw*

*Slow idle adjusting screw location varies by injection pump application. Will either be at location A or D.

ADJUST VARIABLE SPEED (DROOP) ON GENERATOR SET ENGINES (3—5% GOVERNOR REGULATION)—STANADYNE DB2 AND DB4 INJECTION PUMPS

An external speed droop adjusting cap (A) at the rear of the injection pump housing provides precise control of governor sensitivity by decreasing or increasing the effective length (and thereby the rate) of the governor control spring. Fine adjustments can be made while the engine is operating.

1. Start engine and run at rated speed with 50% load applied until it reaches normal operating temperature.

NOTE: If serious surging occurs during the warm-up period, turn the speed droop adjusting cap clockwise until surging stops.

2. When engine has warmed to normal operating temperature, position throttle lever (D or E) to attain full load rated speed (e.g., 1500, 1800 RPM) and apply 100% (full) load.

Adjust the throttle if necessary to obtain satisfactory full load performance.

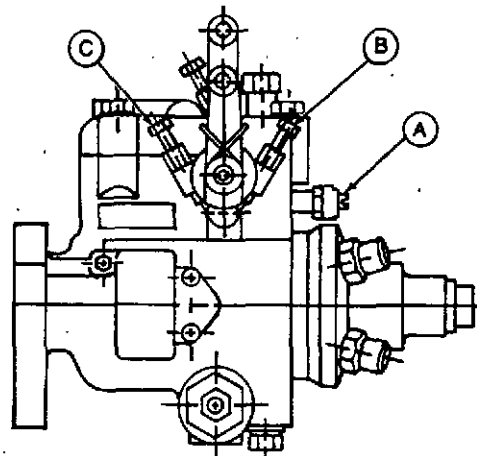
NOTE: Whenever speed droop adjustments are made, throttle position adjustments will also be necessary.

3. Remove load and check for specified no-load speed or frequency.

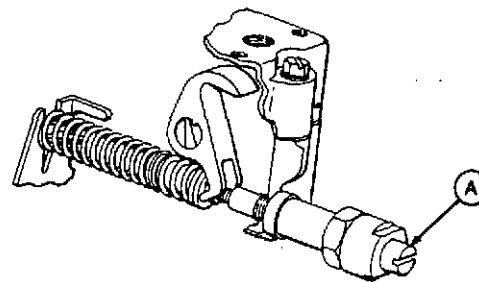
If incorrect, adjust speed droop adjusting cap slightly (clockwise for increased droop or counterclockwise for less droop).

If surging exists upon removing the load, turn the adjusting cap clockwise to eliminate.

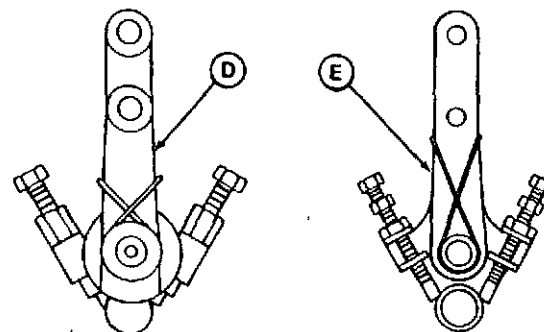
4. Recheck full load and no-load performance and readjust as necessary.



RG5754



RG6395



RG6397

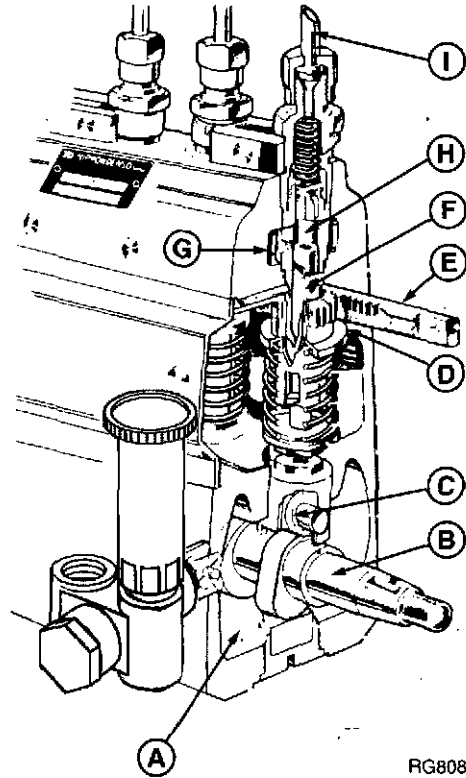
- A—Speed Droop Adjusting Cap
- B—Fast Idle Screw
- C—Slow Idle Screw
- D—Early Throttle Lever
- E—Current Throttle
- F—Throttle Stop

IN-LINE FUEL INJECTION PUMP OPERATION

Filtered fuel under pressure by the supply pump fills the injection pump fuel gallery (G). As the camshaft rotates, roller tappets (C) riding on the camshaft (B) lobes operate the plungers (F) to supply high pressure fuel through the delivery valves (H) to the injection nozzles.

A governor-operated control rack (E) is connected to the control sleeves (D) and plungers to regulate the quantity of fuel delivered to the engine.

Engine lubricating oil is piped to the injection pump crankcase (A) to provide splash lubrication of the working parts. Two drain holes at the front end of the pump determine the level of oil maintained in the crankcase. Excess oil drains out these holes and returns back to the engine through the timing gear housing.



RG8083

- A—Crankcase
- B—Camshaft
- C—Roller Tappet
- D—Control Sleeve
- E—Control Rack
- F—Plunger
- G—Fuel Gallery
- H—Delivery Valve
- I—Delivery Pipe

DIAGNOSE IN-LINE FUEL INJECTION PUMP MALFUNCTIONS

Symptom	Problem	Solution
Engine Starts Hard or Won't Start	Incorrect fuel shut-off lever position (pump control rack not moving all the way forward).	Adjust shut-off cable as required.
	Defective injection pump:	Remove pump from engine and repair. (See Group 35.)
	Injection pump not correctly timed.	Check pump timing.
Slow Idle Speed Irregular	Slow idle stop screw improperly adjusted.	Recheck stop screw adjustment.
	Supplementary idling spring improperly adjusted.	Recheck adjustment.
	Defective injection pump.	Remove pump from engine and repair. (See Group 35.)
Engine Horsepower Low	Pump not properly timed.	Check timing.
	Defective injection pump.	Remove pump from engine and repair. (See Group 35.)

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CHECK FAST IDLE SPEED—IN-LINE FUEL INJECTION PUMP

1. Remove speed control rod. With the engine running, move governor control lever (A) against the fast idle stop screw (B).

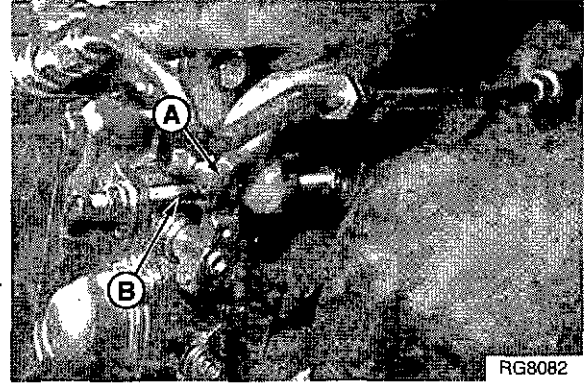
NOTE: The governor control lever on injection pump may be inboard (next to engine block) or outboard (away from engine block), depending upon engine application.

2. Using a tachometer, check fast idle speed to see if it is within specification.

NOTE: For each application, refer to the appropriate machine technical manual for fast idle speed specifications.

IMPORTANT: If fast idle speed must be adjusted, see your authorized diesel repair station.

NOTE: For some applications such as generator sets, special equipment may be required for fast idle adjustment in conjunction with droop adjustment. See your OEM dealer or John Deere Engine Distributor.



RG8082

CHECK AND ADJUST SLOW IDLE SPEED—IN-LINE FUEL INJECTION PUMP

NOTE: Both the slow idle stop screw (A) and the (bumper) spring screw (B) may be used to adjust the slow idle speed.

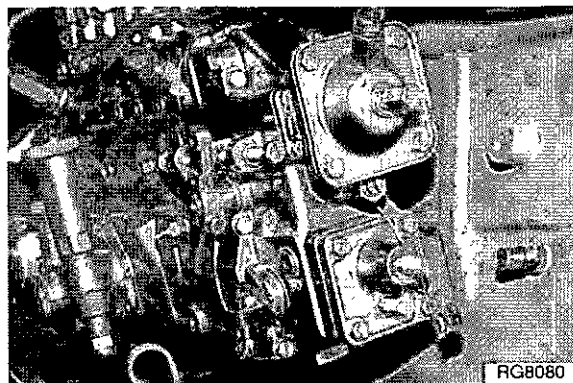
IMPORTANT: Minor adjustment of the slow idle speed may be made with the (bumper) spring screw. However, it should not be used by itself to change engine speed more than 50 rpm, as overspeeding of the engine may result.

If slow idle stop screw and bumper spring screw are not adjusted according to instruction, engine damage could result because of overspeeding.

 **CAUTION: ALWAYS STOP ENGINE** before making adjustments.

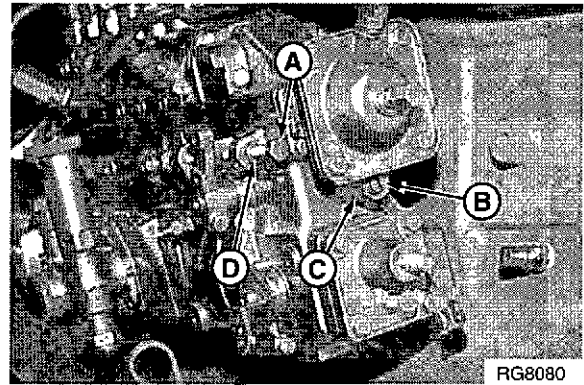
1. With the engine running, pull the governor control lever rearward to the slow idle speed position. Check and adjust slow idle speed to specification.

NOTE: For each application, refer to the appropriate machine technical manual for slow idle speed specifications.



A—Slow Idle Stop Screw
B—(Bumper) Spring Screw
C—Lock Nut
D—Lock Nut

2. Remove slow idle stop screw cover.
3. Loosen lock nut (C) and back out the (bumper) spring adjusting screw (B) three turns.
4. Loosen lock nut (D) and adjust slow idle stop screw (A) to obtain an idle speed 50 rpm less than the desired slow idle speed setting.
5. Turn the (bumper) spring adjusting screw in to increase engine speed a maximum of 50 rpm to desired slow idle speed.



RG8080

- A—Slow Idle Stop Screw
- B—(Bumper) Spring Screw
- C—Lock Nut
- D—Lock Nut

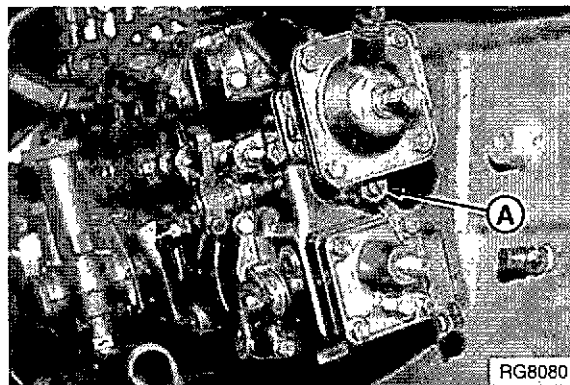
For example, to obtain an 850 rpm slow idle speed, use the slow idle stop screw to set speed at approximately 800 rpm. Then increase speed to 850 rpm using the (bumper) spring adjusting screw.

NOTE: Increasing the slow idle speed a slight amount above the specified speed range may help to reduce engine surge (or hunting). If this occurs, use the procedure given above; but do not exceed 850 rpm.

6. If engine surging or hunting persists at slow idle, the bumper spring and adjustment screw (A) may need to be replaced with a new one.

IMPORTANT: Remove the pump from the engine and have it repaired by an authorized diesel repair station (ADS shop). See Group 35 for fuel injection pump removal and installation.

7. Again check the fast and slow idle speeds. Readjust slow idle speed if not correct.
8. Check all adjusting screw lock nuts for tightness. Install covers (and copper washers) on slow idle stop screw and idling spring adjusting screw.
9. Connect fuel shut-off cable and speed control rod.

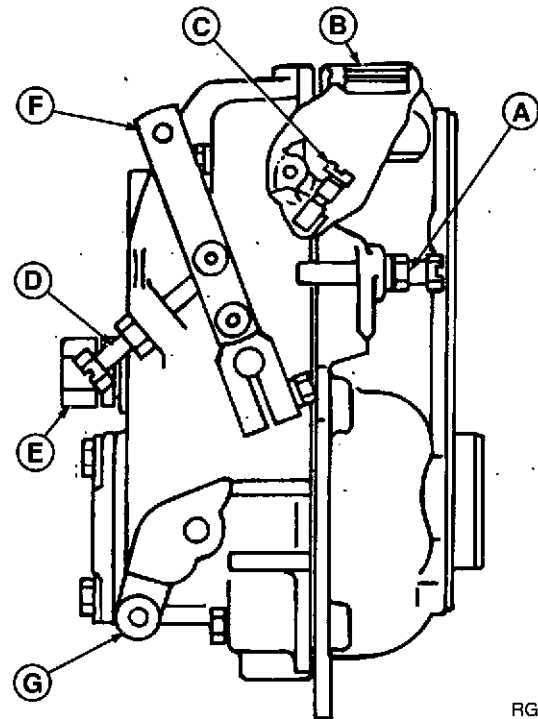


CHANGE ENGINE RATED SPEED FROM 1800 RPM TO 1500 RPM AND ADJUST DROOP—IN-LINE INJECTION PUMPS

1. Start engine and apply 50% load at rated speed until it reaches operating temperature. Remove cap nuts from adjusting screws before making adjustments.
2. When the engine has reached normal operating temperature, adjust fast idle (stop) screw (A) clockwise (CW) to 1500 rpm (50 Hz) with 100% (full) load.
3. Remove load and back out the idle (bumper) spring screw (E), while observing the corresponding drop in engine rpm's until engine quits losing speed.
4. Screw in idle (bumper) spring screw until engine speed increases 5—10 rpm.
5. Check for specified no-load (frequency). If governor regulation is within 5—7% range, proceed to Step 8.

NOTE: A noticeable click will occur at each 1/4 turn of droop adjusting screw. One click CW will increase no-load speed approximately 10 rpm, counter-clockwise (CCW) will reduce speed by 10 rpm.

6. If governor regulation is above 7% or below 5%, stop engine and remove droop adjusting screw access plug (b, shown removed) from top of governor housing.
 - a. Back out slow idle (adjusting) screw (D) and bumper screw. Pull back on throttle lever (F, toward rear of governor housing) by hand until the droop adjusting screw (C) inside housing can be adjusted through the access plug hole.
 - b. Screw the droop screw in (CW) counting the turns until screw bottoms out. Then, return screw to original setting.



RG5752

- A—Fast Idle (Stop) Screw
- B—Droop Adjusting Screw Access Plug Location
- C—Droop Adjusting Screw
- D—Slow Idle (Adjusting) Screw
- E—Idle (Bumper) Spring Screw
- F—Throttle Lever
- G—Mechanical Shutoff Lever

- c. Screw in the droop screw (CW) no more than 1/2 turn (two clicks) at a time to reduce governor droop. CCW no more than two licks at a time to increase governor droop (to reduce governor sensitivity).
 - d. Replace access plug in top of governor housing. Start engine, apply full (100%) load, and readjust high idle adjusting screw until 1500 rpm (50 Hz) is obtained at the specified power.
 - e. Screw in idle (bumper) spring until engine speed increases 5—10 rpm.
7. Repeat Steps 6 (a-d) until governor regulation is within the 5—7% range.

Replace all cap nuts onto adjusting screws and tighten lock nuts securely.

HOW THE ANEROID WORKS IF EQUIPPED)—IN-LINE INJECTION PUMPS

Intake manifold pressure (created by the turbocharger) enters aneroid at (A). It is directed to upper side of diaphragm chamber (C) and exerts pressure on diaphragm (D).

When the pressure rises to about 100 kPa (1 bar) (15 psi), or about 1000 engine rpm under moderate to heavy loads, spring (E) pressure is overcome. Diaphragm then moves aneroid control shaft (F) downward.

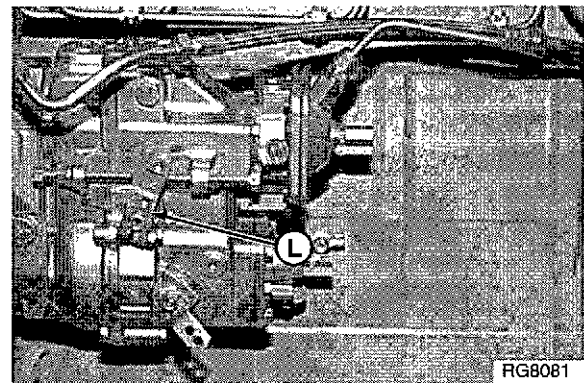
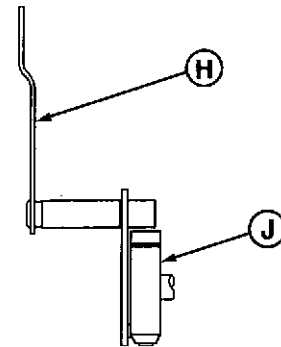
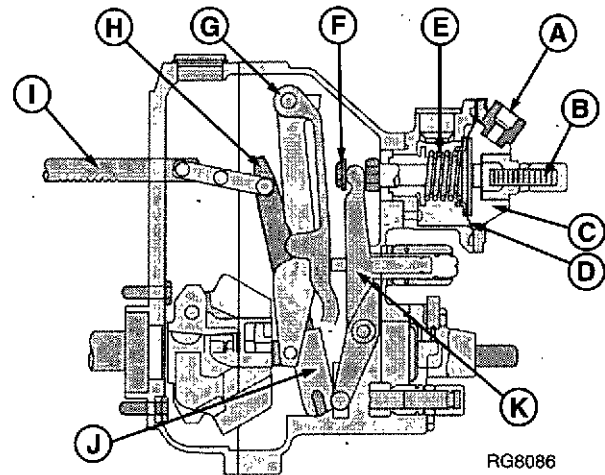
Control lever (H) has "two" legs. The inner leg connects with control block (J) and the aneroid control lever (K) and bears on the flat surface of aneroid control shaft. The outer leg bears against a block riveted to the control rack (I).

NOTE: Diaphragm adjusting screw (B) regulates the minimum fuel delivery quantity at a specified rpm and zero pressure acting on the diaphragm. The diaphragm spring determines acceleration time (the greater the spring tension, the greater the manifold pressure required to overcome spring tension; hence, a slower acceleration).

Downward movement of the throttle lever (L) causes arm to rotate on fuel control shaft, permitting control rack to move its normal amount.

In the intake manifold pressure is below 100 kPa (1 bar) (15 psi) because of low engine speed, or is under light load at higher engine speeds, the aneroid spring pressure is greater than the intake manifold pressure. As a result, the control rack travel is limited (therefore, fuel delivery is limited) by the arm and adjusting shaft.

Aneroid control will be in effect until the manifold pressure is high enough to overcome diaphragm spring pressure.



- A—Intake Manifold Pressure Line Connection
- B—Diaphragm Adjusting Screw
- C—Diaphragm Chamber
- D—Diaphragm
- E—Spring
- F—Aneroid Control Shaft
- G—Guide Lever
- H—Control Lever
- I—Control Rack
- J—Control Block
- K—Aneroid Control Lever
- L—Throttle Lever

DIAGNOSE ANEROID MALFUNCTION

Symptom	Problem	Solution
Slow Engine Acceleration	Loose pipe or broken connection at inlet fitting.	Repair as required. (See Group 35.)
	Aneroid cover cracked around inlet fitting.	Repair as required. (See Group 35.)
	Defective diaphragm.	Repair as required. (See Group 35)
	Aneroid not correctly adjusted.	Remove injection pump (see Group 35) and adjust on test stand.
Excessive Smoke When Accelerating Engine	Aneroid not correctly adjusted	Remove injection pump (see Group 35) and adjust on test stand.

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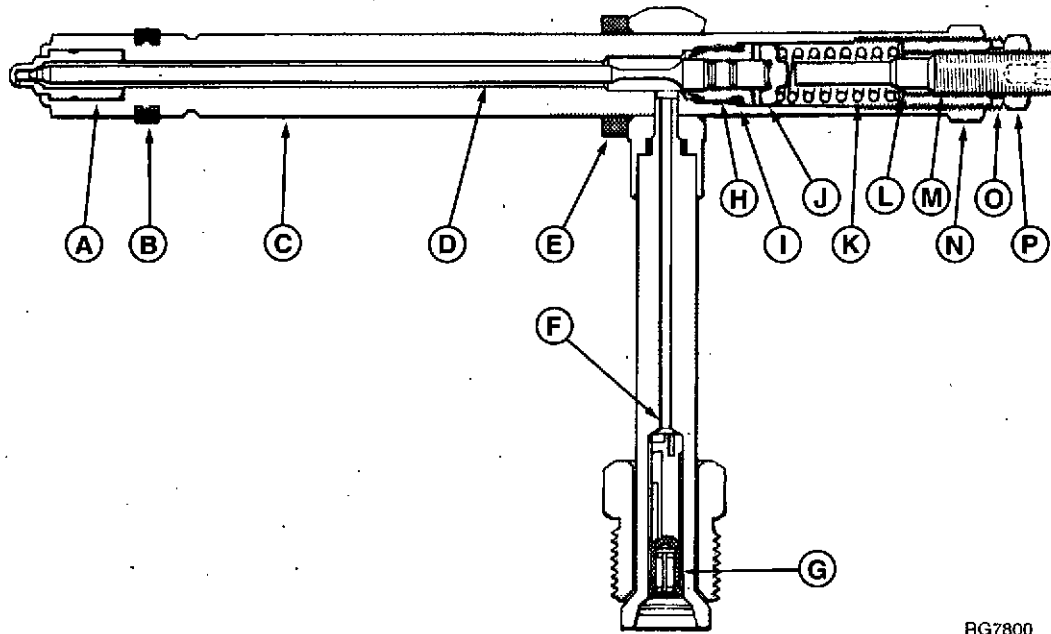
Use information contained in the chart above to help diagnose aneroid malfunctions.

See Group 35 for instructions on how to repair and adjust the aneroid.

The aneroid controls fuel delivery when intake manifold pressure is about 100 kPa (1 bar) (15 psi) or less. Therefore, all final adjustments are to be made on the test stand with aneroid mounted on injection pump.

IMPORTANT: Correct aneroid adjustments are essential for satisfactory engine performance. Whenever the aneroid adjustments have been altered, the injection pump (including aneroid) must be calibrated on the test stand by an authorized diesel injection repair station before releasing the pump for service.

FUEL INJECTION NOZZLES—GENERAL INFORMATION AND OPERATION



RG7800

A—Nozzle Tip
 B—Carbon Stop Seal
 C—Nozzle Body
 D—Nozzle Valve

E—Upper Seal Washer
 F—Edge-Type Filter
 G—Fuel Inlet
 H—Upper Guide

I—Upper Seal
 J—Spring Seat
 K—Valve Spring
 L—Spring Washer

M—Lift Adjusting Screw
 N—Lock Nut
 O—Pressure Adjusting Screw
 P—Lock Nut

Refer to illustration on previous page.

The injection nozzles are located in the engine cylinder head and are of the spring and valve type, hydraulically operated by fuel delivered from the injection pump.

A locating clamp positions the nozzle assembly in the cylinder head. The nozzle is sealed at the top end by a seal washer (E). A carbon stop seal (B), located on the lower end of the nozzle body (C), prevents carbon from collecting around the nozzle in the cylinder head.

Enclosed in the nozzle body are the valve (D), valve spring (K), and spring seat (J). The nozzle operating pressure is controlled by the pressure adjusting screw (N) in the upper end of the nozzle body. Valve lift is adjusted by the lift adjusting screw (L) located in the pressure adjusting screw. The nozzle tip (A) is pressed into the nozzle body and cannot be separated.

A leak-off line tee is attached to the upper end of the injection nozzle, secured by a grommet and hex nut.

Metered fuel, under high pressure, is delivered by the injection pump through the nozzle inlet (G) on the valve body into the area surrounding the valve. When fuel pressure reaches nozzle opening pressure, the valve is forced from its seat against the pressure of the spring, permitting a measured amount of fuel to enter the combustion chamber through four small holes in the nozzle tip.

After fuel has been injected, the spring closes the valve. In actual operation, the valve opens and closes very rapidly, providing a distinct chatter.

A small amount of fuel leaks past the valve into the spring area. This provides lubrication for the nozzle working parts. This excess fuel is then removed from the nozzle at the top by means of a leak-off line routed to the fuel source.

DIAGNOSE FUEL INJECTION NOZZLE MALFUNCTIONS

Fuel injection nozzles are usually removed and tested or replaced when there is a noticeable loss of power or excessive smoking.

Listed in the following chart are various malfunctions which may occur on the 9.5 mm nozzles. Only possible defects related to these nozzles are listed. Failures in other components of the fuel injection system are listed under their respective headings in this group.

Refer to Group 35 for repair information.

Symptom	Problem	Solution
Engine Has Low Horsepower	Nozzle orifices plugged.	Repair. (See Group 35.)
	Incorrect nozzle valve opening pressure.	Adjust. (See Group 35.)
	Broken, worn or damaged parts: —Broken nozzle valve spring —Cracked or split nozzle tip —Cracked or split nozzle body —Internal leak	Repair as required. (See Group 35.)
	Wrong nozzle assembly installed.	Install correct nozzle assembly. (See Group 35.)
Engine Emits Too Much Smoke	Nozzle loose in cylinder head.	Make sure nozzle assembly is correctly installed. Tighten clamp cap screw to specified torque. (See Group 35.)
	Nozzle orifices plugged.	Repair. (See Group 35.)
	Broken, worn or damaged parts: —Broken nozzle valve spring —Cracked or split nozzle tip —Cracked or split nozzle body —Internal leak	Repair as required. (See Group 35.)
	Wrong nozzle assembly installed.	Install correct nozzle assembly. (See Group 35.)

TEST FUEL INJECTION NOZZLES (ENGINE RUNNING)

1. Operate engine at intermediate speed with no load.
2. Slowly loosen the fuel pressure line at one of the nozzles until fuel escapes at the connection (fuel not opening nozzle valve).
3. Repeat test for each remaining nozzle assembly.
4. Remove faulty injection nozzles and repair as required. (See Group 35.)

NOTE: The injection nozzle before and/or after nozzle being checked could be the faulty nozzle.

- If engine speed changes, the injection nozzle is probably working satisfactory.
- If engine speed does not change, a nozzle is faulty and must be checked and repaired (or replaced).

FUEL DRAIN BACK TEST PROCEDURE

Fuel draining back through the fuel system may cause hard starting. This procedure will determine if air is entering the system at connections and allowing fuel to siphon back to the fuel tank.

1. Disconnect fuel supply and return lines at fuel tank.

IMPORTANT: Fuel return line MUST extend below fuel level in fuel tank before performing this test. Fill fuel tank if necessary.

2. Drain all fuel from the system, including the fuel transfer pump, fuel injection pump, fuel filters, and water separator (if equipped).
3. Securely plug off the end of the fuel return pipe.



CAUTION: Maximum air pressure should be 100 kPa (1 bar) (15 psi) when performing this test.

4. Using a low pressure air source, pressurize the fuel system at the fuel supply line.

5. Apply liquid soap and water solution to all joints and connections in the fuel system and inspect for leaks.

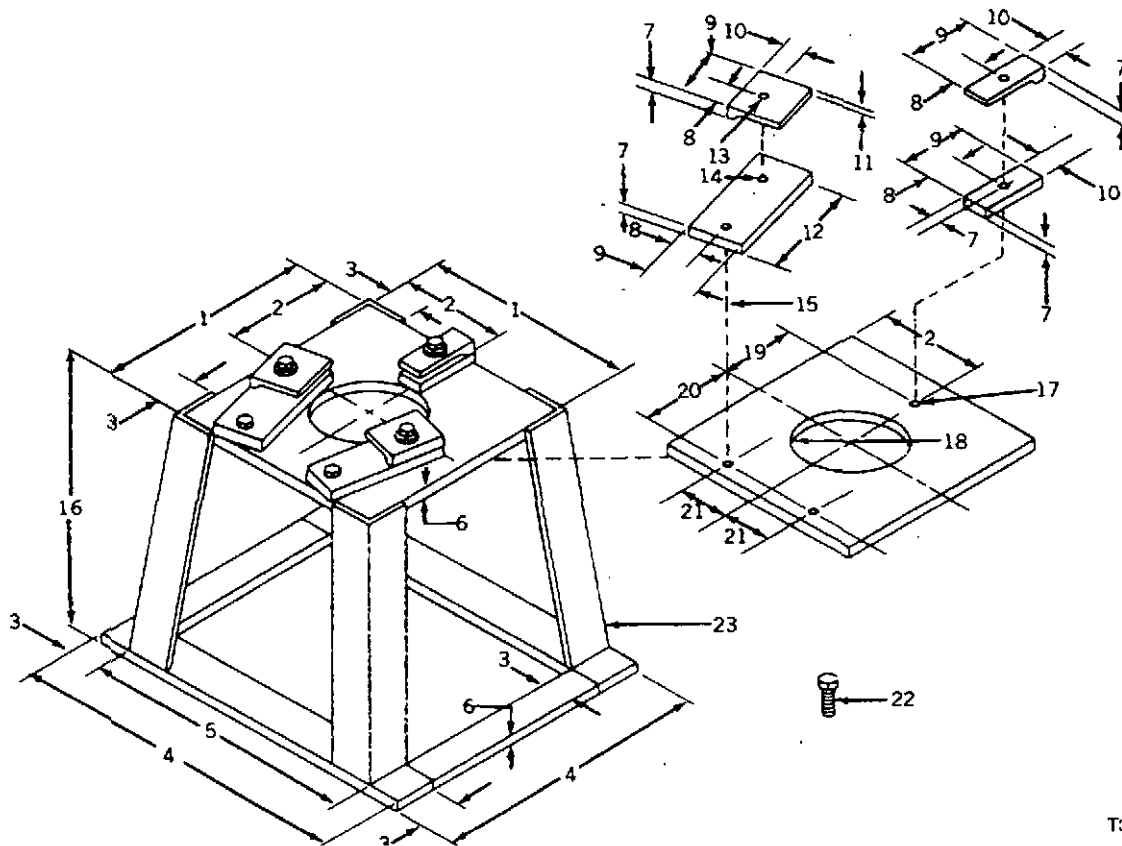
NOTE: Connections may allow air to enter the system without allowing fuel to leak out.

6. If any leaks are found, take necessary steps to repair.
7. Reconnect supply and return lines and prime system.
8. Start engine and run for approximately 10 minutes.
9. Allow engine to sit overnight and try starting the following morning.

HOW TO MAKE TOOLS

This tool can be made in a service shop using common shop tools and locally obtained materials.

DFRG3—CYLINDER LINER HOLDING FIXTURE



T36748N

1—254.0 mm (10 in.)
2—127.0 mm (5 in.)
3—38.1 mm (1.5 in.)
4—405.4 mm (16 in.)
5—330.2 mm (13 in.)
6—9.52 mm (0.38 in.)

7—12.7 mm (0.5 in.)
8—31.8 mm (1.25 in.)
9—63.5 mm (2.5 in.)
10—25.4 mm (1 in.)
11—6.35 mm (0.25 in.)
12—152.4 mm (6 in.)

13—0.328 in. Drill Through
14—5/16 in. -18 Tap
15—2 used
16—304.8 mm (12 in.)
17—5/16 in. -18 Tap
18—69.85 mm (2.75 in.) Radius

19—101.6 mm (4 in.)
20—111.25 mm (4.38 in.)
21—60.45 mm (2.38 in.)
22—5/16 in. x 1 in. Cap Screw
23—38.1 mm (1.5 in.) Angle Iron

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